Biological and Water Quality Monitoring
of two core sites in Spring 2006

prepared for City of Ryde

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Report Number: 2006/0006

File Reference: File Reference: G: Projects\0-1\PM000067\City of Ryde\Report Spring 2006\City of Ryde Spring 2006 report 14_1_07 final v2.doc

December 2006

Executive Summary

This report has been developed by Sydney Water Corporation in response to engagement under Ryde City Council Tender Number COR-EOC-06/06.

This report contributes to Ryde City Council's implementation of its Biological and Chemical Water Quality Monitoring Strategy using macroinvertebrates and water chemistry in the main creek systems within its area. This report covers the third year of the strategy and focuses upon Archers and Shrimptons creeks. Spring 2006 sampling was conducted on 28th September, 18th October and 15th November.

Water quality results of Spring 2006 indicate Archers Creek did not meet ANZECC (2000) guidelines on protection of aquatic ecosystems for dissolved oxygen, total nitrogen and total phosphorus on all sample occasions. The same trend was observed for Shrimptons Creek except total nitrogen met this criteria on one sample occasion. Oxidised nitrogen also did not meet this criteria on at least one occasion in each creek. Turbidity levels were within acceptable limits as set out by ANZECC (2000) with one exception for Shrimptons Creek in November 2006. Conductivity and ammoniacal nitrogen met ANZECC (2000) guidelines on protection of aquatic ecosystems. Faecal coliforms assessed against ANZECC (2000) secondary contact guidelines met criteria on all but one occasion for Archers Creek.

A total of 1,074 macroinvertebrates were collected and examined from the Spring 2006 sampling period from Shrimptons and Archers creeks. The dominant taxa for both sampling sites in Shrimpton's and Archer's creeks were the true fly larvae (Dipterans). From Archers Creek 31 taxa were recorded, and this compares with 35 taxa from the previous four sampling occasions (Spring 2004 to Autumn 2006). From Shrimptons Creek 27 taxa were recorded, compared with 32 taxa from the previous four sampling occasions.

Macroinvertebrate results of Spring 2006 indicate Archers and Shrimptons creeks have impaired macroinvertebrate communities with similar results recorded in Spring 2004 to Autumn 2006. Sensitive taxa as measured by EPT richness were virtually absent and a number of predicted EPT taxa were not observed. Multivariate analyses suggested a change in composition of Shrimptons Creek samples occurred in Spring 2006, but this was not reflected in taxa richness. Direct measurement of ecosystem health using SIGNAL-F and measurement via AUSRIVAS predictive model OE50 outcomes both reflected impaired ecosystem health of Archers and Shrimptons creeks. Differences between sampling periods were more evident in SIGNAL-F than O/E ratios. AUSRIVAS OE50 SIGNAL2 was the only univariate measure to give a contradictory result. The AUSRIVAS OEO SIGNAL2 measure improved results in line with SIGNAL-F and AUSRIVAS OE50 and is perhaps a more suitable measure of AUSRIVAS output than AUSRIVAS OE50 SIGNAL2.

Recommendations are also made for refinements to the Biological and Chemical Water Quality Monitoring Strategy.

Contents

List of Figures

List of Tables

Appendixes

1 Introduction

This report has been developed by Sydney Water Limited (SWC) in response to engagement under Ryde City Council Tender Number COR-EOC-06/06.

This report contributes to Ryde City Council's implementation of its Biological and Chemical Water Quality Monitoring Strategy using macroinvertebrates and water chemistry in the main creek systems within its area. This strategy was originally planned as a seven year program of which the first two years of the program have been completed where five creeks have been monitored. The broad program for the remaining five years will target two of the five creeks each year on a rotational basis. This report covers the third year of the strategy and focuses upon Archers and Shrimptons creeks.

Under the Biological and Chemical Water Quality Monitoring Strategy, macroinvertebrates and water chemistry were sampled once each month within the Spring 2006 (September, October & November) and Autumn 2007 (March, April & May).

Monitoring macroinvertebrates and water chemistry enables Ryde City Council to:

- Evaluate the 'health' of aquatic ecosystems in designated waterways within the council area for short & long term interpretation and temporal evaluation over the duration of the strategy;
- Determine a suitable monitoring program ie. where, when and how often sampling should be undertaken to assess stream health within Ryde Local Government Area based on existing site data, physical parameters and trends identified;
- Develop a methodology to determine how to sample for macroinvertebrates within the AUSRIVAS model framework;
- Establish a series of options for identification of samples using the AUSRIVAS key indicator organisms;
- Identify suitable indices such as SIGNAL 2 and SIGNAL F to assess water quality, including calculation of the Observed/Expected ratios from the respective AUSRIVAS predictive model;
- Determine how this strategy could be incorporated into a community monitoring program eg. Streamwatch.

2 Study Area

2.1 Site locations

The five designated sites (Figure 1) of the Ryde City Council's Biological and Chemical Water Quality Monitoring Strategy are:

- Site 1 – Terrys Creek near M2 motorway at the end of Somerset Road, North Epping
- Site 2 – Shrimptons Creek at Wilga Park
- Site 3 – Porters Creek, accessed through the Ryde City Depot, after the creek is piped under the depot
- Site 4 – Buffalo Creek, accessed through privat property (52 Higginbotham Rd)
- Site 5 – Archers Creek at Maze Park

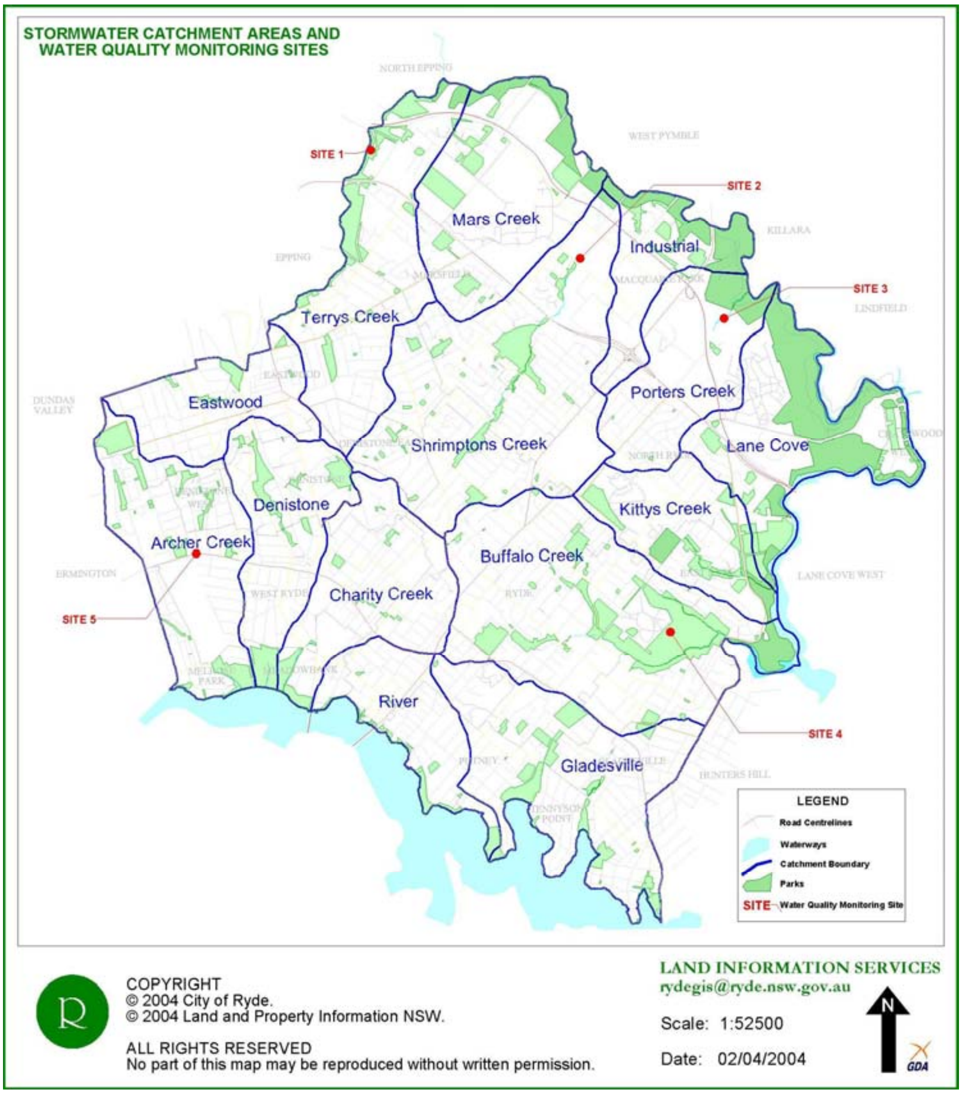

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Figure 1. Site locations of the Biological and Chemical Water Quality Monitoring Strategy of the City of Ryde

2.2 Spring 2006 sampling events

Three sampling events were conducted for Spring 2006 for the City of Ryde Biological and Chemical Water Quality Monitoring Strategy. Sampling was conducted in separate months as required under COR-EOC-06/06 at Archers and Shrimptons creeks. Sampling occurred on:

- 28th September 2006
- 18th October 2006
- 15th November 2006

3 Methodology

3.1 Macroinvertebrate sampling

Rapid assessment macroinvertebrate sampling was conducted in accordance with AUSRIVAS protocols for NSW (Turak *et al*., 2004). Sydney Water staff that have met criteria of in-house test method for macroinvertebrate identification and enumeration, conducted field sampling. Use of experienced staff addresses issues identified by Metzeling *et al.* (2003).

Three edge samples were collected from each site within a pre-selected area each month within the season of Spring 2006 as specified in the City of Ryde Biological and Chemical Water Quality Monitoring tender document COR-EOC-06/06. Edge, defined as areas with little or no current. These areas were sampled with a hand-held dip net with 320 mm by 250 mm opening and 0.25 mm (250 µm) mesh that conformed to ISO 7828-1985 (E). The net was swept from open water towards the shore, working over a bank length of about 10 m moving in an upstream direction. In the process, deposits of silt and detritus on the stream bottom were stirred up so that benthic animals were suspended and then caught in the net.

The net contents were then 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 period of 40 minutes. If new taxa are collected between 30 and 40 minutes, sorting will continue for a further 10 minutes. If no new taxa are found after 10 minutes the picking ceases. If new taxa are found, the 10 minute processing cycle is continued up to a maximum total sorting time of 1 hour. There is no set minimum number of animals collected using the NSW protocols (Turak, *et al.,* 2004).

All specimens collected will be preserved in small glass specimen jars containing 70% ethanol with a clear label indicating site code, creek name, date, habitat and name of SWC staff sampler. Sampling equipment will be washed thoroughly between samples to prevent the cross contamination of animals.

3.2 Macroinvertebrate sample processing

Macroinvertebrates were identified and enumerated to the family taxonomic level, except for: non-biting midges (Chironomids) to sub-family; aquatic worms to Class Oligochaeta; and aquatic mites to Order Acarina. 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 National Association of Testing Authorities (NATA) and has been employed since 1997. In particular, macroinvertebrate identification was performed using appropriate published keys listed in Hawking (2000), internal keys to the Sydney water macroinvertebrate reference 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 5% of samples collected for this study. Quality assurance is further described in Appendix A.

3.3 Water quality sampling

Water chemistry was sampled once each month within Spring 2006 (September, October & November) at the time of macroinvertebrate sampling.

Samples were taken by filling the sample bottles directly from the surface of the stream. Temperature and dissolved oxygen were measured on site as per methods summarised in Table 1. The dissolved oxygen results in mg/L were then converted to % saturation according to Water On The Web (2005).

Table 1. Water chemistry parameters, method of analysis in field

ANALYTE	METHOD
pH, temperature	Yeokal 611 WTW meter
Dissolved Oxygen (mg/L)	HACH meter

Samples for the analysis of turbidity, conductivity, total dissolved solids (TDS), faecal coliforms, total phospohorus, total nitrogen (as a measure of total oxidised nitrogen and total Kjeldahl nitrogen), total alkalinity and ammonia were returned to the laboratory and analysed by the methods summarised in Table 2 within 12 hrs of sampling. Quality assurance of water chemistry analysis is further described in Appendix A.

Table 2. Water chemistry parameters, method of analysis in laboratory

ANALYTE	DETECTION LIMIT	METHOD
Turbidity	0.10 NTU	APHA 2130B
Total Dissolved Solids	10 mg/L	APHA 2450 C
Faecal Coliforms	1 cfu/100mL	APHA 9222-D
Total Phosphorus	0.002 mg/L	APHA4500P- H
Alkalinity ($CaCO_3$/L)	0.5 mg/L	APHA 2320 B
Oxidised Nitrogen	0.01 mg/L	APHA 4500-NO3 I
Total Kjeldahl Nitrogen	0.1 mg/L	Calculation
Ammoniacal Nitrogen	0.01 mg/L	APHA 4500-NH3 H
Conductivity	0.1 mS/m	APHA 2510 B

3.4 Rainfall Data

Daily rainfall data from the Marsfield Bureau of Meterology Station number 066156 are presented where records were recorded. For the few missing records from station 066156, data were substituted from Sydney Water Meterology Station number 566040 at West Epping.

3.5 Comparison with historical data

The Ryde City Council Tender Number COR-EOC-06/06 requested compilation and analysis of all historic raw data (where comparable) back to 2004 and, where data was available back to 2001, for assessment with Spring 2006 study data to provide a temporal evaluation of ecological health of Archers and Shrimptons Creeks. Ecowise supplied raw macroinvertebrate and water chemistry data (Spring 2004 to Autumn 2006) and together with Spring 2006 data allowed the compilation of data points as summarised in Table 3. Previous data were unavailable in a suitable format for this purpose or had comparability issues.

Table 3. Summary of when each variable was sampled between Spring 2004 and Autumn 2006.

	Sampling period																								
	Spring 2004					Autumn 2005					Spring 2005					Autumn 2006					Spring 2006				
	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archers Ck
Macroinvertebrates	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Alkalinity (Total)	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Ammonia NH3-N						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Conductivity (mS/m)						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
DO (mg/L)	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Faecal Coliform	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Oxidised Nitrogen NOx-N						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
pH	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Temp	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
TN						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Total Dissolved Solids	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Total Kjeldahl Nitrogen						*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Total Phosphorus	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*
Turbidity	*	*			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*			*

3.6 Data analyses

After identification and enumeration of macroinvertebrates the data were analysed with univariate and multivariate analysis techniques.

Univariate methods

Data analyses were performed using a number of biological indices and predictive models. These included:

- Diversity index Taxa richness,
- Diversity index EPT (mayfly, stonefly, caddis fly) richness
- Biotic index SIGNAL-F
- Output from AUSRIVAS predictive models (eastern edge Autumn; eastern edge Spring)
    - AUSRIVAS OE50
    - AUSRIVAS OE50 SIGNAL
    - AUSRIVAS OEO SIGNAL
- SIGNAL-2 scoring system for macroinvertebrates

Taxa richness

Taxa richness refers to the number of different types of animals collected in a sample, and is a simple measure of the macroinvertebrate diversity of a site. In this study, taxa specifically refers to the number of families, and it also includes the non-biting midge (Chironomid) sub-families, aquatic worms (Oligochaeta) and aquatic mites (Acarina). Immature stages that could not be identified to family or one of these other groups due to the lack of taxonomic information were excluded.

In general, a sample containing a large number of taxa is indicative of a biologically healthy or clean site, and conversely a sample containing few taxa is indicative of a biologically disturbed or polluted site. In disturbed streams with degraded environmental quality only a few types of taxa can tolerate and thrive. These taxa typically comprise worms, snails and non-biting midges.

Some caution must be given in interpreting the patterns observed with the taxa richness, as this relationship is not strictly a linear function. Many of the undisturbed sandstone streams in the greater Sydney region have naturally low levels of productivity and may not contain a particularly diverse macroinvertebrate fauna. However, the composition of the fauna of the relatively undisturbed sandstone streams generally contains many of the pollution-sensitive fauna such as mayflies, stoneflies and caddisflies, as well as a diverse number of mite taxa.

EPT richness

The biotic index EPT (Ephemeroptera - mayfly, Plecoptera - stonefly and Trichoptera - caddisfly families) richness is based upon the sensitivity of these taxa to respond to changes in water quality condition (Lenat 1988). Generally the number of these taxa found at a site can be used as an indicator of stream biological health.

Some caution must be given when interpreting patterns based on MSC taxa as many of these macroinvertebrates are also sensitive to natural changes in streams, such as altitude. In general, EPT taxa favour higher altitude streams to low altitude streams. However, a diverse range of these taxa has been observed by Sydney Water, at altitudes as low as 10 meters in undisturbed waterways in Sydney and in the Clyde River. The absence of these taxa in streams may be attributable to human disturbances within urban catchments.

SIGNAL-F

The original version of the Stream Invertebrate Grade Number Average Level (SIGNAL) biotic index (Chessman, 1995-SWC data) has been refined by testing that included the response of SIGNAL to natural and human influenced (anthropogenic) environmental factors (Growns *et al*. 1995), variations in sampling and sample processing methods (Growns *et al*. 1997; Metzeling *et al*. 2003) and setting sensitivity grades of the taxa objectively (Chessman *et al*. 1997; Chessman *et al*. 2002). –F indicates taxonomy is at the family level. SIGNAL-F has been derived from macroinvertebrate data of the greater Sydney region (Chessman *et al.*, submitted). Water quality status of clean water has been established in the index using data from near pristine reference sites in the bushland fringes of Sydney by using the 10th percentile of the average score of these reference sites. SIGNAL-F allows a direct measure of test site condition and incorporates abundance information from the rapid assessment sampling.

The first step in calculating a SIGNAL-F score is applying predetermined sensitivity grade numbers (from 1, tolerant to 10, highly sensitive) to family counts that occur within a location habitat sample. Then multiply the square root transformed count of each family by the sensitivity grade number for that family, summing the products, and dividing by the total square root transformed number of individuals in all graded families. Families that were present in the samples but with no grade numbers available (relatively few) were removed from the calculation of the SIGNAL-F score for the sample. This procedure was repeated for each sample. Then calculation of location specific average and a measure of variation (plus and minus one standard deviation of the average score) through time as recommended by Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters (2000) was made to allow ecosystem health comparisons between sampling occasions for each creek and between creeks. Comparisons in this manner allow ranking of stream health as a guide to management decisions.

As aquatic mites (Order Acarina) and aquatic worms (Class Oligochaeta) are left at higher taxonomic levels in the AUSRIVAS protocol, the respective SIGNAL-F grades of the families of aquatic mites and worms were averaged and used in the calculation of SIGNAL-F scores for this report.

Arbitrary pollution categories can be assigned (Table 4). Sydney Water has successfully demonstrated the application of this index in stream monitoring of management changes to the sewerage system and subsequent organic pollution responses in creeks from these decisions (SWC 2002, 2003).

Table 4. Interpretation of SIGNAL-F scores (Chessman et al., submitted).

SIGNAL-F score	Water quality status
> 6.4	Clean water
5.5-6.4	Possible mild organic pollution
4.6-5.5	Probable moderate organic pollution
< 4.6	Probable severe organic pollution

AusRivAS predictive models

AUSRIVAS (AUStralian RIVers Assessment System) predictive model is based on the British bioassessment system RIVPACS (River Invertebrate Prediction and Classification System; Wright 1995). The RIVPACS model was modified to suit the environmental conditions present only in Australia (Turak *et al.* 2004). The AUSRIVAS model is an interactive software package, which uses the macroinvertebrate and environmental data collected from numerous reference river sites across the state of NSW. It is a tool that can quickly assess the ecological health of any river or creek site. Collected macroinvertebrate data are transformed into presence absence (1 or 0) form, which is also referred to as binary data. The predictor environmental variables required to run for each model vary as outlined in Tables 4 and 5 but generally include altitude, location (latitude and longitude), stream size characteristics, substratum composition, river alkalinity and rainfall (Turak 2001). These environmental variables allow the software to compare test sites, in this case Archers and Shrimptons creek samples, to comparable reference site groups with similar environmental characteristics.

AUSRIVAS models can incorporate data taken from pool edge or riffle habitats. The paucity of riffle habitats at the sites under study by the City of Ryde in sampling conducted for the program to date preclude use of the riffle models. Only four riffle samples were collected by Ecowise between Spring 2004 and Autumn 2006. Hence in comparison of Spring 2006 data with historical data the respective edge models have been employed.

The applicable AUSRIVAS models for comparison of the City of Ryde test creek sites are: the eastern edge Autumn model; eastern edge Spring model; and combined eastern edge model. However Ecowise (Spring 2005) suggested the later model does not allow changes in condition between seasonal sampling events for the City of Ryde strategy.

The respective model uses the test site information and comparable reference site group information to calculate a score called the “OE50 ratio” (observed/expected number of macroinvertebrate families with greater than 50% probability of occurring at a test site) (Coysh et al

(2000). The OE50 ratio provides a measure of impairment at a test site (Ransom *et al.*, 2004). The OE50 ratio of each test site sample also corresponds to a band that assists in interpretation and aids management decisions (Coysh *et al.*, 2000). That is, the band helps to categorise each test site showing how it compares with reference sites from rivers of the same type. Interpretation of the five possible bands of river condition is detailed in Table 5 (Coysh *et al.*, 2000). Thresholds that correspond to these bands of each respective model are detailed in Table 6.

Table 5. Interpretation of bands associated with OE50 model output (Coysh et al., 2000).

Band	Description	O/E taxa	O/E taxa interpretations
X	More biologically diverse that 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 6. Upper thresholds for bands of impairment (O/E-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

AUSRIVAS output identifies taxa that were expected from the respective reference site group to which a test site is being compared. As part of this output missing taxa are listed with greater than 50% probability of occurrence. To provide consistency in this report the definition used by Ecowise (2004, 2005a, 2005b, 2006) has been used in this report. That is, indicator taxa are defined as taxa within the EPT (Ephemeroptera - mayfly, Plecoptera - stonefly and Trichoptera – caddisfly) orders with SIGNAL2 scores of greater than 6.

SIGNAL-2

Together with OE50 output each AUSRIVAS model also generates OE50-SIGNAL values. This output incorporates SIGNAL2 (Chessman 2003a) tolerance grades derived from reference sites sampled to create the AUSRIVAS models in NSW. Please note SIGNAL2 tolerance grades are different to the greater Sydney region tolerance grades of SIGNAL-F. OE50-SIGNAL values allow another assessment of test site condition. An example calculation of these values is provided in previous Ecowise reports, which sourced this example from Chessman (2003a). No bands have been developed for SIGNAL2 (Coysh *et al.* 2000), however, values of around 1 would be similar to reference condition (Chessman pers comm.). Using AUSRIVAS calculated values is recommended by Chessman (2003a) as a way to overcome natural variation.

There is another way to calculate SIGNAL2 scores that may be applicable for community group use (Chessman 2003b). At small spatial scales such as contrasting disturbed and pristine sites within a district, raw SIGNAL2 scores (Chessman 2003a) may be appropriate. These can be calculated with family taxonomy or with a mixture of Order, Class, and Phylum taxonomy as set out in Chessman (2003b). This provides an indication of what the condition of the site may be Chessman (2003b) (Figure 2). Results can be plotted on a biplot of SIGNAL2 scores against number of families or number of Orders, Classes and Phylums. "The biplot provides an indication of things that may be affecting macroinvertebrates at a site, such as water quality and habitat quality" (Chessman 2003b). This approach with Order, Class, and Phylum taxonomy may be an option for involvement of community groups in sampling other creeks of the City of Ryde to expand knowledge of the district. A draw back to this method is the borders between quadrants need to be set against reference site data of region.

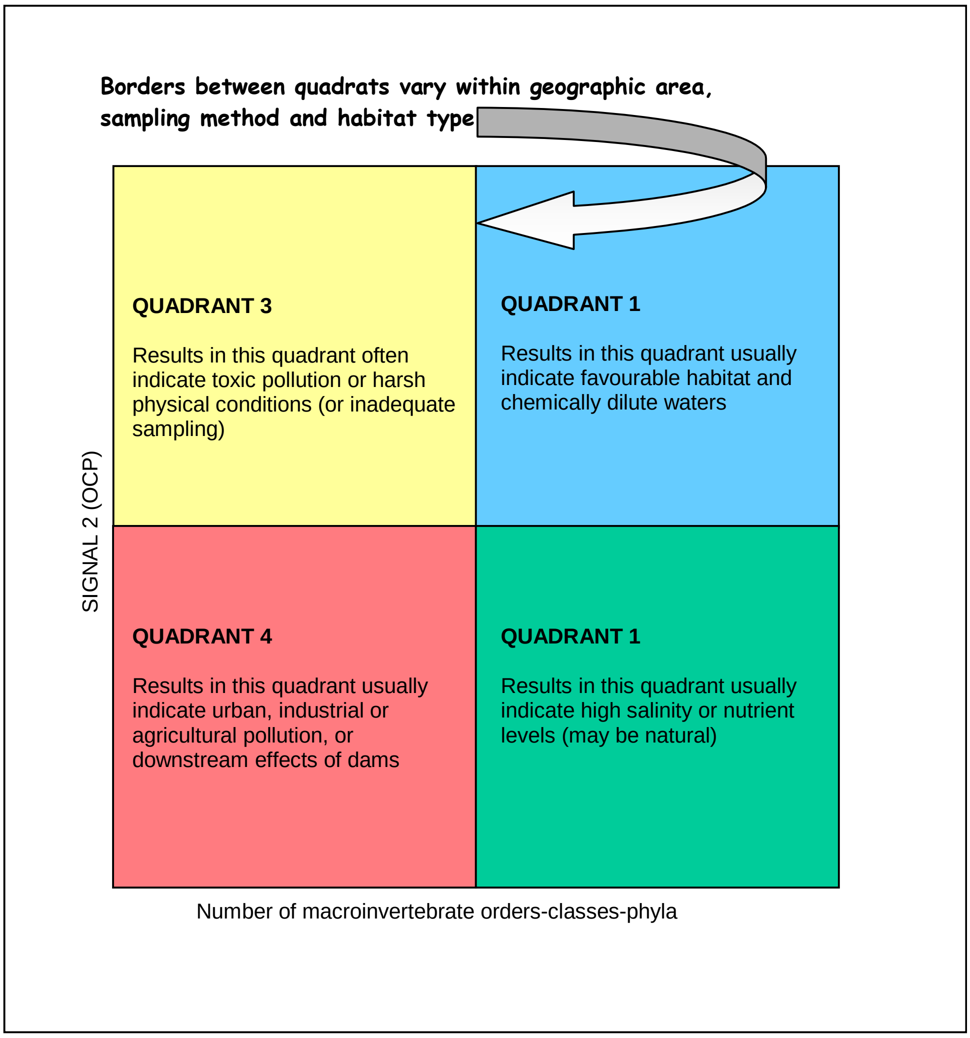

Figure 2. Interpretation of SIGNAL2 after Chessman (2003b)

Multivariate methods

Data analyses were performed using the PRIMER software package (Clark and Warwick 2001). Analysis techniques included:

- Classification and ordination,
- SIMPER
- BIOENV

These analysis techniques complement univariate analyses by exploring patterns of macroinvertebrate communities. Prior to analysis the data from the field survey was square root transformed and rare taxa observed in only one sample were removed.

Spring 2006 macroinvertebrate samples from Archers and Shrimptons creeks were compared in an ordination with 2005 and 2006 data for the other three creeks of the monitoring program to look at context of community composition. Macroinvertebrate data of Archers Creek were then explored for 2005 and 2006 and the same exploration made for Shrimptons Creek.

Classification and Ordination

The group average classification technique was used to place the sampling sites into groups, each of which had a characteristic macroinvertebrate community based on relative similarity of their attributes. Similarities (distances) between the fauna of each pair of sites were calculated using the Bray-Curtis measure, which is not sensitive to rough approximations in the estimation of taxa abundances (Faith *et al.* 1987), as is the case with rapid assessment sampling. The group average classification technique initially forms pairs of samples with the most similar taxa and gradually fuses the pairs into larger and larger groups (clusters) with increasing internal variability.

Classification techniques will form groups even if the data set actually forms a continuum. In order to determine whether the groups were 'real' the samples were ordinated using the non-metric multidimensional scaling (MDS) technique. Ordination produces a plot of sites on two or three axes such that sites with a similar taxa lie close together and sites with a differing taxon composition lie farther apart. Output from classification is then checked against ordination groupings to assist with interpretation.

Any ordination procedure inevitably introduces distortion when trying to simultaneously represent the similarities between a large number of sites in only two or three dimensions. The success of the procedure is measured by a stress value, which indicates the degree of distortion imposed. In the PRIMER software package a stress value of below 0.2 indicates an acceptable representation of the original data although lower values are desirable.

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.

BIOENV

The physical and chemical characteristics of the creeks were compared with macroinvertebrate community structure using the BIOENV routine. The underlying similarity matrix was constructed with the normalised Euclidean Distance association measure option. This option enabled a comparison of water quality variables without undue weight being assigned by differing unit scales. Untransformed water chemistry data were used in the BIOENV analysis.

4 Results

4.1 Water quality & site observations

The field and laboratory results for water quality parameters measured at Shrimptons and Archers creeks in Spring 2006 (Table 7) have been compared with ANZECC (2000) guidelines.

The dissolved oxygen saturation levels from Shrimptons and Archers creeks during Spring 2006 were well below the 85% recommended level within ANZECC (2000) for the protection of aquatic ecosystems within all samples. In October 2006, dissolved oxygen levels fell as low as 21.5% saturation within Shrimptons Creek and 41.5% for Archers Creek. This may be having a severe impact on the survival of aquatic life within the streams.

In this report bacteriological results were compared with ANZECC (2000) guidelines for secondary contact recreation. Since water quality bodies being sampled were unlikely to be used for primary contact purposes such as swimming, it was felt that application of the secondary contact guidelines were appropriate. However, it must be noted that comparisons with these guidelines do not infer a measure of compliance with the guidelines, as samples have not been collected under an appropriate regime for compliance monitoring (five samples in a 30 day period). The comparisons are indicative only to provide a degree of context to bacteriological results obtained. The November 2006 sample from Archers Creek was the only sample to have Faecal Coliforms (1700 CFU) exceed the recommended secondary contact level (ANZECC, 2000) of 1000/100mL, that is 1.7 times the acceptable limit. All other samples from Shrimptons and Archers creeks were within safe levels for secondary contact.

Turbidity levels were within acceptable ANZECC (2000) ranges for five of the six samples taken from Shrimptons and Archers creeks in Spring 2006. The only sample to exceed these guidelines was the November sample at Shrimptons Creek. When this creek was sampled it was observed that sections of the creek had been eroded by approximately 0.5 m. This erosion was observed on the clay and boulder embankment on the west bank. The creek banks had probably been undercut more intensely during the rain periods of early September when nearly 200mm fell within a couple of days. The subsequent rainfall of 40mm that occurred earlier in the week that November sampling occurred would appear to have caused the bank collapse. The observed erosion most likely explains the observed turbidity in November 2006 at Shrimptons Ck. Also observed in November 2006 in Archers Creek was a small section of the creek bank that had collapsed into the creek, however, turbidity levels were not elevated.

Total Phosphorus and Total Nitrogen as measures of nutrient levels were elevated above ANZECC (2000) guidelines for the protection of aquatic ecosystems for all samples at Shrimptons Creek and for five of the six samples at Archers Creek in Spring 2006. Shrimptons Creek had the highest results in October and November 2006 with levels over two and four times the acceptable limits.

Ammonia levels and conductivity as a measure of salinity were within ANZECC (2000) recommendations for all samples at Shrimptons and Archers creeks for Spring 2006 and Total Oxidised Nitrogen was within recommendations for 50% of samples from both creeks this season.

The pH was within acceptable ranges (ANZECC, 2000) for most samples within Spring 2006 at both Shrimptons and Archers creeks. Shrimptons Creek had one reading outside of the recommended guidelines, but more notable was the consistence with which the historical data shows that over half of the Shrimptons Creek samples have exceeded the recommended guidelines through time.

The Spring 2004 sampling regime did not collect total, ammoniacal, oxidised and total kjeldahl nitrogen or conductivity and as such precludes the use of Spring 2004 data in multivariate analysis using the BIOENV routine.

Water quality results for comparable samples (Table 3) are consolidated in Appendix 2.

Table 7. Water quality results at Shrimptons Creek and Archers Creek for Spring 2006 in relation to the ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia) and Recreational Water Quality & Aesthetics (Secondary).

Parameter		NH^{4+}	NOx	TP	TKN	TN	Alkalinity	TDS	Turb	DO	Conductivity	Faecal Coliform	Temp	PH
Units		µg/L	µg/L	µg/L	µg/L	µg/L	mg $CaCO_3$/L	mg/L	NTU	% Sat	µS/cm	CFU/100mL	^{0}C	
ANZECC (2000)	*Aquatic Eco-systems*	*320*	*40*	*50*	*N/A*	*500*	*N/A*	*N/A*	*50*	*85-110*	*125-2200*	-	-	*6.8-8.0*
	Secondary Contact	-	-	-	-	-	-	-	-	-	-	*1000*	-	-
Shrimptons Ck	*Sep*	130	140	64	580	720	94.5	420	7.8	45.0	717	69	17.30	7.12
	Oct	10	20	136	1180	1200	66.5	311	6.34	21.5	481	160	15.40	6.54
	Nov	70	1200	68	800	2000	58	265	96.7	43.5	384	560	17.20	7.41
Archers Ck	*Sep*	5	5	104	520	520	83	293	2.03	67.5	509	340	18.30	7.37
	Oct	5	10	90	500	510	70	295	2.32	41.5	448	880	17.50	6.93
	Nov	20	40	50	360	400	84	310	1.78	76.5	502	1700	18.60	7.21

4.2 Rainfall Data

Daily rainfall data from the Marsfield Bureau of Meterology Station number 066156 presented below displays the Spring 2006 sampling period and preceding four months (Figure 3). The initial Spring 2006 sampling occasion was delayed to let creek conditions settle after 196 mm of rain fell over seven days of early September 2006. The last event of this magnitude occurred in October 2004 when 227 mm fell over eight days (Appendix 3). Rainfall in the last three calendar years (2004 - 905 mm; 2005 - 788 mm; and 2006 to mid November 730 mm) was below average. The most recent year with about average rainfall was 2003 with 1262 mm. Hence data presented in this report is from a relatively dry period.

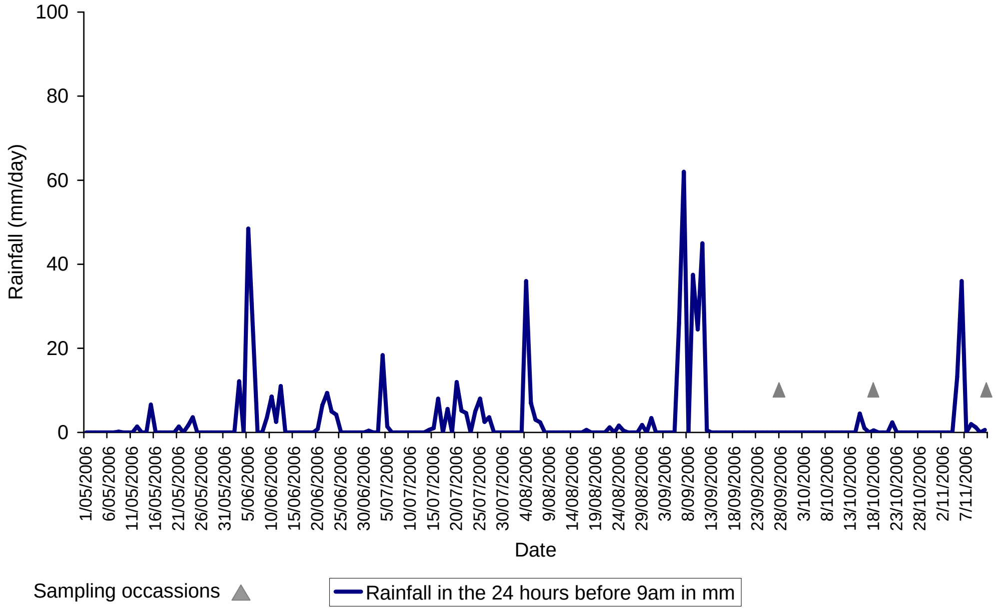

Figure 3. Daily rainfall data 1st May 2006 to 10th November 2006 with sampling occasions indicated.

4.3 Macroinvertebrate Results

General Characteristics of Aquatic Macroinvertebrate Assemblages

A total of 1,074 macroinvertebrates were collected and examined from the Spring 2006 sampling period from Shrimptons and Archers creeks with 39 taxa recorded. The dominant taxa for both sampling sites in Shrimpton's and Archer's creeks were the true fly larvae (Dipterans).

From Archers Creek 31 were recorded, comprised mainly of true fly larvae with 11 taxa, dragon fly larvae (Odonates) with 6 taxa and freshwater snails (Gastropods) with 3 taxa. In Shrimptons Creek 27 taxa were recorded, comprised of true fly larvae with 6 taxa, and dragon fly larvae and freshwater snails with 5 taxa each, and true bugs (Hemipterans) with 3 taxa.

A total of 35 taxa were recorded from Archers Creek in the previous four sampling occasions from Spring 2004 to Autumn 2006 and 32 taxa were recorded from Shrimptons Creek in this same period.

Neither the Sydney Hawk Dragonfly *Austrocordulia leonardi* (listed as endangered under the *FM Act*) or the Adams Emerald Dragonfly *Archaeophya adamsi* (listed as vulnerable under the *FM Act 1994*) were observed in Spring 2006 and are not listed in historical data supplied.

Macroinvertebrate results for comparable samples (Table 3) are consolidated in Appendix 4.

Taxa richness

Comparison of Spring and Autumn macroinvertebrate results from 2004 to 2006 indicated generally more taxa were collected from Archers Creek than Shrimptons Creek in each season (Figure 4). The variance of the Spring 2006 data with nine collected samples was similar to other seasons where only 3 samples were collected for both creeks. Variance is represented by the lie associated with each average value score and represents plus and minus one standard deviation of the average score.

To place taxa richness of Archers and Shrimptons creeks in context with the other creeks of the City of Ryde Biological/Chemical Water Quality Monitoring Strategy taxa richness was summarised for all seasons sampled (Figure 5). More taxa on average were collected in Buffalo, Porters and Terrys creeks compared with Shrimptons Creek. The average number of taxa collected in Archers Creek was intermediate to that of Shrimptons Creek and the other three creeks.

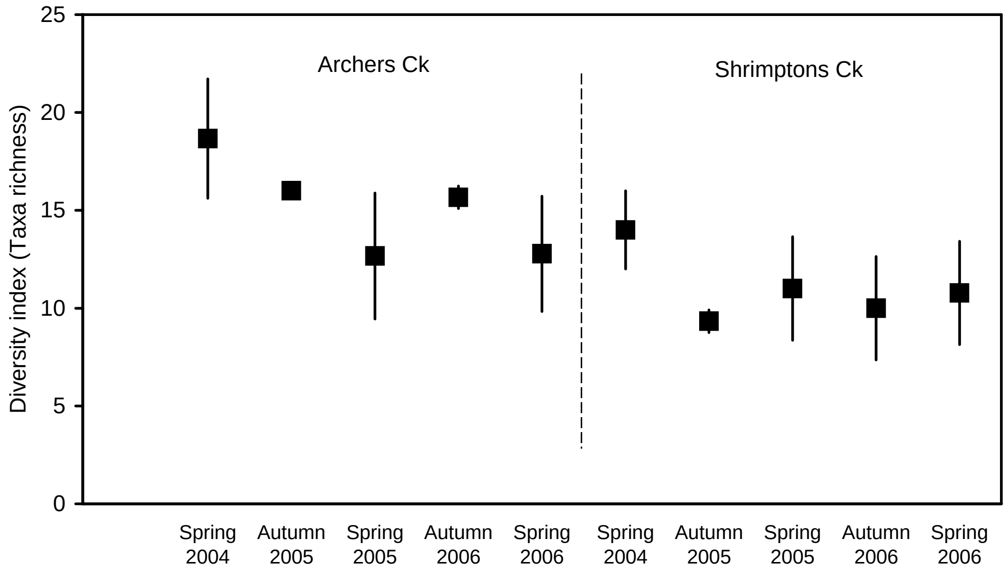

Figure 4. Taxa richness by season

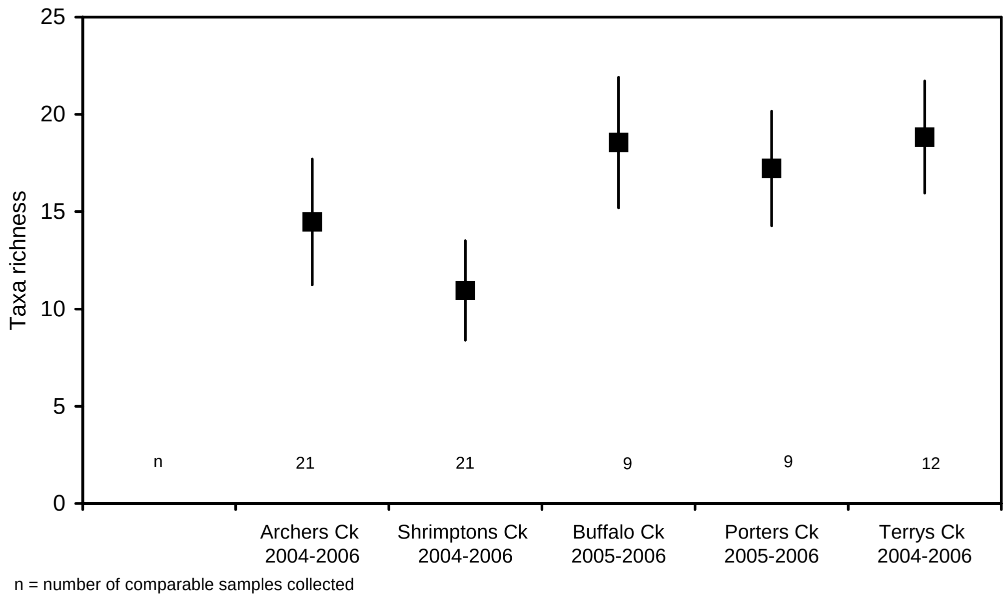

Figure 5. Taxa richness of all creeks of monitoring program

EPT richness

Comparison of Spring and Autumn macroinvertebrate results from 2004 to 2006 indicated EPT taxa were rarely collected from Archers and Shrimptons creeks. The most EPT taxa were collected in Spring 2004, although typically one per sample (Figure 6).

To place EPT taxa richness of Archers and Shrimptons creeks in context with the other creeks of the City of Ryde Biological/Chemical Water Quality Monitoring Strategy EPT taxa richness was summarised for all seasons sampled (Figure 7). This summary indicated EPT taxa were rarely collected from the five streams, although Porters Creeks on most occasions had a single EPT family in each sample.

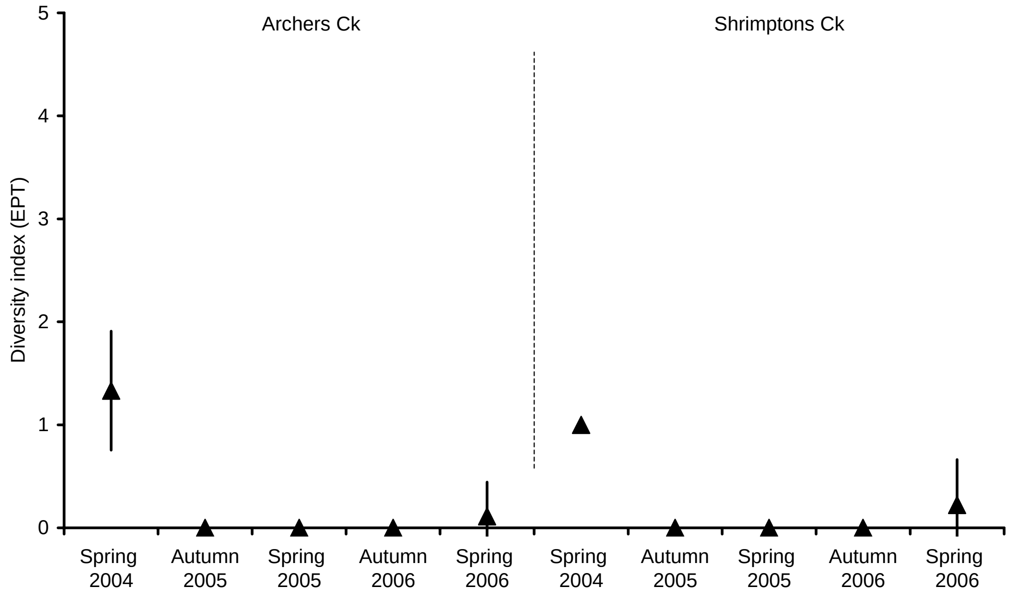

Figure 6. EPT richness by season

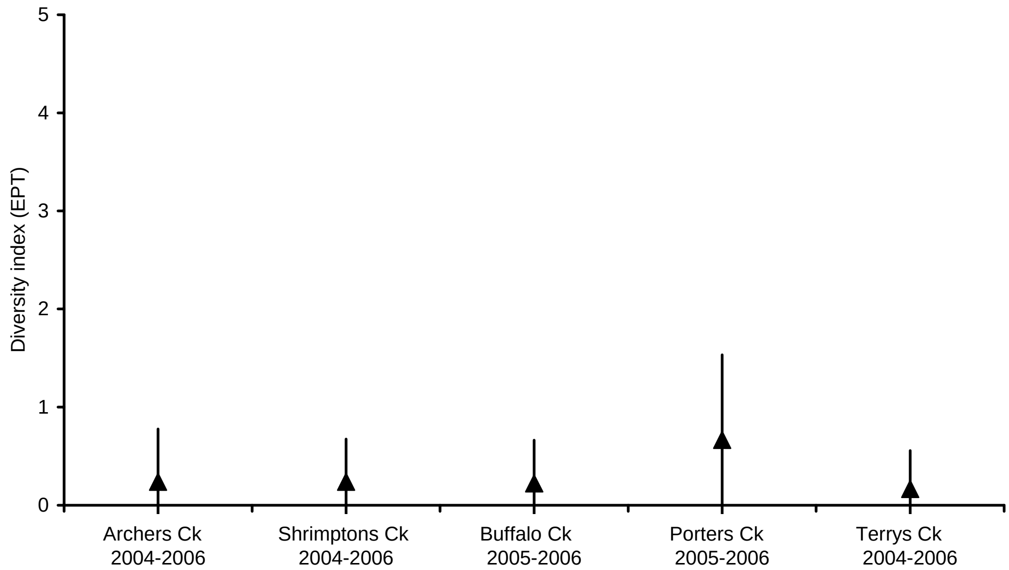

Figure 7. EPT richness of all creeks of monitoring program

SIGNAL-F

Ecosystem health as described by the SIGNAL-F biotic index results indicate pollution transport occurs in the catchments of Archers and Shrimptons creeks (Figure 8).

In context with other creeks of the City of Ryde Biological/Chemical Water Quality Monitoring Strategy ecosystem health of all creeks is impaired (Figure 9). Average ecosystem health as measured with SIGNAL-F was marginally lower for Shrimptons Creek but not significantly, when assessed in terms of ANZECC (2000) guidelines that incorporates the range of ecosystem health that has been recorded from macroinvertebrate sampling between 2004 and 2006. The range of ecosystem health is represented by the line associated with each average score and represents plus and minus one standard deviation of the average score as recommended by ANZECC (2000). Average scores of these five creeks occur in the probable moderate organic pollution category.

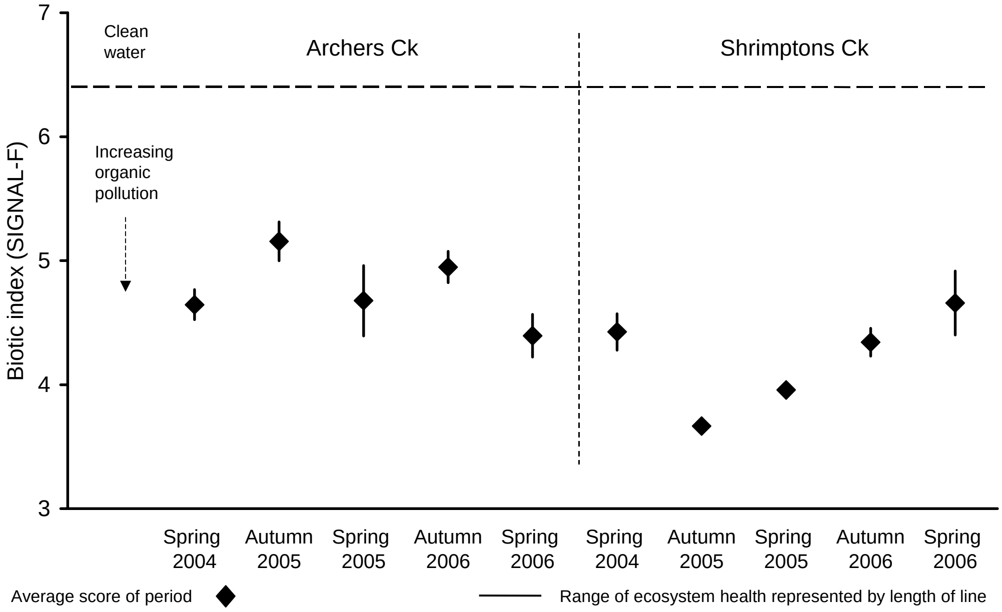

Figure 8. SIGNAL-F by season

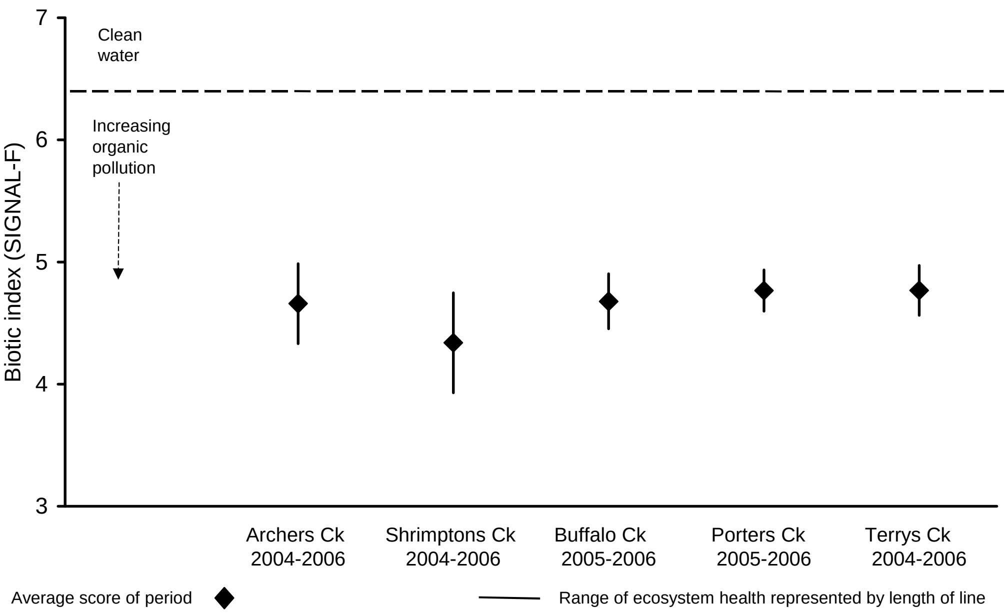

Figure 9. SIGNAL-F of all creeks of monitoring program

AUSRIVAS

Spring season OE50 results from 2004 to 2006 indicate macroinvertebrate communities of Archers and Shrimptons creeks are severely to extremely impaired (Figure 10). Autumn season OE50 results from 2005 to 2006 indicate similar results for Shrimptons Creek and improved results for Archers Creek with results falling in the next higher band of significantly impaired (Figure 11).

In context with other creeks of the City of Ryde Biological/Chemical Water Quality Monitoring Strategy ecosystem health of all creeks was severely impaired for the Spring season edge AUSRIVAS model results (Figure 12). Whereas the Autumn season edge AUSRIVAS model results for Archers Porters and Terrys creeks occurred in the next higher band of significantly impaired while results for Shrimptons and Buffalo creeks remained in the severely impaired band (Figure 13).

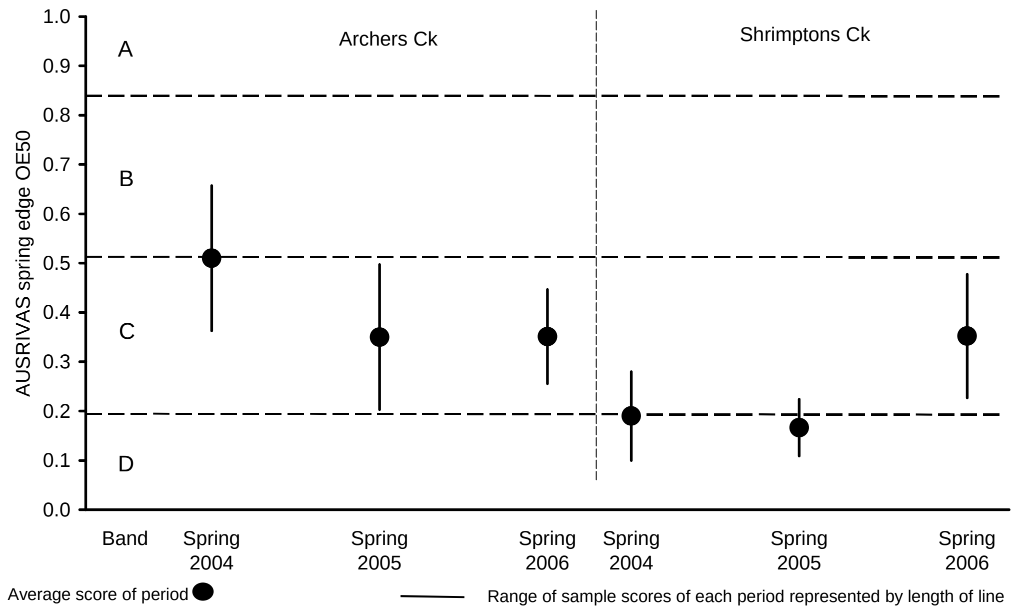

Figure 10. OE50 by season from Spring edge model

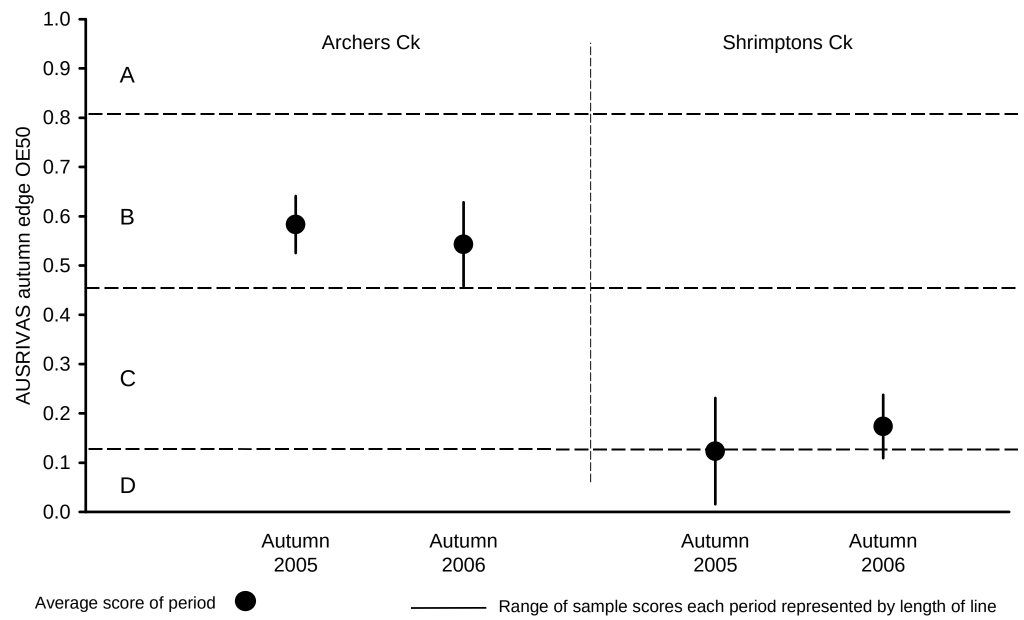

Figure 11. OE50 by season from Autumn edge model

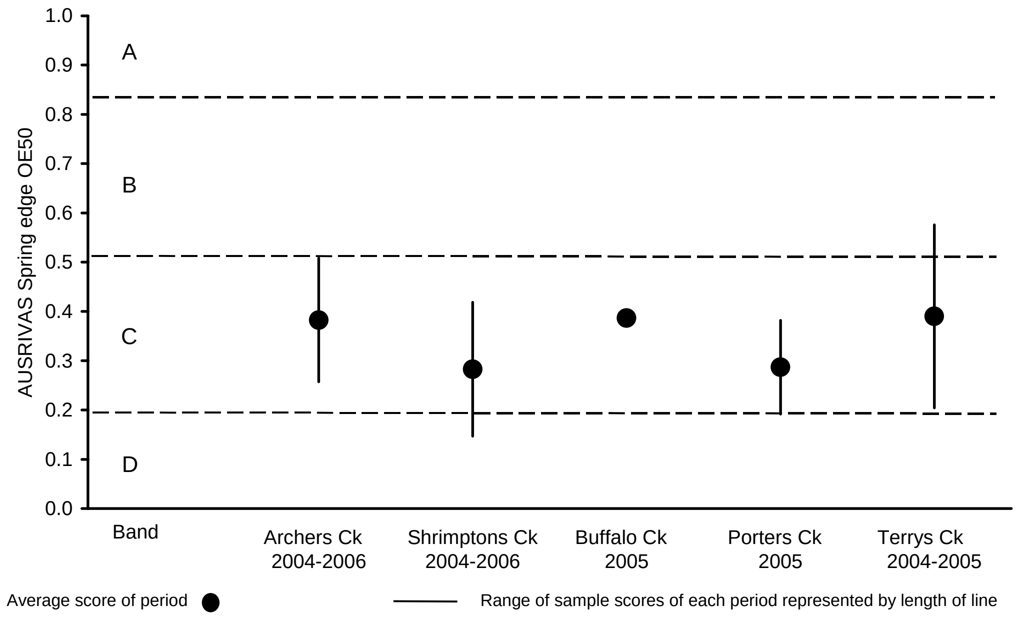

Figure 12. OE50 of all creeks of monitoring program from Spring edge model

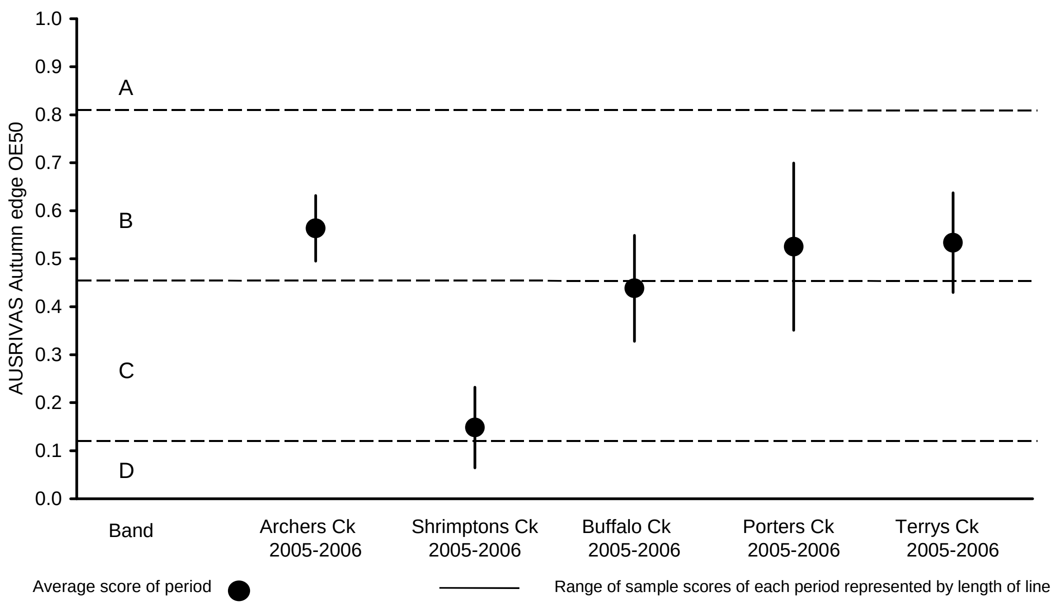

Figure 13. OE50 of all creeks of monitoring program from Autumn edge model

In Archers Creek missing EPT indicator taxa identified by AUSRIVAS output for the Spring edge model listed 14 taxa as missing with two mayfly larvae (Ephemeroptera), two stonefly larvae (Plecoptera) and ten caddisfly larvae (Trichoptera) and 15 taxa for the Autumn edge model with three mayfly larvae (Ephemeroptera), two stonefly larvae (Plecoptera) and ten caddisfly larvae (Trichoptera).

In Shrimptons Creek missing EPT indicator taxa identified by AUSRIVAS output for the Spring edge model listed 14 taxa as missing with two mayfly larvae (Ephemeroptera), two stonefly larvae (Plecoptera) and ten caddisfly larvae (Trichoptera) and 17 taxa for the Autumn edge model with three mayfly larvae (Ephemeroptera), two stonefly larvae (Plecoptera) and 12 caddisfly larvae (Trichoptera).

Across the five creeks of the monitoring program missing EPT indicator taxa identified by AUSRIVAS output for the Spring edge model listed 16 taxa as missing with two mayfly larvae (Ephemeroptera), five stonefly larvae (Plecoptera) and nine caddisfly larvae (Trichoptera) and 17 taxa for the Autumn edge model with three mayfly larvae (Ephemeroptera), six stonefly larvae (Plecoptera) and eight caddisfly larvae (Trichoptera).

AUSRIVAS SIGNAL2

SIGNAL2 scores from the output of the AUSRIVAS (Chessman 2003a) Spring eastern edge model and Autumn eastern edge model are presented in Figure 14 to Figure 17 for Archers and Shrimptons creeks. AUSRIVAS SIGNAL2 scores based on OE50 SIGNAL, particularly for Shrimptons Creek, were more variable than those based on OEO SIGNAL which included additional taxa with less than 50% probability of occurrence in calculation of the OEO SIGNAL scores. The inclusion of these additional taxa reduced variation in this measure.

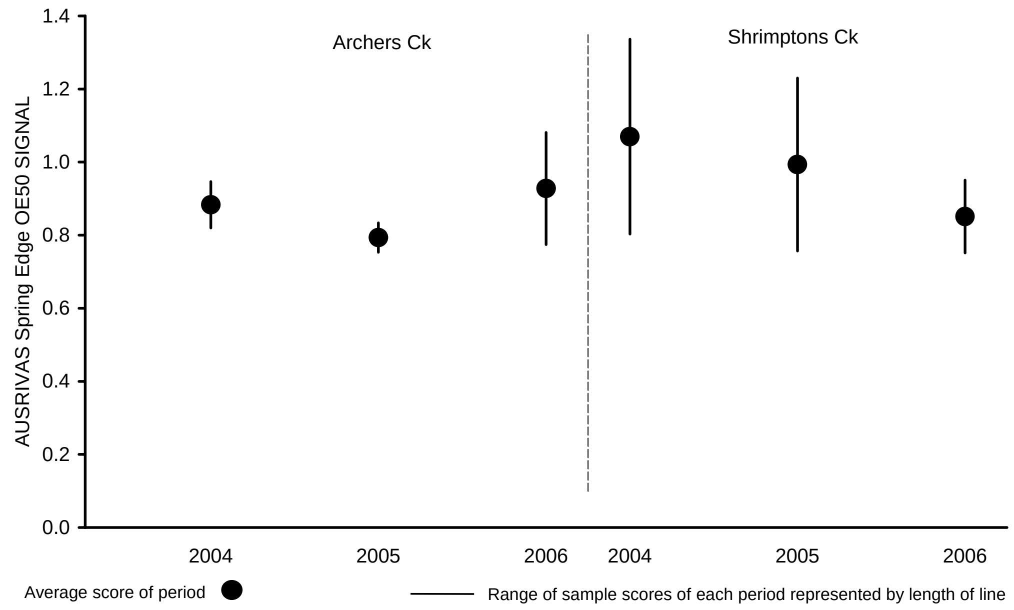

Figure 14. AUSRIVAS SIGNAL2 from OE50 SIGNAL by season from Spring edge model

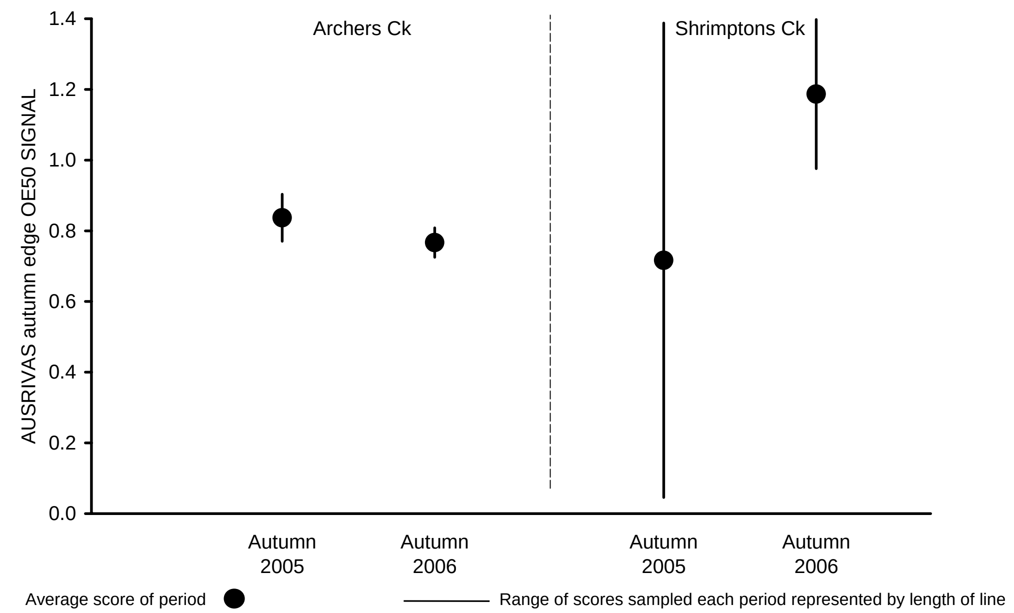

Figure 15. AUSRIVAS SIGNAL2 from OE50 SIGNAL by season from Autumn edge model

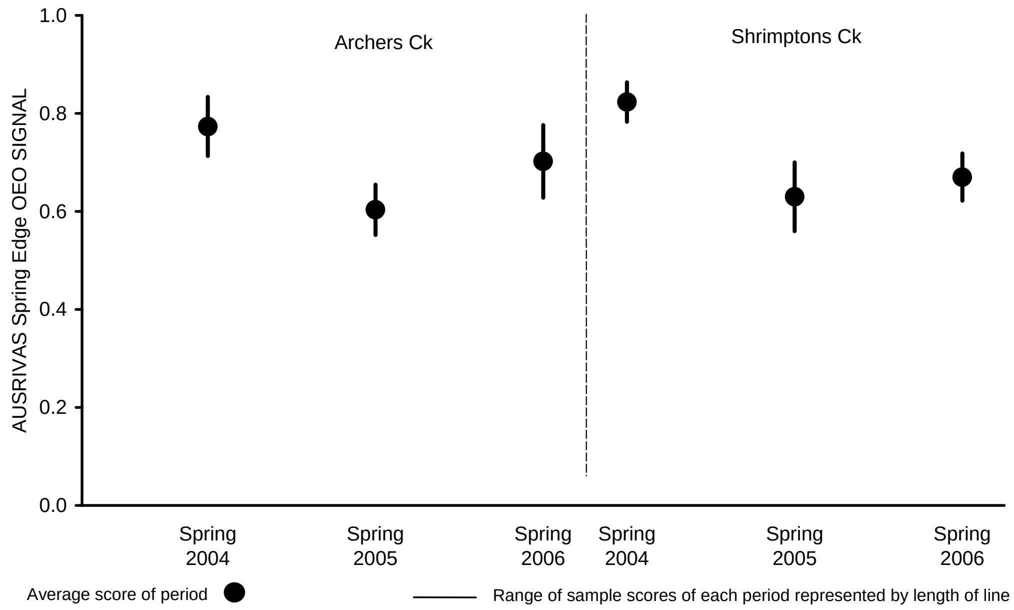

Figure 16. AUSRIVAS SIGNAL2 from OE0 SIGNAL by season from Autumn edge model

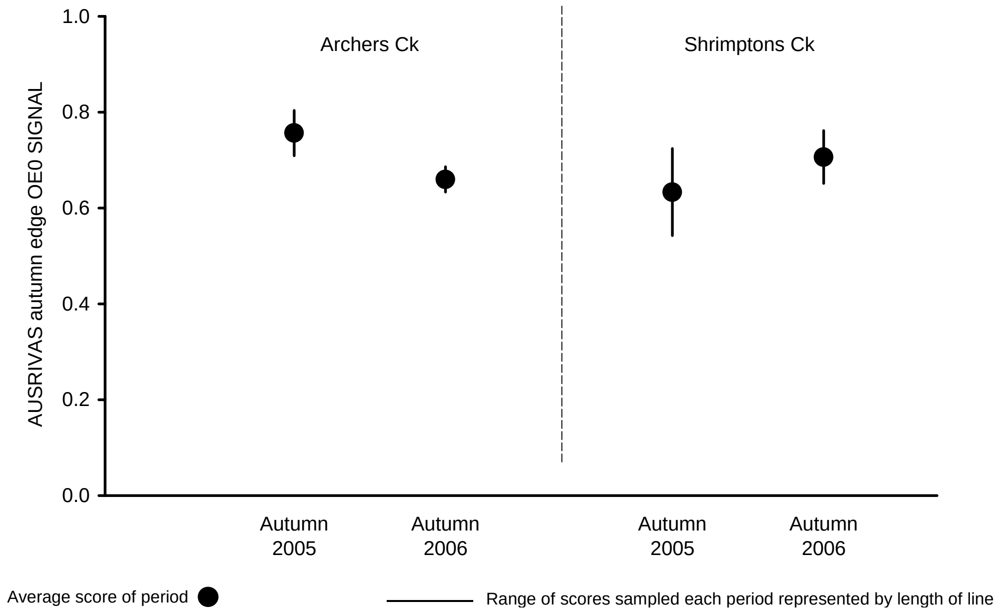

Figure 17. AUSRIVAS SIGNAL2 from OE0 SIGNAL by season from Autumn edge model

The second approach to calculating SIGNAL2 of Chessman (2003b) when calculated with family level taxonomy is most similar to output of the AUSRIVAS SIGNAL2 OEO SIGNAL results. Biplots based on family level taxonomy are presented below (Figure 18 and Figure 19). Spring 2006 samples mostly fell with observations from previous collection periods.

The most useful approach for community group involvement in Streamwatch type programs that do not have access to AUSRIVAS models is presented below in the biplots based on Order, Phylum and Class taxonomy (Figure 20 and Figure 21). Results of Family and Order, Phylum and Class taxonomy fall in a similar area of the biplot.

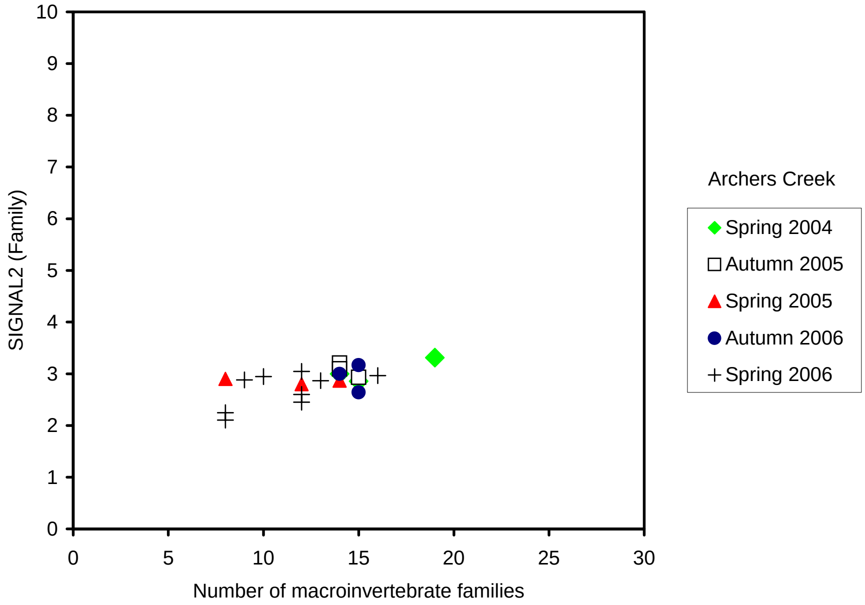

Figure 18. Biplot of SIGNAL2 scores calculated after Chessman (2003b) for Archers Ck based on family level taxonomy

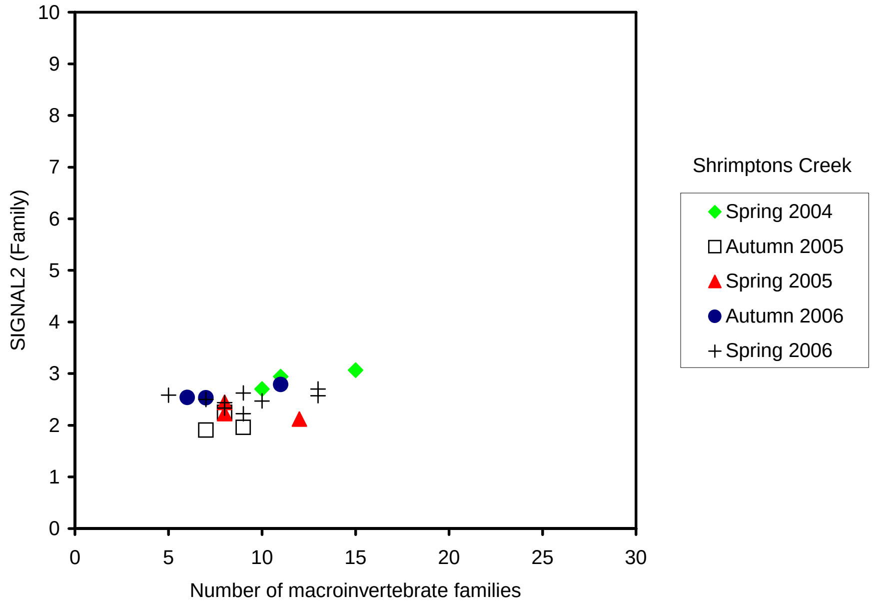

Figure 19. Biplot of SIGNAL2 scores calculated after Chessman (2003b) for Shrimptons Ck based on family level taxonomy

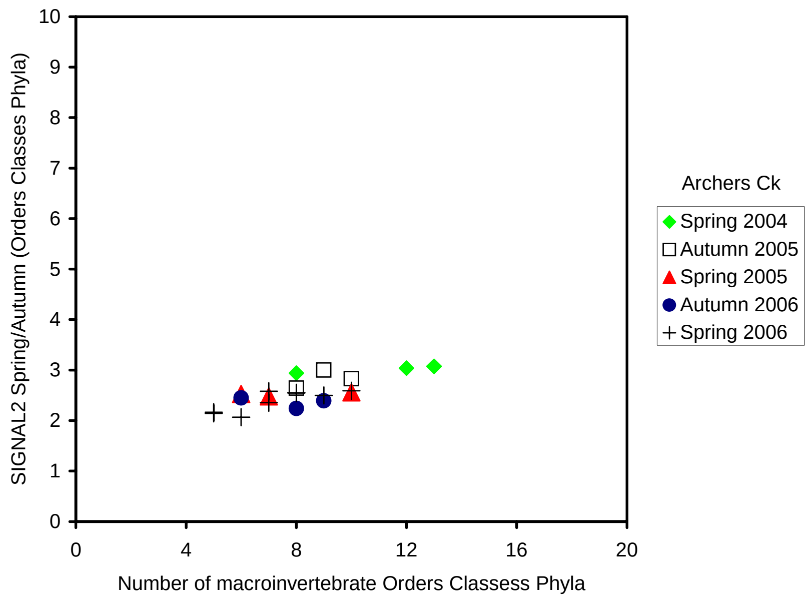

Figure 20. Biplot of SIGNAL2 scores calculated after Chessman (2003b) for Archers Ck based on Order Class and Phyla level taxonomy

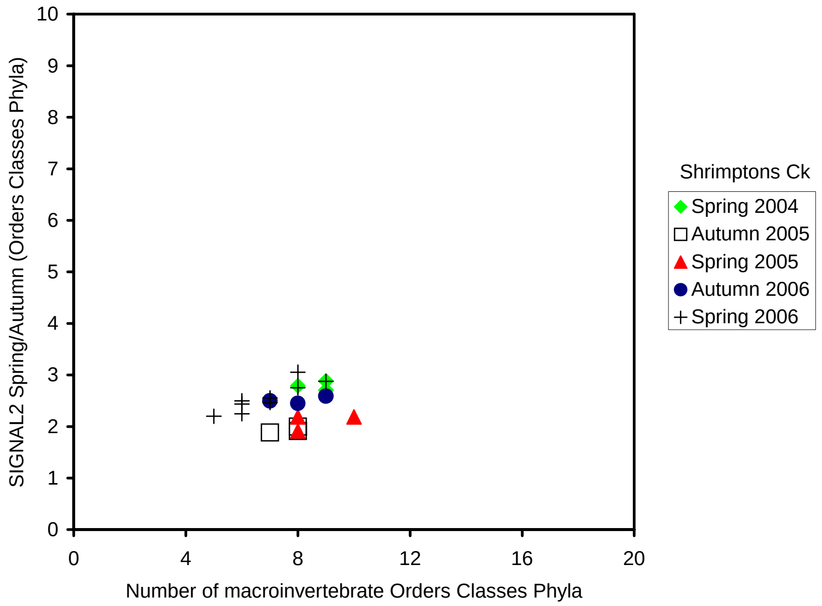

Figure 21. Biplot of SIGNAL2 scores calculated after Chessman (2003b) for Shrimptons Ck based on Order Class and Phyla level taxonomy

Multivariate Analyses

Classification and Ordination

Results of ordination and classification for macroinvertebrate data of 2005 and 2006 from all five creeks indicated three main groups of site samples occurred. One group contained Archers Creek samples for all seasons prior to Spring 2006. Another group contained samples from Spring 2006 of Archers and Shrimptons creeks while the third group contained all other samples (Figure 22).

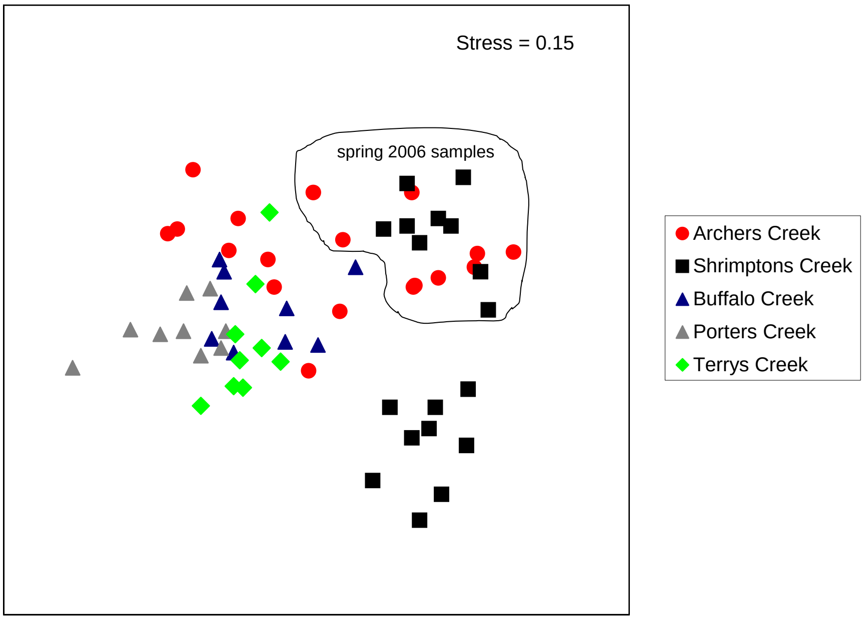

Figure 22. Plot of non-metric multiidimensional scaling ordination results of dimensions 1 and 2 of 3-dimension analysis for 2005 and 2006 data of all creeks.

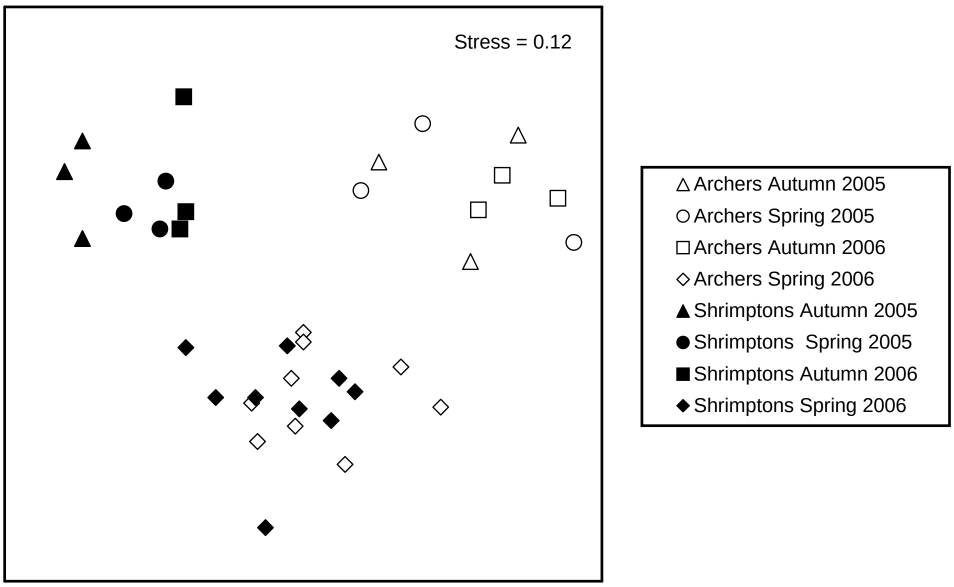

Figure 23. Plot of non-metric multiidimensional scaling ordination results of dimensions 1 and 2 of 2-dimension analysis for 2005 and 2006 data of Archers and Shrimptons creeks.

Results of ordination and classification for macroinvertebrate data of 2005 and 2006 from Archers and Shrimptons creeks indicated three main groups of site samples occurred. One group contained Archers Creek samples for all seasons prior to Spring 2006. Another group contained Shrimptons Creek samples for all seasons prior to Spring 2006 with samples from Spring 2006 of Archers and Shrimptons creeks in the third group (Figure 23).

Results of classification and ordination of Archers Creek macroinvertebrate data from 2005 and 2006 indicated samples from the same season were most similar. The first division of the classification analysis indicated Spring 2006 samples were most dissimilar to all other samples (Figure 24). The same trend was observed for Shrimptons Creek (Figure 25).

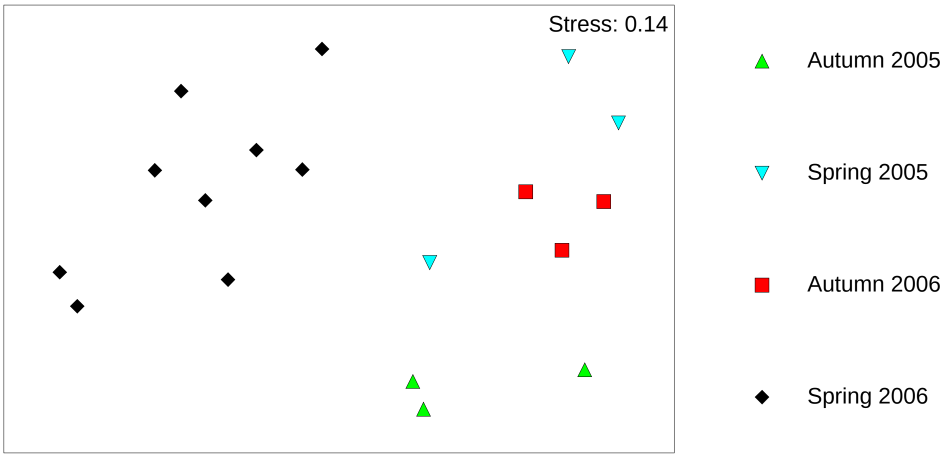

Figure 24. Plot of non-metric Multiidimensional Scaling ordination results of dimensions 1 and 2 of 2-dimension analysis for 2005 and 2006 data from Archers Creek.

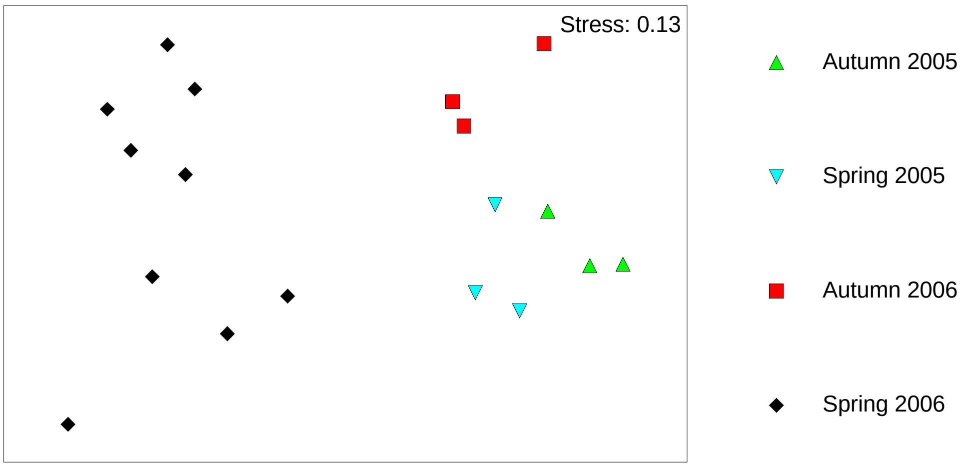

Figure 25. Plot of non-metric Multiidimensional Scaling ordination results of dimensions 1 and 2 of 2-dimension analysis for 2005 and 2006 data from Shrimptons Creek.

SIMPER

Samples collected in the same season for Archers Creek were most similar in community composition whereas comparisons between seasons were less similar (Appendix 5). This is reflected in the pattern observed in the corresponding ordination plot that displayed same season samples were most similar (Figure 24). The same trend was present for Shrimptons Creek (Figure 25, Appendix 5).

In Shrimptons Creek taxa that contributed to these season sample patterns were fewer than occurred in Archers Creek and were dominated by non-insect taxa with generally only one insect taxa present except for Spring 2006 when three insect taxa were present. The dominant taxa abundances also changed between seasons. In contrast, Archers Creek was dominated by insect taxa in all seasons except Spring 2006 when non-insects became more abundant taxa (Appendix 5).

SIMPER indicated the Spring 2006 samples from Shrimptons Creek changed composition to a mix of non-insect and insects and this probably explains the relative closeness of Shrimptons Creek and Archers Creek Spring 2006 samples in the five creek ordination plot of 2005 and 2006 macroinvertebrate data (Figure 22) and the ordination plot of Archers and Shrimptons creeks (Figure 23).

BIOENV

The output of BIOEVN routine is presented in Appendix 6. The correlation of the water quality and physical variables with macroinvertebrate sample data of all five creeks for 2005 and 2006 was quite weak at 0.28. Investigation of Archers Creek records of water quality and physical variables with macroinvertebrate sample data for 2005 and 2006 had mild correlation of 0.56, with total dissolved solids highlighted. Results for Shrimptons Creek produced a moderate 0.77 correlation and indicated Oxidised Nitrogen, Total Kjeldahl Nitrogen, Total Dissolved Solids, Bedrock and Boulder as best explaining sample separation.

5 Discussion

Water quality

The results of the Spring 2006 water quality sampling regime for Shrimptons and Archers creeks of the Biological and Chemical Water Quality Monitoring Strategy of Ryde City Council indicate that urban pollution transport is having a moderate impact on the instream water quality. This impact is notable by records of low levels of dissolved oxygen and the high levels of nutrients. This trend has also been observed in previous sampling events in 2005 and 2006 (Ecowise 2004, 2005a 2005b 2006).

The oxygen balance in waters is dependant upon physical, chemical and biochemical conditions in the water body. Oxygen input results from 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 the respiratory rate of aquatic organisms increases with temperature (Connell, 1993). Aquatic ecosystems are thus acutely sensitive to any reduction in dissolved oxygen levels.

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.

Nevertheless, the poor levels of dissolved oxygen in the water and non-conformance to the ANZECC (2000) guidelines for all samples at Shrimptons and Archers creeks in Spring 2006 can be attributed to the low flows being experienced in southeastern New South Wales during the current drought. Furthermore, the accumulation of organic matter in the form of plant debris during this period of low flow increases the decomposition load within the relatively small streams and respiration of the decomposers increases. This leads to further reductions in dissolved oxygen levels.

Historically, Shrimptons and Archers creeks have performed consistently with the current data with no past sample event producing a dissolved oxygen level within the acceptable range of 85% - 110% saturation levels. This suggests the creeks have been influenced by urban pollution for a long period of time. The current results for Shrimptons and Archers creek show a small improvement in the mean levels of dissolved oxygen over Spring 2006 but this may be reduced again with a significant rain period due to the burden of more nutrient and debris loads.

Faecal coliform concentrations varied widely between sample months, especially for Archers Creek, which was found to be well within recommended ANZECC (2000) levels in September 2006 and then exceeded the accepted secondary contact levels in November 2006. This is to be expected because of the variety of factors that can influence faecal contamination of streams including urban runoff, presence of waterfowl and other wildlife and illegal dumping of waste. 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 occurance 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.

Together with colour, turbidity determines whether stream water is aesthetically acceptable to the public. Turbidity determines the depth to which sunlight will penetrate a water body and changes in light penetration can alter the composition of aquatic organisms. It can be detrimental to larger organisms that are unable to locate a suitable food supply yet can be beneficial in reducing algal blooms by limiting the amount of incident light necessary for photosynthesis. The relatively high level of turbidity recorded in November 2006 at Shrimptons Creek was a one off occurrence and did not appear to effect macroinvertebrate assemblages at this site.

Nitrogen and phosphorus are essential elements for life. They are found naturally in the earth's crusts (phosphorus) and atmosphere (nitrogen) but are not directly available to most living organisms. As a result, lack of these elements is often the factor limiting growth of algae, bacteria and other plants. Increasing the readily available phosphorus and nitrogen loads in streams can lead to algal blooms and excessive plant growth. The elevated nutrient levels found in Shrimptons and Archers creeks during Spring 2006 were most likely from urban runoff from eroded catchments, decomposing organic matter and low dissolved oxygen levels, which is known to be a significant factor in increasing the amounts of readily available nutrients from sediments via chemical synthesis.

Ammoniacal nitrogen is often present in sewage effluent, because of the decomposition of nitrogen containing compounds in the treated waste. The undissociated form, NH_3, is far more toxic to aquatic life than the ionic form, NH_4^+. During low pH and temperature NH_3 dissociates to the less toxic form NH_4^+. This is then reversed during periods of high pH and temperature. Neither high pH or temperature were recorded during the Spring 2006 sampling season and relatively low levels of ammoniacal nitrogen were observed. These results are consistent with historical data as no samples from Shrimptons and Archers creeks have exceeded the recommended ANZECC (2000) guideline levels for ammoniacal nitrogen.

Aquatic ecosystems are influenced by pH because of its effects on chemical speciation. As previously discussed the toxicity of ammoniacal nitrogen is extremely pH dependant. Most natural water bodies are slightly alkaline but acidic conditions can arise because of the breakdown of organic matter. The pH results for Shrimptons Creek have exceeded the ANZECC (2000) guidelines once in Spring 2006 and in over half of the historical samples. This may be attributed to high organic loads from urban runoff and the overall size of the catchment and stream in relation to Archers Creek.

Macroinvertebrates

Results of the Spring 2006 macroinvertebrate sample collection of the Biological and Chemical Water Quality Monitoring Strategy of Ryde City Council indicate Archers and Shrimptons creeks have impaired macroinvertebrate communities with similar results recorded in Spring 2004 to Autumn 2006. Sensitive taxa as measured by EPT richness were virtually absent and a number of predicted EPT taxa were not observed. Multivariate analyses suggested a change in composition of Shrimptons Creek samples occurred in Spring 2006, but this was not reflected in taxa richness. Direct measurement of ecosystem health using SIGNAL-F and measurement via AUSRIVAS predictive model OE50 outcomes both reflected impaired ecosystem health of Archers and Shrimptons creeks. Differences between sampling periods were more evident in SIGNAL-F than O/E ratios. AUSRIVAS OE50 SIGNAL2 was the only univariate measure to give a contradictory result. The AUSRIVAS OEO SIGNAL2 measure improved results in line with SIGNAL-F and AUSRIVAS OE50 and is perhaps a more suitable measure of AUSRIVAS output than AUSRIVAS OE50 SIGNAL2.

AUSRIVAS OEO SIGNAL2 includes more taxa in its calculation than AUSRIVAS OE50 SIGNAL2, and this additional taxa inclusion is responsible for reduced variance compared with AUSRIVAS OE50 SIGNAL2 particularly for Shrimptons Creek results.

The biological signature or community (assemblage) structure of Archers and Shrimptons creeks has virtually no indicator EPT taxa. SIMPER results indicated community structure, in Archers Creek was dominated by tolerant non-insect taxa whereas Shrimptons Creek generally had a community structure dominated by tolerant insect taxa although tolerant non-insect taxa are also present. Abundances of these taxa changed between sampling periods, which influenced observed multivariate patterns and also would have contributed to recorded SIGNAL-F variation of different sampling periods. As AUSRIVAS models use binary data no contribution to these measures is provided by abundances.

ANZECC (2000) indicates adequate base line data is required to establish an acceptable level of change before informed management judgements can be made that take account of natural variability in an indicator. ANZECC (2000) suggests three to five years of data be gathered from control or reference locations. To this end, for the macroinvertebrate indicator use of the Sydney specific SIGNAL-F index and NSW AUSRIVAS predictive models provides this data by the statistically defined 10th percentile of mean reference condition values. Natural variability of each site with comparable data are being gathered under the Biological and Chemical Water Quality Monitoring Strategy. The range of each measure has been plotted in this report with +/-1 standard deviation of the mean for basing ecological decisions (ANZECC, 2000). Presenting data in this way attempts to take account of variation at study sites and provide a basis in future years to enable management tracking and or as a basis for making management decisions.

The full extent of variation at Archers and Shrimptons creeks may not have yet been captured given the relatively dry period from which comparable date were available. Collected to date from Archers Creek were 35 taxa and 32 taxa from Shrimptons Creek. More taxa may be collected under wetter conditions and is suggested by two other creeks with similar SIGNAL-F scores that have yielded a greater number of taxa. Waitara Creek (NB83) has an average SIGNAL-F of 4.8, and 45 taxa have been collected over the last ten years that incorporate dryer and wetter periods. Upper Cattai Creek (NC8) has an average SIGNAL-F of 4.3, and 43 taxa have been collected over the last 11 years (SWC 2005). Aquatic mite and worm taxa in SWC (2005) were pooled to allow comparison here.

The SIGNAL-F version (Chessman *et al.* submitted) has been submitted for publication and until accepted by the respective journal SIGNAL-F scores presented in this report must be treated as interim results.

Growns *et al.* (1997) found taxa (family) richness to be a weaker measure of the effects of pollution by municipial sewage effluent and urban stormwater than EPT (family) richness and SIGNAL (original version Chessman, 1995) for 12 streams of outer suburban Sydney and the lower Blue Mountains. Walsh (2006) in a study of 16 streams subject to urban disturbance in eastern Melbourne found SIGNAL and EPT richness to be more sensitive indicators than OE ratios of the AUSRIVAS models and taxa (family) richness. The non-linear relationship of changes in community structure in response to pollution is probably responsible for weakness of the family richness measure.

Due to the status of EPT taxa in City of Ryde study creeks, this measure is limited in being able to infer information of any future negative impacts on stream health. In light of the lesser sensitivity of taxa richness determined by Growns *et al.* (1997) and Walsh (2006) in urban streams, and the limitation in EPT richness noted here, SIGNAL-F, OE50 and OEO SIGNAL2 would be better for basing management tracking and decisions upon. Although the sensitivity of OE50 has been questioned by Walsh (2006).

A limitation with AUSRIVAS models is the difference in band threshold values for Autumn, Spring, and combined Autumn Spring models. Although the threshold (10^{th} percentile) for band A (similar to reference) is virtually the same for these three models, mixing Autumn and Spring output should not occur as Coysh *et al.* (2000) indicates mixing assessments based on different season models should be discouraged. Hence, Autumn and Spring results were presented separately for AUSRIVAS output. SIGNAL-F (Chessman *et al.*, submitted) does not have this seasonal limitation.

Chessman *et al.* (2006) determined twice as many taxa appeared to favour sites in good geomorphic condition as favoured poor sites. Chessman *et al.* (2006) also indicated many taxa associated with sites in poor condition are introduced taxa. The dominant aquatic snail was the introduced *Physa acuta* and aquatic worms had numerous specimens of the introduced *Lumbriculus variegatus.* Chessman *et al.* (2006) suggests rehabilitation of geomorphic condition can assist in the rehabilitation of native riverine biota.

Walsh (2004) determined community composition was strongly explained by the gradient of urban density and that most sensitive taxa were absent from urban sites with greater than 20% connection of impervious surfaces to streams by pipes.

6 Recommendations

Diversity index Taxa Richness

In light of the performance reported by Growns *et al.* (1997) and Walsh (2006) it is recommended that the univariate measure Diversity index Taxa Richness is not included in future reports.

AUSRIVAS SIGNAL2 - 0E50 SIGNAL & OEO SIGNAL

Based on the contradictory results from AUSRIVAS SIGNAL2 0E50 SIGNAL and its large associated variance, it is recommended that this univariate measure not be included in future reports, and that AUSRIVAS SIGNAL2 OEO SIGNAL be included instead as the later presented less variation that would allow detection of future change.

Another AUSRIVAS measure to consider – the combined season eastern edge model

Coysh *et al.* (2000) indicates data collected from two habitats in two seasons will give the most comprehensive AUSRIVAS site assessment, as this should yield the most comprehensive list of families. The lack of riffle habitat in City of Ryde study creeks prohibited the two habitat approach. This leaves the next best option, the combined season eastern edge model where Spring and Autumn data are combined. Ecowise (2005b) suggested the combined season model does not allow for changes in condition between seasonal sampling events for the City of Ryde strategy. It is thought that if less variance is afforded by the combined season model it may offer advantages in tracking changes in the City of Ryde relatively long term Biological and Chemical Water Quality Monitoring Strategy. Hence, at the time of the next report an examination of the AUSRIVAS combined season eastern edge model output could be performed to see if it affords less variance than the Autumn and Spring model outputs.

Summary of univarate methods recommended for future reports

- Diversity index EPT (mayfly, stonefly, caddis fly) richness
- Biotic index SIGNAL-F
- Output from AUSRIVAS predictive models (eastern edge Autumn; eastern edge Spring; and eastern edge combined seasons)
- AUSRIVAS OE50
- AUSRIVAS SIGNAL2 - OEO SIGNAL

Cost efficient design to incorporate relatively drier and wetter periods

To obtain a measure of variation in community structure in relatively drier and wetter periods, it is recommended that consideration be given to sampling twice within a season with two replicates per site. Sampling should occur at all five sites of the Biological and Chemical Water Quality Monitoring Strategy, rather than rotation of two sites each year that may not allow incorporation of data from wetter periods. This would represent four samples from each site in each season and an increase of only two samples over the current 18 collected in Spring 2006.

A second advantage of collecting four samples from each site in each season is that an additional multivariate analysis tool, Analysis of Similarities (ANOSIM), could be employed. This tool would allow investigation of differences of community structure between site groups between sample periods.

Stormwater Drainage Connection

Conclusions of research conducted in the greater Melbourne area that looked at water quality, epilithic diatoms, benthic algae and macroinvertebrate indicators suggested minimisation of directly piped stormwater drainage connection of impervious surfaces to be beneficial in mitigation of urban impacts on receiving streams (Hatt *et al.*, 2004; Walsh, 2004; Taylor *et al.* 2004; Newall & Walsh, in press). The primary degrading process to urban steams is suggested to be effective imperviousness (the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater pipes) (Walsh *et al.*, 2005a) provided sewer overflows, sewage treatment plant discharges, or long-lived pollutants from earlier land uses are not operable as these can obscure stormwater impacts (Walsh *et al.*, 2005b).

The direct connection of impervious surfaces to a stream allows small rainfall events to produce surface runoff that cause frequent disturbance to the stream through regular delivery of water and pollutants (Walsh *et al.*, 2005). Drainage methods that intercept small rainfall events and facilitate infiltration, evaporation, transpiration or storage for later in-house use contribute to near natural runoff and minimise the impact of effective imperviousness. An example of one such method being used is installation of stormwater drainage pits for new residential and redevelopment applications. In catchments with existing drainage networks, policies that facilitate infiltration, evaporation, transpiration or storage for later in-house use will gradually benefit stream health in the longer term based on outcomes of research conducted in Melbourne.

If the City of Ryde can find resources in the future, it is recommended that calculation of the percentage of effective imperviousness in each of the five catchments under the Biological and Chemical Water Quality Monitoring Strategy be made. This calculation would then allow ranking of streams by this measure. This ranking could be used to guide allocation of resources to yield ecological benefit via: enhancement of in-stream habitat; restoration of riparian zones; or pollution load reductions.

Method of tracking for community group involvement

A challenge for community group involvement is providing an interpretable way of tracking results without the need for complex statistical analyses. Community group involvement in sampling other creeks of the City of Ryde would help expand knowledge of the district. The Chessman (2003b) approach of calculating SIGNAL2 with Order, Class, and Phylum taxonomy may be an option to allow tracking by community groups. This approach offers some indication of what the condition of each site may be (Chessman, 2003b). Notable community findings could be used as a basis for further investigation under the Biological and Chemical Water Quality Monitoring Strategy of Ryde City Council.

This method does have a draw back. The borders between quadrants providing explanation of water quality categories, need to be set against reference site data of the region (Figure 2). Sydney Water may be able to assist with setting these boundaries using suitable data already to hand.

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Appendix 1 Quality assurance

Sydney Water Analytical Services is a quality business organisation, certified to AS/NZS ISO 9001:2000 *Quality management systems - requirements* certification number 2764, issued by Benchmark 31st November 2004 for the Monitoring Process Management System. All investigations performed for the production of this report, and all business operations of the organisation, have been conducted to the requirements of this standard including project management, macroinvertebrate sampling, water quality sampling and interpretive reporting.

Macroinvertebrates have been identified and enumerated to the genus or species taxonomic level, (as appropriate for the study) by the Aquatic Ecology team. The method used SSWI433 *In-house test method macroinvertebrate cataloguing, identification and counting* is in compliance with the requirements of AS ISO/IEC 17025:1999 *General Requirements for the Competence of Testing and Calibration Laboratories* was added under technical accreditation number 610 issued by National Association of Testing Authorities (NATA) in 1997. In particular macroinvertebrate identification was performed with appropriate published keys listed in Hawking (2000), internal keys to the macroinvertebrate collection, unpublished descriptions and voucher specimens. Where a specimen could not be keyed to a formally described species, a morphospecies number has been assigned as per in-house test method SSWI433. Terrestrial macroinvertebrate morphospecies have been shown to produce similar patterns to those obtained using formally described species (Oliver and Beattie, 1996).

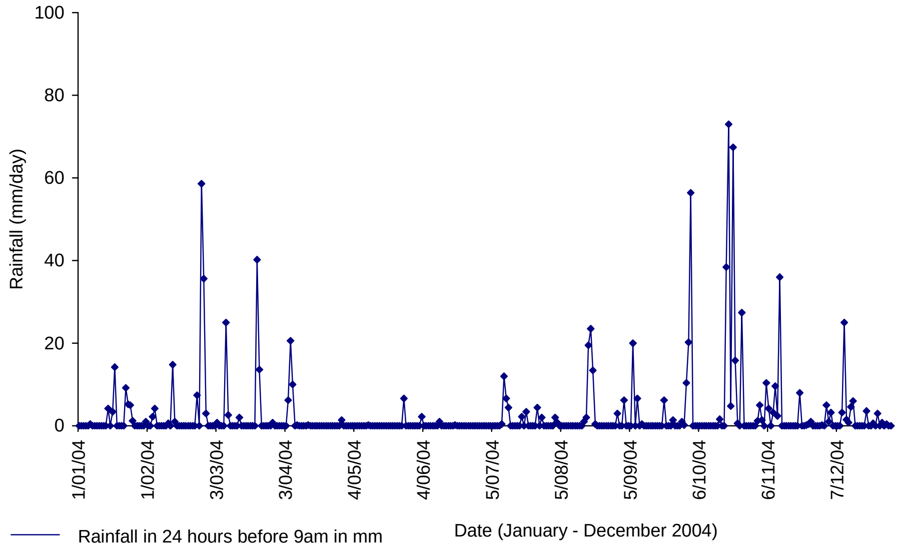
Quality assurance was conducted as per SSWI434 In-house test method quality control of macroinvertebrate identification, counting and archiving of collections in compliance with the requirements of AS ISO/IEC 17025:1999 General Requirements for the Competence of Testing and Calibration Laboratories was added under technical accreditation number 610 in 1997. Quality assurance was conducted on at least 5% of samples collected for this study, and identification and counting errors on average are less than 10% for the study.

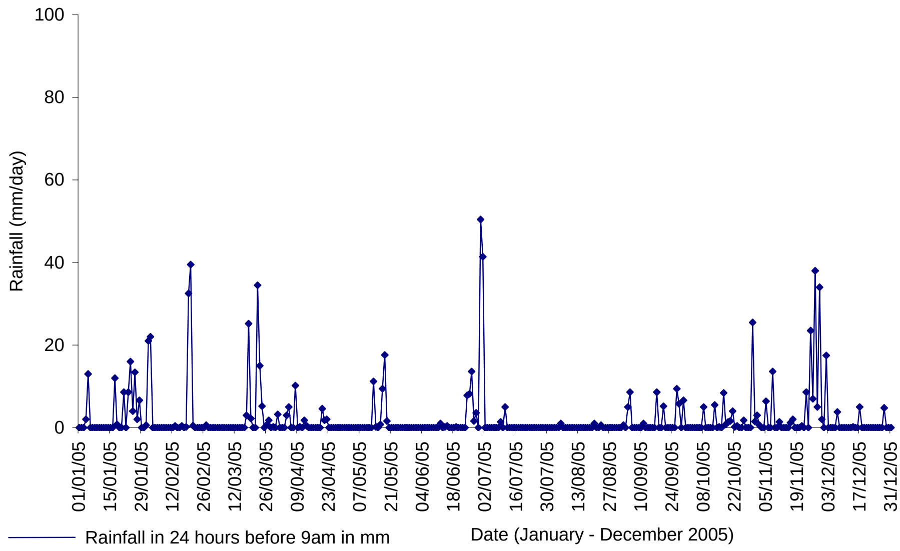
Appendix 2 Water quality results

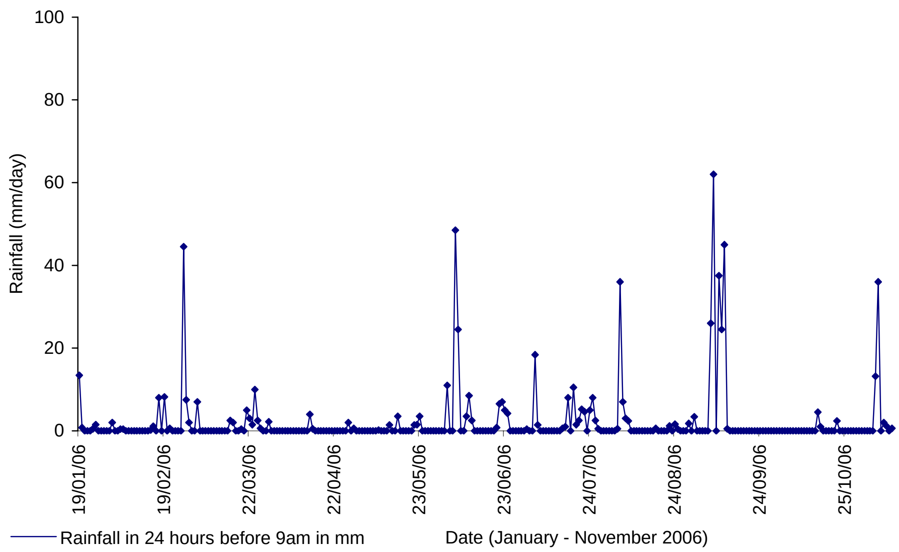
Stream	Site code	Season	Sample date	Faecal Coliforms	Ammonia	Oxidised Nitrogen NOx	Total Phosphorus TP	Total Kjeldahl Nitrogen TKN	Total Nitrogen TN	Alkalinity	Turbidity	Conductivity	Total Dissolved Solids	pH	Dissolved Oxygen DO
				CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L	mg CaCO3/L	NTU	µS/cm	mg/L		mg/L
Shrimptons Ck	Site 2	spring 2006	28/09/06	69	130	140	64	580	720	94.5	7.8	717	420	7.12	4.33
Archers Ck	Site 5	spring 2006	28/09/06	160	5	5	104	520	520	83	2.0	509	293	7.37	6.53
Shrimptons Ck	Site 2	spring 2006	18/10/06	560	10	20	136	1180	1200	66.5	6.3	481	311	6.54	2.21
Archers Ck	Site 5	spring 2006	18/10/06	340	5	10	90	500	510	70	2.3	448	295	6.93	3.94
Shrimptons Ck	Site 2	spring 2006	10/11/06	880	70	1200	68	800	2000	58	96.7	384	265	7.41	4.16
Archers Ck	Site 5	spring 2006	10/11/06	1700	20	40	50	360	400	84	1.8	502	310	7.21	7.19
Terrs Ck	Site 1	autumn 2006	9-10/03/06	160	<10	60	30	310	370	50	2.27	381	180	6.82	4.99
Shrimptons Ck	Site 2	autumn 2006	9-10/03/06	330	40	<10	50	380	390	85	4.56	435	230	6.74	2.13
Porters Ck	Site 3	autumn 2006	9-10/03/06	9800	820	760	20	1500	2300	48	1.88	3712	2200	7.40	7.41
Buffalo Ck	Site 4	autumn 2006	9-10/03/06	220	130	470	70	500	1000	90	7.96	738	390	7.19	4.36
Archers Ck	Site 5	autumn 2006	9-10/03/06	140	90	80	100	520	600	95	2.52	1482	830	6.98	4.09
Terrs Ck	Site 1	autumn 2006	19-20/04/06	560	450	90	100	1100	1200	45	3.20	306	180	6.95	2.40
Shrimptons Ck	Site 2	autumn 2006	19-20/04/06	860	30	30	80	480	510	40	5.0	281	160	6.74	4.61
Porters Ck	Site 3	autumn 2006	19-20/04/06	290	350	630	20	700	1300	45	2.3	3792	2100	7.63	8.30
Buffalo Ck	Site 4	autumn 2006	19-20/04/06	170	90	450	60	470	920	70	5.1	749	400	7.23	4.64
Archers Ck	Site 5	autumn 2006	19-20/04/06	240	90	470	70	390	860	45	4.1	259	150	7.09	4.38
Terrs Ck	Site 1	autumn 2006	9-10/05/06	66	70	240	50	380	620	60	2.35	358	220	7.07	3.98
Shrimptons Ck	Site 2	autumn 2006	9-10/05/06	750	20	40	80	340	380	35	7.69	264	140	6.76	5.04
Porters Ck	Site 3	autumn 2006	9-10/05/06	40	400	650	10	800	1400	0.25	1.17	2916	1700	7.34	8.33
Buffalo Ck	Site 4	autumn 2006	9-10/05/06	110	60	480	60	240	720	90	4.39	667	400	7.32	4.72
Archers Ck	Site 5	autumn 2006	9-10/05/06	28	50	370	40	300	670	55	5.13	245	120	7.19	6.31
Terrs Ck	Site 1	spring 2005	6-7/09/05	300	59	48	10	90	140	43	6.5	187	140	6.66	8.10
Shrimptons Ck	Site 2	spring 2005	6-7/09/05	90	5	37	4	28	65	42	7	164	140	6.72	4.31
Porters Ck	Site 3	spring 2005	6-7/09/05	500	110	58	2	240	300	37	3	6141	4000	6.97	8.72
Buffalo Ck	Site 4	spring 2005	6-7/09/05	16	10	50	8	27	77	79	5.5	620	380	6.98	6.19
Archers Ck	Site 5	spring 2005	6-7/09/05	2000	17	26	11	56	82	56	10	245	160	6.84	5.56
Terrs Ck	Site 1	spring 2005	11-12/10/05	2000	10	33	10	52	85	47	2.2	245	180	7.14	4.49
Shrimptons Ck	Site 2	spring 2005	11-12/10/05	32000	16	36	10	54	90	43	3.9	246	150	7.15	3.26
Porters Ck	Site 3	spring 2005	11-12/10/05	16000	54	51	5	130	180	31	4.5	3965	2600	7.63	8.67
Buffalo Ck	Site 4	spring 2005	11-12/10/05	6500	26	63	20	70	130	44	29	472	210	7.62	9.16
Archers Ck	Site 5	spring 2005	11-12/10/05	3800	6	54	10	50	100	30	5.1	206	100	7.25	4.56
Terrs Ck	Site 1	spring 2005	2/11/05	380	<1	2	4	37	39	37	1	159	110	6.48	5.40
Shrimptons Ck	Site 2	spring 2005	2/11/05	500	6	19	6	45	64	50	6.1	226	150	6.55	5.24
Porters Ck	Site 3	spring 2005	2/11/05	260	83	42	<1	210	250	30	6.4	5633	3500	7.14	7.89
Buffalo Ck	Site 4	spring 2005	2/11/05	2000	5	28	5	35	63	60	4.1	299	200	7.01	5.65
Archers Ck	Site 5	spring 2005	2/11/05	640	6	18	4	56	74	79	12.6	350	210	6.89	5.58

Stream	Site code	Season	Sample date	Faecal Coliforms	Ammonia	Oxidised Nitrogen NOx	Total Phosphorus TP	Total Kjeldahl Nitrogen TKN	Total Nitrogen TN	Alkalinity	Turbidity	Conductivity	Total Dissolved Solids	pH	Dissolved Oxygen DO
				CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L	mg CaCO3/L	NTU	µS/cm	mg/L		mg/L
Terrs Ck	Site 1	autumn 2005	30-31/03/05	60000	590	170	100	800	970	40	42	315	130	7.22	8.44
Shrimptons Ck	Site 2	autumn 2005	30-31/03/05	3400	20	240	40	280	520	52	9	305	170	6.71	4.46
Porters Ck	Site 3	autumn 2005	30-31/03/05	1000	670	820	40	1100	1900	99	18.9	1719	1100	7.31	7.61
Buffalo Ck	Site 4	autumn 2005	30-31/03/05	36	130	290	30	370	660	59	17.4	241	140	7.63	8.37
Archers Ck	Site 5	autumn 2005	30-31/03/05	360	20	50	60	350	400	68	22.2	183	180	7.05	7.49
Terrs Ck	Site 1	autumn 2005	26-27/04/05	90	70	140	40	300	440	62	1.66	264	180	6.60	6.60
Shrimptons Ck	Site 2	autumn 2005	26-27/04/05	940	40	100	30	270	370	65	3.21	236	160	6.44	5.73
Porters Ck	Site 3	autumn 2005	26-27/04/05	220	400	590	20	1100	1700	35	3.64	2520	1800	7.24	8.77
Buffalo Ck	Site 4	autumn 2005	26-27/04/05	520	80	940	40	.	770	95	7.56	548	390	6.7	5.4
Archers Ck	Site 5	autumn 2005	26-27/04/05	300	40	20	10	240	260	78	1.45	261	160	6.84	5.80
Terrs Ck	Site 1	autumn 2005	26-27/05/05	130	40	110	30	260	370	61	1.80	325	180	7.25	8.34
Shrimptons Ck	Site 2	autumn 2005	26-27/05/05	400	40	290	30	.	560	65	4.94	333	180	7.18	5.65
Porters Ck	Site 3	autumn 2005	26-27/05/05	59	350	640	20	1100	1700	30	1.53	2305	1500	7.75	10.02
Buffalo Ck	Site 4	autumn 2005	26-27/05/05	170	90	350	40	300	650	92	7.14	641	360	7.54	7.39
Archers Ck	Site 5	autumn 2005	26-27/05/05	360	60	70	20	310	380	99	3.32	376	200	7.40	8.14
Terrs Ck	Site 1	spring 2004	14-15/09/04	80	.	.	110	.	.	50	2.4	.	150	6.84	5.08
Shrimptons Ck	Site 2	spring 2004	14-15/09/04	880	.	.	90	.	.	58	3.1	.	140	6.83	2.20
Archers Ck	Site 5	spring 2004	14-15/09/04	650	.	.	150	.	.	70	0.6	.	110	7.01	6.53
Terrs Ck	Site 1	spring 2004	11-12/10/04	44	.	.	30	.	.	64	0.3	.	310	7.64	5.01
Shrimptons Ck	Site 2	spring 2004	11-12/10/04	110	.	.	60	.	.	76	0.5	.	260	7.43	5.69
Archers Ck	Site 5	spring 2004	11-12/10/04	1500	.	.	50	.	.	82	0.8	.	230	7.51	4.27
Terrs Ck	Site 1	spring 2004	23-24/11/04	150	.	.	40	.	.	56	2.6	.	180	6.70	6.90
Shrimptons Ck	Site 2	spring 2004	23-24/11/04	1000	.	.	90	.	.	75	11.5	.	190	6.38	2.93
Archers Ck	Site 5	spring 2004	23-24/11/04	1700	.	.	40	.	.	84	4.7	.	270	6.55	8.02

Appendix 3 Rainfall







Appendix 4 Macroinvertebrate results

			S1 spring 2004 Terrys Ck	S2 spring 2004 Shrimptons Ck	S5 spring 2004 Archers Ck	S1 spring 2004 Terrys Ck	S2 spring 2004 Shrimptons Ck	S5 spring 2004 Archers Ck	S1 spring 2004 Terrys Ck	S2 spring 2004 Shrimptons Ck	S5 spring 2004 Archers Ck	S1 autumn 2005 Terrys Ck	S2 autumn 2005 Shrimptons Ck	S3 autumn 2005 Porters Ck	S4 autumn 2005 Buffalo Ck	S5 autumn 2005 Archers Ck	S1 autumn 2005 Terrys Ck	S2 autumn 2005 Shrimptons Ck	S3 autumn 2005 Porters Ck	S4 autumn 2005 Buffalo Ck	S5 autumn 2005 Archers Ck	S1 autumn 2005 Terrys Ck	S2 autumn 2005 Shrimptons Ck	S3 autumn 2005 Porters Ck	S4 autumn 2005 Buffalo Ck	S5 autumn 2005 Archers Ck	S1 spring 2005 Terrys Ck	S2 spring 2005 Shrimptons Ck	S3 spring 2005 Porters Ck	S4 spring 2005 Buffalo Ck	S5 spring 2005 Archers Ck	S1 spring 2005 Terrys Ck	S2 spring 2005 Shrimptons Ck	S3 spring 2005 Porters Ck	S4 spring 2005 Buffalo Ck	S5 spring 2005 Archers Ck	S1 spring 2005 Terrys Ck	S2 spring 2005 Shrimptons Ck	S3 spring 2005 Porters Ck	S4 spring 2005 Buffalo Ck	S5 spring 2005 Archers Ck
Aquatic mites	Acarina	Acarina		1	1			3		3	1	2	1	1	2	3				2	3	1			1		1	1		6		7			1		4	2	1	1	1
Beetles	Coleoptera	Dytiscidae						3								1					1								1		2	1		1	2				2		1
Beetles	Coleoptera	Elmidae	1						3			6					1																				3				
Beetles	Coleoptera	Hydraenidae																																							
Beetles	Coleoptera	Hydrophilidae													1										1																
Beetles	Coleoptera	Psephenidae																																							
Beetles	Coleoptera	Scirtidae	1																	1		1		1																	
Caddisfly larvae	Trichoptera	Hydroptilidae		2	2	1	3				3														3																
Caddisfly larvae	Trichoptera	Leptoceridae						1		1				1										1																	
Dobsonfly larvae	Megaloptera	Corydalidae																																							
Dragonfly larvae	Odonata	Aeshnidae			1			1				1		2	3	2			2	1				2	1	14			1		5					5	1			1	
Dragonfly larvae	Odonata	Coenagrionidae	1	3	7	1	6	5	3		5		1	3	5	6	3		10	8	3	4	2	13	15	29		3	9		21					7	7		2		4
Dragonfly larvae	Odonata	Gomphidae	1	1																									1												
Dragonfly larvae	Odonata	Hemicorduliidae	2	1	2	4	4	6	7	2	1	2		9	1	4	6	1	8	16	3	20		8	19	18	21		11	7	25										
Dragonfly larvae	Odonata	Isostictidae							2			6		21			8		19	1		6		13	2		8		9	1		5		5			7		7		
Dragonfly larvae	Odonata	Lestidae								1	3																														
Dragonfly larvae	Odonata	Libellulidae			2		3	4			5			1		3			3	5	9			4	2	8			2	2	1	14	2	5	1	15	13	4	9	13	14
Dragonfly larvae	Odonata	Megapodagrionidae	6			10	2	2	12			16		6	9	15	26		14	21	22	14		8	19	5	11		4	20	6	8					7		2	3	1
Dragonfly larvae	Odonata	Synlestidae																									6														
Dragonfly larvae	Odonata	Synthemistidae																		1																					
Dragonfly larvae	Odonata	Telephlebiidae																																							
Fairy shripms	Decapoda	Atyidae						1	1					5		6					11					17								2							
Flatworms	Turbellaria	Dugesiidae	1	2	2	3	4	3	3	9	1	6	14	5	4	3	14	19	3	6	15	4	11		5	7	2	14	2	3		2	12		2	1	3	10		6	2
Leeches	Hirudinea	Erpobdellidae																					9		1				2					2					1		
Leeches	Hirudinea	Glossiphoniidae						1			4	3	15	2	2		2	5	7	1	1	1	9	5	2			7	3			1	9	4			1	12	5		
Mayfly larvae	Ephemeroptera	Baetidae									1			1																											
Mussels	Bivalvia	Corbiculidae				5	4	1	1		1	3	9		3		5	3	4	8		10	10	2	7	1	2	6		5		9	4		1	3	3	12		11	3
Mussels	Bivalvia	Sphaeriidae	4	2		1	3	3	3	10																															
Round Worms	Nematoda	Nematoda		1				1			1																														
Sand hoppers	Amphipoda	Ceinidae										3								1		1			2		1		3	2	2	3		1	8						
Sand hoppers	Amphipoda	Talitridae																																							
Slatters	Isopoda	Oniscidae																									1	2	1	3	7				4					2	1

			Terrys Ck spring 2004 S1	Shrimptons Ck spring 2004 S2	Archers Ck spring 2004 S5	Terrys Ck spring 2004 S1	Shrimptons Ck spring 2004 S2	Archers Ck spring 2004 S5	Terrys Ck spring 2004 S1	Shrimptons Ck spring 2004 S2	Archers Ck spring 2004 S5	Terrys Ck autumn 2005 S1	Shrimptons Ck autumn 2005 S2	Porters Ck autumn 2005 S3	Buffalo Ck autumn 2005 S4	Archers Ck autumn 2005 S5	Terrys Ck autumn 2005 S1	Shrimptons Ck autumn 2005 S2	Porters Ck autumn 2005 S3	Buffalo Ck autumn 2005 S4	Archers Ck autumn 2005 S5	Terrys Ck autumn 2005 S1	Shrimptons Ck autumn 2005 S2	Porters Ck autumn 2005 S3	Buffalo Ck autumn 2005 S4	Archers Ck autumn 2005 S5	Terrys Ck spring 2005 S1	Shrimptons Ck spring 2005 S2	Porters Ck spring 2005 S3	Buffalo Ck spring 2005 S4	Archers Ck spring 2005 S5	Terrys Ck spring 2005 S1	Shrimptons Ck spring 2005 S2	Porters Ck spring 2005 S3	Buffalo Ck spring 2005 S4	Archers Ck spring 2005 S5	Terrys Ck spring 2005 S1	Shrimptons Ck spring 2005 S2	Porters Ck spring 2005 S3	Buffalo Ck spring 2005 S4
Snails	Gastropoda	Ancylidae		1			1		1	1				1																										
Snails	Gastropoda	Hydrobiidae	4		1	7	1	3	6		2	11		30	6		10		22	4		13		13	18				23	11		14		13	13		11	3	34	7
Snails	Gastropoda	Lymnaeidae	1																								5	1			1	3								
Snails	Gastropoda	Physidae	4	6	3	4	7	5	6	10	10	3	17	12	4	4	8	17	10	1	4	8	12	7	6	1	12	14	4	7	9	11	20	8	12	5	7	15	7	24
Snails	Gastropoda	Planorbidae		2		1	3		5	10		2	11	4	2		4	2	6	2		4	6	6	3		1	4					11	2			4	11	2	1
Stonefly larvae	Plecoptera	Eustheniidae																																						
True bugs	Hemiptera	Belostomatidae	1																																					
True bugs	Hemiptera	Corixidae					3			2					1						1					10		2	1					2	1		5		9	
True bugs	Hemiptera	Gelastocoridae																				1	1					1					2							
True bugs	Hemiptera	Gerridae				1																2										1					2			
True bugs	Hemiptera	Mesoveliidae																																						
True bugs	Hemiptera	Naucoridae							1								1																							
True bugs	Hemiptera	Nepidae																											1											
True bugs	Hemiptera	Notonectidae							3		2	11		2	11		2			10		7		2	10	11	4		1	4		1			4		2			1
True bugs	Hemiptera	Pleidae																																						
True bugs	Hemiptera	Veliidae			3			1								6			3		5	3				3											1			
True Fly larvae	Diptera	Bibionidae																																						
True Fly larvae	Diptera	Ceratopogonidae		1																		1			1							2								
True Fly larvae	Diptera	Culicidae																		1									1		17	3			5	1				
True Fly larvae	Diptera	Muscidae																																						
True Fly larvae	Diptera	Psychodidae																																						
True Fly larvae	Diptera	s-f Chironominae	8	12	9	11	11	10	11	10	11	3		34	9	9	17	1	48	13	5	28		46	36	22	33	5	77	26	69	32	10	132	31	94	30	15	100	74
True Fly larvae	Diptera	s-f Orthocladiinae	2		1				2		10	2		7	2	1		1	1			1																		
True Fly larvae	Diptera	s-f Tanypodinae			1	2		6	1		3	3		4	2	1	4		2	2	1	21		14	7	1	11			2	7	6					1			
True Fly larvae	Diptera	Simuliidae																									1								1		1			
True Fly larvae	Diptera	Stratiomyidae	1		3		1	1				1	1		2	1	2		2	1	2		4		3	6		1	1	1	1	1								
True Fly larvae	Diptera	Syrphidae													1																									
True Fly larvae	Diptera	Tipulidae			1			1				4			1																									
Worms	Oligochaeta	Oligochaeta	7	7	4	10	6	6	7	12	12	4	10	3	11	4	15	9	6	11	16	8	17	10	9	15	9	16	10	32	24	15	13	5	17	19	7	17	7	18
Yabbies	Decapoda	Parastacidae																																						

			autumn 2006 Terrys Ck S1	autumn 2006 Shrimptons Ck S2	autumn 2006 Porters Ck S3	autumn 2006 Buffalo Ck S4	autumn 2006 Archers Ck S5	autumn 2006 Terrys Ck S1	autumn 2006 Shrimptons Ck S2	autumn 2006 Porters Ck S3	autumn 2006 Buffalo Ck S4	autumn 2006 Archers Ck S5	autumn 2006 Terrys Ck S1	autumn 2006 Shrimptons Ck S2	autumn 2006 Porters Ck S3	autumn 2006 Buffalo Ck S4	autumn 2006 Archers Ck S5	springa 2006 Shrimptons Ck S2	springb 2006 Shrimptons Ck S2	springc 2006 Shrimptons Ck S2	springa 2006 Archers Ck S5	springb 2006 Archers Ck S5	springc 2006 Archers Ck S5	springa 2006 Shrimptons Ck S2	springb 2006 Shrimptons Ck S2	springc 2006 Shrimptons Ck S2	springa 2006 Archers Ck S5	springb 2006 Archers Ck S5	springc 2006 Archers Ck S5	springa 2006 Shrimptons Ck S2	springb 2006 Shrimptons Ck S2	springc 2006 Shrimptons Ck S2	springa 2006 Archers Ck S5	springb 2006 Archers Ck S5	springc 2006 Archers Ck S5
Aquatic mites	Acarina	Acarina	2	4				3	5	1			2	4					2	4	1			1	1	7	3	4	1		1	1	1		
Beetles	Coleoptera	Dytiscidae																								1									
Beetles	Coleoptera	Elmidae	4					1																											
Beetles	Coleoptera	Hydraenidae																			1		1												
Beetles	Coleoptera	Hydrophilidae									1																		1						
Beetles	Coleoptera	Psephenidae			1																														
Beetles	Coleoptera	Scirtidae																																	
Caddisfly larvae	Trichoptera	Hydroptilidae	1																				1												
Caddisfly larvae	Trichoptera	Leptoceridae			1					1																									
Dobsonfly larvae	Megaloptera	Corydalidae	1																																
Dragonfly larvae	Odonata	Aeshnidae	1		3	3				5	6	11			7	3	8																		
Dragonfly larvae	Odonata	Coenagrionidae	7	3	15	5	1	5	1	7	6	7	2		12	12	6		3	1			5	1			1								
Dragonfly larvae	Odonata	Gomphidae																																	
Dragonfly larvae	Odonata	Hemicorduliidae	17	7	5	13	1	16	4	5	4	7	26	1	13	2	5		2	1		1	2	5	4	4			10	2					1
Dragonfly larvae	Odonata	Isostictidae	4		18	2		2		7			4		7	2								1											
Dragonfly larvae	Odonata	Lestidae																																	
Dragonfly larvae	Odonata	Libellulidae	2	1	5	13	7	1		1	10	2	4	1	3	4	4					1					1								
Dragonfly larvae	Odonata	Megapodagrionidae	42		10	9	2	17		7	2	7	18		26	8	5				1	1	1			1			6			1			
Dragonfly larvae	Odonata	Synlestidae																								2	1	2	3	1	8	3	1		
Dragonfly larvae	Odonata	Synthemistidae																															1		
Dragonfly larvae	Odonata	Telephlebiidae																																	
Fairy shripms	Decapoda	Atyidae			5		5			5		1			14																				
Flatworms	Turbellaria	Dugesiidae	10	7		3	1	2	8		4	4	11	9		3	4	4	2	3	9	10	9	1		2	7	16	2		8	2	3	11	2
Leeches	Hirudinea	Erpobdellidae																																	
Leeches	Hirudinea	Glossiphoniidae	2	1	8	4	6	2	1	16	9	6			3		2						1						1			1			
Mayfly larvae	Ephemeroptera	Baetidae									4																				1	1			
Mussels	Bivalvia	Corbiculidae	9	9		4			6		6		8	3		7																			
Mussels	Bivalvia	Sphaeriidae																1					1												
Round Worms	Nematoda	Nematoda																																	
Sand hoppers	Amphipoda	Ceinidae																																	
Sand hoppers	Amphipoda	Talitridae						1			1		2		1																				
Slatters	Isopoda	Oniscidae				1	3														1						4	1							

			S1 autumn 2006 Terrys Ck	S2 autumn 2006 Shrimptons Ck	S3 autumn 2006 Porters Ck	S4 autumn 2006 Buffalo Ck	S5 autumn 2006 Archers Ck	S1 autumn 2006 Terrys Ck	S2 autumn 2006 Shrimptons Ck	S3 autumn 2006 Porters Ck	S4 autumn 2006 Buffalo Ck	S5 autumn 2006 Archers Ck	S1 autumn 2006 Terrys Ck	S2 autumn 2006 Shrimptons Ck	S3 autumn 2006 Porters Ck	S4 autumn 2006 Buffalo Ck	S5 autumn 2006 Archers Ck	S2 springa 2006 Shrimptons Ck	S2 springb 2006 Shrimptons Ck	S2 springc 2006 Shrimptons Ck	S5 springa 2006 Archers Ck	S5 springb 2006 Archers Ck	S5 springc 2006 Archers Ck	S2 springa 2006 Shrimptons Ck	S2 springb 2006 Shrimptons Ck	S2 springc 2006 Shrimptons Ck	S5 springa 2006 Archers Ck	S5 springb 2006 Archers Ck	S5 springc 2006 Archers Ck	S2 springa 2006 Shrimptons Ck	S2 springb 2006 Shrimptons Ck	S2 springc 2006 Shrimptons Ck	S5 springa 2006 Archers Ck	S5 springb 2006 Archers Ck	S5 springc 2006 Archers Ck
Snails	Gastropoda	Ancylidae																	1											1					
Snails	Gastropoda	Hydrobiidae	25		23	2		4		10			14		18				2		2	1	7	1			4	3	11			1	1		10
Snails	Gastropoda	Lymnaeidae	1	1		1						1				1								1		1			1						
Snails	Gastropoda	Physidae	1	5	2	8	1	9	11	7	7	5	9	11	3	5		13	13	13	8	15	8	16	10	9	4	3	7	8	10	14	12	7	11
Snails	Gastropoda	Planorbidae	2	2						2					2			3	1					1	2					6					
Stonefly larvae	Plecoptera	Eustheniidae			1																														
True bugs	Hemiptera	Belostomatidae																																	
True bugs	Hemiptera	Corixidae																																	
True bugs	Hemiptera	Gelastocoridae																		1	1							1							
True bugs	Hemiptera	Gerridae	3			1	1	3		1	1		3				1																		
True bugs	Hemiptera	Mesoveliidae									1																								
True bugs	Hemiptera	Naucoridae																																	
True bugs	Hemiptera	Nepidae																																	
True bugs	Hemiptera	Notonectidae	5		4	14	2	6		8	10	1	4			14	4		2	2					1	1				2	4	1			
True bugs	Hemiptera	Pleidae		1																															
True bugs	Hemiptera	Veliidae	4				2	1				2			2		1				1		1					2			1		1	2	2
True Fly larvae	Diptera	Bibionidae																					2												
True Fly larvae	Diptera	Ceratopogonidae														2		1																	
True Fly larvae	Diptera	Culicidae					1	1			1					2	1			8				2			1	11	14					6	
True Fly larvae	Diptera	Muscidae																					1												
True Fly larvae	Diptera	Psychodidae																					1												
True Fly larvae	Diptera	s-f Chironominae	2			78	71	19	2	10	46	72	5	3	7	56	109	21	20	18	22	27	34	25	32	26	15	6	32	21	18	12	19	8	18
True Fly larvae	Diptera	s-f Orthocladiinae			1	2		1			4					2					7	1	6	1			1	2				1		1	
True Fly larvae	Diptera	s-f Tanypodinae	1					9		18		3	11		11	4	10		1	2	2	1	2	1			1	1	2			1		1	2
True Fly larvae	Diptera	Simuliidae																			1														
True Fly larvae	Diptera	Stratiomyidae	5			1	1				1					5	1							1			1	2		1	1	1	4	6	1
True Fly larvae	Diptera	Syrphidae																											1						
True Fly larvae	Diptera	Tipulidae															1					2													2
Worms	Oligochaeta	Oligochaeta	18	13	6	8	8	14	11	6	3	13	17	17	8	10	14	10	1	3	12	11	4	4	8	3	9	3	8	8	10		8	1	3
Yabbies	Decapoda	Parastacidae		1														2														1			

Appendix 5 SIMPER output

SIMPER Archers Creek 2005 and 2006

Worksheet
File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\Archers Ck 2005 2006.pri
Sample selection: All
Variable selection: All

Parameters
Standardise data: No
Transform: Square root
Cut off for low contributions: 90.00%
Factor name: Season Year

Factor groups
Autumn 2005
Spring 2005
Autumn 2006
Spring 2006

Group Autumn 2005
Average similarity: 68.02

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Odonata Megapodagrionidae	14.00	7.56	2.16	11.11	11.11
Decapoda Atyidae	11.33	7.18	8.38	10.56	21.67
Oligochaeta	11.67	6.80	3.09	9.99	31.67
Diptera s-f Chironominae	12.00	6.58	5.68	9.67	41.33
Odonata Libellulidae	6.67	5.47	4.54	8.04	49.37
Turbellaria Dugesiidae	8.33	5.32	5.50	7.82	57.19
Odonata Coenagrionidae	12.67	5.20	4.94	7.65	64.83
Hemiptera Veliidae	4.67	5.09	3.65	7.49	72.32
Odonata Hemicorduliidae	8.33	4.82	8.37	7.08	79.40
Gastropoda Physidae	3.00	3.65	1.80	5.36	84.77
Diptera Stratiomyidae	3.00	2.98	7.13	4.38	89.15
Diptera s-f Tanypodinae	1.00	2.65	8.58	3.90	93.04

Group Spring 2005
Average similarity: 59.54

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Diptera s-f Chironominae	67.00	20.16	6.42	33.86	33.86
Oligochaeta	18.00	10.74	6.84	18.05	51.91
Gastropoda Physidae	9.00	7.29	7.01	12.25	64.15
Odonata Coenagrionidae	10.67	6.49	6.73	10.91	75.06
Odonata Libellulidae	10.00	6.08	1.04	10.21	85.27
Odonata Aeshnidae	3.33	2.04	0.58	3.43	88.70
Bivalvia Corbiculidae	2.00	1.97	0.58	3.32	92.01

Group Autumn 2006
Average similarity: 72.35

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Diptera s-f Chironominae	84.00	23.36	19.19	32.29	32.29
Oligochaeta	11.67	8.50	11.35	11.74	44.04
Hirudinea Glossiphoniidae	4.67	4.91	2.60	6.79	50.82
Odonata Megapodagrionidae	4.67	4.62	4.53	6.39	57.21
Odonata Libellulidae	4.33	4.46	4.33	6.17	63.38
Odonata Coenagrionidae	4.67	4.02	1.99	5.56	68.94
Odonata Hemicorduliidae	4.33	3.84	2.25	5.30	74.24
Turbellaria Dugesiidae	3.00	3.63	2.69	5.02	79.26
Hemiptera Veliidae	1.67	3.17	3.92	4.38	83.63
Hemiptera Notonectidae	2.33	3.16	4.33	4.36	88.00
Odonata Aeshnidae	6.33	2.45	0.58	3.38	91.38

Group Spring 2006
Average similarity: 62.07

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Diptera s-f Chironominae	20.11	15.42	4.03	24.84	24.84
Gastropoda Physidae	8.33	10.35	3.57	16.68	41.52
Turbellaria Dugesiidae	7.67	8.92	2.79	14.37	55.89
Oligochaeta	6.56	8.11	2.85	13.06	68.95
Gastropoda Hydrobiidae	4.33	4.66	1.47	7.51	76.47
Diptera s-f Tanypodinae	1.33	3.48	1.76	5.61	82.08
Hemiptera Veliidae	1.00	2.03	0.80	3.27	85.35
Diptera s-f Orthocladiinae	2.00	1.98	0.79	3.20	88.54
Diptera Stratiomyidae	1.56	1.57	0.57	2.53	91.08

SIMPER Shrimptons Creek 2005 and 2006

Worksheet
File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\Shrimptons Ck 2005 2006.pri
Sample selection: All
Variable selection: All

Parameters
Standardise data: No
Transform: Square root
Cut off for low contributions: 90.00%
Factor name: Season Year

Factor groups
Autumn 2005
Spring 2005
Autumn 2006
Spring 2006

Group Autumn 2005
Average similarity: 75.89

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Gastropoda Physidae	15.33	16.31	7.41	21.49	21.49
Turbellaria Dugesiidae	14.67	15.30	9.53	20.16	41.65
Oligochaeta	12.00	13.48	44.44	17.77	59.41
Hirudinea Glossiphoniidae	9.67	10.94	8.30	14.42	73.83
Bivalvia Corbiculidae	7.33	9.41	3.56	12.40	86.23
Gastropoda Planorbidae	6.33	7.68	3.56	10.12	96.35

Group Spring 2005
Average similarity: 79.06

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Gastropoda Physidae	16.33	13.73	23.91	17.36	17.36
Oligochaeta	15.33	13.54	21.04	17.13	34.49
Turbellaria Dugesiidae	12.00	11.85	9.99	14.99	49.48
Hirudinea Glossiphoniidae	9.33	10.02	14.50	12.67	62.15
Diptera s-f Chironominae	10.00	9.21	5.14	11.65	73.80
Gastropoda Planorbidae	8.67	8.81	3.40	11.15	84.95
Bivalvia Corbiculidae	7.33	7.78	10.29	9.84	94.79

Group Autumn 2006
Average similarity: 76.70

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Oligochaeta	13.67	16.90	13.74	22.03	22.03
Turbellaria Dugesiidae	8.00	13.43	9.18	17.51	39.55
Gastropoda Physidae	9.00	13.00	3.19	16.95	56.50
Acarina	4.33	9.91	14.34	12.92	69.42
Bivalvia Corbiculidae	6.00	9.70	6.21	12.64	82.06
Odonata Hemicorduliidae	4.00	6.51	2.65	8.49	90.55

Group Spring 2006
Average similarity: 63.54

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Diptera s-f Chironominae	21.44	21.25	6.91	33.45	33.45
Gastropoda Physidae	11.78	15.93	9.77	25.07	58.52
Oligochaeta	5.22	7.26	1.40	11.43	69.95
Turbellaria Dugesiidae	2.44	3.86	1.09	6.08	76.03
Hemiptera Notonectidae	1.44	3.25	1.14	5.12	81.15
Acarina	1.89	3.06	1.11	4.81	85.96
Odonata Hemicorduliidae	2.00	2.87	0.78	4.52	90.47

Appendix 6 BIOENV output

BIOENV of all five creeks of 2005 and 2006

Worksheet

File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\mv edge 2005 2006 wq.pri
Sample selection: All
Variable selection: All

Similarity Matrix

File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\mv edge 2005 2006.sid
Data type: Similarities
Sample selection: All

Parameters

Rank correlation method: Spearman
Maximum number of variables: 5

Similarity Matrix Parameters for sample data worksheet:
Analyse between: Samples
Similarity measure: Normalised Euclidean distance
Standardise: No
Transform: None

Variables

1 Faecal Coliform (Log10)
2 Ammonia NH3-N
3 Oxidised Nitrogen NOx-N
4 Total Phosphorus
5 Total Kjeldahl Nitrogen
6 TN by calculation
7 Alkalinity (Total)
8 Turbidity
9 Conductivity
10 Total Dissolved Solids
11 pH
12 DO
13 Temp
14 Rainfall
15 Altitude
16 Bedrock
17 Boulder
18 Cobble

Best results

No. Vars	Corr.	Selections
5	0.280	1,8,9,14,16
4	0.280	9,14,16,18
5	0.280	1,4,8,14,16
3	0.278	9,14,18
5	0.277	4,9,14,16,18
5	0.276	6,9,14,16,18
4	0.276	8,9,14,16
5	0.276	8,9,14,16,18
4	0.276	8,9,14,18
5	0.275	1,8,10,14,16

BIOENV of Archers Creek 2005 and 2006

Worksheet

File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\Archers Ck 2005 2006 wq.pri
Sample selection: All
Variable selection: All

Similarity Matrix

File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\Archers Ck 2005 2006.sid
Data type: Similarities
Sample selection: All

Parameters

Rank correlation method: Spearman
Maximum number of variables: 5

Similarity Matrix Parameters for sample data worksheet:
Analyse between: Samples
Similarity measure: Normalised Euclidean distance
Standardise: No
Transform: None

Variables

1 Faecal Coliform (Log10)
2 Ammonia NH3 -N
3 Oxidised Nitrogen NOx-N
4 Total Phosphorus
5 Total Kjeldahl Nitrogen
6 TN
7 Alkalinity
8 Turbidity
9 Conductivity
10 Total Dissolved Solids
11 pH
12 DO
13 Temperature
14 Rainfall
15 Bedrock
16 Boulder
17 Cobble

Best results

No. Vars	Corr.	Selections
1	0.563	10
2	0.542	9,10
3	0.517	9,10,14
1	0.507	14
2	0.505	10,14
2	0.497	9,14
2	0.497	14,16
2	0.492	10,16
3	0.482	9,10,16
4	0.482	5,9,10,14

BIOENV of Shrimptons Creek 2005 and 2006

Worksheet

File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\Shrimptons Ck 2005 2006 wq.csv
Sample selection: All
Variable selection: All

Similarity Matrix

File: G:\PROJECTS\40-41\WR004027\City of Ryde\analysis\mv\Shrimptons Ck 2005 2006.sid
Data type: Similarities
Sample selection: All

Parameters

Rank correlation method: Spearman
Maximum number of variables: 5

Similarity Matrix Parameters for sample data worksheet:
Analyse between: Samples
Similarity measure: Normalised Euclidean distance
Standardise: No
Transform: None

Variables

1 Faecal Coliform (Log10)
2 Ammonia NH3 -N
3 Oxidised Nitrogen NOx-N
4 Total Phosphorus
5 Total Kjeldahl Nitrogen
6 TN
7 Alkalinity
8 Turbidity
9 Conductivity
10 Total Dissolved Solids
11 pH
12 DO
13 Temperature
14 Rainfall
15 Bedrock
16 Boulder
17 Cobble

Best results

No. Vars	Corr.	Selections
5	0.771	3,5,10,15,16
5	0.768	5,8,10,15,16
3	0.767	4,6,15
5	0.758	4,8,10,15,16
5	0.755	3,4,10,15,16
3	0.755	5,6,15
5	0.751	5,8,9,15,16
5	0.744	3,5,9,15,16
5	0.744	4,5,8,10,15
1	0.740	15