City of Ryde Biological and Chemical Monitoring

Macroinvertebrate & Water Quality Report
Autumn 2017

Sydney Water Monitoring Services™

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Executive Summary

This report presents the findings of water quality monitoring carried out in Autumn 2017. The survey area included the Archers, Buffalo, Porters, Shrimptons and Terrys Creek catchments.

High and consistent rainfall in autumn had an impact that was visible in the water quality data results. Overall there was an improvement in dissolved oxygen concentration in all catchments. There was, however, an increase in faecal coliforms, with six sites exceeding the recommended guidelines. The nutrient results were elevated above the recommended guidelines, which is consistent with historical data and highly impacted urban streams.

Macroinvertebrate results were comparable to previous sampling seasons. Taxa richness remained consistent for Archers Creek and had a moderate decrease in all other sites. One EPT taxa family, *Hydroptilidae,* was recorded at Buffalo and Archers creeks, while no EPT taxa were recorded at Terrys, Porters and Shrimptons creeks.

Survey results suggest that macroinvertebrate community assemblages in all five creeks are consistent with urban systems. SIGNAL2 scores for all sites fluctuate within the natural range around their historical scores. SIGNAL-SF scores remain the most reliable and consistent index to measure creek health which suggests minor change has occurred during autumn 2017 and historically. AUSRIVAS OE0 and OE50 scores showed opposite trends and high variation compared to historical data. Both these indices continue to be an unreliable measure of creek health for the City of Ryde.

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1 Glossary

Item	Meaning
Abundance	The total number of individual specimens; in a sample, community, ecosystem etc.
Algae	Comparatively simple chlorophyll-bearing plants, most of which are aquatic and microscopic in size.
Alkalinity	The ability of a solution to neutralise acid (or buffer).
Aquatic ecosystem	Community of aquatic plants and animals together with the physical and chemical environment in which they live.
Ammonia	A colourless gas. In the aquatic environment, it exists in the relatively harmLess form ammonium (NH4) and the toxic form ammonia (NH3).
Analyte	The physical and chemical parameters (indicators) to be measured.
Anthropogenic	Impacts on an environment that are produced or caused by humans.
ANZECC	ANZECC is a forum for member governments to develop coordinated policies about national and international environment and conservation issues.
AUSRIVAS	AUSRIVAS is a rapid prediction model used to assess the biological health of Australian rivers.
Baseline Data	Is previously collected data that allows comparison for subsequently collected data, enabling comparison to 'normal' background levels.
Benthic	Refers to the lowest areas of a water body; the sediment layer; referring to the organisms that live within this area.
Catchment	The area that is drained by a river, lake or other water body.
Community	Assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.
Concentration	The quantifiable amount of a chemical divided by the total volume of a mixture.
Conductivity	The measure of salt content in soil or water; it refers to the ability of the substance to transfer an electrical charge.
Detection limit	The smallest concentration or amount of a substance that can be defined by an analytical process for reporting with a specific degree of certainty.
Detritus	Pieces of dead and decomposing plants and organisms (generally in the form of small pieces) found in a water body.
Dissolved Oxygen	The measurement of the concentration of oxygen that is dissolved in a water body.
Diversity (Biological)	The measure of the number and/or degree of available organisms in an environment.

Item	Meaning
Edge habitat	The edge habitat is an area of unbroken water surface that is within 2 m of the bank.
Effluent	A waste product that is discharged to the environment, usually in reference to waste water discharged from sewage treatment plants.
Ethanol	Alcohol used to preserve macroinvertebrates for long-term reference and identification.
Eutrophication	Enrichment of a water body with nutrients that results in increased aquatic plant growth and low oxygen levels.
Faecal Coliforms	Bacteria which inhabit the intestines of humans and other vertebrates and are present in faeces. Used as a primary indicator of sewage pollution in the environment.
Guideline (water quality)	Concentration limit or narrative statement recommended to support and maintain a designated water use.
Habitat	The place where a population lives and its surroundings, both living and non-living.
Indicator	A parameter (chemical, biological or geological) that can be used to provide a measure of the quality of water or the condition of an ecosystem.
Invertebrate	Animal lacking a dorsal column of vertebrae (backbone) or a notochord.
Macroinvertebrate (Aquatic)	Animals without backbones that when mature are greater than 1 millimetre; live in the water column, on the water surface or on the bottom of a waterway.
Macrophyte	Plant species that are adapted to growing in or on permanent water and have a definite life form related to the aquatic environment.
Multivariate Analysis	The statistical analysis of data containing more than one variable.
Nitrogen (Aquatic)	An element that is essential for plant and animal growth, it occurs in three forms Nitrate, Nitrite and ammonium.
Nutrients	Compounds required for growth by plants and other organisms. Major plant nutrients are phosphorus and nitrogen.
Organic Pollution (Aquatic)	Organic compounds in the form of contaminants (pollution) in a water body that in time can be oxidised by microorganisms (biodegrade).
Pathogens	Disease-causing organisms, such as bacteria and viruses.
pH	A measure of the degree of acidity or alkalinity; expressed on a logarithmic scale of 1 to 14 (1 is most acid, 7 neutral and 14 most alkaline).
Phosphorus	Is an element that is essential for plant and animal growth, excess concentrations can lead to eutrophication.
Photosynthesis	The conversion of carbon dioxide to carbohydrates in the presence of chlorophyll using light energy.

Item	Meaning
Physico-Chemical (Aquatic)	The measure and relationship between the physical and chemical identities of a water body.
Reference Site	A sampling site that occurs in a catchment largely void of human related impacts.
Sensitive organism	An organism that's survival is highly susceptible to shifts in environmental conditions.
Sewage	The waste water from homes, offices, shops, factories and other premises discharged to the sewer. Is usually 99% water.
Sewage overflow	A sewage release to prevent sewage flowing back into houses.
SIGNAL	SIGNAL (Stream Invertebrate Grade Number Average Level) is a biotic index using aquatic macroinvertebrates to assess stream health.
Stormwater	Rainwater that runs off the land, frequently carrying various forms of pollution such as litter and detritus, animal droppings and dissolved chemicals. This untreated water is carried in stormwater channels and discharged directly into water bodies.
Stormwater system	The system of pipes, canals and other channels used to carry stormwater to bodies of water, such as rivers or oceans. The system does not usually involve any significant form of treatment.
Taxon (plural taxa)	The definite entity and classification formally recognised by taxonomists of any given organism.
Taxonomic Level	Refers to the classification type of an organism; kingdom, phylum, class, order, family, genus, species.
Tolerant organism	Is an organism that can survive in highly variable environmental conditions.
Turbidity	A measure of the amount of suspended solids (usually fine clay or silt particles) in water and thus the degree of scattering or absorption of light in the water.
Univariate Analyses	Refers to the statistical analysis of data containing one variable.
WSUD	Water Sensitive Urban Design

2 Acronyms and abbreviations

Acronyms/ Abbreviation	Meaning
ANZECC	Australian and New Zealand Environment and Conservation Council
ANOVA	Analysis of Variance
AUSRIVAS	Australian River Assessment System
CFU	Colony Forming Unit
EPT	Ephemeroptera, Plecoptera, Trichoptera
LGA	Local Government Area
mg/L	Milligrams per litre
MDS	Multi-Dimensional Scaling
NATA	National Association of Testing Authorities of Australia
NTU	Nephelometric Turbidity Units
SIGNAL-SF	Stream Invertebrate Grade Number Average Level – Sydney Family
SIGNAL2	Stream Invertebrate Grade Number Average Level – National scores (2003)
µg/L	Micrograms per litre
µS/cm	Micro-siemens per centimetre (unit of conductivity)

3 Introduction

3.1 Background

Water quality monitoring is carried out by the City of Ryde to inform environmental management and development decisions. This report will provide:

- physical and chemical water analysis of five major creeks within the City of Ryde LGA during dry weather
- diversity and abundance of macroinvertebrate communities at five creeks within the study area
- environmental and ecosystem health data which will assist in monitoring the effect of future developments, creek restoration, stormwater management, bushland rehabilitation and general anthropogenic activities and incidents within the catchment
- on-going information to assist the direction of future water quality monitoring plans

Biological and chemical monitoring enables the City of Ryde to:

- build on baseline data that enables the temporal evaluation and analysis of the health of the catchments of the strategy
- identify and track new and existing impacts affecting the catchments
- provide direction and monitor potential infrastructural works within the LGA, i.e. in-stream or riparian rehabilitation and stormwater treatment projects
- build on the known taxa list for each catchment and to aid in the identification of key indicator taxa

3.2 Study area

3.2.1 Catchment

The City of Ryde LGA is 40.651 km^2 in area and is located 12 km north west of central Sydney. Dominated by residential housing it is comprised of 16 suburbs and 14 separate stormwater catchments. It includes several important retail centres and light industry/manufacturing sectors.

Limited areas of natural bushland fringe the urban infrastructure including several significant natural bush corridors and areas of open space that support recreation and sporting activities. There are small sections of Lane Cove National Park present on the eastern and northern borders of Shrimptons, Porters and Buffalo creeks. The creeks surveyed all drain into the greater Parramatta River catchment. Archers Creek enters Parramatta River directly and the remaining creeks through the Lane Cove River catchment.

3.2.2 Sampling sites

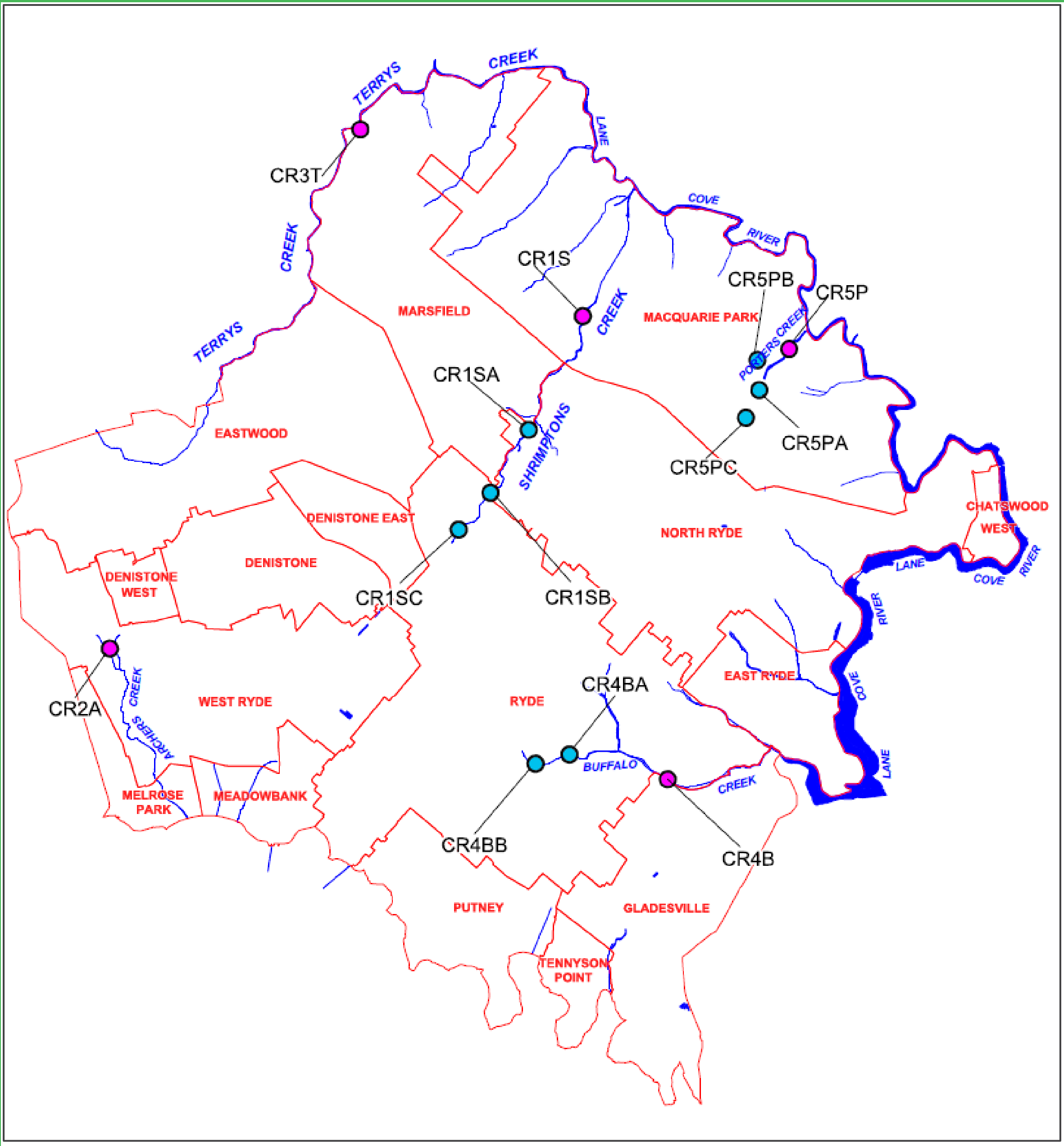
The five core sites sampled for macroinvertebrates and water quality are shown in Table 1 and Figure 1. The eight additional water quality sites are shown in Table 2 and Figure 1. Sites were sampled for water quality and macroinvertebrates on the 11th of April, 2017.

Table 1 Core sampling sites (water quality and macroinvertebrate sampling sites)

Site code	Site name	Latitude / Longitude
CR1S	Shrimptons Creek	-33.780530, 151.118628
CR2A	Archers Creek	-33.805555, 151.074272
CR3T	Terrys Creek	-33.765792, 151.098345
CR4B	Buffalo Creek	-33.816451, 151.125705
CR5P	Porters Creek	-33.783362, 151.137671

Table 2 Water quality only sites

Site code	Site name	Latitude / Longitude
CR1SA	Shrimptons Creek @ Kent Road	-33.789246, 151.113419
CR1SB	Shrimptons Creek @ Bridge Rd	-33.794061, 151.109779
CR1SC	Shrimptons Creek @ Quarry Rd	-33.796856, 151.106775
CR4BA	Buffalo Creek Downstream Burrows Park	-33.814392, 151.116656
CR4BB	Buffalos Creek Upstream Burrows Park	-33.815060, 151.113502
CR5PA	Porters Creek @ Main Branch	-33.786500, 151.134839
CR5PB	Porters Creek @ Spur Branch	-33.784181, 151.134708
CR5PC	Porters Creek @ Wicks Rd	-33.788613, 151.133557



Site Code	Site Name	Description
CR1S	Shrimptons Creek	water quality and macroinvertebrate sampling site
CR2A	Archers Creek	water quality and macroinvertebrate sampling site
CR3T	Terrys Creek	water quality and macroinvertebrate sampling site
CR4B	Buffalo Creek	water quality and macroinvertebrate sampling site
CR5P	Porters Creek	water quality and macroinvertebrate sampling site
CR1SA	Shrimptons Creek @ Kent Rd	water quality only site
CR1SB	Shrimptons Creek @ Bridge St	water quality only site
CR1SC	Shrimptons Creek @ Quarry Rd	water quality only site
CR4BA	Buffalo Creek Downstream Burrows Park	water quality only site
CR4BB	Buffalo Creek Upstream Burrows Park	water quality only site
CR5PA	Porters @ Main Branch	water quality only site
CR5PB	Porters @ Spur Branch	water quality only site
CR5PC	Porters @ Wicks Rd	water quality only site

Legend

Water Features

Water quality and macroinvertebrate sampling sites

Water quality only sites

N
W E
S

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Figure 1 Map of macroinvertebrate and water quality sampling sites

4 Methods

All field sampling and laboratory methods adhered to internal methods and ISO/IEC 17025 requirements. NATA accreditation details are summarised in Table 3.

Table 3 Sydney Water laboratories' NATA accreditation numbers

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

4.1 Sampling methods

4.1.1 Water quality sampling

Site locations were determined through consultation between City of Ryde and Sydney Water including the water quality monitoring program design.

Samples were collected in bottles pre-labeled with a unique identification number, site code, location and date of collection. Field measurements and observations for each site were recorded at the time of sampling. Aseptic techniques were followed to ensure sample integrity.

Samples were collected from 20-30 cm below the water surface. To avoid collecting benthic sediment in shallower waterways, surface samples were collected. Surface samples may contain surface contaminates, such as scum, dust or pollen, which may not be present below the waterway surface.

Select water chemistry analytes are analysed in the field using specific instruments (Table 4). A visual assessment of the site is conducted to record sample clarity, algae presence, recent rain, visual pollution and flow rate (visual assessment).

Table 4 Water chemistry parameters and field analysis methods

Analyte	Method
Dissolved Oxygen (%)	WTW Multiliner Universal Meter
Dissolved Oxygen (mg/L)	WTW Multiliner Universal Meter
Conductivity (µS/cm)	WTW Multiliner Universal Meter
pH (pH units)	WTW Multiliner Universal Meter
Turbidity (NTU)	HACH Turbidimeter
Temperature (ºC)	Digital Thermometer

4.1.2 Macroinvertebrate sampling and identifications

Macroinvertebrate sampling was completed in accordance with AUSRIVAS protocols for New South Wales (Turak et al. 2004) and in-house test methods. For each sampling site, two edge habitats were sampled with a hand-held dip net. Edge habitats were defined as areas with little to no current within a 100 m stretch of creek.

The contents of the net were emptied into a large sorting tray with a small amount of water. The live macroinvertebrate specimens were collected with fine forceps and pipettes for a minimum period of 40 minutes (Figure 2). Specimens were preserved in small glass specimen jars containing 85% un-denatured ethanol.

Macroinvertebrates were identified and enumerated to the family taxonomic level, except the family *Chironomidae*, which were identified to sub-family. For AUSRIVAS analysis specimens were combined for Oligochaeta at class and Acarina at order level.

Figure 2 **Sampling technique, sample jars and a picked specimen, Hemipteran, Notonectidae *Enithares* (Back-swimmer).**

4.2 Data analysis methods

4.2.1 Water quality

Water quality results allow characterisation of each study creek against Australian and New Zealand Environment and Conservation Council (ANZECC 2000) guidelines for Aquatic Ecosystems (Lowland River in south eastern Australia) and Recreational Water Quality and Aesthetics (Secondary) (Table 5).

Although the ANZECC (2000) recommended guidelines, were for slightly disturbed ecosystems, they do provide an indication of water quality compared to other systems within south eastern Australia. Daily rainfall data was collected from the Sydney Water rain gauge at West Ryde Pumping Station. Water hardness categories, based on values, are presented in Table 6. Analytes that have recommended guideline values that vary per water hardness are summarised in Table 7 with their adjusted recommended guidelines.

Table 5 **ANZECC (2000) indicators and guideline values. H indicates recommended guideline values that depend on water hardness values.**

Indicator	Guideline value	Unit	Guideline reference
Dissolved Oxygen	85 to 110	% saturation	Protection of aquatic ecosystem (ANZECC 2000)
pH	6.5 to 8.5	pH unit	Protection of aquatic ecosystem (ANZECC 2000)
Turbidity	6 to 50	NTU	Protection of aquatic ecosystem (ANZECC 2000)
Conductivity	125 to 2,500	µS/cm	Protection of aquatic ecosystem (ANZECC 2000)
Ammonia nitrogen	20	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Oxidised nitrogen	40	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Total nitrogen	350	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Total phosphorus	25	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Faecal coliforms	1,000	CFU/100 mL	Secondary contact recreation (ANZECC 2000)
Chromium	0.001	mg/L	Toxicants at 95% level of protection
Manganese	1.9	mg/L	Toxicants at 95% level of protection
Iron	ID	mg/L	Toxicants at 95% level of protection
Copper H	0.0014	mg/L	Toxicants at 95% level of protection
Zinc H	0.008	mg/L	Toxicants at 95% level of protection
Arsenic	0.013	mg/L	Toxicants at 95% level of protection
Cadmium H	0.002	mg/L	Toxicants at 95% level of protection

Lead	H	0.0034	mg/L	Toxicants at 95% level of protection
Mercury	B	ID	mg/L	Toxicants at 95% level of protection

Table 6 ANZECC (2000) recommended guideline value adjustments for water hardness

Hardness category (mg $CaCO_3$ /L)	Hardness range (mg $CaCO_3$ /L)	Chromium (Cr)	Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)
Soft	0-59	TV	TV	TV	TV	TV
Moderate	60-119	x 2.5	x 2.7	x 2.5	x 4.0	x 2.5
Hard	120-179	x 3.7	x 4.2	x 3.9	x 7.6	x 3.9
Very hard	180-240	x 4.9	x 5.7	x 5.2	x 11.8	x 5.2
Extremely hard	400	x 8.4	x 10.0	x 9.0	x 26.7	x 9.0

Table 7 Water hardness adjusted recommended guideline values

Hardness category (mg/L as $CaCO_3$)	Hardness range (mg/L as $CaCO_3$)	Chromium (Cr) mg/L	Cadmium (Cd) mg/L	Copper (Cu) mg/L	Lead (Pb) mg/L	Zinc (Zn) mg/L
Soft	0-59	0.001	0.002	0.001	0.003	0.008
Moderate	60-119	0.0027	0.0005	0.0035	0.0136	0.02
Hard	120-179	0.0042	0.00074	0.00546	0.02584	0.0312
Very hard	180-240	0.0057	0.00098	0.00728	0.04012	0.0416
Extremely hard	400	0.01	0.00168	0.0126	0.09078	0.072

4.2.2 Macroinvertebrate Analyses

Univariate Analyses;

- Taxa Richness
- EPT Taxa Richness

Biological Indices;

- SIGNAL2
- SIGNAL-SF
- AUSRIVAS

5 Site observations

CR3 Terrys Creek

The Terrys Creek sampling site is located within Somerset Park under the M2 overpass in the suburb of Epping. The surrounding land use is residential, and the creek flows through a bushland corridor. The riparian area and bank edge is a mix of native and exotic plant species. The creek bed is predominately bedrock, gravel and sand. There were no notable site observations recorded in autumn 2017.

Figure 3 Edge habitat at Terrys Creek, (L-R) spring 2007 and spring 2013.

Within Terrys Creek there has been stabilization/erosion and riparian planting projects at Foresters Park, and regrade/riffle improvements at Jim Walsh Park Tributary.

CR1 Shrimptons Creek

The Shrimptons Creek core sampling site is located within Wilga Park in the suburb of Macquarie Park and the surrounding land use comprises a mix of residential, commercial and light industrial. The creek flows through a thin riparian/vegetation corridor, which is a mix of native and exotic species. The riparian area is periodically cleared but at times has been overgrown with exotic plant species. The creek bed is predominately bedrock and sand/silt. There are gross pollutant traps along the sampling site, however domestic rubbish, excessive organic debris and other refuse has been periodically observed at the site. Deceased animals have been observed at this sampling site.

Figure 4 Shrimptons Creek: gross pollutant trap (L) sampling site facing downstream (M) and upstream (R).

CR1SA Shrimptons Creek at Kent Road

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

CR1SB Shrimptons Creek at Bridge Road

The Bridge Road site is located at the downstream section of Santa Rosa Park, just before it flows under Bridge Rd and is surrounded by residential areas. Santa Rosa Park consists largely of cleared grass fields.

The riparian area has at times been thickly vegetated with native and exotic weeds and shrubs that have choked the creek. More recently growth has been predominately *Eleocharis* and *Myriophylum sp* and various grasses and weeds (Figure 5).

CR1SC Shrimptons Creek at Quarry Road

The Quarry Road site is located at the upstream section of Santa Rosa Park, at the point where Shrimptons Creek emerges from the underground stormwater system. This site has experienced similar changes as Bridge Rd with clearing and revegetation. Odour, oil and scum has been observed on the water surface with organic and domestic debris during recent and past surveys (Figure 5).

Figure 5 Shrimptons Creek, spring 2013, Bridge Rd (L) and Quarry Rd (R).

CR5 Porters Creek

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

The riparian area is dominated by native plants with a small amount of exotic species. The creek bed has historically composed of bedrock with some cobble, boulder and sand. A considerable sandbank has built up in the middle of the creek below the bridge (picture below (R)). No macrophyte growth has been observed at the site however there has been varying levels of algal growth present. The water was clear in autumn 2017, which is consistent with historical observations.

Figure 6 Porters Creek, autumn 2013 (L) and spring 2016 (R).

CR5PA Porters Creek at Main Branch

The Main Branch site is located on the western boundary of the depot and consists of an open concrete channel. The sampling point is in a retention basin at the end of the channel immediately before the creek flows underground for the remainder of its path through the depot. There is usually extensive algal growth along the edge of the concrete channel and there is often a varying amount of oil and scum on the water surface. This site could not be accessed in autumn 2017 and was not sampled.

CR5PB Porters Creek at Spur Branch

The Spur Branch site is located in the north-western corner of the depot in an underground drainage pit where several underground stormwater lines meet before joining and draining to the main Porters Creek line. In spring 2013 the drainage grate and surrounding concrete had collapsed (

Figure 7), rendering the site impossible to sample. A new access point was established for autumn 2017, further upstream, at the base of a concrete pipe

Figure 7 Porters Creek at Spur Branch in autumn 2017 (L) and Wicks Rd in autumn 2017 (R).

CR5PC Porters Creek at Wicks Road

The Wicks Road site is located at the first point that Porters Creek drains from the underground stormwater system. The site is surrounded by commercial and industrial land uses and the vegetation mostly consists of exotic trees and shrubs. Oil and scum has been regularly observed on the water surface. This site could not be accessed in spring 2016 due to construction of a new stormwater system, it was sampled during autumn 2017.

CR4 Buffalo Creek

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

The creek bed is mostly a mix of sand, silt and gravel. There is usually some macrophyte growth, *Egeria* and *Potamogeton*, and little algal growth has been observed. Sedimentation has occurred periodically, along with a significant amount of organic debris and domestic rubbish (Figure 8).

There has been bank stabilisation and erosion control works removing sediment islands at Burrows Park in September 2016.

Figure 8 Buffalo Creek, CR4B facing upstream in spring 2009 (L) and in autumn 2014 (R).

CR4BA Buffalo Creek downstream of Burrows Park

The downstream Burrows Park site is accessed off Buffalo Rd and is positioned just before the creek flows under the road. The surrounding land use is residential and Burrows Park consists mostly of a bush corridor. There are usually obvious signs of bird activity around this site, including extensive bird droppings. During the current surveys wood duck and ibis were present at the site. There have been increased turbidity levels observed at this site most notably in autumn 2008 (Figure 9, left) and on several non-sampling site visits.

Figure 9 Buffalo Creek, downstream Burrows Park in spring 2008 (L) and upstream Burrows Park in autumn 2014 (R).

CR4BB Buffalo Creek upstream of Burrows Park

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

CR2 Archers Creek

The core Archers Creek sampling site is located at Maze Park in the suburb of West Ryde and is positioned just upstream of the Victoria Rd crossing. The surrounding land use is mostly residential and a golf course is present downstream. There is mostly native vegetation along both banks of the creek. The creek bed is mostly bedrock with banks of sediment (sand, silt and organic matter). There is thick growth of various native and exotic plants along most of the sampling area including both terrestrial and semiaquatic species (Figure 10). There has been extensive algal growth within the creek, this was not observed during autumn 2017. A new grose pollutant trap was installed at Deakin Street adjacent to the golf course in 2016.

Figure 10 Archers Creek in autumn 2008 (L) and spring 2016 (R).

6 Rainfall results and interpretation

Rainfall information provides context for water quality and macroinvertebrate data. Rainfall plays an important role in driving water quality in urban streams through input of pollutants and increased flow.

Rainfall events can cause bank erosion, resulting in a loss of habitat and altered channel complexity (Walsh 2005). Urban catchments often have a high amount of connected impervious surfaces, such as roads and building. This results in increased storm water runoff, which often discharges into streams. This can cause an increase in turbidity, nutrients and other pollutants.

All samples for autumn 2017 were collected on April 11. During March 2017, rainfall was recorded on 20 out of 31 days and 4 out of the first 10 days of April. Consistent and continuous rainfall can change the flow regime of a creek, with the potential to increase dissolved oxygen. Fecal coliforms and nutrients may also increase due to increased storm water inflow.

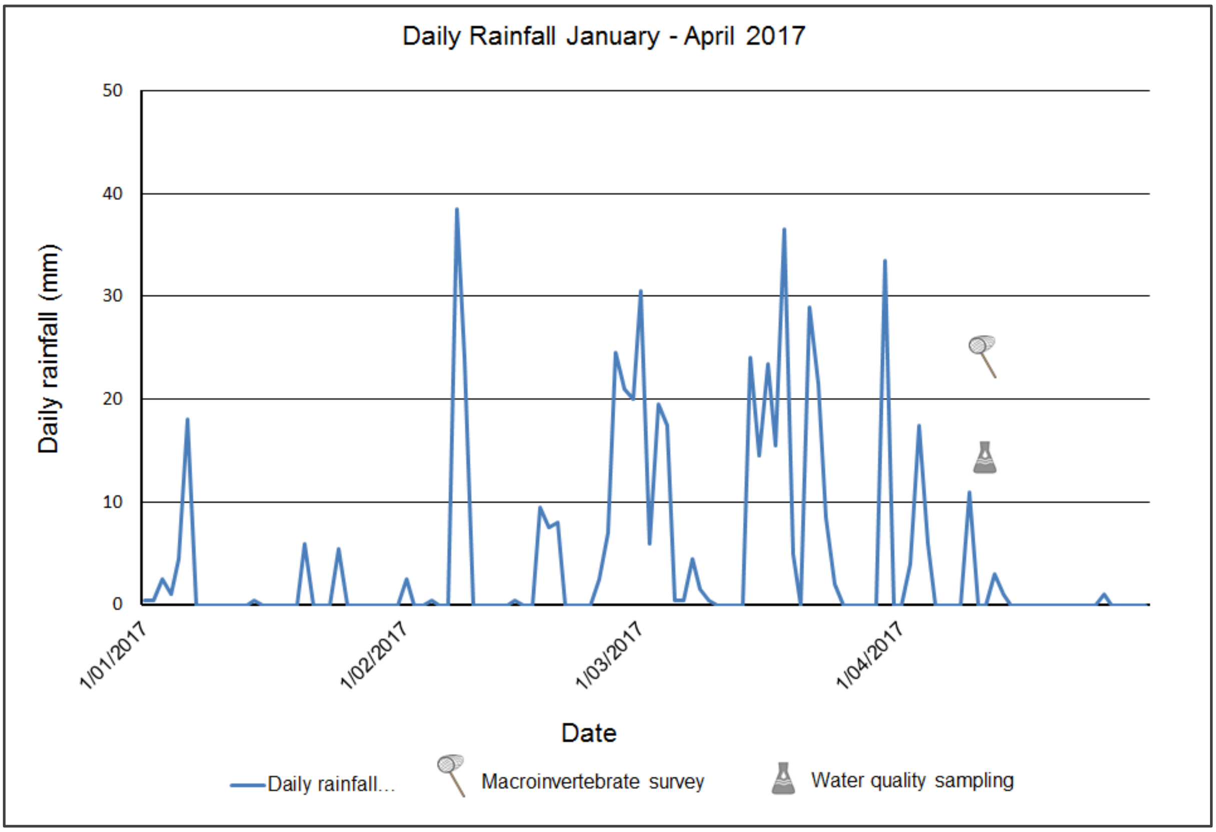

Figure 11 Daily rainfall data 2017

7 Water quality results and interpretation

7.1 Results

The data presented in this section includes historical medians (2004-2016, or where available) and autumn 2017 data. All water quality sites, for the current period, were sampled on April 11. The water quality results are presented in the following sections, by location, then site. Each section will cover results for:

- physico-chemical variables
- alkalinity and hardness
- Bacteria and nutrients
- metals

Arrows indicating the changes between autumn and historical median results are added to the tables in the results section to aid with visual interpretation of the data. Values that exceed the recommended ANZECC (2000) guidelines appear in red text. The metals results are presented under the elemental symbols, chromium (Cr), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg).

Due to access issues, one water quality site in Porters Creek, CRP5A, could not be sampled during autumn 2017. The two remaining water quality sites for Porters Creek were sampled and analysed for metals for the first time since this monitoring program began.

7.1.1 **Terrys Creek**

Physico-chemical

Dissolved oxygen improved in autumn 2017 compared to the historical median, moving into the recommended guidelines compared (Table 8). Temperature was the same as the historical median and all remaining variables were within recommended guidelines.

Alkalinity and hardness

Alkalinity increased in this season (Table 9) and magnesium, calcium and hardness decreased. Hardness remained in the *moderate* category (60-119 mg $CaCO_3$/L).

Bacteria and nutrients

Faecal coliforms exceeded in autumn 2017, with a value 2.7x the recommended guidelines (Table 10), which is much higher than the historical median. Ammonia, total nitrogen, oxidised nitrogen and total phosphorus all exceed recommended guidelines this season.

Metals

The only metal exceedance was for copper (Table 11), for both this season and the historical median.

Table 8 **Terrys Creek physico-chemical results**

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR3T	*Historical Median*	15.7	6.5	**64.1**	7.2	2.6	150
	Autumn 2017	15.7 -	8.9 ↑	87 ↑	7.47 ↑	8.19 ↑	396 ↑

Table 9 **Terrys Creek alkalinity and hardness results, water hardness indicated by * for *moderate***

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg/L $CaCO_3$	mg/L $CaCO_3$
Guideline		NA	NA	NA	NA
CR3T	*Historical Median*	7.7	30.3	107	61.9
	Autumn 2017	6.83 ↓	25.6 ↓	92 ↓	78 ↑

Table 10 **Terrys Creek bacteriological and nutrient results**

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen $No_{x\text{-}N}$	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR3T	*Historical Median*	150	20	**595**	350	**170**	**33**
	Autumn 2017	**2700** ↑	**80** ↑	**840** ↑	330 ↓	**430** ↑	**54** ↑

Table 11 **Terrys Creek metal results, * indicates recommended guideline values water hardness for *moderate***

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.00054*	1.9	NA	0.0035*	0.02*	0.013	0.0025*	0.0136*	0.0006
CR3T	*Historical Median*	0.0005*	0.033	0.734	**0.0049***	0.014*	0.0005	0.0005*	0.0005*	0.00015
	Autumn 2017	0.0004* ↓	0.0104 ↑	0.716 ↓	**0.0054*** ↑	0.015* ↑	0.0006 ↑	0.0006* ↑	0.0009* ↑	0.0003 ↑

7.1.2 Shrimptons Creek

- CR1S – Shrimptons Creek at Wilga Park
- CR1SA - Shrimptons Creek at Kent Road
- CR1SB - Shrimptons Creek at Bridge Street (downstream of Santa Rosa Park)
- CR1SC - Shrimptons Creek at Quarry Road (upstream of Santa Rosa Park)

Physico-chemical

All Shrimptons Creek sites had dissolved oxygen lower than the recommended guidelines, except for CR1SA, which had 95.1% (Table 12). All remaining variables were within the recommended guidelines.

Alkalinity and hardness

All sites were within the moderate range, except for CR1SC, which was in the hard range (Table 13). This site had a historical median within the moderate range. There were no overall trends across the sites and through time for all sites.

Bacteria and nutrients

There were no faecal coliform exceedances for autumn 2017 for all Shrimptons Creek sites (Table 14). Total nitrogen results exceeded at all sites, which was consistent with the historical medians. Ammonia only had two exceedances for this season, the core site CR1S and the water quality site CR1SB. Total phosphorus was lower than the historical median at all sites, however, CR1SC was the only site that was within the recommended guidelines. Oxidised nitrogen also exceeded at all sites for this season.

Metals

There was one exceedance for metals in autumn 2017, this was zinc at CR1SA (Table 15).

Table 12 Shrimptons Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR1S	*Historical Median*	16.3	5.2	**52**	7.11	5.72	368
	Autumn 2017	17.25 ↑	4.32 ↓	**45.95** ↓	7.11 -	4.925 ↓	358 ↓
CR1SA	*Historical Median*	17	4.7	**46.4**	7.08	4.32	408
	Autumn 2017	19.2 ↑	8.89 ↑	95.1 ↑	7.67 ↑	3.77 ↓	645 ↑
CR1SB	*Historical Median*	17.7	5.5	**55.5**	7.09	4.58	650
	Autumn 2017	17.3 ↓	7.47 ↑	**76.6** ↑	7.09 -	2.06 ↓	537 ↓
CR1SC	*Historical Median*	17.7	7.4	**75.8**	7.33	3.17	899
	Autumn 2017	16.6 ↓	8.18 ↑	**82.8** ↑	7.11 ↓	4.32 ↑	397 ↓

Table 13 Shrimptons Creek alkalinity and hardness results, water hardness indicated by * for *moderate* and ** for *hard*

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR1S	*Historical Median*	6.02	25.1	87*	75
	Autumn 2017	4.66 ↓	26.5 ↑	85* ↓	66.75 ↓
CR1SA	*Historical Median*	6.96	20.9	79*	64.7
	Autumn 2017	6.48 ↓	23.1 ↑	84* ↑	65 ↑
CR1SB	*Historical Median*	7.69	27	99.2*	80
	Autumn 2017	8.37 ↑	30.7 ↑	110* ↑	79 ↓
CR1SC	*Historical Median*	8.34	21.5	88.1*	79.7
	Autumn 2017	10.2 ↑	33.7 ↑	130** ↑	86 ↓

Table 14 Shrimptons Creek bacteriological and nutrient results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NO_{x}-N	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR1S	*Historical Median*	800	**50**	**820**	380	**380**	**59**
	Autumn 2017	435 ↓	**30** ↓	**650** ↓	485 ↑	**90** ↓	**53.5** ↓
CR1SA	*Historical Median*	430	20	**620**	490	**60**	**41**
	Autumn 2017	500 ↑	10 ↓	**540** ↓	220 ↓	**290** ↑	**26** ↓
CR1SB	*Historical Median*	230	**20**	**540**	410	30	**26**
	Autumn 2017	490 ↑	**20** -	**650** ↑	250 ↓	**390** ↑	**18** ↓
CR1SC	*Historical Median*	460	**40**	**1390**	500	**670**	**48**
	Autumn 2017	820 ↑	10 ↓	**1100** ↓	120 ↓	**900** ↑	23 ↓

Table 15 Shrimptons Creek metal results, * indicates recommended guideline values water hardness for *moderate* and ** for *hard*

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.00054* 0.00084**	1.9	NA	0.0035* 0.0055**	0.02* 0.031**	0.013	0.0025* 0.0037**	0.0136* 0.0258**	0.0006
CR1S	*Historical Median*	0.0004*	0.0174	0.865	0.0037*	0.016*	0.0006	0.0006*	0.0011*	0.0003
	Autumn 2017	0.0005* ↑	0.043 ↑	1.07 ↑	0.0031* ↓	0.018* ↑	0.001 ↑	0.0005* ↓	0.0015* ↑	0.00015 ↓
CR1SA	*Historical Median*	0.0005*	0.0382	1.19	0.0018*	0.015*	0.0005	0.0005*	0.0005*	0.00015
	Autumn 2017	0.0002* ↓	0.007 ↓	0.511 ↓	0.0099* ↑	**0.024*** ↑	0.0004 ↓	0.0004* ↓	0.001* ↓	0.0003 ↑
CR1SB	*Historical Median*	0.0005*	0.031	1.12	0.002*	**0.022***	0.0005	0.0005*	0.0005*	0.00015
	Autumn 2017	0.0002* ↓	0.0238 ↓	0.43 ↓	0.0018* ↓	0.019* ↓	0.0003 ↓	0.0003* ↓	0.0003* ↓	0.0003 ↑
CR1SC	*Historical Median*	0.0005*	0.016	0.227	0.002*	0.014*	0.0005	0.0005*	0.0005*	0.00015
	Autumn 2017	0.0002** ↓	0.0134 ↓	0.207 ↓	0.0019** ↓	0.014** -	0.0004 ↓	0.0004** ↓	0.0003** ↓	0.0003 ↑

7.1.3 Porters Creek

- CR5P – Porters Creek downstream of council depot
- CR5PA – Porters Creek at Main Branch (could not be sampled – data no included)
- CR5PB – Porters Creek at Spur Branch
- CR5PC – Porters Creek at Wicks Road

Physico-chemical

Autumn 2017 dissolved oxygen results were within the recommended guidelines at all sites except the core site CR5P, which was 80.8% (Table 16). The remaining analytes varied and there was no overall trend.

Alkalinity and hardness

Hardness results were in the *hard* category for the core sites CR5P, and *moderate* for the remaining two sites (Table 17). This is consistent with the historical medians at all sites. The most variation from the median across the remaining analytes was alkalinity. For CR5P, the autumn 2017 value was close to double the historical, and close to 70% increase at CR5PB. This was the first sampling event for magnesium, calcium and hardness for CR5PB.

Bacteria and nutrients

There was only one faecal coliform result that exceeded the recommended guidelines, at CR5PC with 3.5x the guideline (Table 18). Total nitrogen, oxidised nitrogen and total phosphorus exceeded the recommended guidelines at all sites this season. The core site, CR5P, had the highest ammonia, total nitrogen, oxidised nitrogen and total phosphorus results compared to the remaining Porters Creek sites. The ammonia at CR5P was high at 7450 µg/L but it was lower than the spring 2016 result, which was 11200 µg/L.

Metals

This was the first time that CRPB was sampled for metals, so there are no historical medians available. Copper was the only metal analyte that had an exceedance for this season, at CR5PC (Table 19).

Table 16 **Porters Creek physico-chemical results**

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR5P	*Historical Median*	18.135	8.365	91.15	7.63	3.925	621
	Autumn 2017	16.2 ↓	8.08 ↓	**80.8** ↓	7.65 ↑	15.8 ↑	669 ↑
CR5PB	*Historical Median*	18.15	9.45	99	7.6	4.355	342.5
	Autumn 2017	19.1 ↑	10.1 ↑	106.8 ↑	8.65 ↑	2.63 ↓	355 ↑
CR5PC	*Historical Median*	18.45	8.75	92.6	7.685	5.895	503
	Autumn 2017	19.4 ↑	8.86 ↑	95.6 ↑	8.14 ↑	4.57 ↓	476 ↓

Table 17 **Porters Creek alkalinity and hardness results, water hardness indicated by * for *moderate* and ** for *hard***

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR5P	*Historical Median*	11.8	45.2	162**	87.65
	Autumn 2017	12.7 ↑	43.6 ↓	160** ↓	172 ↑
CR5PB	*Historical Median*	N/A	N/A	N/A	70.05
	Autumn 2017	6.49 -	34.5 -	110* -	118 ↑
CR5PC	*Historical Median*	8.05	30.2	108.5*	79
	Autumn 2017	7.58 ↓	31.5 ↑	110* ↑	78 ↓

Table 18 Porters Creek bacteriological and nutrient results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen No_{x-N}	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR5P	*Historical Median*	360	**625**	**2355**	1100	**1235**	**26**
	Autumn 2017	580 ↑	**4520** ↑	**7450** ↑	4690 ↑	**1970** ↑	**57** ↑
CR5PB	*Historical Median*	122	**75**	**745**	430	**260**	**38.5**
	Autumn 2017	51 ↓	10 ↓	**560** ↓	39 ↓	**100** ↓	**40** ↑
CR5PC	*Historical Median*	560	**60**	**1495**	425	**1005**	**31**
	Autumn 2017	**3500** ↑	**70** ↑	**1940** ↑	390 ↓	**1550** ↑	**44** ↑

Table 19 Porters Creek metal results, * indicates recommended guideline values water hardness for *moderate* and ** for *hard*

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.00054* 0.00084**	1.9	NA	0.0035* 0.0055**	0.02* 0.031**	0.013	0.0025* 0.0037**	0.0136* 0.0258**	0.0006
CR5P	*Historical Median*	0.0005**	0.055	1.1	0.003**	0.017**	0.0005	0.0005**	0.0005**	0.00015
	Autumn 2017	0.0006** ↑	0.0277 ↓	0.874 ↓	0.0044** ↓	0.018** ↑	0.0007 ↑	0.0007** ↑	0.0007** ↑	0.0003 ↑
CR5PB	*Historical Median*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Autumn 2017	0.002* ↑	0.0114 ↑	0.128 ↑	**0.0056*** -	0.005* ↓	0.0006 ↑	0.0006* ↓	0.0002* ↓	0.0003 ↓
CR5PC	*Historical Median*	0.0015*	0.032	1.705	**0.015***	**0.0735***	0.0005	0.0005*	0.00125*	0.00015
	Autumn 2017	0.0005* ↓	0.0145 ↑	0.382 ↓	**0.0056*** ↑	0.015* ↓	0.0005 -	0.0005* -	0.0004* ↓	0.0003 ↑

7.1.4 Buffalo Creek

- CR4B – Buffalo Creek at Higginbotham Road
- CR4BA – Buffalo Creek downstream of Burrows Park
- CR4BB – Buffalo Creek upstream of Burrows Park

Physico-chemical

Dissolved oxygen was within the recommended guidelines for the Buffalo Creek water quality sites, but was lower than the accepted range at the core site (Table 20). This is an improvement on the historical average for all sites. Turbidity and pH were also within the recommended guideline for all sites. Conductivity was the only analyte that consistently decreased this season compared to historical medians

Alkalinity and hardness

All Buffalo Creek sites were in the *hard* category for water hardness (Table 21). This is consistent with spring 2016 and the historical medians for the water quality sites. The core site, CR4B had a historical median of *moderate* hardness. Alkalinity and calcium results were similar across the three sites this season.

Bacteria and nutrients

Faecal coliforms exceeded the recommended guidelines at both water quality sites, CR4BA with 4.9x and CR4BB 2.5 the guideline (Table 22). This is the reverse of spring 2016, which only and an exceedance at the core site CR4B. Ammonia exceeded at the core site only in this season. Total oxidised nitrogen and total phosphorus exceeded at all sites. Total nitrogen was within guidelines for CR4BA only, with CR4B 3.2x and CR4BB 5.1x the guideline.

Metals

The only metals results that exceeded recommended guidelines was copper at CR4BA and CR4BB (Table 23). In spring 2016 zinc exceeded at CR4BB only.

Table 20 **Buffalo Creek physico-chemical results**

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR4B	*Historical Median*	17.25	6.875	**71.4**	7.31	5.075	664.5
	Autumn 2017	15.6 ↓	8.43 ↑	**82.6** ↑	7.44 ↑	15.8 ↑	523 ↓
CR4BA	*Historical Median*	17.9	7.5	**78.9**	7.18	7.47	1137.5
	Autumn 2017	18.3 ↑	9.2 ↑	97.1 ↑	7.23 ↑	7.09 ↓	707 ↓
CR4BB	*Historical Median*	17.7	7.9	**84.2**	7.63	3.775	909
	Autumn 2017	18.6 ↑	8.76 ↑	91.6 ↑	7.6 ↓	3.37 ↓	590 ↓

Table 21 **Buffalo Creek alkalinity and Hardness results, water hardness indicated by * for moderate and ** for hard**

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR4B	*Historical Median*	9.37	24.8	101*	78
	Autumn 2017	9.28 ↓	31.4 ↑	120** ↑	90 ↑
CR4BA	*Historical Median*	13.5	34.9	143**	98.05
	Autumn 2017	11.4 ↓	32.9 ↓	130** ↓	93 ↓
CR4BB	*Historical Median*	10.5	33.7	128**	102
	Autumn 2017	9.49 ↓	32.1 ↓	120** ↓	94 ↓

Table 22 Buffalo Creek Bacteria and nutrients results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen $No_{x\text{-}N}$	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR4B	*Historical Median*	195	**655**	**655**	430	**235**	**38**
	Autumn 2017	450 ↑	**30** ↓	**1120** ↑	260 ↓	**750** ↑	**45** ↑
CR4BA	*Historical Median*	820	**980**	**980**	500	**545**	**48**
	Autumn 2017	**4900** ↑	10 ↓	168 ↓	240 ↓	**1390** ↑	**59** ↑
CR4BB	*Historical Median*	440	**850**	**850**	340	**510**	**53**
	Autumn 2017	**2500** ↑	10 ↓	**1800** ↑	310 ↓	**1490** ↑	**99** ↑

Table 23 Buffalo Creek metal results, * indicates recommended guideline values water hardness for *moderate* and ** for *hard*

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.00054* 0.00084**	1.9	NA	0.0035* 0.0055**	0.02* 0.031**	0.013	0.0025* 0.0037**	0.0136* 0.0258**	0.0006
CR4B	*Historical Median*	0.0005*	0.026	0.974	0.003*	0.016*	0.0005	0.0005*	0.0005*	0.00015
	Autumn 2017	0.0004** ↓	0.0174 ↓	1.22 ↑	0.0045** ↑	0.021** ↑	0.0005 -	0.0005** -	0.0016** ↑	0.0003 ↑
CR4BA	*Historical Median*	0.0005**	0.094	1.44	**0.006****	0.027**	0.0005	0.0005**	0.001**	0.00015
	Autumn 2017	0.0003** ↓	0.0415 ↑	1.1 ↓	**0.0068**** ↑	0.028** ↑	0.0006 ↑	0.0006** ↑	0.001** -	0.0003 ↑
CR4BB	*Historical Median*	0.0005**	0.0375	0.513	**0.0081****	**0.034****	0.001	0.0005**	0.0005**	0.00015
	Autumn 2017	0.0003** ↓	0.0063 ↓	0.448 ↓	**0.0101**** ↑	0.029** ↓	0.0006 ↓	0.0006** ↑	0.0007** ↑	0.0003 ↑

7.1.5 Archers Creek

- CR2A – Archers Creek at Maze Park

Physico-chemical

All phyisco-chemical analytes for the Archers Creek site were within the recommended guidelines for this season (Table 24). In spring 2016, the dissolved oxygen result was 57.7% compared to autumn 2017 with 89.8%.

Alkalinity and hardness

All analytes for alkalinity and hardness were similar for this season compared to the historical median. There was an increase in magnesium this season compared to spring 2017, with 9.96 mg/L compared to 5.77 mg/L (Table 25). Water hardness remained in the *moderate* category for this season.

Bacteria and nutrients

All analytes that have a recommended guideline, exceeded this season (Table 26). Faecal coliforms were 3.9x the guideline, which is 10.8x the historical median for this site. Oxidised nitrogen for this season was 2 orders of magnitude greater than the historical median.

Metals

All metal results for the Archers Creek site were within the recommended guidelines for this season. (Table 27).

Table 24 Archers Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR2A	*Historical Median*	17.62	5.815	**59.6**	7.15	2.685	410
	Autumn 2017	16.8 ↓	8.8 ↑	89.8 ↑	7.54 ↑	2.18 ↓	448 ↑

Table 25 Archers Creek alkalinity and hardness results, water hardness indicated by * for *moderate*

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR2A	*Historical Median*	8.7	24.4	96.8*	73
	Autumn 2017	9.96 ↑	22.1 ↓	96* ↓	74 ↑

Table 26 Archers Creek Bacteria and nutrients results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NO_{x-N}	Total Phosphorus
Unit		CFU/100mL	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR2A	*Historical Median*	325	**570**	**570**	370	**80**	**41**
	Autumn 2017	**3900** ↑	**30** ↓	**1640** ↑	320 ↓	**1320** ↑	**32** ↓

Table 27 Archers Creek metal results, * indicates recommended guideline values water hardness for *moderate*

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.0027*	1.9	NA	0.0035*	0.02*	0.013	0.0005*	0.0136*	0.0006
CR2A	*Historical Median*	0.0005*	0.71	0.828	0.0023*	0.014*	0.0005	0.0005*	0.0005*	0.00015
	Autumn 2017	0.0002* ↓	0.0111 ↓	0.203 ↓	0.0018* ↓	0.006* ↓	0.0003 ↓	0.0003* ↓	0.0002* ↓	0.0003 ↑

7.2 Water quality interpretation

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

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

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

7.2.1 Physico-chemical analytes

Temperature

Temperature in waterways varies with water depth, shading and flow, and can affect several other water quality parameters. Temperature can fluctuate throughout the day, particularly in shallow creeks. The temperature data must be analysed with respect to the time and conditions of the sampling event. Temperature fluctuations may affect: chemical and biochemical reaction rates; chemical solubility; growth and respiration rates of aquatic organisms; and reproduction and competitive interaction cues of aquatic organisms.

The temperatures recorded in autumn 2017 varied within and between creek catchments. There was not an overall trend in temperatures this season, as was observed in spring 2016.

Dissolved oxygen

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

Dissolved oxygen concentrations are often subject to large diurnal and seasonal fluctuations, 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.

This season had improved dissolved oxygen results at most sites, compared to the previous season and historical medians. Dissolved oxygen levels were within the recommended range for all water quality sites at Terrys and Archers creeks. These sites have a historical median lower than the recommended range, indicating an oxygen poor system. The core sites at Porters, Shrimptons and Buffalo creeks had dissolved oxygen levels below the recommended range. The remaining water quality sites for the afore mentioned creeks had improved dissolved oxygen results, all within the recommended range. This overall improvement may be driven by the consistent and often heavy rainfall in autumn. The altered hydrology increases flow speeds and reducing areas of ponded or still water.

Turbidity

Turbidity is an indicator of sediment input from runoff. All sites for this season were within the recommended guidelines, being less than 50 NTU. Despite the elevated rainfall in autumn with the potential for increased transport of suspended solids, turbidity levels remained consistent with historical data

pH

pH influences many biological and chemical processes and is an important water quality parameter. pH can change diurnally through photosynthetic and respiration rates. pH results for autumn 2017 were within the guideline range, which is consistent with historical medians.

Alkalinity and hardness

Water hardness is influenced by the concentration of magnesium and calcium ions in the water column.

Total magnesium, total calcium, hardness and alkalinity do not have an ANZECC guideline value, however, hardness has categories based on values. Archers and Terrys creeks both maintained moderate hardness, whilst two sites moved from moderate to hard, including: one site from both Shrimptons and Buffalo creeks. The remaining sites from Shrimptions, Buffalo and Porters creeks stayed in the same category compared to the historical data.

No sites had results in the very hard water category, which is an improvement on the spring 2016 results with one Buffalo Creek water quality site (CR4BA) in that category.

There were no overall trends for the calcium, magnesium and alkalinity results within and between sites.

7.2.2 Bacteria and nutrients

Faecal coliforms

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

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

There were six faecal coliform exceedances in the autumn 2017 period. This is an increase on the single exceedance in spring 2016 at Buffalo Creek core site (CR4B). The autumn exceedances occurred at Terrys Creek core site (CRT3), Porters Creek water quality site (CR5PC), both Buffalo Creek water quality sites (CR4BA, CR4BB) and Archers Creek core site (CR2A). This increase in faecal coliforms could also be explained by increased and sustained rainfall. Rainfall events result in higher inflow of stormwater runoff and/or wet weather overflows.

Ammonia, nitrogen and phosphorus

There were no overall trends in total nitrogen and total phosphorous across all sites for autumn 2017. Terrys, Porters and Archers creeks exceeded the recommended guidelines for ammonia, total nitrogen and phosphorus. Shrimptons and Buffalo creeks had varying results. Whilst some total nitrogen results were very high for autumn, they remained close to historical medians and were an order of magnitude lower than the highest result of spring 2016.

These results are consistent with historical data and it is representative of an urban, high-impacted catchment. Increases in the nutrient loads of catchments can be attributed to increased storm water inflow.

7.2.3 Metals

Metals were found in very low concentrations at the five creeks for spring 2016. Cadmium, mercury, chromium, arsenic and lead were all below the detection limits for all sites. This was the second year of metals testing.

In autumn 2017, there were some minor exceedances of copper and zinc. In spring 2016 there were only exceedances for copper but historically there had been exceedances for both copper and zinc. There is an influence of increased stormwater inflow due to rainfall events that may explain the elevation in zinc.

8 Macroinvertebrate results and interpretation

8.1 Results

8.1.1 Taxa richness

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

The dominant taxa, comprising a significant proportion of total community assemblages, have historically been within the Mollusca (snails and mussels), Diptera (true flies) and Odonata (dragonflies and damselflies) taxa groups. In autumn 2017, the Mollusca and Dipterans have heavily dominated the community assemblages at all five creeks. Odonata was absent having no significant presence at Buffalo, Porters, Shrimptons and Terrys creeks. In Archers Creek, Odonate families Argiolestidae, Libellulidae, Isostictidae and Hemicorduliidae were all present and contributed to the community assemblage. The Lestidae family, present in spring 2016, was not found at any site for autumn 2017. Archers Creek recorded the highest taxa diversity in autumn 2017 with an average of 14.5 families collected. There appears to be a moderate decrease in the average number of taxa at Terrys, Shrimptons, Porters and Buffalo creeks when compared to previous sampling seasons.

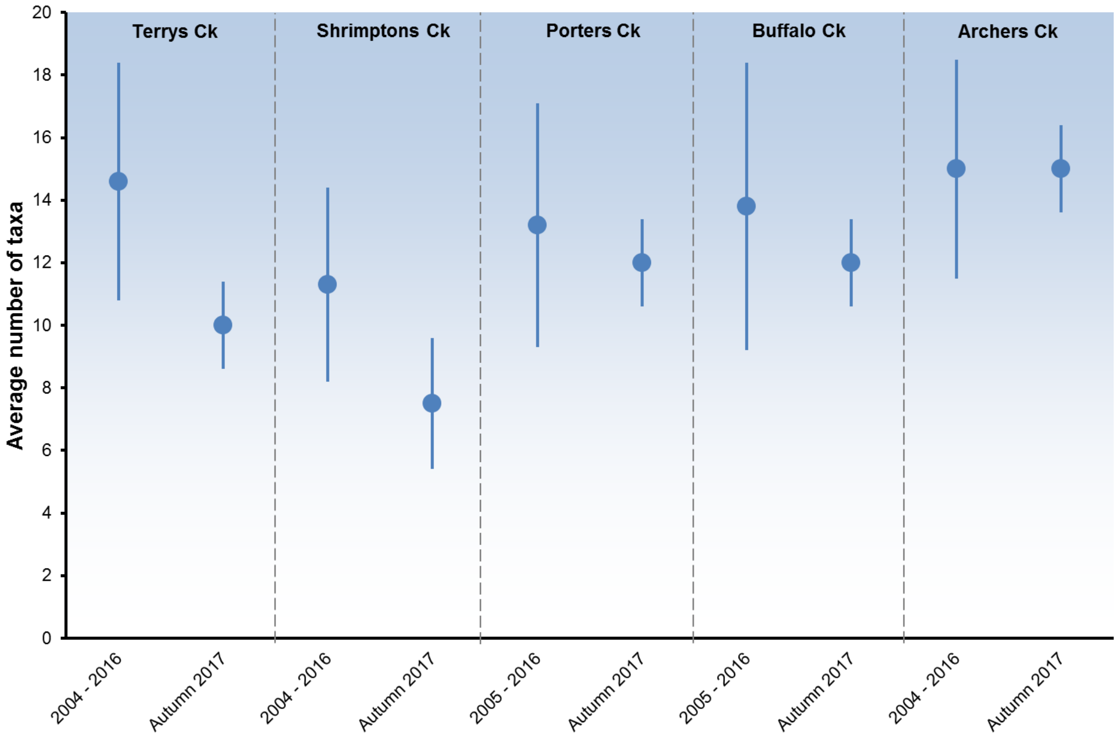

Figure 12 Mean ± SD taxa richness per site between 2004-2016 compared to autumn 2017.

8.1.2 EPT taxa richness

EPT taxa richness shows the abundance of highly sensitive Ephemeroptera (mayfly) Plecoptera (stonefly) and Trichoptera (caddisfly) orders. High EPT richness indicates increased health of an aquatic ecosystem.

In autumn 2017, the average number of EPT taxa found at all macroinvertebrate study sites except Archers Creek was less than 1 per site where only one family, Hydroptilidae (Trichoptera), was found. This remains consistent with historical data from 2004-2016 where the average number of EPT taxa is below 1. No EPT taxa were collected at Terrys, Porters and Shrimptons creeks in autumn 2017.

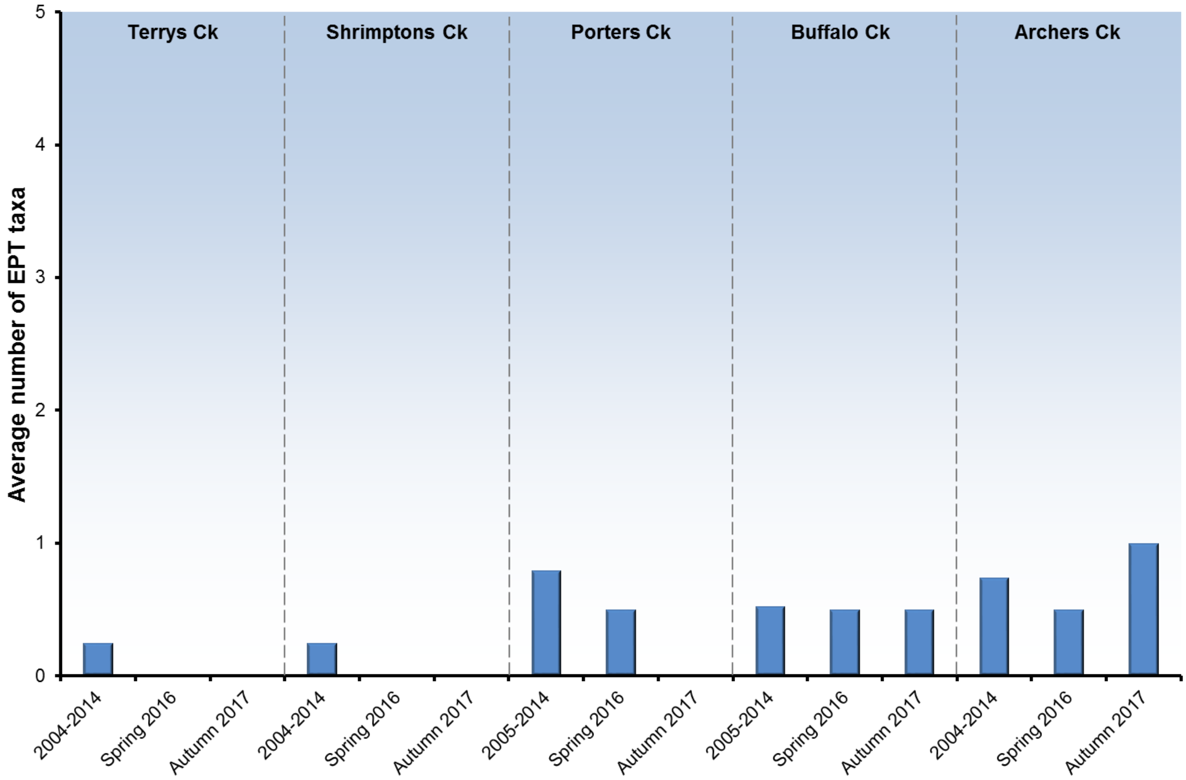

Figure 13 **Mean ± SD EPT taxa collected in spring 2017 compared to 2004-2017.**

8.1.3 Signal2

SIGNAL2 (Stream Invertebrate Grade Number Average Level) biotic index is a relatively simple method used to assess the health of an aquatic ecosystem. This index assigns ‘sensitivity scores’ to macroinvertebrate taxa. A final SIGNAL score combined with the total taxa then places a sample within a quadrant based on potential pollution type.

Mean SIGNAL2 scores are presented in Figure 14 with associated bi-plot placement in Figure 15. All creeks were similarly scored between 2 and 4 for spring and autumn. There was a slight increase in all creeks for autumn 2017 except for Porters Creek which remained consistent with the historical mean.

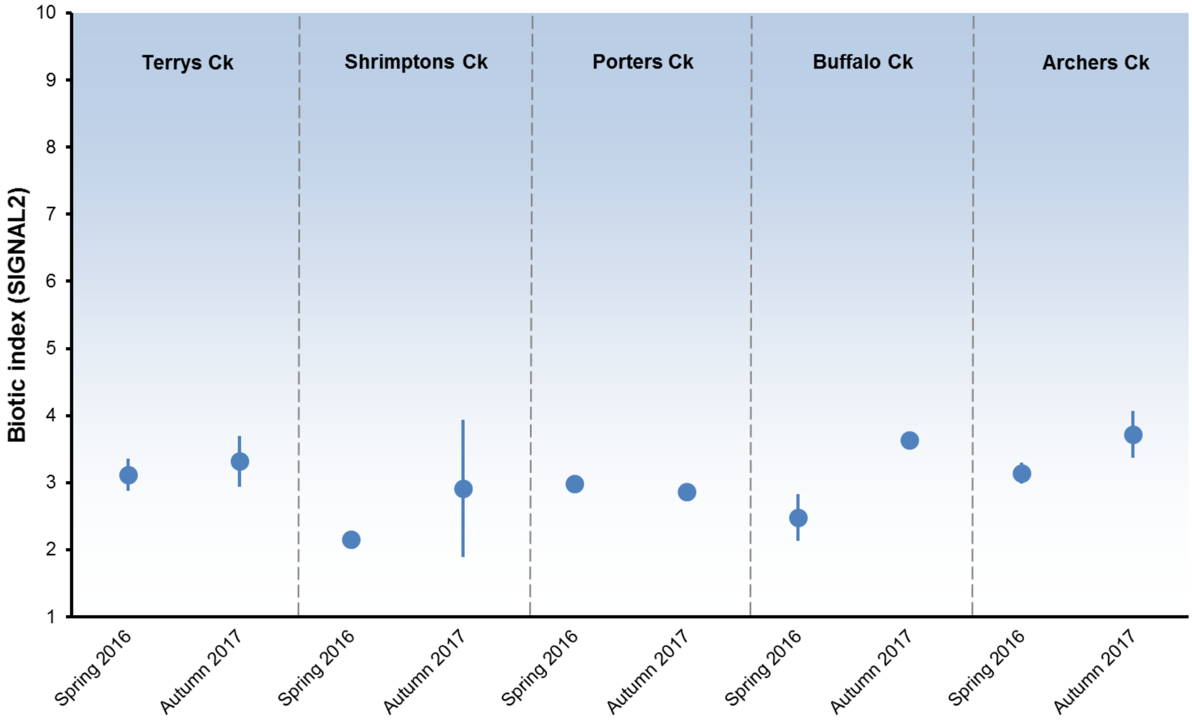

Figure 14 **Mean ± SD SIGNAL2 scores for spring 2016 and autumn 2017.**

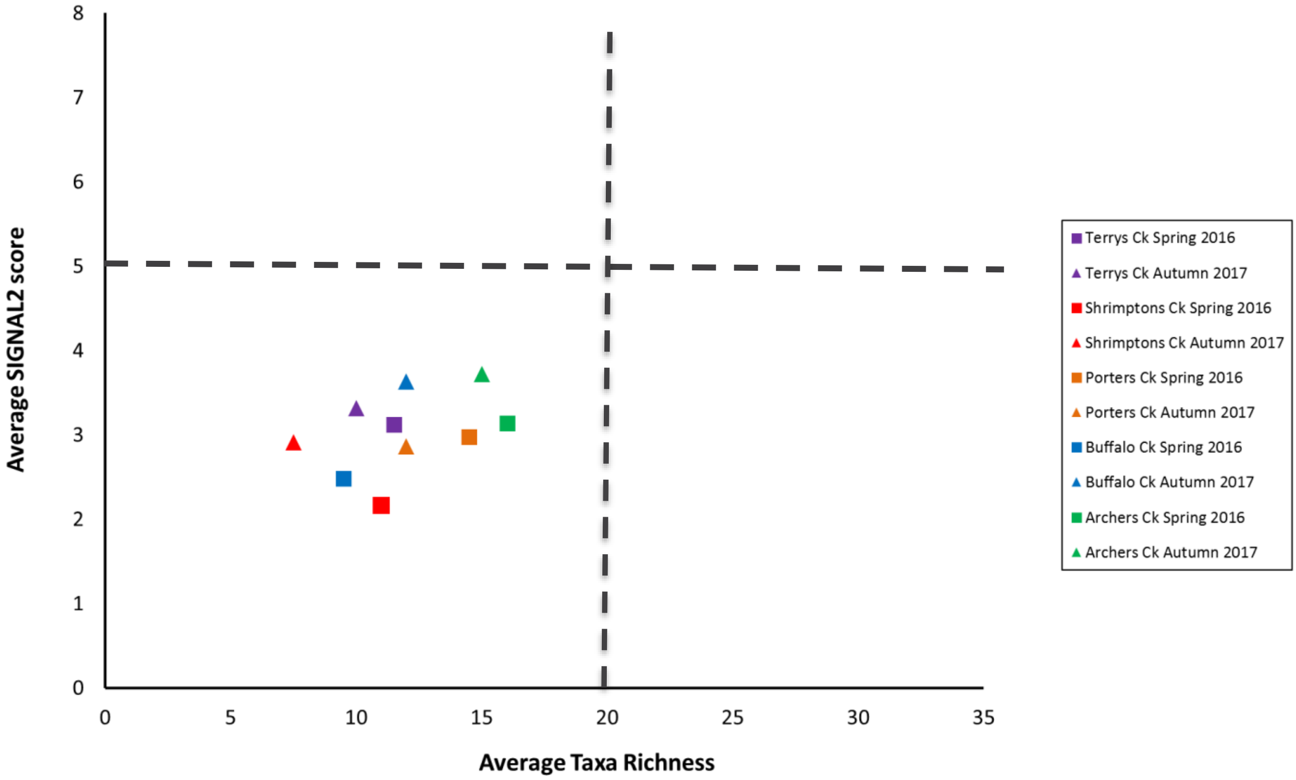

Figure 15 Mean SIGNAL2 bi-plot for spring 2016 and 2017.

8.1.4 Signal-SF

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

SIGNAL-SF results for all macroinvertebrate sites sampled from spring and autumn, 2004 – 2014 compared to spring 2016 and autumn 2017 are shown below in Figure 16. All SIGNAL-SF scores are below the "natural water quality" level of 6.5 indicating moderate organic pollution at all sites. However, the scores are consistent with those recorded in comparable urbanised streams in the Sydney metropolitan area.

The SIGNAL-SF scores calculated from 2004-2017 are similar with no trends apparent. Archers Creek showed a small increase in SIGNAL-SF for autumn 2017 compared to Terrys, Shrimptons, Porters and Buffalo creeks which showed a small decrease.

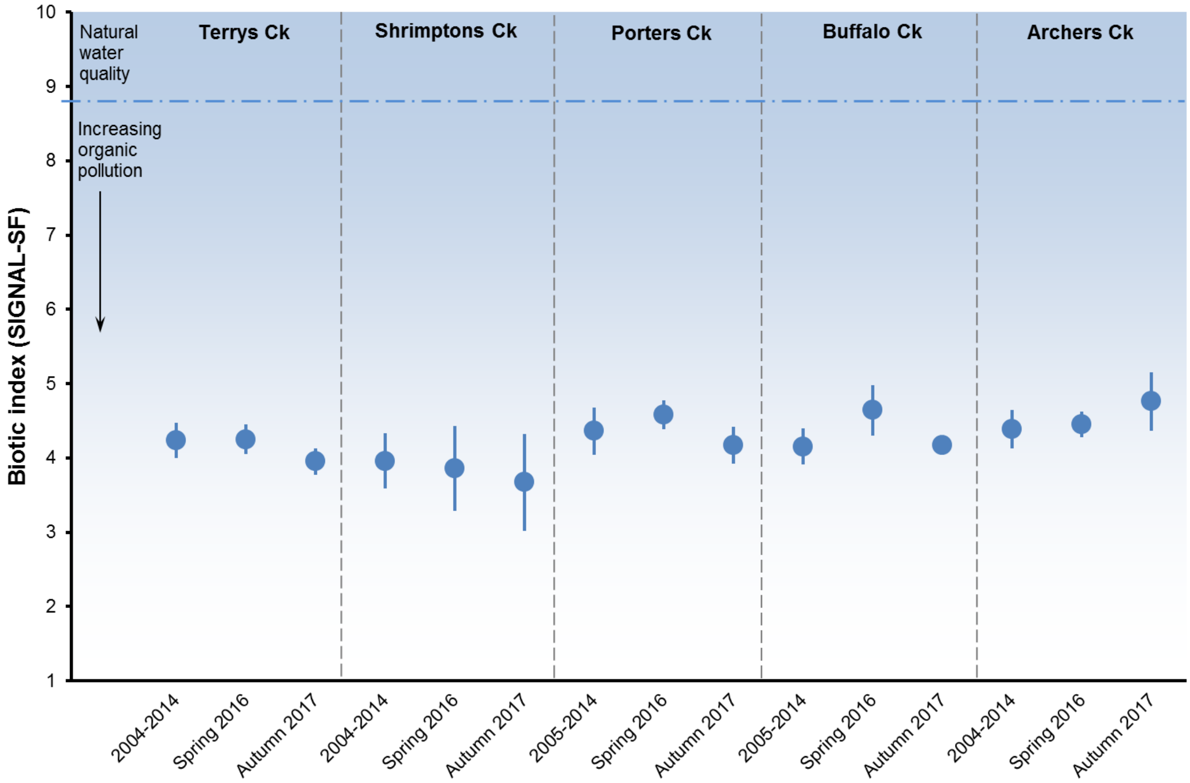

Figure 16 **Mean ± SD Signal-SF scores at all sites for 2004-2014 compared to spring 2016 and autumn 2017.**

8.1.5 AUSRIVAS

AUSRIVAS OE0 SIGNAL

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

Buffalo Creek recorded the highest mean score in autumn 2017 scoring higher than the historical average from 2004 – 2016. Archers, Shrimptons and Porters creeks also scored higher than the historical average compared to Terrys Creek which had considerable variation and scored lower.

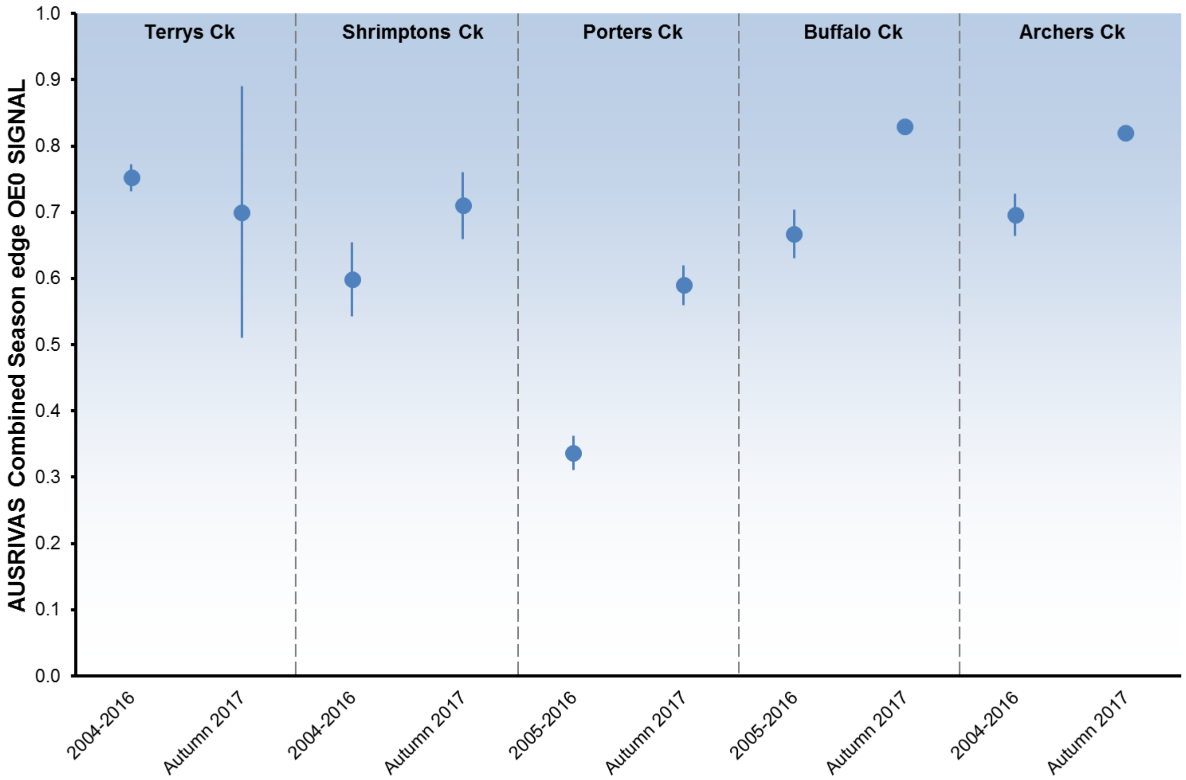

Figure 17 Mean ± SD OE0 Signals comparing 2004-2016 and autumn 2017.

AUSRIVAS OE50

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

The mean autumn 2017 and historical OE50 scores are in Band C and D for all creeks with significant deviation from historical scores. All creeks had lower scores with Shrimptons and Buffalo creeks scored at 0.

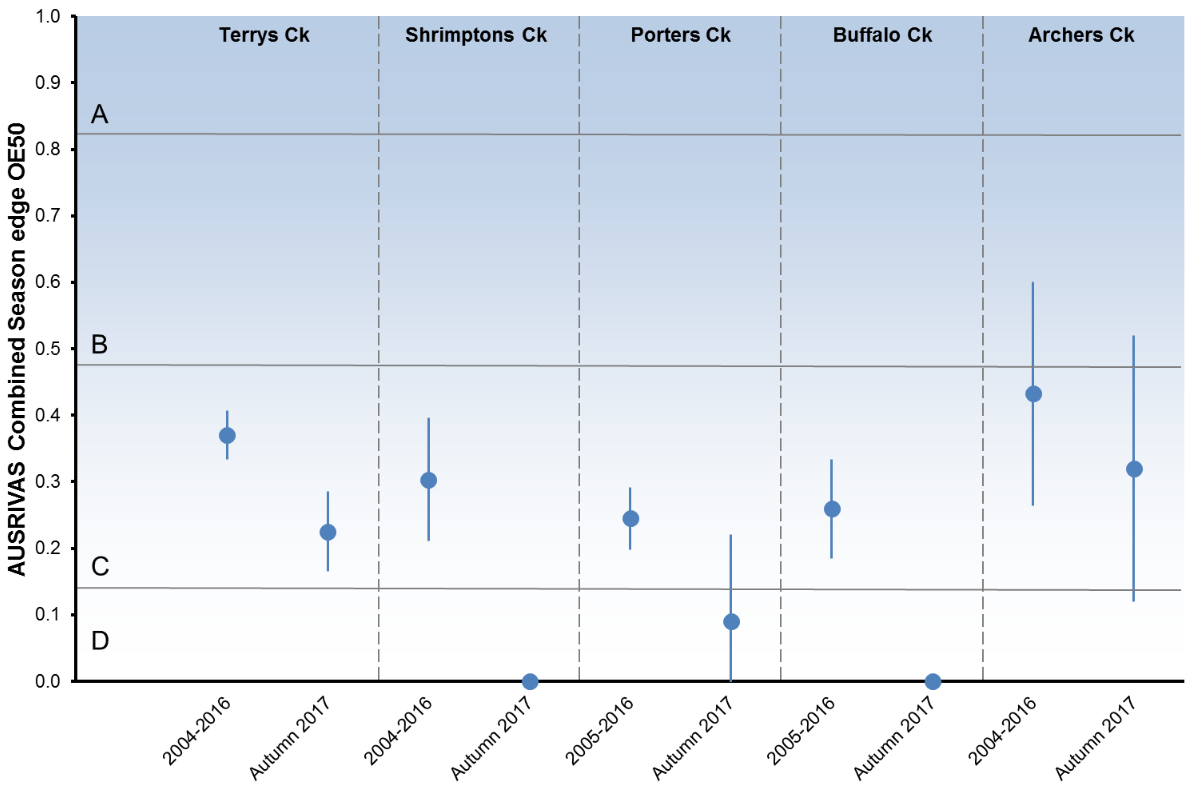

Figure 18 **Mean ± SD AUSRIVAS OE50 score for autumn 2017.**

8.2 Macroinvertebrate interpretation

8.2.1 Macroinvertebrate Assemblage

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

Total taxa richness and EPT taxa richness was again very low in autumn 2017, a typical result from the previous surveys. Three creeks, Shrimptons, Porters and Terrys, did not register a single EPT specimen. Historically no creek in the survey had an average of one EPT taxa (collected from each replicate). The usefulness of this measure, for the survey and City of Ryde, has been questioned in previous reports (Sydney Water 2016) and the current results reflect this is likely to continue.

The environmental conditions required to support healthy populations, of relatively tolerant EPT taxa, is not possible within the catchments of the City of Ryde. EPT taxa generally require freely available high oxygen levels, and natural flowing clear water bodies. They are also very susceptible to toxicants and other pollutants.

Elevated nutrient concentration present in spring 2016 such as total nitrogen recorded at Porters creek of 11 200 µg/L was present again in autumn 2017 at 7850 µg/L. This represents conditions above toxicity thresholds for EPT taxa families like Ephemeroptera.

Research by Beketov et al., (2004), on 6 species of ephemeropterans indicates the lethal concentration to inhibit 50 % of the population (LC50) for nitrogen in the form of ammonia, nitrite and nitrate to be as low as 4950 µg/L. Nitrogen has also been proven to have adverse effects for the one family of EPT taxa found in autumn 2017, Trichoptera *(Hydroptilidae),* when nitrate concentrations are as low as 10 000 µg/L (Camargo *et al.,* 2005). Nitrogen measurements recorded in this study exceed LC50 values for EPT taxa and act as one of the water quality parameters limiting their establishment. The removal of nitrogen from streams through natural processes such as denitrification in sediments, is found to be less effective in urban streams compared to natural forested streams (Walsh et al., 2005). This suggests that natural processes are not sufficient to manage current nutrient loads in City of Ryde creeks.

To improve macroinvertebrate communities, and overall aquatic ecosystem health, adopting the concepts on stream restoration in urban catchments carried out in Melbourne, Australia may be beneficial for the City of Ryde. Research by Walsh et al., 2005, has determined there is a direct correlation between impervious surfaces and degradation of stream habitat, water chemistry and invertebrates. It appears the best investment to improve water quality and subsequent macroinvertebrate assemblages is through alternative drainage approaches to reduce the impacts of stormwater.

8.2.2 Signal-SF and Signal2

The recommended approach for displaying SIGNAL2 data is using the quadrat bi-plot. This resulted in all five creeks being placed in quadrat 4, representative of urban, industrial or agricultural pollution. Placement in this quadrat is due to a combination of low SIGNAL2 scores and low taxa counts. However, the placement of the quadrat boundaries is arbitrary and preferably with the aid of reference sites. This is not possible for the City of Ryde, and the boundaries were placed with data from reference sites from the Sydney region located in relatively natural catchments. Returning the creeks and catchments to a natural and reference like condition is highly unlikely in the City of Ryde locale. Whilst this helps to represent the present conditions, the measure in this format is limited in its usefulness for ongoing monitoring and site assessment for City of Ryde.

The SIGNAL-SF results in autumn 2017 were reflective of what had been previously recorded for all five creeks. The only score which increased slightly from the historical average in autumn 2017 was Archers Creek. The remaining creeks average scores deviated very little from the historical average.

Historically the SIGNAL-SF average scores had a lower variability through time compared to the other univariate and biological indices, however shifts in creek health have been evident. Shrimptons Creek has historically had the biggest variation through time. This index has allowed for a clear tracking of ongoing changes in the creeks, within the context of the naturally occurring variation, in the macroinvertebrate communities. SIGNAL-SF represents the best option for tracking the health of the five creeks and for monitoring impacts or improvements within the catchments. Archers creek supports the greatest number of macroinvertebrates with SIGNAL-SF scores >7 (sensitive macroinvertebrates) compared to the other catchments. We suggest maintenance of this catchment to ensure loss of sensitive taxa does not occur.

8.2.3 AUSRIVAS

The AUSRIVAS autumn edge OE50 results indicated several changes from the historical averages. In autumn 2017 the average scores of all creeks were considerably lower than historical average scores. Compared to spring 2016 when scores were higher.

All scores were placed in Bands C and D, representing severely impaired creek conditions. The OE50 scores have fluctuated historically, in spring 2016 and in autumn 2017. This inconsistent database suggests that it is not a reliable or a suitable index to use when tracking and assessing changes in stream health.

The AUSRIVAS autumn edge OE0 SIGNAL average scores from autumn 2017 are above the historical average for all sites. This is opposite to the trend observed during spring 2016 where Terrys and Archers creeks showed increases and Shrimptons and Buffalo creeks were below the historical average. The OE0 SIGNAL index has less sample variation both historically and in autumn 2017 compared to the OE50 index. The reference sites used by AUSRIVAS are very limited in the Sydney region. Given this, and the creeks being within a heavily urbanised environment, the ability for AUSRIVAS to track creek health through time is potentially limited. This is clear for the current sampling season and is not a recommended index suitable for measuring the health of creeks within the City of Ryde.

Sampling was carried out as close to baseline flows as possible. Results of the current analyses indicate taxa and abundance have not made a shift from historical data. Analysis of all creeks suggest the health has remained consistent with the historical mean after associated error is considered. It is suggested that SIGNAL-SF is likely a more robust and suitable index for tracking the conditions of creek health for the City of Ryde monitoring strategy.

9 Key findings

The macroinvertebrate assemblages have remained stable in autumn 2017 and continues to successfully represent the current biological health of Archers, Porters, Shrimptons, Terrys and Buffalo creeks. We recommend the continuation of this monitoring practice as a stable and robust reference for creek health.

The impact of higher rainfall in Autumn 2017 was visible in the water quality results, with an overall increase in dissolved oxygen. In addition to the changes in hydrology that the rainfall contributed to, there would have been stormwater discharge. This would impact the nutrient and bacteriological loading of the creeks. There were higher occurrences of faecal coliform guideline exceedances and nutrient results varied amongst and between sites.

Maintaining the current regime of macroinvertebrate and water quality monitoring has allowed City of Ryde to continue building on timeseries data. Long term data allows for a greater understanding of the catchments, including naturally occurring seasonal fluctuations in macroinvertebrate assemblages.

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