Brockman River Catchment

Water Quality Monitoring Snapshot

September and October 2016

Plate 1: Westpoint Creek, Brockman River Catchment (2016).

Prepared by the Ellen Brockman Integrated Catchment Group: March 2018

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1. Acknowledgements

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Water samples and monitoring data was collected by officers from the Ellen Brockman Integrated Catchment Group.

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2. Executive Summary

The assessment of water quality within the Brockman River catchment was undertaken in September and October 2016 in compliance with the sampling and analysis plan (EBICG, 2014). The objective of the snapshot was to collect annual data on the water quality within the catchment, to identify trends and priority sub-catchments for nutrient transport and salinity.

Monitoring stream salinity throughout a catchment enables the isolation of areas where the discharge of saline groundwater to streams is greatest. This is important as increasing salinity is the dominant threat to the Brockman catchment. The findings of this report will be used to make recommendations for degraded sites, to identify the major nutrient and salinity contributing subcatchments, to mitigate, improve or maintain water quality, and to prevent detrimental environmental effects downstream.

The Brockman River catchment receives less than 1000mm of rain per annum and much of the salt is stored in the soil profile. Extensive clearing of vegetation for agriculture has reduced evapo-transpiration; increased recharge has resulted in rising groundwater levels, which mobilizes the stored salt. The salt laden groundwater then surfaces as hillside springs and valley floor seeps. Groundwater discharge causes soil salinity and contaminates previously potable water resources (Angell, 2000). Nutrients are not yet an issue in the Brockman catchment. The Brockman River is a contributor to the level of saline water entering the Upper Reaches of the Swan-Canning system and this could potentially alter and degrade ecological environments. Sediment and nutrients bound to particles are carried downstream and add to sediments in the Swan River. Under anoxic conditions these nutrients bound in the sediments are released, causing algal blooms and fish deaths.

It must be noted that this assessment is based on one-off grab sampling of water quality on two separate occasions in September and October 2016 to capture winter and spring flow, from 26 selected sites within the Brockman River catchment (shown in Figure 5).Consequently, the results represent the condition of the water in the catchment at the time of sampling only. All 26 sites were tested for physical parameters (pH, conductivity, temperature and total suspended solids) and nutrients including total nitrogen, soluble organic nitrogen, nitrogen as ammonia, total oxidised nitrogen, total phosphorous and soluble reactive phosphorous. Seven out of the twenty-six sampling sites were strategically identified for the testing of heavy metals and water hardness.

In comparison to past water quality monitoring data collected by the Chittering Landcare Centre, pH values remain relatively stable at most sampling sites, and there is an overall trend of increasing salinity at most of the sampling sites since 1997. This is of great concern for the ecological health and function of the river and catchment. It is also of great concern to agriculture, industry and private landholders. If left unmanaged this could become a major issue for landholders in terms of agricultural production and water quality. Future monitoring will verify trends and patterns as more data is collected over a longer period of time. All data will be entered into the Department of Water's (DOW) Water Information Network (WIN) database.

2.1.1. Key Findings

- Sampling sites within the Brockman River catchment recorded similar concentrations of all forms of nitrogen as in previous years. However the following sites were identified through the 2016 snapshot as consistent contributors of nutrients to the Avon/Swan River and included Total Nitrogen, which were recorded at these sites with concentrations above the ANZECC guidelines (Table 1)

Table 1. Sampling Locations where Total N exceeded ANZECC guidlelines.

Sampling Site Name	Sampling Site Number
Jackson Rd	BRN2
Romany Creek	BRN7
Murphy Gully	BRN1
Wootra	BRN9
Udumung	BRN5
Wannamal South	BRN4
Longbridge Creek	BRN8
Julimar Bridge	BRN18
Yallawirra	BRN25
Lake Chittering	BRN15
Yalliawirra	BRN25

- Total Phosphorus concentrations in the Brockman catchment gradually increased since 2006, when there were no sites that recorded concentrations over the ANZECC guideline of 0.065mg/L for lowland river systems and ecosystem health. Yet in 2016, no sites were over the guideline

- Water Hardness was ‘extremely hard’ at all sites sampled metals except Marbling (BRN23) which was ‘very hard’ on one sampling occasion, and Spoonbill (BRN 13) which was ‘hard’.

- Metal concentrations in the surface waters of the Brockman River Catchment were generally below the Hardness-modified trigger value (HMTV) and ANZECC guidelines on most sampling occasions. Yalliawarra (BRN25) and Grey Rd (BRN26) recorded concentrations above the guideline for Aluminium on both occasions.. All other metals remained below the guidelines and limits of reporting (LOR).

- The Brockman River catchment recorded pH levels predominately within the ANZECC guidelines. Lake Rd (BRN 15) did record a pH of 8.36 on the October sampling occasion.

- Water was more saline at the top of the catchment and became less saline as it flowed southwards towards the Avon River.

Table 2: Number of sites (out of a total of 26) equal to or exceeding the ANZECC water quality guidelines and trigger values.

Note: Heavy metals out of a total of eight sampling sites. Cadmium, chromium, copper, lead, nickel and zinc ANZECC water quality trigger values have been modified according to Water Hardness (Appendix D) and values must be equal to or exceed the Hardness-Modified Trigger Value to be over the Guideline.

	Number of Sampling Sites	**Water Quality Trigger Value - Lowland Rivers**		**TSS - DOW Interim Guideline**	
Physical		September	October	September	October
pH	26	6	12		
Conductivity	26	26	26		
Nutrients					
Total Nitrogen	26	14	2		
Total Oxidised Nitrogen	26	12	7		
Nitrogen as Ammonia	26	0	0		
Total Phosphorous	26	0	0		
Filterable Reactive Phosphorous	26	0	0		
Total Suspended Solids	26			7	11

Metal	**Number of Sampling Sites**	**Hardness Modified Trigger Value (400)**	**Hardness Modified Trigger Value (210)**	**ANZECC Trigger Value (mg/L)**	**September**	**October**
Aluminium	7			0.055	4	4
Arsenic	7			0.024	0	0
Cadmium	7	0.002mg/L	0.0011mg/L	0.0002	0	0
Chromium	7	0.0084mg/L	0.005mg/L	0.001	0	0
Copper	7	0.0126mg/L	0.0072mg/L	0.0014	0	1
Iron	7			0.3	6	7
Nickel	7	0.099mg/L	0.057mg/L	0.011	0	0
Mercury	7			0.0006	0	0
Lead	7	0.09mg/L	0.04mg/L	0.0034	0	0
Zinc	7	0.072mg/L	0.0416mg/L	0.008	0	1

Key

12	Number of sites (out of a total of 26) equal to or exceeding guidelines or trigger value
0	All sites less than guideline or trigger value
-	No guideline or trigger value available
	Sample not analysed for parameter

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4. Background

The Brockman River catchment stretches across 1520 square kilometres and is the largest catchment of the lower Avon and upper Swan catchments. The Brockman River is approximately 90 kilometres in length and flows through the Chittering Valley along the Darling Scarp. The main issues within the catchment include a deteriorating natural resource base due to widespread clearing of native vegetation and an increased economic pressure on agricultural land to be more productive. This has resulted in increased salinity, water logging, erosion, pest plants and animals, and affected waterways due to increased sedimentation and reduced surface and ground water quality (WRC, 2003).

In 1996 discussions in Northam between the Water and Rivers Commission Regional Services, Western Australian state government and local governments in the catchment, documented their requirements for natural resource management. Together with the Shire of Chittering it was decided that the water quality of the Brockman River and its catchment was a priority and developed a successful funding application through the Natural Heritage Trust Fund to prepare an integrated natural resource management plan for the Brockman River catchment (WRC, 2003).

In 2016 the Ellen Brockman Integrated Catchment Group (EBICG) conducted an assessment of the Brockman River catchment surface water quality on 14th Septemberand 12th of October. The objective of the snapshot was to build upon the existing years of data and establish baseline data on the water quality within the catchment. By monitoring stream salinity throughout a catchment, areas where the discharge of saline groundwater to streams is identified can then be targeted for remediation efforts. This sampling program and associated water quality results will be registered and entered into the Department of Water's (DoW) Water Information Network (WIN) database.

4.1. Brockman River Catchment

The Brockman River catchment is located to the north-east of the Perth Metropolitan area in the south-west of Western Australia (Figure 1). The catchment covers an area inclusive of sixty-eight sub catchments, incorporating the townships of Bindoon and Wannamal (WRC, 2002). The largest part of the catchment lies within the Shire of Chittering, with the remainder within the shires of Victoria Plains, Toodyay, Gingin and the City of Swan (Figure 2). Other localities within the catchment include Mooliabeenie, Lower Chittering, Maryville Downs and South Chittering.

While the Brockman River flows into the lower Avon River and is thus, part of the Avon River catchment, its greatest impact is on the Swan River and is therefore considered part of the Swan River catchment. The Brockman River itself follows the Darling Scarp, flowing through the deeply incised Chittering valley to enter the Swan-Avon River 40kms upstream from Perth (WRC, 2002).

The natural resource base of the catchment is deteriorating because of the widespread clearing of native vegetation and the increased economic pressure on agricultural land to be more productive. These impacts have resulted in increased salinity, water logging, soil erosion via wind and water, sedimentation, eutrophication, overgrazing, weed invasion and pest animals within the catchment. These cumulative impacts have an offsite effect on the Brockman River and local wetland systems, and ultimately the Avon-Swan River.

Figure 1: Catchments within the Swan-Canning Catchment (WRC, 2003).

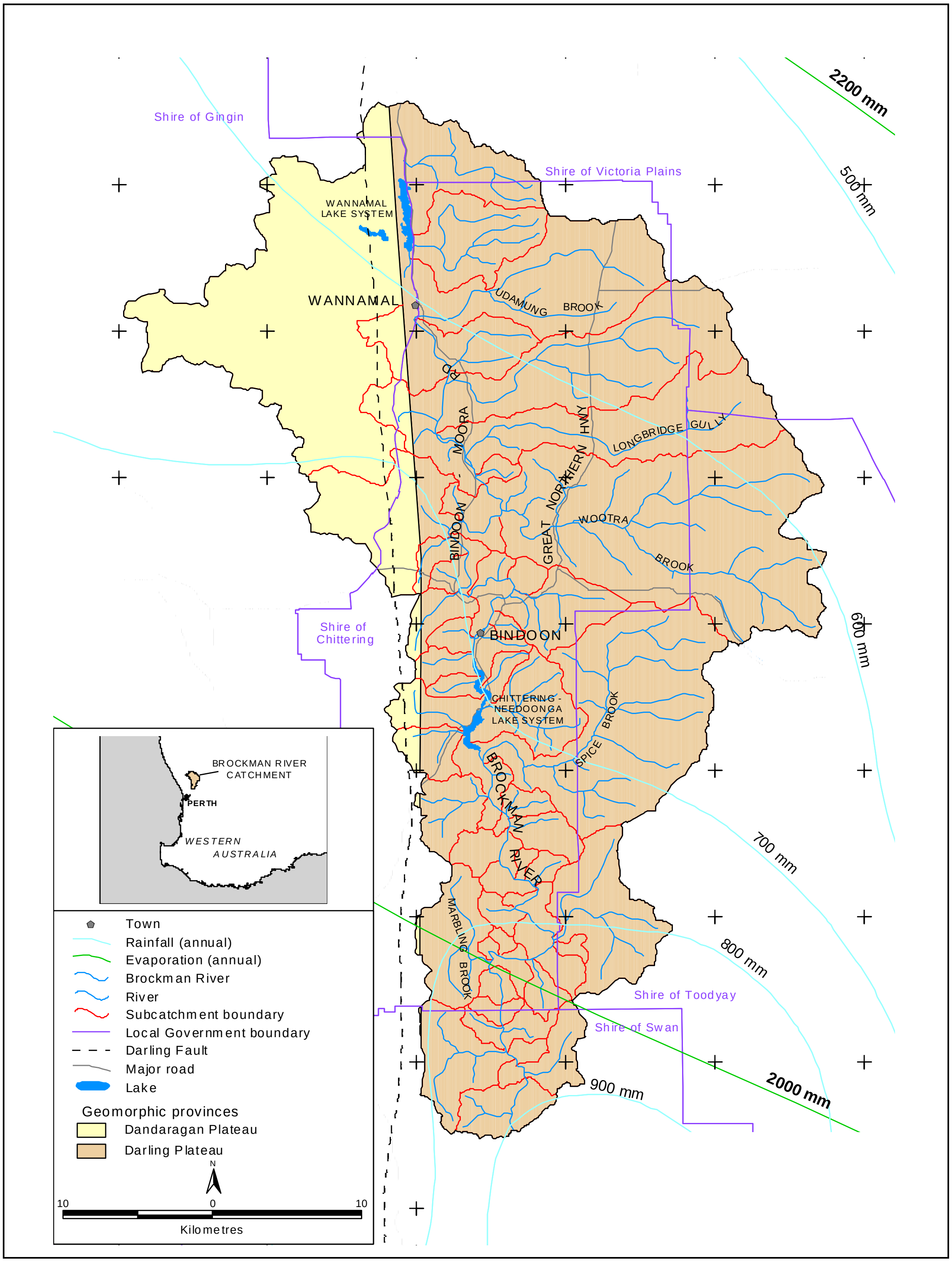


Figure 2: Brockman River Catchment (WRC, 2003).

4.1.1. Climate

The catchment experiences a typical Mediterranean climate of hot dry summers and cool wet winters. Average rainfall for the southern portion is 800mm/yr decreasing to less than 600mm/yr in the northern regions (Bureau of Meteorology, 1998). Above average rainfall occurred in March and April 2016 (Figure 3). The annual rainfall that was received at Wannamal (Station 009040) was 676mm while at Bindoon (Station 009112) a total of 796mm fell (**Figure 3**). These values are above the annual averages (585mm and 677mm respectively).

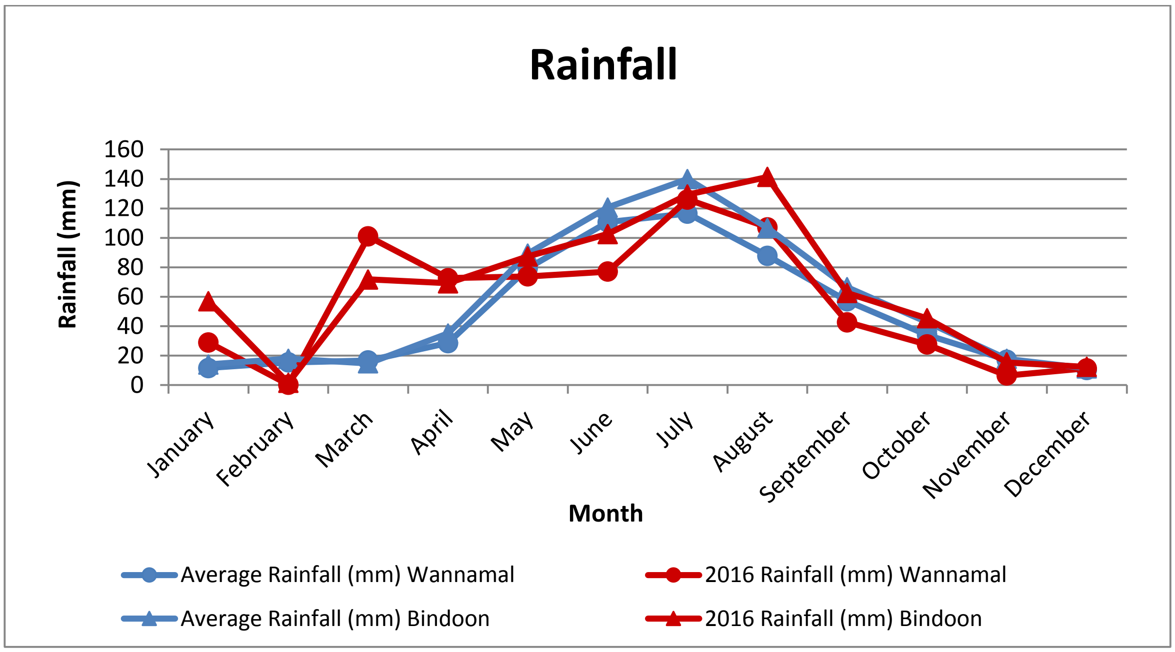


Figure 3: Total monthly rainfall within the Brockman River catchment recorded at Bindoon Station (009112), and Wannamal Station (009040), Bureau of Meteorology, 2016.

Most water courses in the catchment flow during the winter months and have reduced or no flow during the summer months. Weather patterns typically have strong easterly to north-easterly winds in the morning and south-westerly in the afternoon during summer with thunderstorms and lightning common. During winter the winds come from the northwest to southwest (WRC, 2003).

4.1.2. Geology and Geomorphology

The Darling Plateau, an ancient landmass worn down by erosion, underlies most of the eastern portion of the Brockman River catchment. To the west, the catchment extends over the Dandaragan Plateau. A major regional fault line, the Darling Fault, separates these two geomorphic regions (Figure 2).

The Darling Plateau

The Darling Plateau is made up of two major rock sequences. The first sequence is a 10km wide belt of crystalline rocks referred to as the Chittering Metamorphic belt. Intense erosion within the Chittering Metamorphic belt has produced a major north-south trending valley system in which the Brockman River flows south. The second sequence to the east is granitic rock covered with a lateritic cap referred to as the lateritic uplands (Wild and Low, 1978). Laterite is sometimes referred to as ironstone or coffee rock.

The deeply incised Chittering Valley is characterised by dissected, steep slopes and domed granite outcrops high in the landscape with variable and complex soils. Parent materials may be weathered or unweathered gneiss, granite or dolerite or may occur as colluvium. Colluvial lateritic material from the plateau surface may extend down slope. Yellow duplex and brown duplex and gradational earths are the most common soils. Generally, the yellower soils are associated with the granite, and the red and brown soils with dolerite dykes (King and Wells, 1990). Loamy soils, now extensively cleared for agriculture, are found on the lower valley slopes and floodplain.

The lateritic uplands are typified by undulating, dissected land surfaces with, pale orange lateritic soils and pea gravels. Red alluvial, clay soils characterise the valley floors while upland remnants of the plateau surface form higher land with sands and sandy gravels interspersed with laterite outcrops. Saline soils occur within the valley floors.

Most of the area outside reserves is cleared for agriculture with small pockets of native vegetation along fence lines and watercourses. Gully erosion is the predominant erosion hazard but landslips have occurred on the steeper slopes of the Chittering Valley.

The Dandaragan Plateau

The Dandaragan Plateau to the west of the Darling Fault is a wedge shaped erosion remnant of the Perth Basin with sediments covered by recent deposits of sand and laterite (Wild and Low, 1978). Sand plain features dominate the landscape with broad U-shaped valleys, sand-filled drainage lines and some breakaways. The soil pattern is closely related to topography (Churchward, 1980). Brown deep sands, yellow deep sands, pale deep sands, sandy gravels and shallow gravels are dominant, with red deep sandy duplex soils on the valley floors (Moore, 1998).

Soil landscapes are outlined in the Shire of Chittering Land Capability and Management Study prepared by Land Assessment Pty. Ltd. Part 1 – Working Paper and LandSmart™.

4.1.3. Vegetation

Large areas of native vegetation remain in the eastern part of the catchment in the Avon Valley National Park, the proposed Julimar Conservation Park (currently State Forest) and in the Department of Defence Bindoon Training area. Other areas of native vegetation in the catchment are located within the ten DEC nature reserves and on some private property.

The greatest area of native vegetation occurs within the western forest/woodland and eastern heath regions while the central area consists of severely dissected remnants within an agricultural landscape. These areas have been heavily cleared and now the remaining remnants are generally small and dispersed.

Approximately 201 km^2 (13%) is reserved for conservation purposes with much of this conservation land being confined to the eastern Darling Scarp forests and north-western sand plain. The spatial extent of remnant vegetation in the Brockman River catchment is given in Table 3.

Table 3: Spatial extent of remnant vegetation in the Brockman River catchment (WRC, 2002).

Total area (km^2)	1,520
Number of remnants	2,000
Total Area Of Remnant Vegetation (km^2)	770
% Total Remnant Area	51
Remnant Vegetation Reserved (km^2)	201
% Original Area Reserved	13
% Remnant Area Reserved	26

Source: Connell and Ebert (2001).

4.1.4. Land Use

The economy of the Brockman River catchment and the livelihood of its residents are currently based on the natural resources of land and water. Animal products derived from pasture are the most extensive agricultural land use followed by broad scale crops and horticulture (Cook and Hatherly, 1997). The northern part of the catchment is mostly agricultural with cereal, beef, pigs, sheep and wool the major agricultural products with some horticultural products such as grapes and citrus. In the Chittering Valley, production is mostly beef, sheep, citrus and grapes (Figure 4).Expansion of horticulture and viticulture in the catchment is limited by the lack of suitable irrigation water.

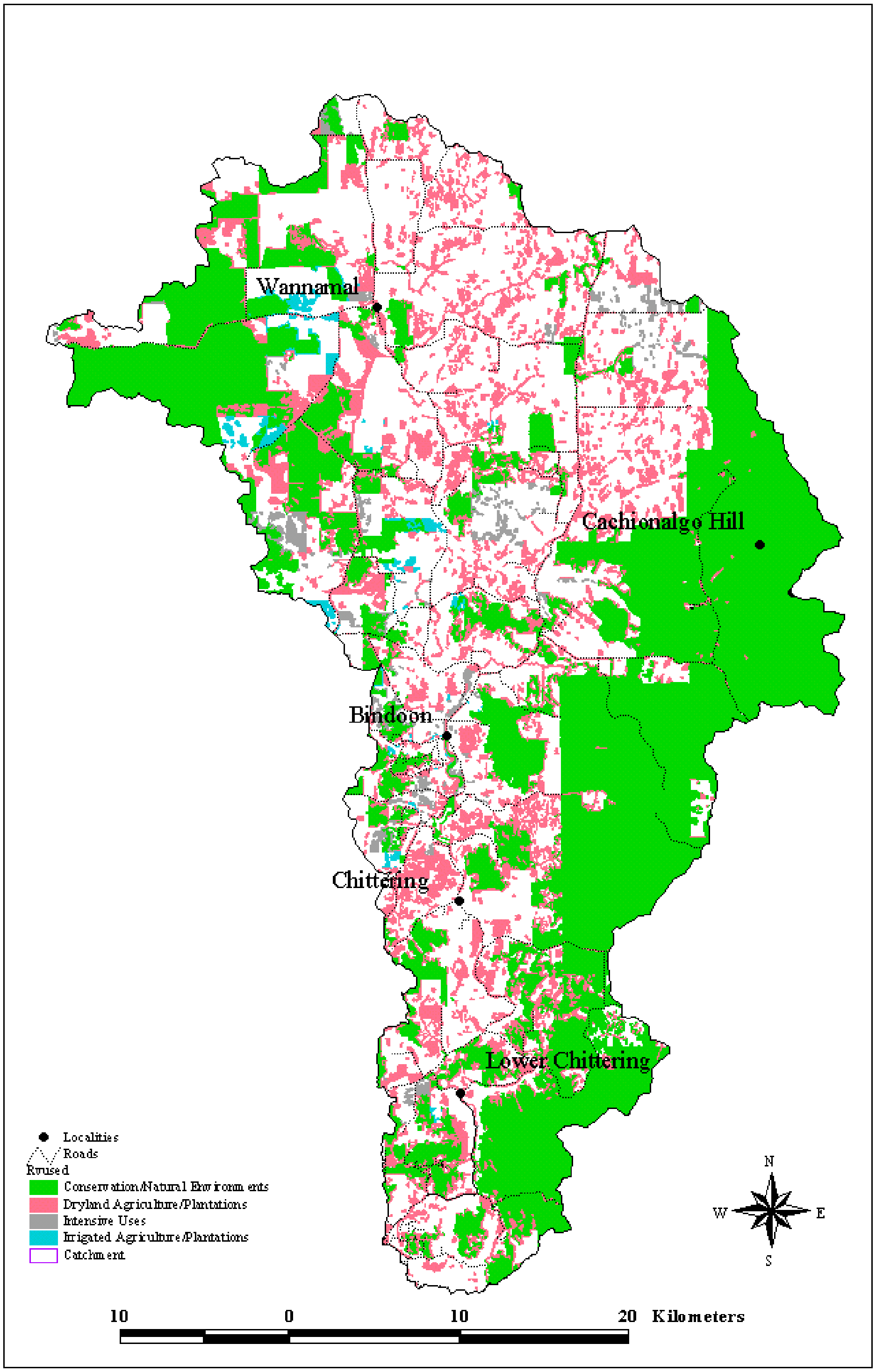


Figure 4: Land use in the Brockman River Catchment.

5. Methodology

5.1.1. Site Selection

Water samples were taken from twenty-six sites within the Brockman River catchment (Figure 5). Crest Hill Road (BRN11) was removed from the sampling program in 2008 and replaced with Grey Road Bridge (BRN27). These sites were selected to be representative of sub-catchments carrying large volumes of water to the Brockman River, to determine their salinity, relative nutrient and metal contribution, and whether they were situated upstream or downstream of potentially high impact land uses or of likely contaminant sources. Table 3 lists the twenty-six sample sites by site number, site name and relative waterway component. Site location is also provided using street names, northings and eastings.

Table 4: Location and description of selected sampling sites within the Brockman River catchment.

Site No.	Site name	Description of waterway (inc. old site number)	Easting	Northing
BRN1	Murphy Gully Creek	BR22 - Bindoon Moora Rd	409205	6561412
BRN2	Jackson Road (Wannamal Lake outlet)	BR21 - Jackson Road	409457	6555480
BRN3	West Point Creek	BR20 - West Point	409754	6555706
BRN4	Wannamal South	Wannamal South Road	407596	6552244
BRN5	Udumung Creek	BR18 - Hay Flat Road	410373	6551048
BRN6	Kangaroo Gully Creek	BR17A - Bindoon Moora Rd	412741	6547952
BRN7	Romany Creek	BR17 - Waldeck West Road - Romany Creek	413360	6546355
BRN8	Longbridge Creek	BR16A - Ashman Rd to gate (2km) over fence & nth on fire break	414649	6542478
BRN9	Wootra Brook	BR15 - Owen's Road	416762	6537439
BRN10	Bindoon River	BR15A - Great Northern Highway small bypass road bridge	417372	6531777
BRN12	Flat Rocks Creek	Densley Road (off Flat Rocks)	415077	6524296
BRN13	Spoonbill Lake	BR12 - spillway from Spoonbill Reserve	412361	6523223
BRN14	Aquila, Hart Drive	BR12A - Flows through Aquila Reserve	412306	6522632
BRN15	Lake Road Brockman River	BR9 - Bridge on Lake Road below Lake Weir	414090	6521308
BRN16	Spice Brook	BR11A - off Lake Road across paddock to bridge	414509	6521156
BRN17	Toodyay Creek Toodyay Creek	100m north of Blue Plains Road on Chittering Road	414561	6518111
BRN18	Julimar/Chittering Bridge Brockman River	BR5 - Julimar Rd/Chittering Rd intersection	415996	6515275
BRN19	Julimar/Chittering Tributary Julimar Rd Creek	BR8 - Julimar Rd (500m up from intersection Chittering Rd)	417103	6515877
BRN20	Chittering Valley	Cnr Chittering Valley and Chittering Road	416288	6510308
BRN21	Keating Road	BR4 - 500m east on Keating Road to gateway - Bitney Springs	419248	6508210
BRN22	South Chittering Creek	Chittering Road just north of Wilson Road	415559	6500608
BRN23	Marbling Brook	Bridge on Chittering Road	414704	6506641
BRN24	Moondyne Brockman River	BR2 - from crossing	416623	6499996
BRN25	Yalliawirra Brockman River	BR1 Gauging Station	416450	6495160
BRN26	Marda Brook	Smith Road bridge/gate	414266	6496860
BRN27	Grey Road Bridge	Brockman River	413885	6528696

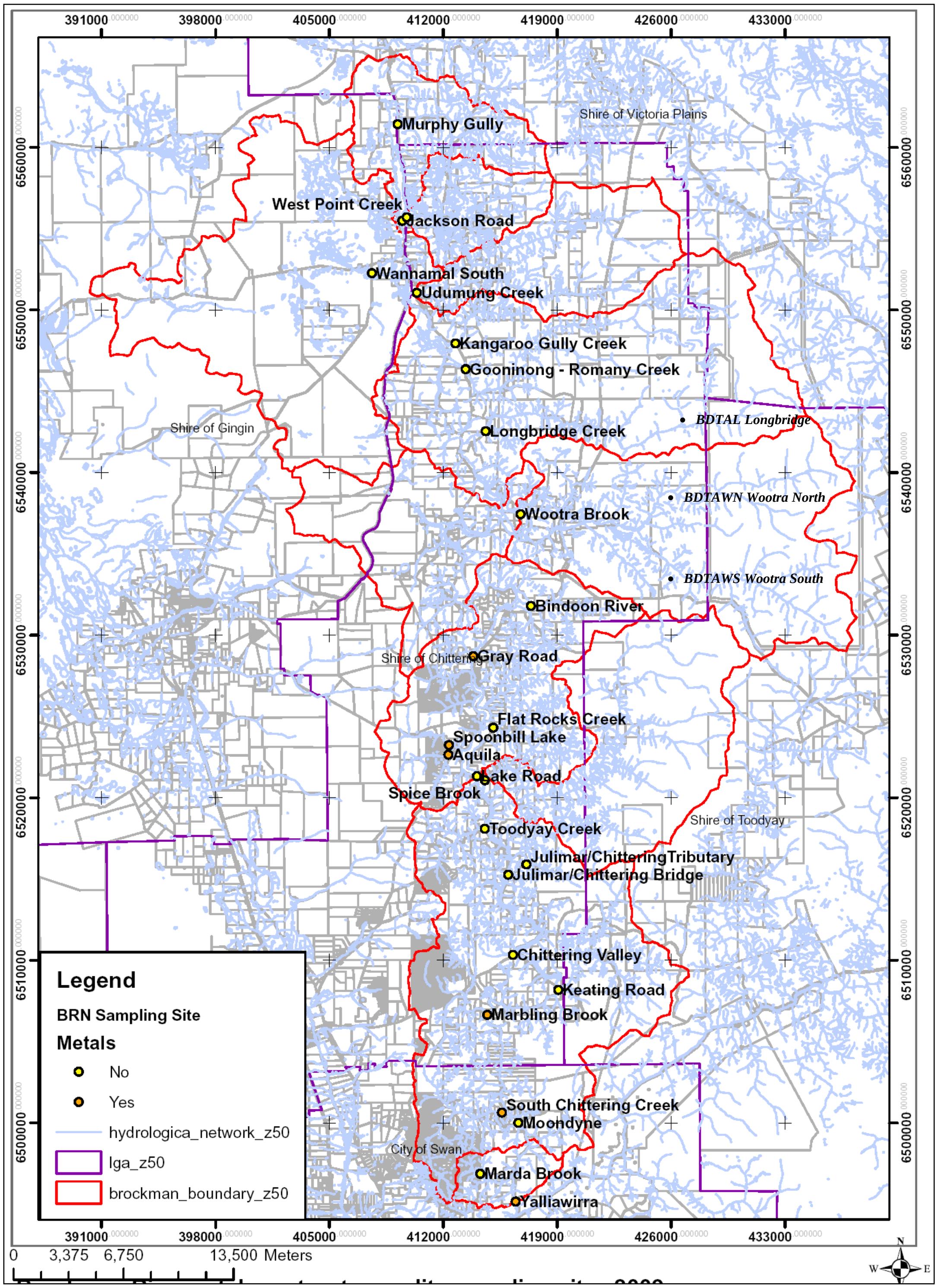


Figure 5: Sampling site locations within the Brockman River Catchment.
NB: Sampling Sites in *'italic'* are not part of the BROCKMANWQ program. These sites were part of the BDTA water quality monitoring program (CLG, 2010).

5.1.2. Water Sampling

Sampling of the Brockman River was undertaken in 2016 on 14th September and 12th of October. The collection of the samples followed strict protocols to prevent contamination and ensure consistency of results. An outline of the sampling collection technique is included in the sampling and analysis plan for the Brockman River catchment (see Appendix E).

Field observation forms were filled out for each water sample. All samples collected from the Brockman River catchment were transported to and analysed by a National Association of Testing Authority (NATA) accredited body - MPL Laboratories (Perth??).

5.1.3. Water Analysis

Water at each of the sites was measured *in situ* for physical properties (pH, specific conductivity, salinity and temperature) using WTW pH and EC probes. Samples were collected and analysed for a range of contaminants likely to be present in semi-rural, agricultural catchments. They were then sent to MPL Laboratories to be analysed for nutrients including total nitrogen, total oxidised nitrogen, nitrogen as ammonia, total organic nitrogen, total phosphorous, filterable reactive phosphorous and total suspended solids.

Water samples from Spoonbill Lake (BRN 13), Aquila (BRN 14), Lake Rd (BRN 15), South Chittering Creek (BRN 22), Marbling Brook (BRN 23), Yalliawarra (BRN 24) and Grey Rd (BRN 27) were also tested for metals. These included cadmium, mercury, arsenic, copper, lead, zinc, aluminium, chromium, iron and nickel.

Table 5 summarizes MPL laboratories analysis techniques used for physical parameters, nutrients and heavy metals.

Table 5: Summary of chemical analysis techniques.

Parameters	Limit of Reporting (LOR)	Variable Unit	Analysis Technique	Lab Reference-WILAB (based on APHA)
Cond (Comp25)	1	uS/cm	direct read	5
pH	0.05		direct read	5
TSS	1	mg/L	grav	5
PO4-P	0.003	mg/L	DA	18
NOx-N	0.005	mg/L	DA	18
TP	0.01	mg/L	DA	18
TN	0.05	mg/L	DA	18
Na	1	mg/L	ICP OES	17
K	0.1	mg/L	ICP OES	17
Ca	0.1	mg/L	ICP OES	17
Mg	0.1	mg/L	ICP OES	17
Hard	1	mg/L	ICP OES	17
Al	0.005	mg/L	ICP OES	17
B	0.05	mg/L	ICP OES	17
Ba	0.001	mg/L	ICP OES	17
Be	0.0005	mg/L	ICP OES	17
Co	0.005	mg/L	ICP OES	17
Cr	0.001	mg/L	ICP OES	17
Cu	0.005	mg/L	ICP OES	17
Fe	0.01	mg/L	ICP OES	17
Mn	0.001	mg/L	ICP OES	17
Mo	0.005	mg/L	ICP OES	17
Ni	0.005	mg/L	ICP OES	17
Sn	0.05	mg/L	ICP OES	17
Sr	0.005	mg/L	ICP OES	17
Ti	0.01	mg/L	ICP OES	17
V	0.002	mg/L	ICP OES	17
Zn	0.005	mg/L	ICP OES	17
As	0.001	mg/L	GFAAS	6
Pb	0.001	mg/L	GFAAS	6

6. Results and Discussion

The National Water Quality Management Strategy provides guidance on both ecosystem and human health protection. Water quality guidelines are provided for a range of environmental values including aquatic ecosystems, primary industries, recreation and aesthetics, drinking water, industrial water, cultural issues, and monitoring and assessment (ANZECC & ARMCANZ, 2000). This report will compare sample concentration results with aquatic ecosystem trigger values for lowland river systems and, when necessary, livestock drinking water trigger values. This is in accordance with the trigger values suggested in the Brockman River Management Plan and the “Swan Canning Cleanup Program Action Plan”.

The Guidelines recognise three levels of protection for aquatic ecosystems; those with high conservation value, slightly to moderately disturbed ecosystems and highly disturbed ecosystems. To assess the level of toxicant contamination in aquatic ecosystems, trigger values were developed from data using toxicity testing on a range of test species. The trigger values (99%, 95%, 90% and 80%) approximately correspond to the levels of protection described above. This report will use the 95% protection level for aquatic ecosystems due to the high conservation value of the receiving environment of the Swan River.

It is important to note that exceeding a trigger value does not indicate that “standards” are not being met, but is rather an indication that further consideration should be given to the situation. It indicates that there is the potential for an impact to occur and should therefore trigger a management response such as further investigation or adaptation of the guidelines according to local conditions (ANZECC & ARMCANZ 2000). No ecosystem is pristine, so when using guidelines the realistic and achievable water quality of the Brockman River should be considered.

6.1.1. Water Quality

Flow and Rainfall

The Brockman catchment makes up approximately 0.5% of the Avon catchment and discharges an average of 34 million cubic metres of water per year, which is roughly 5.5% of the Avon River annual flow (Land Assessment Pty. Ltd, 1999). In comparison to similar data from the Ellen Brook it can be noted that a significantly greater percentage of rainfall is retained and used within the Brockman River catchment.

The Brockman River flows south along the western edge of the Darling Plateau through a deeply incised valley to join the Avon River between the Walyunga and Avon Valley National Parks. The Wannamal Lake system to the north, and seasonal streams flowing from the east and west, drain directly into the Brockman River which meanders through three other wetland reserves including the Mogumber, Betts and Chittering Lakes Nature Reserves.

The Wannamal Lake system is listed as a culturally and ecologically significant wetland (Environment Australia, 2001). Analysis of water quality readings (J. Lane, CALM, pers. Comm.) since 1978 indicates that salinity in the lake is increasing. Observations made by long time residents of the area suggest that during the early 1950's the water was relatively fresh and that good clover pastures grew in nearby paddocks that are now bare salt scalds (Pers. Comm. D. Purser).

The township of Bindoon is situated on the Brockman River where it flows into Lake Needoonga, which is part of the Chittering Lake system and a wetland of National Significance (Environment Australia, 2001).

In the summer months water flow in the Brockman River is only from the southern end of the catchment. In 1975, CALM constructed a weir at the end of the Chittering Lakes Nature Reserve to control the levels of Chittering and Needoonga Lakes. The gates in the weir regulate the flow of water and the depth of the lakes. The weir was installed after a drain was constructed that caused the lakebed to drain prematurely, impacting on the bird-breeding season.

The aim of the water management is to achieve a desirable water level in the lake throughout the year. The lake should be dry from mid-March to the opening rains and the more saline waters that accumulate during mid to late summer should not be released downstream in an uncontrolled manner (P. Dans, pers. Comm.). Thus, during the summer months, only the catchment south of the weir contributes to the water flow in the Brockman River.

The water levels in Lake Chittering are managed for:

- Wildlife management to sustain the lake vegetation survival and regeneration and the annual bird breeding season;
- The farming industry to avoid excessive flooding of adjoining agricultural land, and;
- The horticultural industry to avoid releasing excessively saline waters down the Brockman River that adversely impacts the opportunity for farmers to irrigate horticultural crops.

The Water and Rivers Commission has two monitoring stations along the Brockman River. The first monitoring station Tanamerah (S16006) is located a few kilometres upstream of the town of Bindoon at 413589E, 6531899N. This station records stage flow data for the Upper Catchment, which covers an area of approximately 96,000 hectares (Fulwood, 2001). The second monitoring station, Yalliawirra (S616019) is situated at the base of the Catchment at 416449E, 6495149N. It records stage flow data for the entire catchment, which covers an area of approximately 151,000 hectares.

Spoonbill Lake is one of two remaining fresh to marginal waterways monitored in the Brockman River catchment for salinity. This puts significant importance and pressure on this resource as it continues to feed into the lakes of Chittering and supports downstream irrigation. It must be noted that water extraction has occurred within the Spoonbill subcatchment in recent years. This has resulted in dramatic fluctuations in

Spoonbill Lake. Ongoing monitoring will be required to ensure that the existing ecosystem health and function of the reserve, subcatchment and Chittering Lakes is not negatively affected.

6.1.2. Physical Properties

Temperature

Samples taken were from sites with flowing water at a depth ranging from 10-20cm below the surface and not in contact with the sediment at any time. September temperatures ranged between 11.9 ºC at Marbling (BRN29) and 17.9ºC at Wannamal South (BRN4). Water temperatures were generally warmer during the October sampling run, and ranged between 15.5ºC at Wilson Road (BRN22) and 26.6ºC at Murphy Gully (BRN1), (Figure 6).

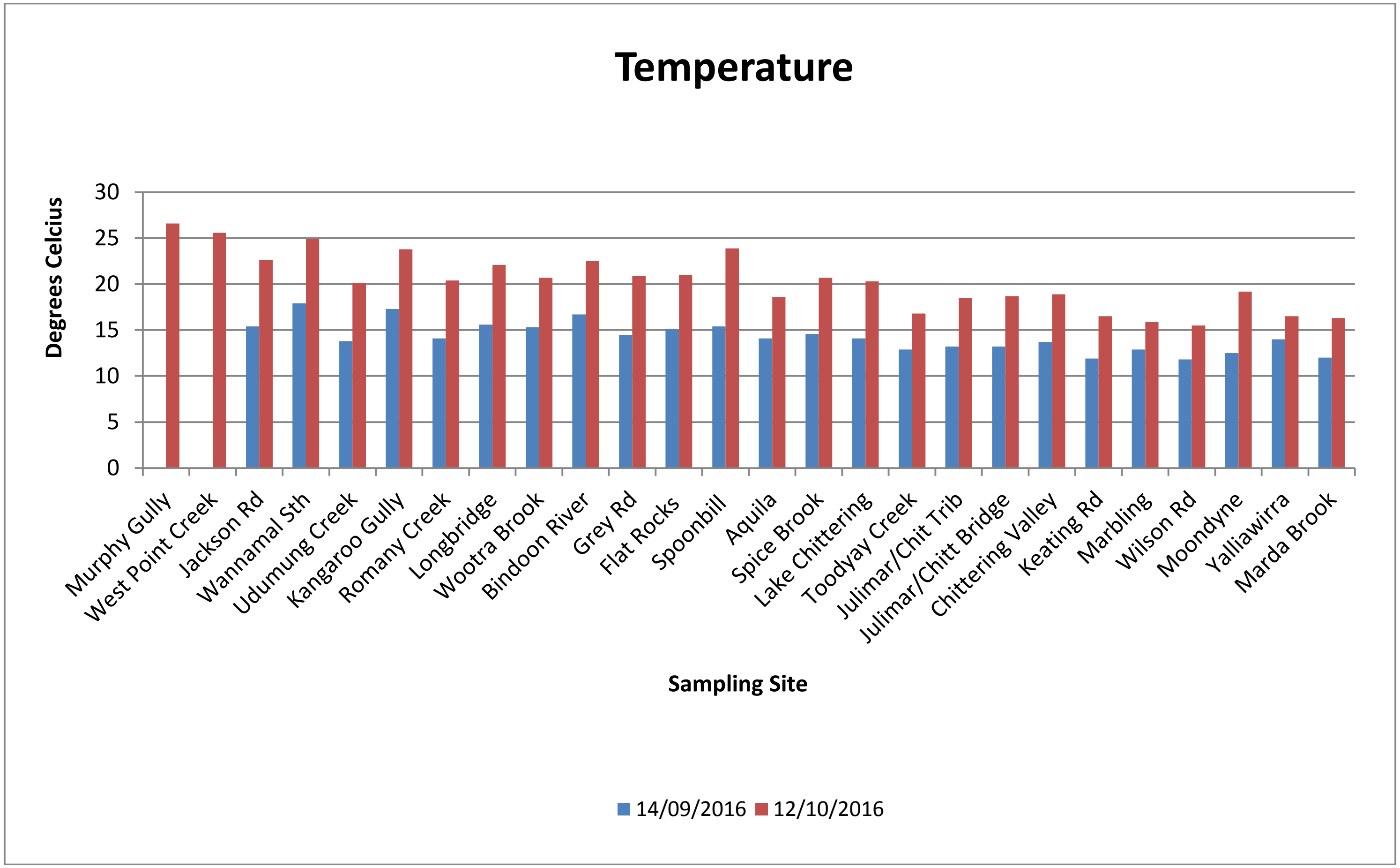
pH

pH is a measure of acidity and alkalinity. With a pH of 7.0 being neutral, a pH of less than 7 being acidic and a pH of greater than 7 being alkaline or basic. pH has an effect on chemical reactions and can alter other water quality parameters. The importance of pH on water quality lies mainly in its effect on other water quality parameters and on chemical reactions. For example, pH can affect the solubility and toxicity of a wide range of metallic contaminants (IEA 2003).

Since 2007 the Brockman River has recorded slightly alkaline pH, but the majority of sites fall within the ANZECC water quality guidelines of 6.5-8 for lowland rivers. Most of the twenty-six sites sampled recorded alkaline results, with the highest pH reading being 8.36 at Lake Chittering (BRN15) during the October sampling occasion. The highest pH reading during the September sampling occasion was 8.08 at Jackson Road (BRN3). Generally the results in 2016 were similar previous years (Table 4). Lake Chittering (BRN15) and Murphy Gully (BRN1) have consistently given alkaline readings, with seven of the last 10 years recording alkaline results.

Table 4. Summary of alkaline sites in previous years

Year	Highest pH Reading	# of Alkaline Sites
2007	8.51	2
2008	9.9	4
2009	8.579	9
2010	10.125	14
2011	9.76	7
2012	9	3
2013	8.304	3
2014	9.22	10
2015	8.45	10
2016	8.36	?



*blanks represent no sample taken

Figure 6: Water temperature of surface water within the Brockman River Catchment 2016.

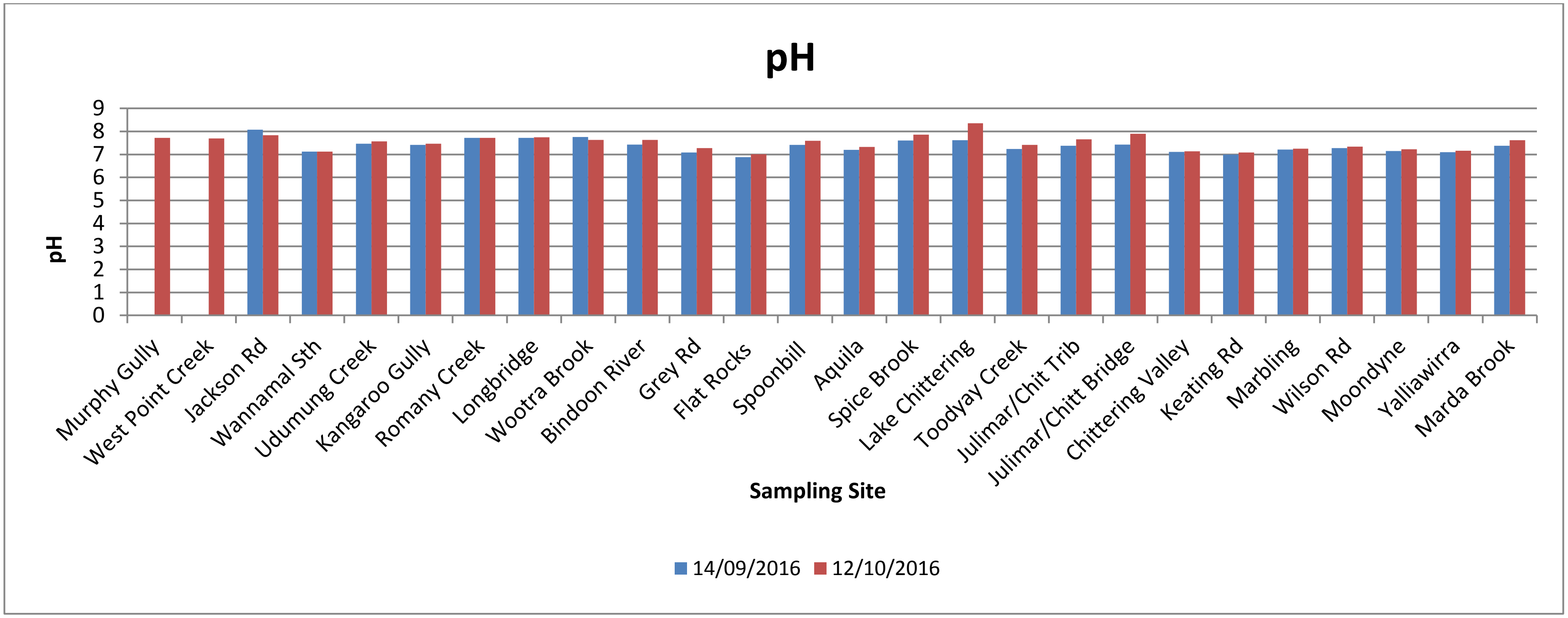


Figure 7: pH of surface water within the Brockman River catchment 2016.

Electrical Conductivity

Electrical conductivity (EC) is the total concentration of inorganic ions (particularly sodium, chlorides, carbonates, magnesium, calcium, potassium and sulfates). Conductivity is often used as a measure of salinity. The conductivity level can directly affect the use of the water. For example, flora and fauna have varying tolerance levels to salinity. Therefore, this can have adverse effects on crops and stock as well.

Electrical conductivity ranged from 0.582mS/cm at Marda Brook (BRN26) to 13.946mS/cm at Murphy Gully (BRN1). All sites consistently exceeded the ANZECC guidelines for freshwater lowland rivers of 0.12mS/cm to 0.3mS/cm (Figure **9**). It should be noted that of the sites that exceeded the guidelines for ecosystem value, the majority of them were also within the brackish levels, with 22 sites within brackish levels on at least one sampling occasion. Brackish water is between 3mS/cm and 9.1mS/cm, saline water is between 9.5mS/cm and 23mS/cm), anything above 2.7 is becoming brackish and would be detrimental for irrigation of stone fruit and citrus orchards (Figure 9).

Marda Brook (BRN26) and Spoonbill (BRN13) recorded marginal levels of EC on both occasions in 2016.

Murphy Gully (BRN1), Jackson Rd (BRN2), Longbridge Gully (BRN8) and Wootra Bk (BRN9), were identified as saline sampling sites. The Marbling Brook which is the last ‘freshwater’ perennial stream in the Brockman River catchment recorded fresh to brackish conductivity readings in 2008-2013, and in 2014 thru 2016 it was recorded as marginal. The increasing conductivity levels in the Marbling Brook could be a direct result of the increased pressure on the aquatic ecosystem due to surrounding development and the number of bores drawing up water in the Maryville estate and the reduced rainfall. These past results have caused landholders in the catchment to voice their concerns over the lack of good quality water required for new and expanding agricultural developments over the years (WRC, 2003). The conductivity readings over the past nine years have showed a slight decreasing trend. Ongoing monitoring is essential.

It is also of great concern for the environmental value that all sites consistently exceeded ANZECC water quality guidelines for lowland river systems, and were generally within the brackish to saline levels. The highest conductivity reading of 13.946mS/cm within the Brockman Catchment was recorded at Murphy Gully which is located at the northern most point of sampling along the Brockman River. Conductivity levels recorded at the sampling sites along the main body of the Brockman River were found to decrease from north to south (Figure 8). This pattern was also noted in the 2006 through to 2015 *Water Quality Monitoring Snapshot of the Brockman River catchment* (EBICG, 2007, 2008, 2009, 2010, 2011, 2012, 2013 & 2014, 2015). Levels dropped to 0.582mS/cm at Marda Brook (BRN26) during the September sampling occasion. This site is located just north of the confluence of the Brockman River and the Avon River. This concentration was above the guideline, marginal and as a result, unacceptable for the irrigation of stone fruit, citrus, peas, carrot, onion, grapes, lettuce and tomato. It is also unacceptable for human consumption or use in hot water systems (Appendix C).

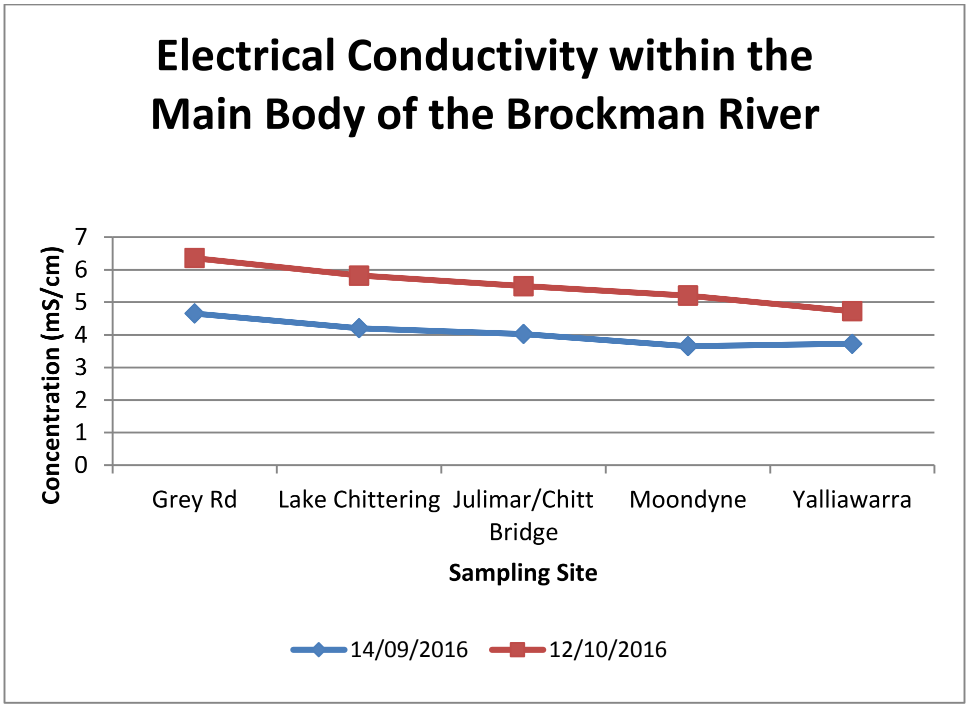


Figure 8: Electrical conductivity within the main body of the Brockman River, recorded at sampling sites Grey Road (BRN27), Lake Chittering (BRN15) Julimar/Chittering Bridge (BRN18), Moondyne (BRN24) and Yalliawirra (BRN25) in 2016.

The high level of vegetation clearing, primarily at the top of the catchment creates a weak correlation with increasing stream salinity, and a strong correlation with increasing groundwater salinity (Fulwood, 2001). This shows that the higher conductivity levels coming down the catchment and tributaries are diluted as they flow through the Brockman River catchment and into the Avon River. This trend was also described in the *Salinity Survey in the Shire of Chittering* (Angell, 2000). Additionally, Angell (2000) found that a considerable portion of stream flow is contributed to the Brockman from saline groundwater sources. Base flow maintains stream flow throughout the year however, if extremely saline, base flow can have devastating effects on the river particularly during low rainfall seasons (approximately 200mm below average). This results in lower surface water inputs and low dilution rates. With exception to rainfall, salinity within the catchment has increased over a period of time (Fulwood, 2001).

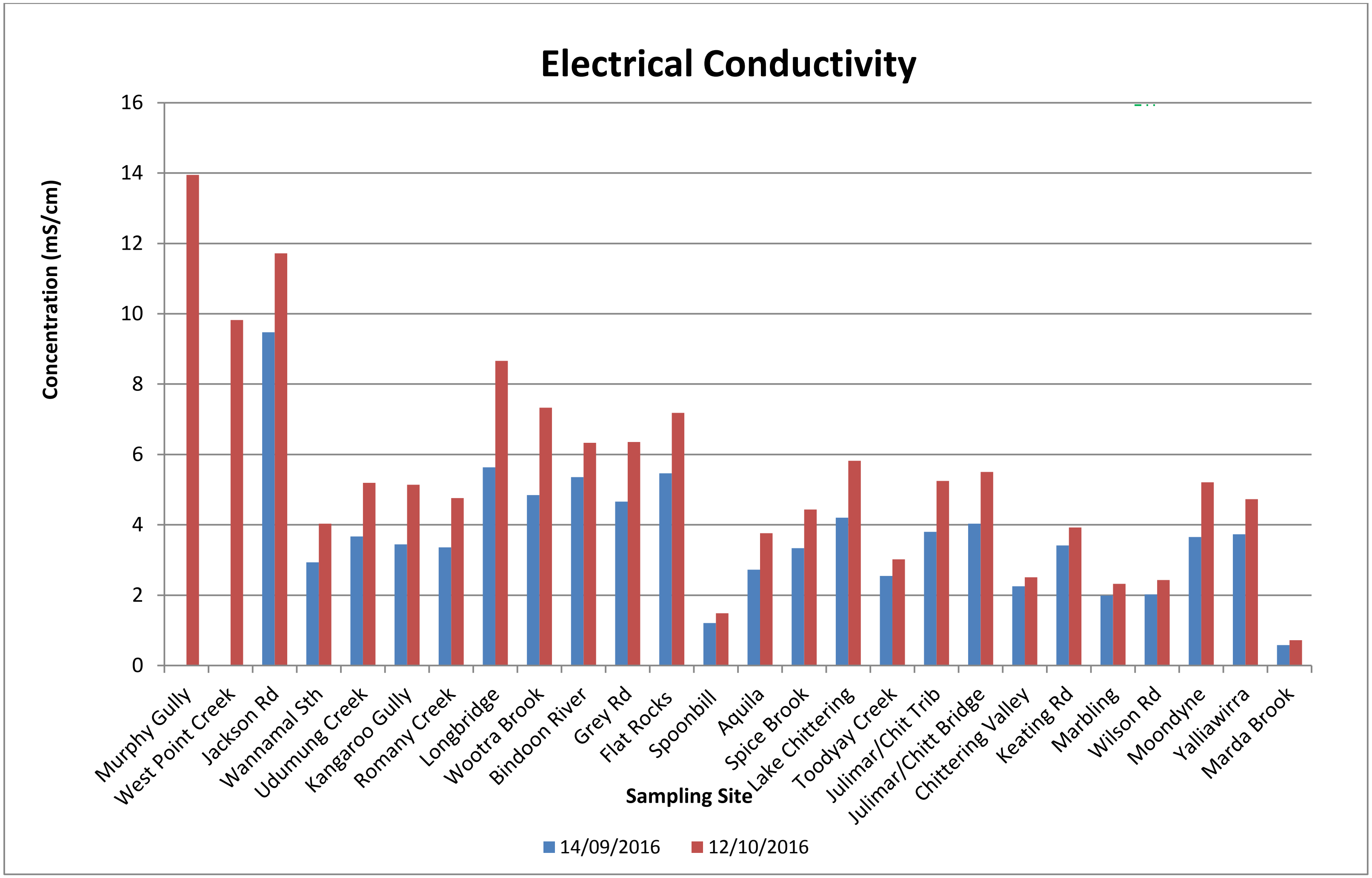


Figure 9: Conductivity in surface water within the Brockman River catchment 2016.

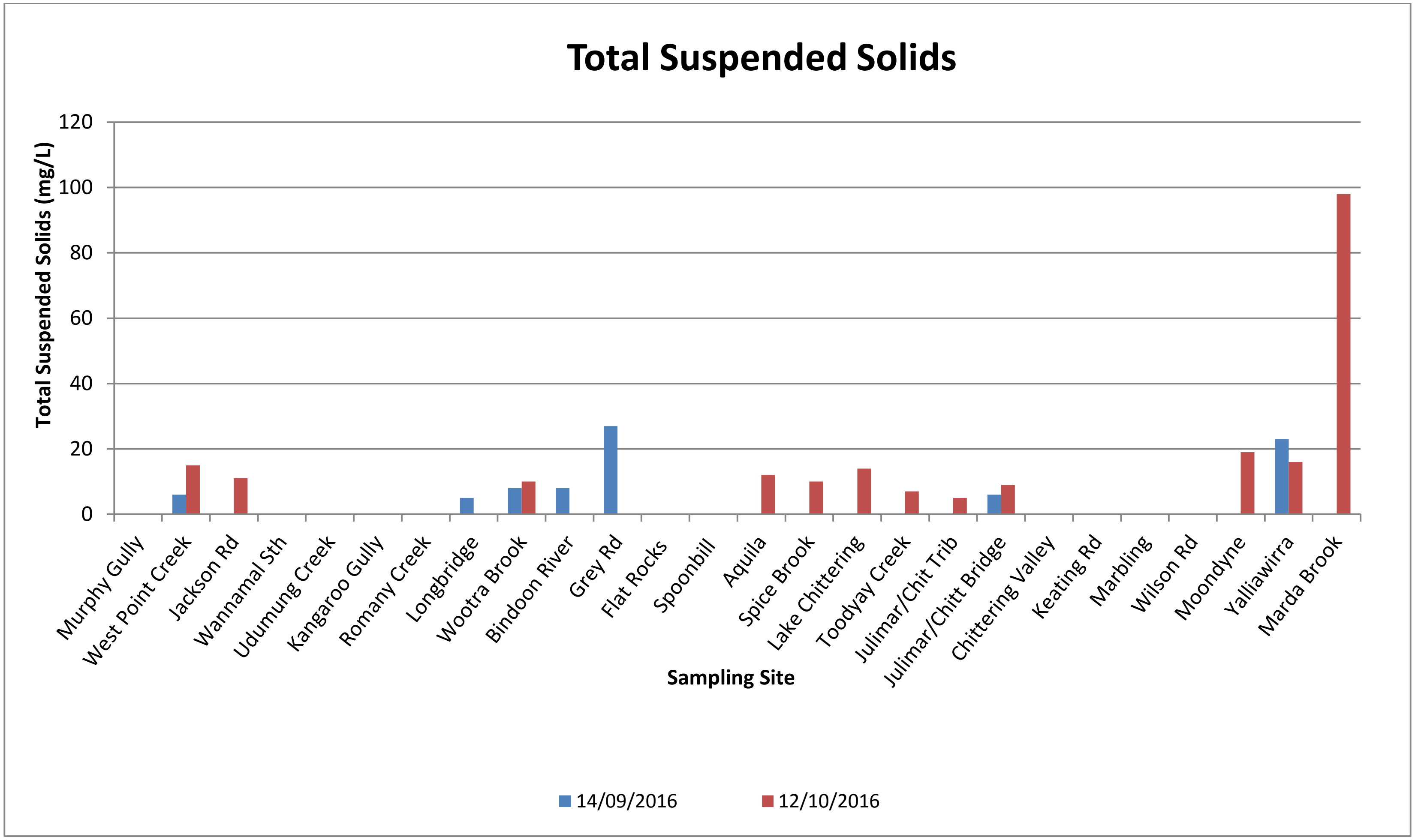
Total Suspended Solids

Total Suspended Solids (TSS) refers to naturally occurring suspended particles including; silt, phytoplankton and organic matter within a water body. Natural sources of TSS include water turbulence from storms, phytoplankton blooms and wind/wave action. However, TSS may also indicate detrimental environmental conditions such as erosion. This makes levels higher than normal in the water body and can result in increased deposition of material to the substrate that may smother faunal communities (McTaggart, 2002).

There are large variations in TSS throughout water bodies, therefore guidelines should be determined by including information on natural levels within the regional area of sampling. As no ANZECC guideline currently exists for TSS, this report will use the interim guideline of 6mg/L adopted by the Department of Water and originally developed by the Waters and Rivers commission for the Wilson Inlet report to community (October 2000). TSS in the Brockman catchment ranged between laboratory detection limits and 36mg/L recorded at Marbling Brook (BRN23).

7 of the sites recorded a result over the guideline of 6mg/L for TSS during the September sampling run, while there were10 sites with a reading over the guideline during the October sampling occasion.

High TSS levels from contributing sub catchments are located across the catchment in areas of intensive stocking rates and grazing, high levels of cleared vegetation and a lack of riparian vegetation. Stock have access to waterways in most of these areas causing increased erosion rates and sedimentation.



***blanks represent no sample taken or below limit of reporting**

Figure 10: Total Suspended Solids in surface water within the Brockman River catchment 2016.

6.1.3. Nutrient concentrations in water

Most nutrients present in the catchment are stored in the soils and are transported to the Brockman River via surface water (tributaries, drains and general run-off). The original sources of nutrients include; weathering, leaching from soils particularly in eroded areas, fertiliser run-off, detergents, sewerage, fixation by some plants, and decomposition of plant matter, animal wastes and other organic wastes (IEA 2003). Nitrogen and phosphorus are the two major essential elements to plants. Excessive amounts of nutrients in waterways can result in eutrophication with plant and algae growth, increases in nuisance insect numbers and unbalanced aquatic ecosystems. Nutrients include nitrogen in the form of ammonia, nitrate and nitrite, and phosphorus in the form of phosphate either dissolved (soluble reactive phosphate) or particulate (suspended).

Total Nitrogen

When plants or animals die they release nitrogen in the form of ammonium (NH_4) that can then be oxidised by nitrifying bacteria to become nitrite and nitrate in a process known as nitrification. Total nitrogen (TN) refers to all forms of nitrogen present including organic (e.g. plant decay matter) and inorganic in the forms of ammonia, nitrate and nitrite (McTaggart 2002). Sources of nitrogen include fertilisers, industrial cleaning operations, feed lots, animal droppings, combustion of fossil fuels and plant debris.

The majority of the readings that were above the ANZECC guideline of 1.2mg/L were on the ASeptember sampling occasion when10 of the twenty-six sites had a result greater or equal to the guideline.The majority were in the northern end of the catchment. Only 3 sites recorded Total Nitrogen readings above the guideline in OctoberRomany Creek (BRN7) recorded the highest concentration of32.2mg/L on the Septembersampling occasion while Wannamal South(BRN 4) recorded the highest concentration for the October sampling run, with 2.8mg/L. Further monitoring is recommended.

Ammonia as Nitrogen

All sites were within the ANZECC guideline of 0.08mg/L on both sampling occasions (Figure 12). West Point Road (BRN3) and Flat Rocks Road (BRN1\2) did record levels above the guideline which is highly unusual. These two sites are also consecutive in terms of the main channel of the Brockman River. The likely cause is related to the chittering lake system discharging runoff however more investigations need to be made.

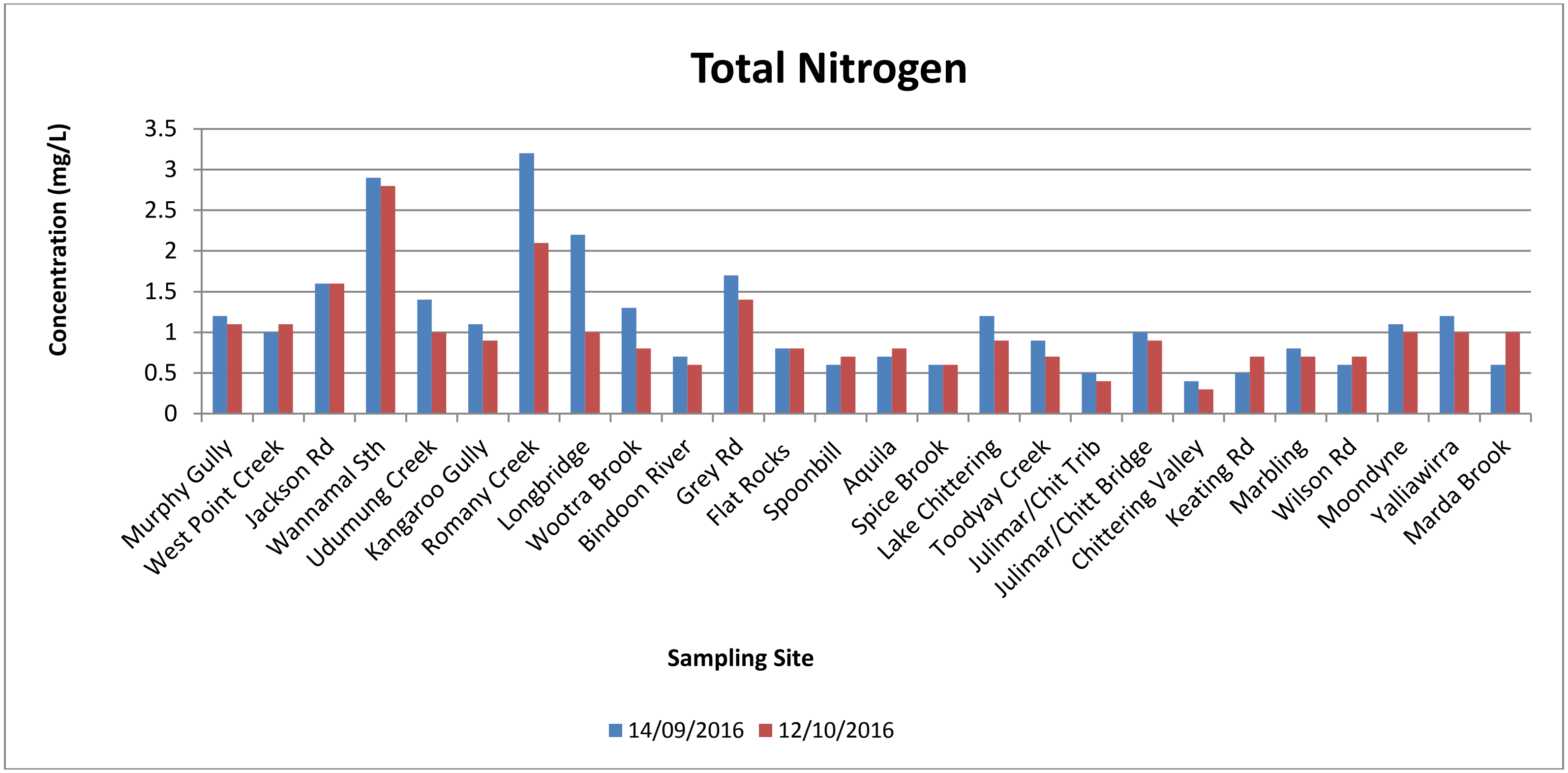
Ammonia is used in fertilisers and cleaning agents. The majority of sampling sites are surrounded by agriculture including cattle grazing, pastures and cropping, stock yards, orchards and horticulture which are sources of ammonia nitrogen.

Total Oxidised Nitrogen

Total oxidised nitrogen is the sum of the oxidised forms of nitrogen, which includes nitrite and nitrate, and is often referred to as NO_X. Nitrite can be converted to nitrogen gas by denitrifying bacteria and ammonium (NH_4) and in the form of nitrate; hence plants can easily absorb this form of nitrogen in a continuous cycle as it is readily soluble in water and is rapidly transported through the catchment via surface run-off, sub-surface and groundwater flows (Horwood, 1997).

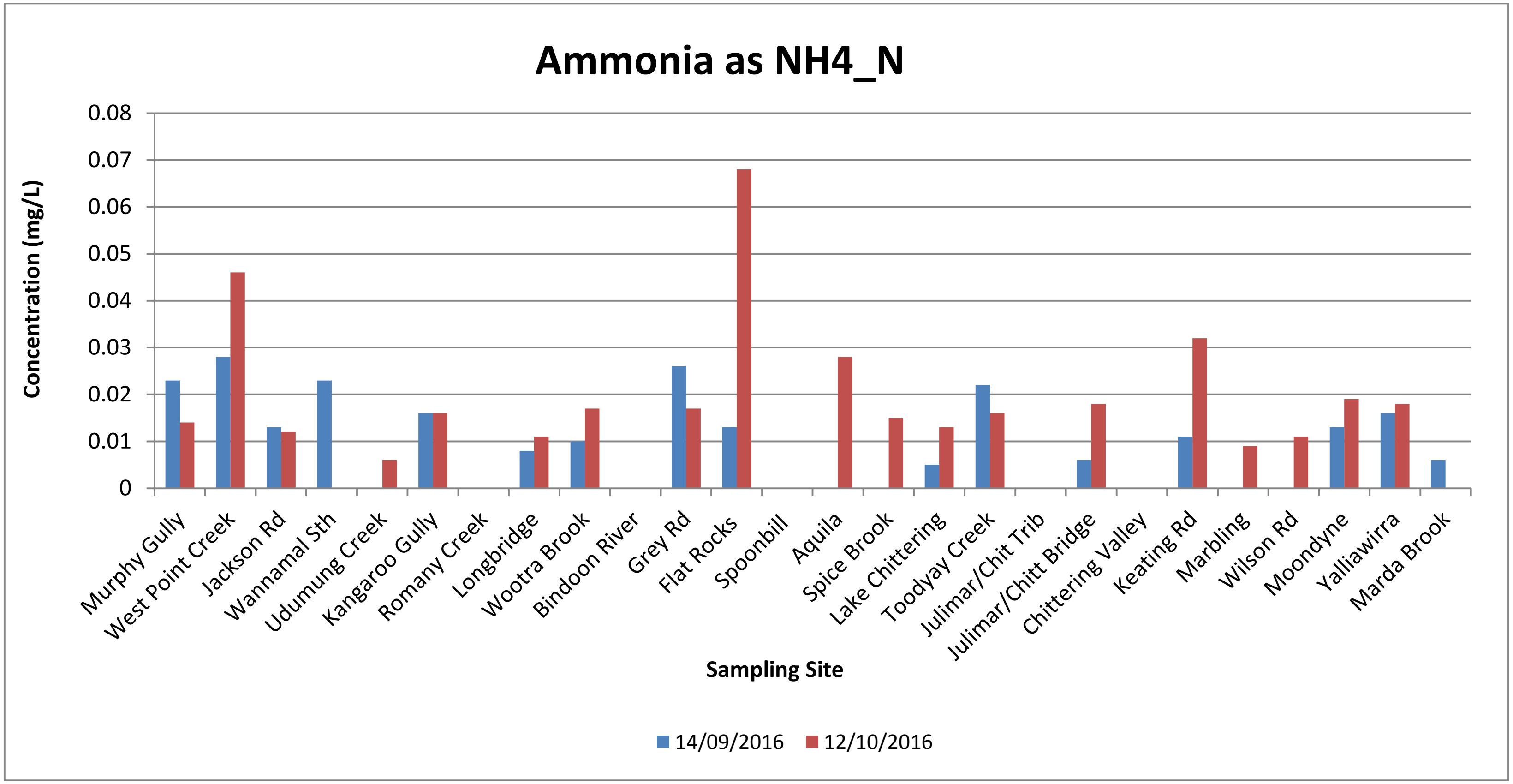
Unfortunately due to an laboratory error TON was not measured for the 2015 sampling period. This will be looked at closely in 2016. The levels from 2014 have been included in this report as an illustration of the previous years results.

Cereal production, beef, pigs, and sheep may contribute to the higher concentrations of TON in the northern half of the catchment. In comparison, the primary production of the southern half of the catchment in the Chittering valley is vineyards and orchards. As a result the TON entering the river upstream from runoff carrying manure and organic matter is diluted as it flows through the catchment.



*blanks represent no sample taken or below limit of reporting

Figure 11: Total Nitrogen in surface water within the Brockman River catchment 2016.



*blanks represent no sample taken

Figure 12: Ammonia as NH4N concentrations in surface water within the Brockman River catchment 2016.

*note blanks represent no sample taken

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Total Phosphorus

Total phosphorus (TP) is a measure of all phosphorus in the water including the available and unavailable (or potentially available) forms of phosphorus including orthophosphates (fertilisers), organic phosphate (plants & animals) and condensed phosphates (inorganic cleaning agents). Sources of phosphorus include fertilisers, plant debris, detergents, industrial wastes and lubricants (McTaggart 2002). Phosphorus is naturally occurring in the environment and is usually the limiting factor for aquatic plant growth as it is generally lower than nitrogen in most waterways. However, an increase in the total P level in freshwater bodies stimulates the production of *Chlorophyll a* in phytoplankton and results in an algal bloom (Russell, 2001).

As plants and animals excrete waste or die then decay, the organic phosphate sinks to the bottom of the waterway where bacteria convert it back to inorganic phosphate. Inorganic phosphate returns to the water column when sediments are disturbed, making it available again to plants which uptake it and it continues in the cycle. Inorganic phosphate is not as mobile as soluble forms of nutrients and tends to be absorbed by most soils and particulate material. This results in a steady accumulation of phosphorus slowly moving through the soil profile. Holding time of phosphorus in the catchment depends on the recharge rate to groundwater, rate of adsorption to soil particles and the extent of soil saturation (Gerritse, 1996).

Table 5. Number of sites (out of 26) equal to or exceeding the ANZECC Total Phosphorus guideline for lowland rivers.

Year	Number of Sites
2006	0
2007	0
2008	7
2009	4
2010	11
2011	10
2012	11
2013	3
2014	0
2015	0
2016	0

Phosphorus concentrations in the Brockman catchment had gradually increased since 2006, when there were no sites that recorded concentrations over the ANZECC guideline of 0.065mg/L for lowland river systems and ecosystem health. In 2016, no sites were over the guideline (Table 5). No site recorded a value over the limit of reporting (0.05mg/L).

Duplex soils of sand over clay and loamy clays with high nutrient retention capabilities dominate on the Darling and Dandaragan Plateaus of the Brockman River catchment. These soils have a high nutrient retention capacity which reduces the level of nutrients entering the waterways other than through erosion and sedimentation (DEBCMP, 2001).

According to Russell (2001) it is storm events that trigger the hydrological pathways important for phosphorous loss. Export of phosphorus during peak flow times can get up to 20 times higher than pre-storm levels in stream flow from an agricultural catchment. Most of the phosphorus exported from an area during these periods of heavy rainfall and storm activity are in particulate form as it is carried primarily in sediment and soil as a result of rill, gully and sheet erosion. Because of this total phosphorous concentrations are generally higher at the beginning of the rainfall season when the creeks and rivers are experiencing the “First flush”.

This theory may explain why the recordings have varied so much over the last decade, and we may find that the levels correlate with the time since a heavy weather event at the time of sampling. Continued long term monitoring is recommended to gain an understanding of phosphorous export from this catchment.

Soluble Reactive Phosphorus

Soluble reactive phosphorus (SRP) measures only the dissolved phosphorus in water and provides a measure of the immediately available phosphate in the system at the time of sampling; it is also referred to as PO_4. As this form of phosphorus is readily available it is more likely to stimulate algal blooms and this can lead to more decaying vegetation which alters river characteristics including elevated temperature, reduced oxygen and fish kills. This nutrient enrichment process is known as eutrophication (McTaggart, 2002).

SRP concentrations in surface water within the Brockman catchment were below the ANZECC water quality guideline for lowland river systems value of 0.04mg/L at all sites and below the Limit of Reporting (LOR) at most sampling sites on both sampling occasions (

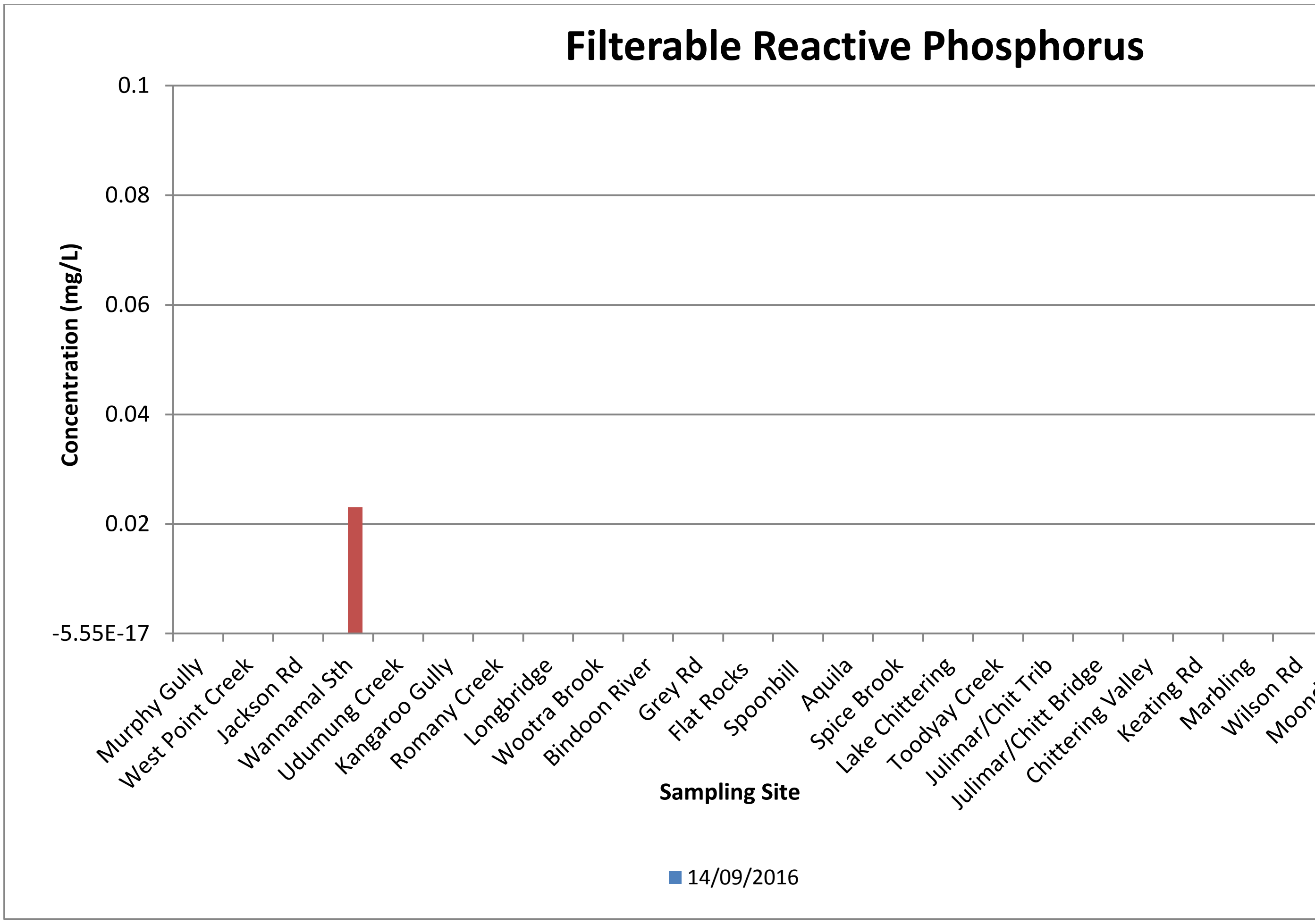

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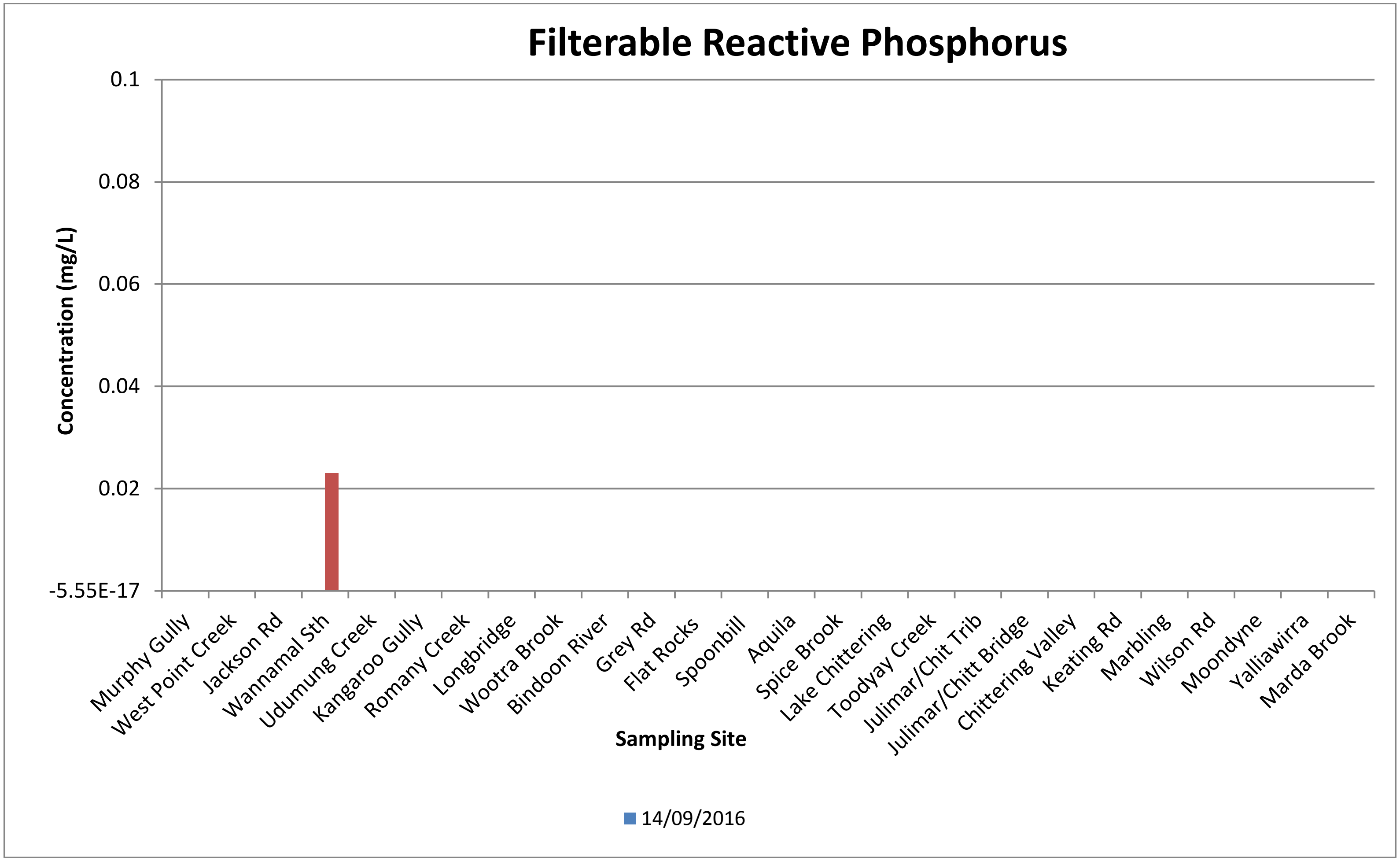
Figure 13).



*blanks represent no sample taken

Figure 13: Filterable Reactive Phosphorous concentrations in surface water within the Brockman River catchment 2016.

6.1.4. Metals in surface water

Metals are usually found naturally in aquatic ecosystems; however, in excessive amounts they are associated with toxicity and pollution. They are derived from a variety of sources such as industrial waste, refuse leachate, corrosion of pipes and roofs (McTaggart, 2002). The most common sources of metal contaminants in the Brockman are pesticides and fertiliser application. Copper, zinc and cadmium in particular are often found in fertilisers. In the Brockman catchment most metals would enter the river via surface water run-off and groundwater contamination.

Aquatic organisms have varying tolerance levels to different metals. Metals that are essential for growth can become toxic to aquatic organisms at levels beyond their tolerance. This may only be slightly higher than normal concentrations. Metals may also accumulate in fatty tissues of animals and in the human body, so repeated exposure to heavy metals can cause levels to build up to a toxic level (IEA 2003). This is known as “bioaccumulation”.

Biomagnification can result in animals at the top end of the food chain accumulating a high concentration of heavy metals even if the organisms consumed at lower levels of the food chain have acceptable levels of heavy metals. Tolerance levels of aquatic organisms to heavy metals and ability to absorb those metals can be influenced by many factors including; interaction with other metals and formation of organic complexes (e.g. with organic carbon compounds), the chemical form of the metal, dissolved oxygen levels, salinity levels, temperature and the hardness of the water.

Metals were sampled for at 8 strategically identified sites including Spoonbill (BRN13), Aquila (BRN14), Lake Road (BRN15), South Chittering Creek (BRN22), Marbling Brook (BRN23), Yalliawirra (BRN25) ,Gray Road (BRN27) and Jackson Rd (BRN2) in 2016.

In 2006 and 2007, heavy metal concentrations in the waters of the Brockman River catchment were well below the ANZECC guideline and Hardness-Modified Trigger Values apart from on one occasion. These heavy metals included aluminium, arsenic, iron, cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc.

From 2008 to 2015, there have been many more results that are over the ANZECC guidelines for the various metals. Aluminium and Iron have recorded values above the guideline more so than the other metals. The elevated concentrations of these metals could be a result of surrounding land use and practices including fertiliser application, soil erosion carrying heavy metals to the waterways, groundwater contamination and sub-surface flow, and the natural occurrence of these trace elements in the soil. Water hardness affects the toxicity of the heavy metals in the environment. (Appendix A).

Sites which have been tested since 2006 include Udumung (BRN5), Spoonbill (BRN13), Aquila (BRN14), Lake Rd (BRN15), Julimar/Chittering Tributary (BRN19), Chittering Valley (BRN20), Keating Rd (BRN21), South Chittering Creek (BRN22), Marbling (BRN23), Moondyne (BRN24), Yalliawarra (BRN25), Marda Brook (BRN26), Gray Rd (BRN27) and Jackson Rd (BRN2).

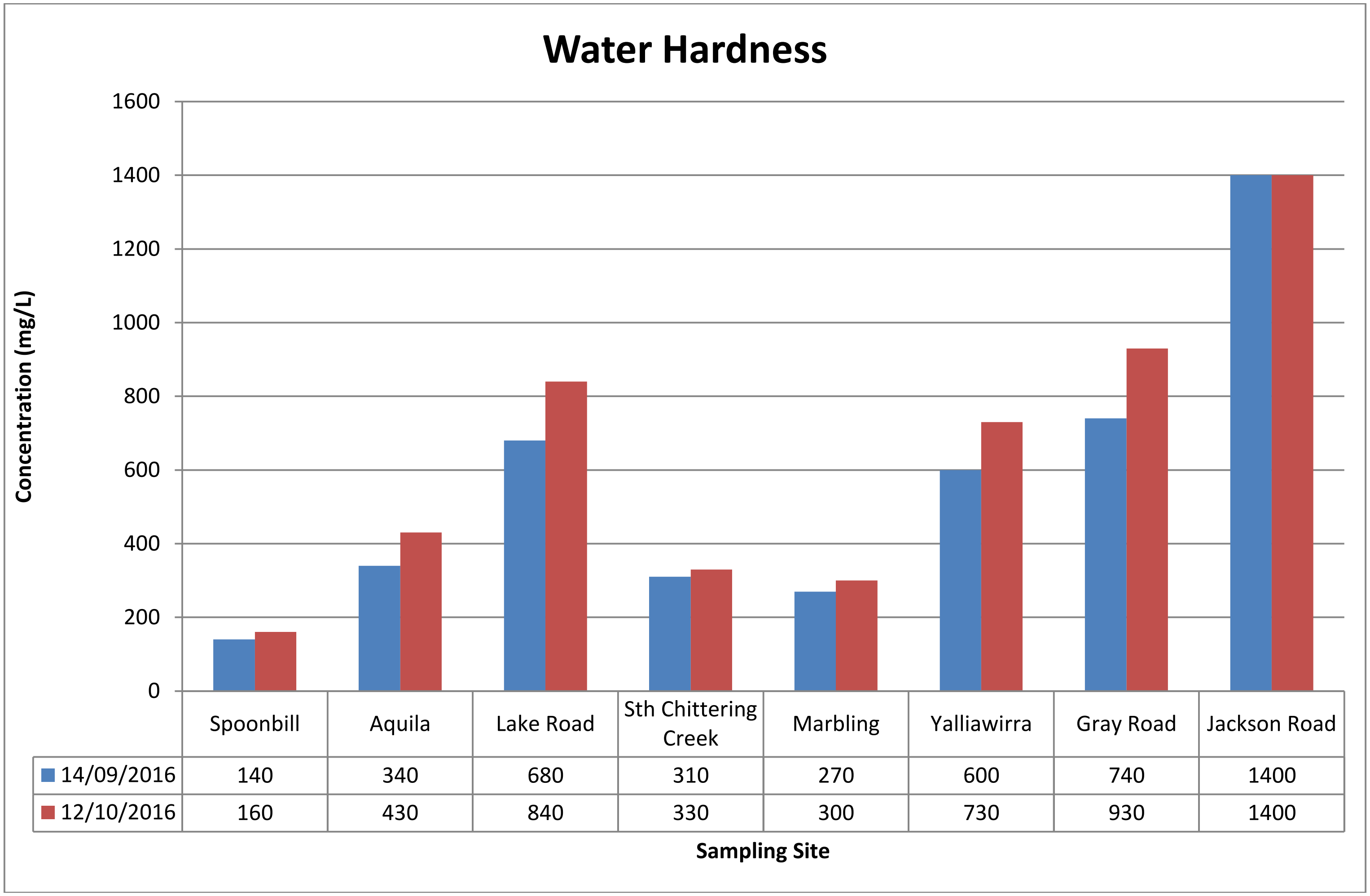
Hardness

Total hardness, expressed as calcium carbonate ($CaC0_3$), is the combined concentration of alkali-earth metals, predominantly magnesium (Mg^{2+}) and calcium (Ca^{2+}), and some strontium (Sr^{2+}). The source of this hardness is possibly through the weathering of granite. Hardness levels range from <60mg/L (soft) to >400 mg/L (extremely hard).

Water hardness can have an ameliorating effect on the toxicity of some heavy metals including cadmium, copper, zinc, lead, nickel and chromium, as the calcium and carbonate ions compete directly for the same uptake pathways as these metals. Water samples with higher concentrations of water hardness need to have the trigger values for these metals adjusted by a hardness-dependent algorithm or the approximate factors applied to soft water trigger values of varying water hardness provided in ANZECC and ARMCANZ (2000), (Appendix D). Refer to Table 6 for the calculated Hardness-Modified Trigger Values (HMTV) for cadmium, copper, chromium, lead, nickel and zinc. Hardness ranged between 140mg/L at Spoonbill Lake (BRN13) – hard, and 1400mg/L at Jackson Rd (BRN2) – extremely hard (Figure 14).

Table 6: Hardness-Modified Trigger Values (HMTV) for Cadmium, Copper, Chromium, Lead, Nickel and Zinc based on Figure 14 and Appendix D calculations.

Metal	ANZECC Trigger Value	HMTV for hard water (120 – 180).	HMTV for very hard water (180 – 240).	HMTV for extremely hard water (250 - >400)
Cadmium	0.0002	0.00084	0.0011	0.002
Copper	0.0014	0.00546	0.0072	0.0126
Chromium	0.001	0.0037	0.005	0.0084
Nickel	0.011	0.0429	0.057	0.099
Lead	0.0034	0.02584	0.04	0.09
Zinc	0.008	0.0312	0.04	0.07



	Spoonbill	Aquila	Lake Road	Sth Chittering Creek	Marbling	Yalliawirra	Gray Road	Jackson Road
14/09/2016	140	340	680	310	270	600	740	1400
12/10/2016	160	430	840	330	300	730	930	1400

Figure 14: Water Hardness sampled from surface waters within the Brockman River catchment 2016.

Aluminium

Jackson Rd (BRN2), Yalliawarra (BRN25) and Gray Rd (BRN 27) were over the ANZECC guideline of 0.055mg/L on one or both occasions (Figure 17). Values ranged from 003/L at Lake Rd (BRN 15) to 1.1mg/L at Grey Rd (BRN 27). On this occasion the pH was within the guideline however alkalinity may have affected the result.

Iron

There is no ANZECC guideline trigger value or environmental concern level (ECLs) available for iron in fresh water as a result of insufficient data (ANZECC and ARMCANZ, 2000). No sites were below the current Canadian guideline of 0.3mg/L on any sampling occasion (Figure 16). This guideline is advised by the ANZECC water quality guidelines to be used as an interim indicative working level for aquatic ecosystems and requires further monitoring.

Zinc

All sites were below the Hardness Modified Trigger Values (HMTV) of 0.07mg/L for sites with extremely hard water, 0.0312mg/L for sites with hard water (Figure 19).

It is important to note that total zinc concentrations of less than 20mg/L in livestock drinking water is highly unlikely to be a threat to the health of livestock. Concentrations of Zinc rarely go over 0.01mg/L in natural water. Higher concentrations on Zinc can be associated with pollution from industrial wastes or corrosion of zinc coated plumbing or galvanised water tanks particularly of areas of low pH.

Copper

All sites were well below the hardness-modified trigger values (HMTV) of 0.00546mg/L for hard water and 0.0126mg/L for extremely hard water. In fact all sites were below the limit of reporting (0.001mg/L) for the August and September sampling run (Figure 18).

All sites are well below the recommended ANZECC trigger values for livestock, which are 0.5mg/L for sheep, 1mg/L for cattle, and 5mg/L for pigs and poultry (low risk) in livestock drinking water on all sampling occasions.

Copper is used in building material, electrical and heat conductors, and in household products. It is also an essential trace element; however in sufficient amounts it can be toxic.

Nickel

All sites were well below the hardness-modified trigger values (HMTV) of 0.057mg/L for very hard water and 0.099mg/L for extremely hard water. In fact all sites were below the ANZECC guideline of 0.011mg/L for fresh water in the south west of Western Australia on the September and October sampling occasions (Figure 18). It is important to note that nickel concentrations in livestock drinking water greater then 1mg/L may have adverse effects on animal health (ANZECC and ARMCANZ, 2000). The levels recorded in the Brockman are well below this guideline on both sampling occasions.

The concentration of nickel in natural waters is usually below 0.01 mg/L unless it has been contaminated by either corrosion of nickel plated plumbing, industrial waste or fallout from burning of fossil fuels.

Other Metals

Chromium (Cr), Arsenic (As), Lead (Pb) and Mercury (Hg) all recorded concentration levels below the relative limits of reporting (LOR) and ANZECC Trigger Values on both sampling occasions.

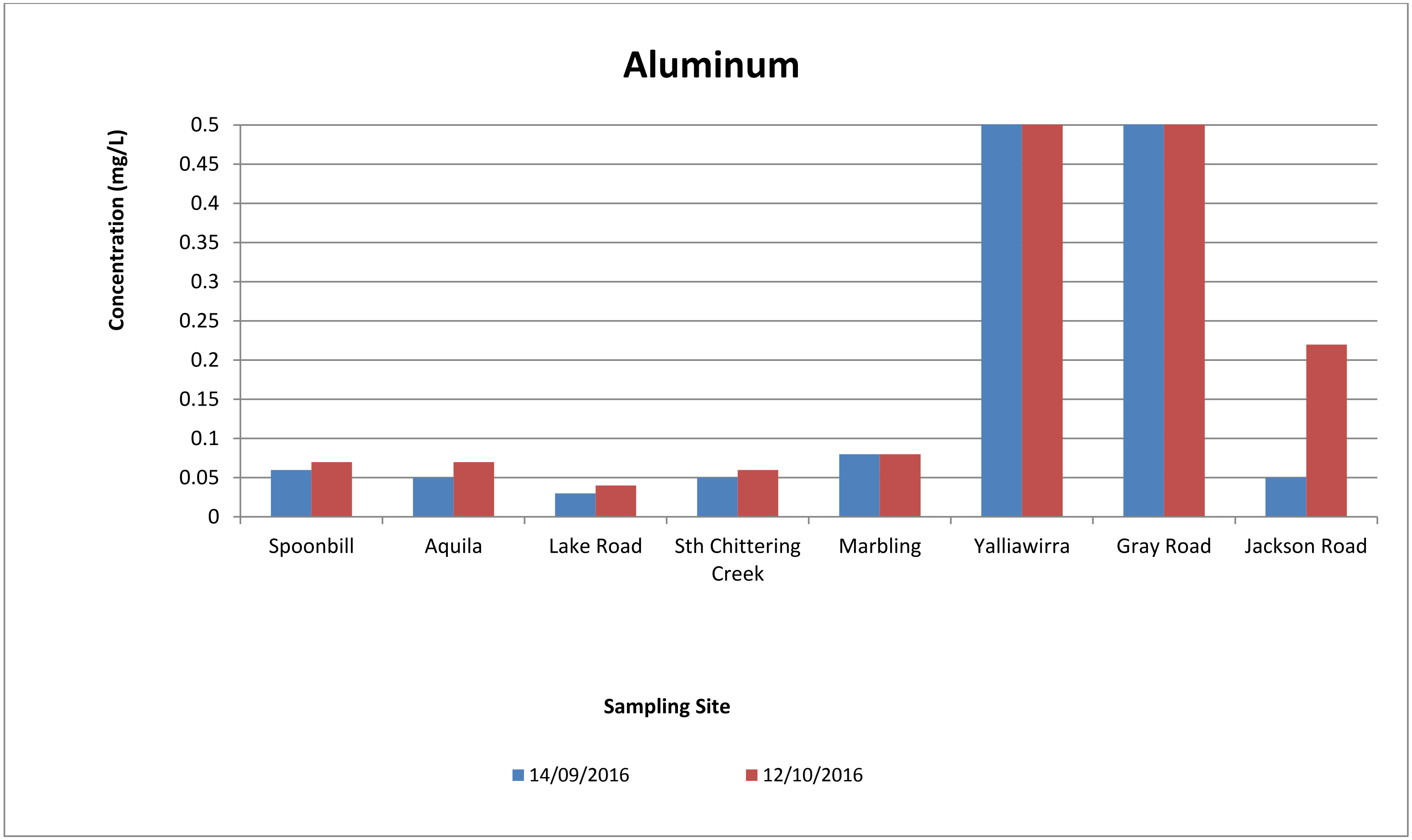


Figure 15: Aluminium concentrations in surface water within the Brockman River catchment 2016.

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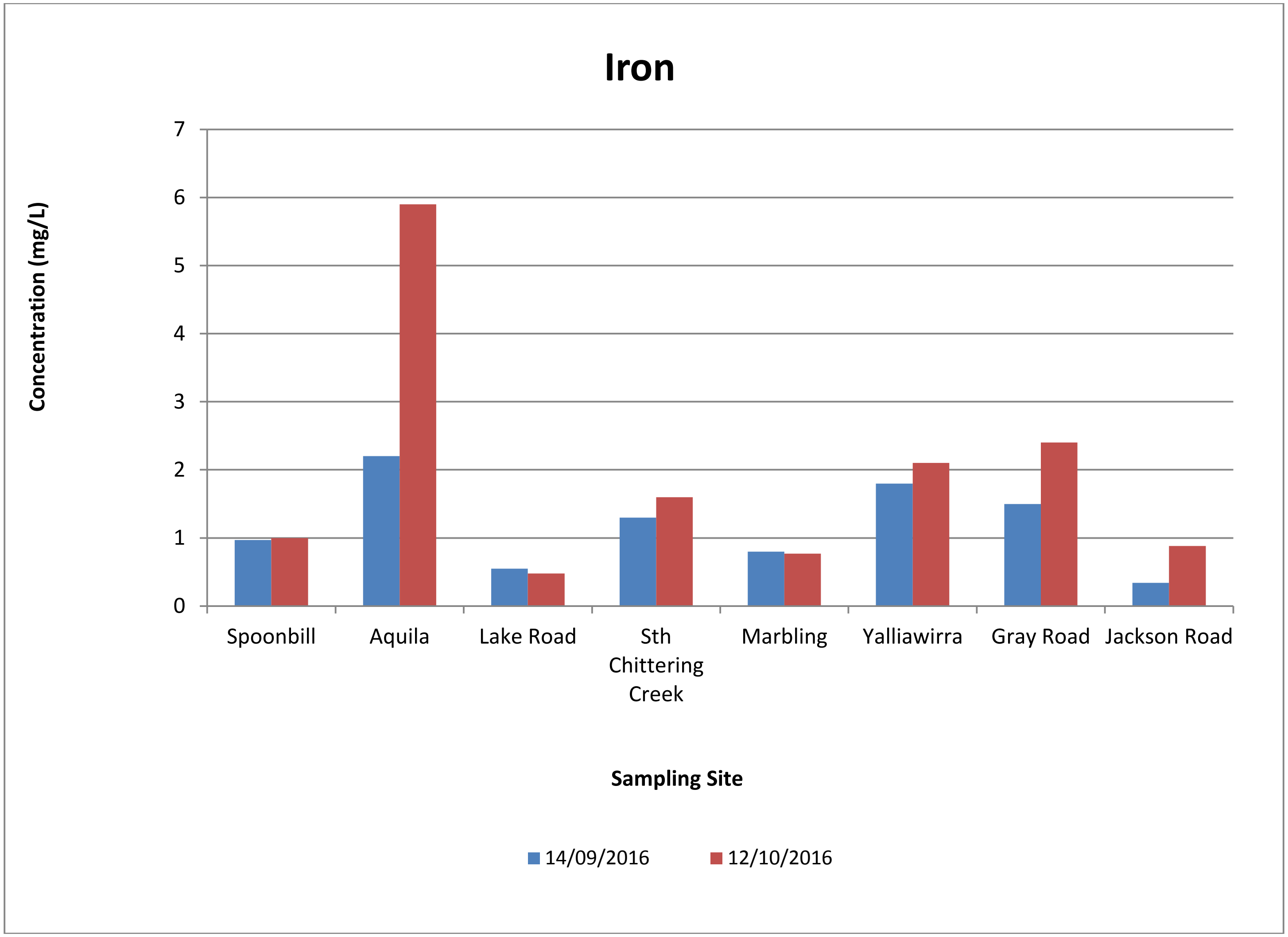


Figure 16: Iron concentrations in surface water within the Brockman River Catchment 2016.

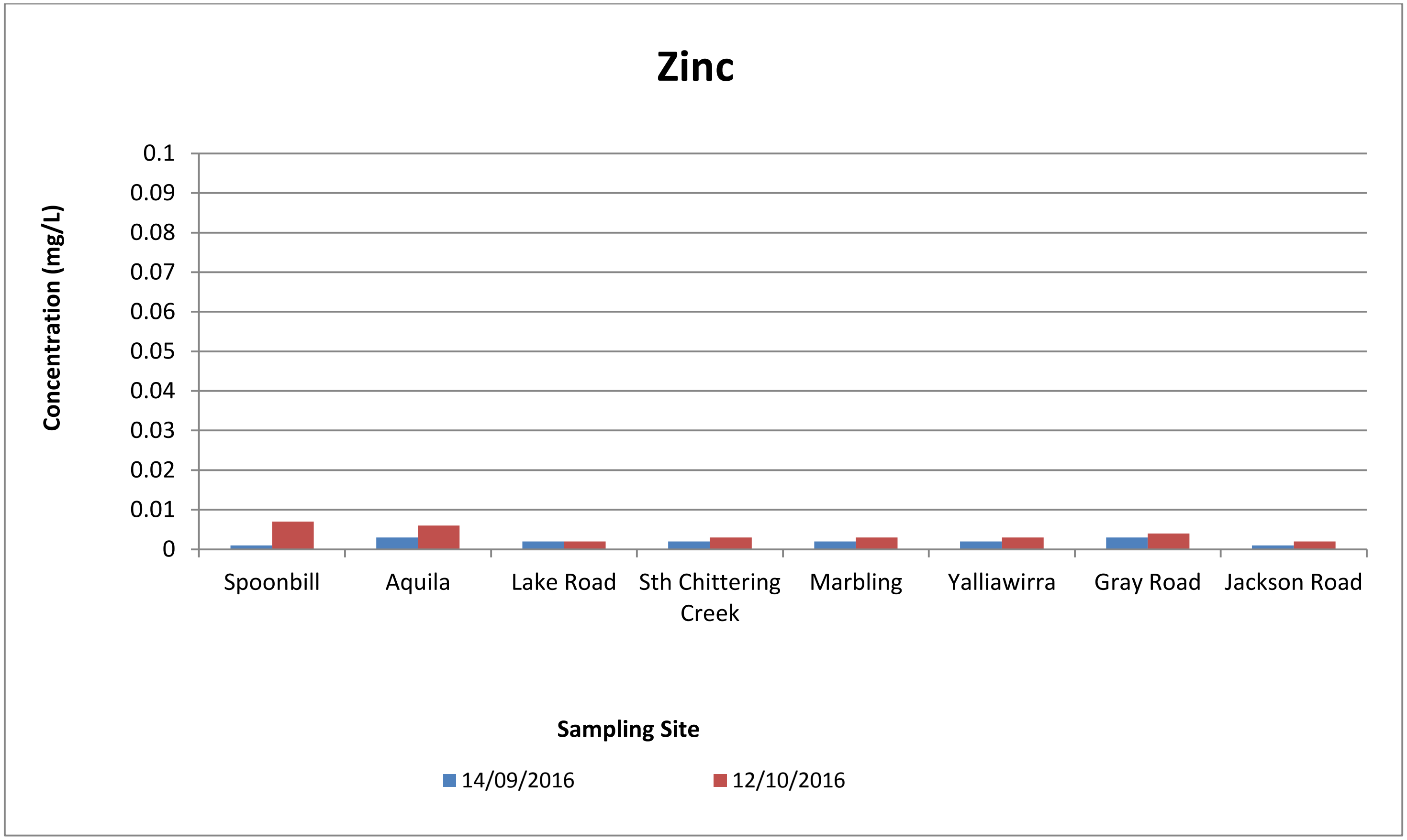


Figure 17: Zinc concentrations in surface water within the Brockman River catchment 2016.

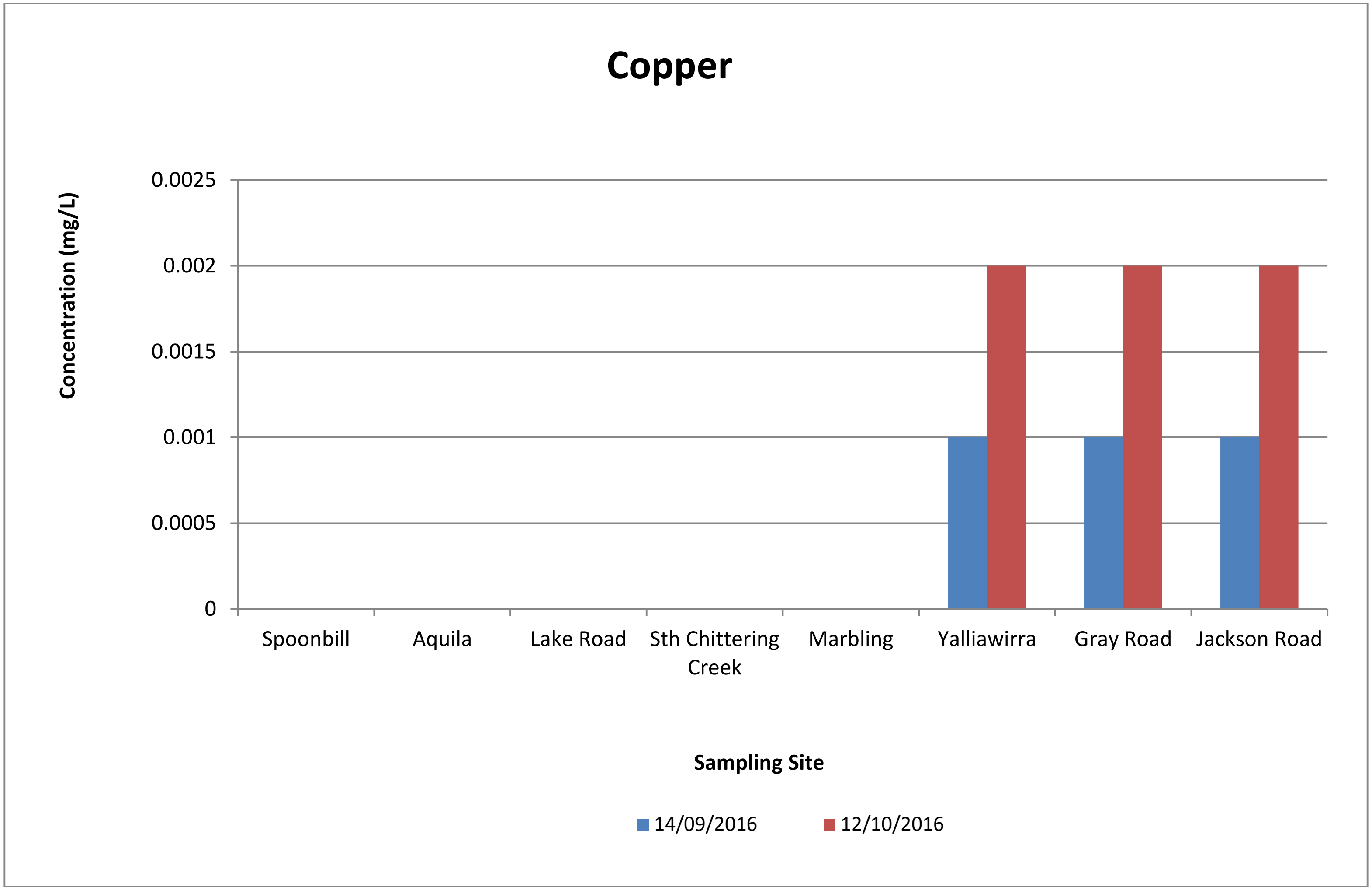
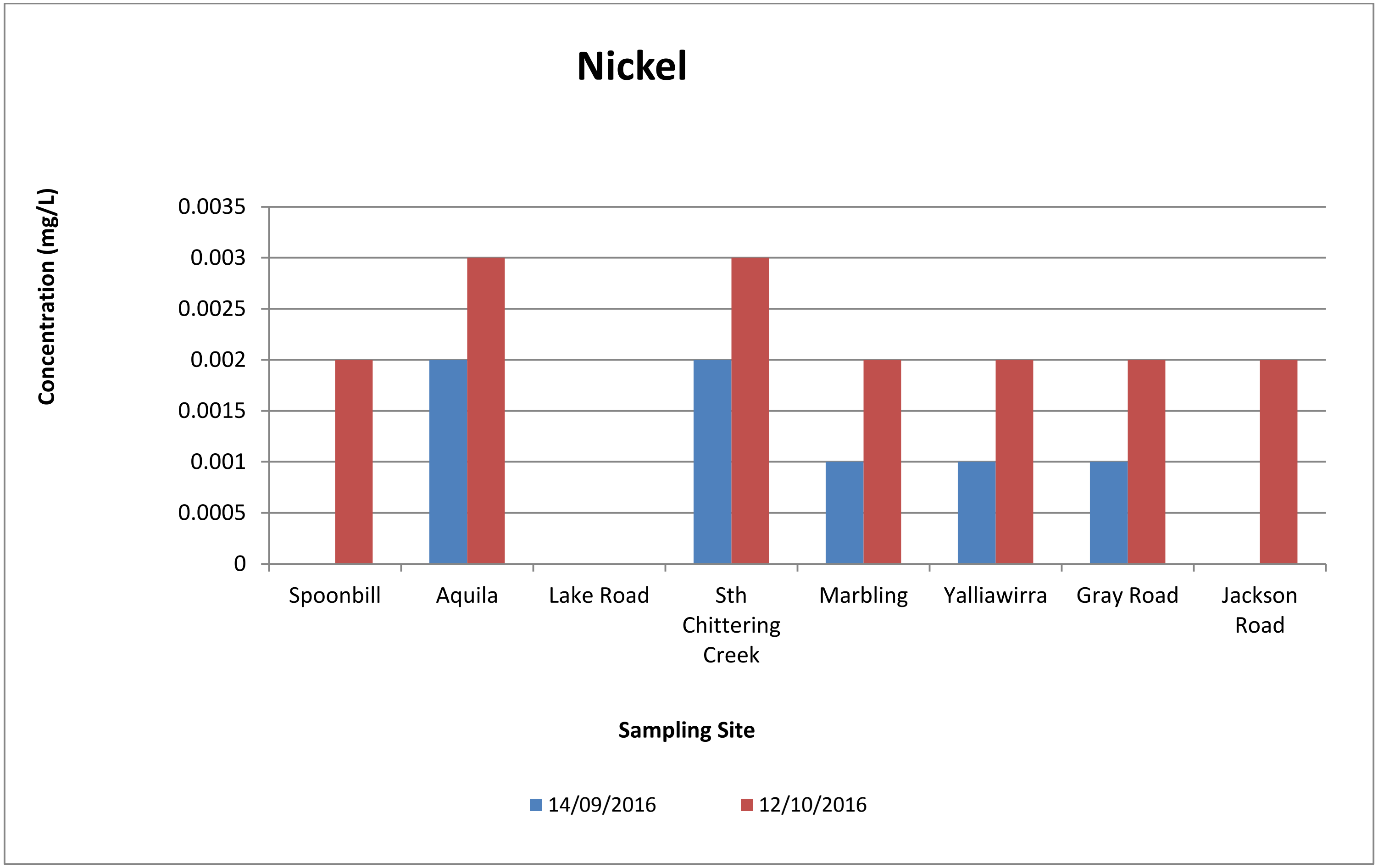


Figure 18: Copper concentrations in surface water within the Brockman River catchment 2016.



*blanks represent not measured

Figure 19: Nickel concentrations in surface water within the Brockman River catchment 2016.

1. Comparison with previous results

The Brockman River Catchment Water Quality Monitoring Snapshot September 2006, was the first snapshot developed by EBICG for this catchment. Conductivity data of the sampling sites listed in Table 6 have been collected on a regular basis since 2006 by officers at the Chittering Landcare Centre. This data was collected using WTW EC meters and represents the water quality at the time of sampling only. This provides some certainty in comparing the data over the years of sampling. Table 7 provides the salinity (conductivity) of the subcatchments within the Brockman River catchment between 2006 and 2016.

As stated in previous 'Water Quality Snapshots', there has been a steady increase in the salinisation of waterways within the Brockman River catchment over the past six years. Table 7 shows a direct relationship between salinity and location in the catchment where the sample has been taken. Northern sampling sites have been affected the most by salinity over the years and as the river flows southwards and receives more inflow from fresh tributaries, salinity appears to reduce (Table 7). However, without flow estimates load cannot be calculated so it is difficult to pinpoint areas of high salt input within the catchment and subsequent sites for remediation works (Angell, 2000).

pH levels in the Brockman River catchment appear to remain relatively stable, although slightly alkaline, over the years of sampling.

Nutrient concentrations in the Brockman River catchment are generally not of concern; however concentrations of Total Nitrogen (TN), Total Oxidised Nitrogen (NO_X_N/TON), Filterable Organic Nitrogen, Ammonia (NH3N), and Total Phosphorous (TP) have been recorded at various sites above the ANZECC guidelines on a number of sampling occasions. This is of concern and should continue to be monitored to determine whether or not the Brockman River catchment is contributing significant levels of nutrients to the Avon/Swan River.

Table 7: Sub catchment salinity measurement based on seven years of data between 2006 and 2015.

Site Name	Salinity Measurement
BRN1 Murphy Gully Road	Saline
BRN2 Jackson Road	Brackish-Saline
BRN3 West Point Creek	Brackish-Saline
BRN4 Wannamal South	Brackish
BRN5 Udumung Creek	Brackish
BRN6 Kangaroo Gully Creek	Brackish
BRN7 Romany Creek	Brackish
BRN8 Longbridge Creek	Brackish
BRN9 Wootra Brook	Brackish
BRN10 Bindoon River	Brackish
BRN11 Cresthill Road	Brackish
BRN12 Flat Rocks Creek	Brackish
BRN13 Spoonbill Lake	Marginal
BRN14 Aquila	Brackish
BRN15 Lake Road	Brackish
BRN16 Spice Brook	Brackish
BRN17 Toodyay Creek	Brackish
BRN18 Julimar/Chittering Bridge	Brackish
BRN19 Julimar/Chittering Tributary	Brackish
BRN20 Chittering Valley	Marginal
BRN21 Keating Road	Brackish
BRN22 South Chittering Creek	Marginal
BRN23 Marbling Brook	Marginal
BRN24 Moondyne	Brackish
BRN25 Yalliawirra	Brackish
BRN26 Marda Brook	Marginal
BRN27 Grey Road Bridge	Brackish

NB: The ANZECC guideline for conductivity in Lowland Rivers is 0.12mS/cm to 0.3mS/cm.

2. Recommendations

- Continue the sampling and analysis monitoring program within the Brockman River catchment and add new sampling sites where nutrient transport or salinity is expected to be significant, or to increase the number of sampling events as funding permits.

- Identify areas of future rehabilitation, revegetation and waterway protection based on the results of the sampling program.

- Identify subcatchments which contribute significant amounts of saline water, nutrients or metals to the Brockman River, determine possible causes and conduct remediation works.

- Subcatchments have been prioritised according to water quality, surrounding land use, and influence on their immediate environment. See table below. Sub catchment scale monitoring/progress reports will be conducted on one priority sub catchment per year, commencing with priority 1 (Spoonbill) and working towards priority 14 (Keating). It is the aim of these reports to compliment existing water quality monitoring snapshots; utilise monitoring data to determine existing trends over the years of sampling; to determine the impacts of on-ground works and monitor their success; and to provide detailed information on the priority subcatchments of the Brockman River catchment.

Priority	**Sub-catchment**
1	Spoonbill
2	Marbling
3	Udumung
4	West Point
5	Flat Rocks
6	Blue Plains
7	Chittering Creek
8	Marda Brook
9	Murphy Gully

10	Romany Creek
11	Kangaroo Gully
12	Longbridge
13	Wootra
14	Keating

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Appendix A: Water Quality Results (raw)

Physical Parameters

SITE NAME	SITE	DATE	TEMP °C	pH	COND mS/cm
WQG (Aquatic Ecosystems; upland and lowland rivers)				***6.5-8***	***0.12-0.3***
Murphy Gully Creek	BRN1	14/09/2016	NS -D	NS -D	NS -D
		12/10/2016	26.6	7.72	13.946
West Point Creek	BRN3	14/09/2016	NS -D	NS -D	NS -D
		12/10/2016	25.6	7.69	9.824
Jackson Road	BRN2	14/09/2016	15.4	8.08	9.473
		12/10/2016	22.6	7.83	11.718
Wannamal South	BRN4	14/09/2016	17.9	7.12	2.933
		12/10/2016	24.9	7.12	4.033
Udumung Creek	BRN5	14/09/2016	13.8	7.46	3.666
		12/10/2016	20.1	7.57	5.191
Kangaroo Gully Creek	BRN6	14/09/2016	17.3	7.42	3.446
		12/10/2016	23.8	7.47	5.141
Romany Creek	BRN7	14/09/2016	14.1	7.72	3.363
		12/10/2016	20.4	7.72	4.761
Longbridge Creek	BRN8	14/09/2016	15.6	7.72	5.636
		12/10/2016	22.1	7.75	8.661
Wootra Brook	BRN9	14/09/2016	15.3	7.76	4.849
		12/10/2016	20.7	7.63	7.331
Bindoon River	BRN10	14/09/2016	16.7	7.43	5.355
		12/10/2016	22.5	7.63	6.331
Grey Road	BRN27	14/09/2016	14.5	7.08	4.656
		12/10/2016	20.9	7.28	6.358
Flat Rocks Creek	BRN12	14/09/2016	15.1	6.88	5.462
		12/10/2016	21	7.01	7.185
Spoonbill Lake	BRN13	14/09/2016	15.4	7.41	1.207
		12/10/2016	23.9	7.59	1.487
Aquilla	BRN14	14/09/2016	14.1	7.2	2.725
		12/10/2016	18.6	7.33	3.764
Spice Brook	BRN16	14/09/2016	14.6	7.6	3.339
		12/10/2016	20.7	7.86	4.436
Lake Road	BRN15	14/09/2016	14.1	7.62	4.207
		12/10/2016	20.3	8.36	5.824
Toodyay Creek	BRN17	14/09/2016	12.9	7.24	2.545
		12/10/2016	16.8	7.42	3.016
Julimar Tributary	BRN19	14/09/2016	13.2	7.38	3.802
		12/10/2016	18.5	7.66	5.249
Julimar Bridge	BRN18	14/09/2016	13.2	7.43	4.03
		12/10/2016	18.7	7.9	5.501
Chittering Valley	BRN20	14/09/2016	13.7	7.11	2.251

		12/10/2016	18.9	7.14	2.51
Keating Road	BRN21	14/09/2016	11.9	7	3.415
		12/10/2016	16.5	7.08	3.922
Marbling Brook	BRN23	14/09/2016	12.9	7.21	1.988
		12/10/2016	15.9	7.25	2.319
South Chittering Creek	BRN22	14/09/2016	11.8	7.27	2.021
		12/10/2016	15.5	7.34	2.432
Moondyne	BRN24	14/09/2016	12.5	7.15	3.656
		12/10/2016	19.2	7.22	5.208
Yalliawirra	BRN25	14/09/2016	14	7.09	3.731
		12/10/2016	16.5	7.16	4.727
Marda Brook	BRN26	14/09/2016	12	7.37	0.582
		12/10/2016	16.3	7.62	0.723

Nutrients

SITE NAME	SITE	DATE	TSS	NOx_N	Tot N	Tot P	NH4_N	PO4_P
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
LOR			**1**	**0.005**	**0.05**	**0.01**	**0.005**	**0.005**
Murphy Gully Creek	BRN1	14/09/2016	<5		1.2	<0.05	0.023	<0.005
		12/10/2016	<5		1.1	<0.05	0.014	<0.005
West Point Creek	BRN3	14/09/2016	6		1	<0.05	0.028	<0.005
		12/10/2016	15		1.1	<0.05	0.046	<0.005
Jackson Road	BRN2	14/09/2016	<5		1.6	<0.05	0.013	<0.005
		12/10/2016	11		1.6	<0.05	0.012	<0.005
Wannamal South	BRN4	14/09/2016	<5		2.9	<0.05	<0.005	0.023
		12/10/2016	<5		2.8	<0.05	<0.005	0.023
Udumung Creek	BRN5	14/09/2016	<5		1.4	<0.05	<0.005	<0.005
		12/10/2016	<5		1	<0.05	0.006	<0.005
Kangaroo Gully Creek	BRN6	14/09/2016	<5		1.1	<0.05	0.016	<0.005
		12/10/2016	<5		0.9	<0.05	0.016	<0.005
Romany Creek	BRN7	14/09/2016	<5		3.2	<0.05	<0.005	<0.005
		12/10/2016	<5		2.1	<0.05	<0.005	<0.005
Longbridge Creek	BRN8	14/09/2016	5		2.2	<0.05	0.008	<0.005
		12/10/2016	<5		1	<0.05	0.011	<0.005
Wootra Brook	BRN9	14/09/2016	8		1.3	<0.05	0.01	<0.005
		12/10/2016	10		0.8	<0.05	0.017	<0.005
Bindoon River	BRN10	14/09/2016	8		0.7	<0.05	<0.005	<0.005
		12/10/2016	<5		0.6	<0.05	<0.005	<0.005
Grey Road	BRN27	14/09/2016	27		1.7	<0.05	0.026	<0.005
		12/10/2016	31		1.4	<0.05	0.017	<0.005
Flat Rocks Creek	BRN12	14/09/2016	<5		0.8	<0.05	0.013	<0.005
		12/10/2016	<5		0.8	<0.05	0.068	<0.005
Spoonbill Lake	BRN13	14/09/2016	<5		0.6	<0.05	<0.005	<0.005
		12/10/2016	<5		0.7	<0.05	<0.005	<0.005
Aquilla	BRN14	14/09/2016	<5		0.7	<0.05	<0.005	<0.005
		12/10/2016	12		0.8	<0.05	0.028	<0.005
Spice Brook	BRN16	14/09/2016	<5		0.6	<0.05	<0.005	<0.005
		12/10/2016	10		0.6	<0.05	0.015	<0.005

Lake Road	BRN15	14/09/2016	<5		1.2	<0.05	0.005	<0.005
		12/10/2016	14		0.9	<0.05	0.013	<0.005
Toodyay Creek	BRN17	14/09/2016	<5		0.9	<0.05	0.022	<0.005
		12/10/2016	7		0.7	<0.05	0.016	<0.005
Julimar Tributary	BRN19	14/09/2016	<5		0.5	<0.05	<0.005	<0.005
		12/10/2016	5		0.4	<0.05	<0.005	<0.005
Julimar Bridge	BRN18	14/09/2016	6		1	<0.05	0.006	<0.005
		12/10/2016	9		0.9	<0.05	0.018	<0.005
Chittering Valley	BRN20	14/09/2016	<5		0.4	<0.05	<0.005	<0.005
		12/10/2016	<5		0.3	<0.05	<0.005	<0.005
Keating Road	BRN21	14/09/2016	<5		0.5	<0.05	0.011	<0.005
		12/10/2016	<5		0.7	<0.05	0.032	<0.005
Marbling Brook	BRN23	14/09/2016	<5		0.8	<0.05	<0.005	<0.005
		12/10/2016	<5		0.7	<0.05	0.009	<0.005
South Chittering Creek	BRN22	14/09/2016	<5		0.6	<0.05	<0.005	<0.005
		12/10/2016	<5		0.7	<0.05	0.011	<0.005
Moondyne	BRN24	14/09/2016	16		1.1	<0.05	0.013	<0.005
		12/10/2016	19		1	<0.05	0.019	<0.005
Yalliawirra	BRN25	14/09/2016	23		1.2	<0.05	0.016	<0.005
		12/10/2016	18		1	<0.05	0.018	<0.005
Marda Brook	BRN26	14/09/2016	<5		0.6	<0.05	0.006	<0.005
		12/10/2016	98		1	<0.05	<0.005	<0.005

Note NT means not tested at this time

Metals

SITE NAME	SITE	DATE	Hardness	Al	Cr	Fe	Ni	Zn
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
				0.005	0.001	0.01	0.005	0.005
ANZECC				**0.055mg/L**	**0.001mg/L**	**0.3mg/L**	**0.011mg/L**	**0.008mg/L**
Spoonbill Lake	BRN13	14/09/2016	140	0.06	<0.001	0.97	<0.001	0.001
		12/10/2016	160	0.07	<0.001	1	0.002	0.007
Aquilla	BRN14	14/09/2016	340	0.05	<0.001	2.2	0.002	0.003
		12/10/2016	430	0.07	0.001	5.9	0.003	0.006
Lake Road	BRN15	14/09/2016	680	0.03	<0.001	0.55	<0.001	0.002
		12/10/2016	840	0.04	<0.001	0.48	<0.001	0.002
South Chittering Creek	BRN22	14/09/2016	310	0.05	<0.001	1.3	0.002	0.002
		12/10/2016	330	0.06	<0.001	1.6	0.003	0.003
Marbling Brook	BRN23	14/09/2016	270	0.08	<0.001	0.8	0.001	0.002
		12/10/2016	300	0.08	<0.001	0.77	0.002	0.003
Yalliawirra	BRN25	14/09/2016	600	0.68	0.001	1.8	0.001	0.002
		12/10/2016	730	0.7	<0.001	2.1	0.002	0.003
Grey Road	BRN27	14/09/2016	740	0.67	0.001	1.5	0.001	0.003
		12/10/2016	930	1.1	<0.001	2.4	0.002	0.004
Jackson Road	BRN 2	14/09/2016	1400	0.05	<0.001	0.34	<0.001	0.001
		12/10/2016	1400	0.22	<0.001	0.88	0.002	0.002

** Note: '<' represents a value below the limit of reporting.*

SITE NAME	SITE	DATE	As	Cd	Cu	Pb	Hg
			mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**
			0.001	**0.0001**	**0.001**	**0.001**	**0.0001**
ANZECC			**0.024mg/L**	**0.0002mg/L**	**0.0014mg/L**	**0.0034mg/L**	**0.0006mg/L**
Spoonbill Lake	BRN13	14/09/2016	<0.001	NA	<0.001	NA	NA
		12/10/2016	<0.001	NA	<0.001	<0.001	<0.00005
Aquilla	BRN14	14/09/2016	<0.001	NA	<0.001	NA	NA
		12/10/2016	<0.001	NA	<0.001	<0.001	<0.00005
Lake Road	BRN15	14/09/2016	<0.001	NA	<0.001	NA	NA
		12/10/2016	<0.001	NA	<0.001	<0.001	<0.00005
South Chittering Creek	BRN22	14/09/2016	<0.001	NA	<0.001	NA	NA
		12/10/2016	<0.001	NA	<0.001	<0.001	<0.00005
Marbling Brook	BRN23	14/09/2016	<0.001	NA	<0.001	NA	NA
		12/10/2016	<0.001	NA	<0.001	<0.001	<0.00005
Yalliawirra	BRN25	14/09/2016	<0.001	NA	0.001	NA	NA
		12/10/2016	<0.001	NA	0.002	<0.001	<0.00005
Grey Road	BRN27	14/09/2016	<0.001	NA	0.001	NA	NA
		12/10/2016	<0.001	NA	0.002	<0.001	<0.00005
Jackson Road	BRN 2	14/09/2016	<0.001	NA	0.001	NA	NA
		12/10/2016		NA	0.002	<0.001	<0.00005

** Note: '<' represents a value below the limit of reporting.*

Appendix B – Freshwater Trigger Values and Guidelines

Trigger values and guidelines for nutrient concentrations and physical properties in lowland rivers and freshwater

Guideline	EC mScm	D0 % Sat	pH	Temp ºC	TN mg/L	NO_XN mg/L	NH4N mg/L	TP mg/L	FRP mg/L
ANZECC Water Quality Guideline – Recreational (2000)	-	>80 (>6.5 mg/L)	6.5-8.5	-	-	10	-	-	-
ANZECC Water Quality Trigger Values - lowland river (2000)	0.12-0.3	80-120	6.5-8.0	-	1.2	0.150	0.08	0.065	0.04
ANZECC Water Quality Guidelines – Freshwater (1992)	-	>80-90 (>6mg/L)	6.5-9.0		<2 increase	20-30	0.01	0.01-0.1	-

6.1.5. Trigger values and guidelines for toxicants (heavy metals) in freshwater

* Trigger values not corrected for hardness, ID = insufficient data to have ANZECC water quality guideline

Guideline	As mg/L	Cr mg/L	Cu* mg/L	Fe mg/L	Mo mg/L	Mn mg/L	Ni* mg/L
ANZECC Water Quality Guidelines – Recreational (2000)	0.05	0.05	1	0.3	ID	0.1	0.1
ANZECC Water Quality Trigger Values Freshwater 99% (2000)	0.001	0.00001	0.001	ID	ID	1.2	0.008
ANZECC Water Quality Trigger Values Freshwater 95% (2000)	0.024	0.001	0.0014	ID	ID	1.9	0.011
ANZECC Water Quality Trigger Values Freshwater 90% (2000)	0.094	0.006	0.0018	ID	ID	2.5	0.013
ANZECC Water Quality Trigger Values Freshwater 80% (2000)	0.360	0.04	0.0025	ID	ID	3.6	0.017
ANZECC Water Quality Guidelines – Freshwater (1992)	0.05	0.01	0.002-0.005	ID	ID	ID	0.015-0.15
Limit of reporting	0.001	0.001	0.001	0.01	0.005	0.001	0.001

Trigger values and guidelines for toxicants (heavy metals) in freshwater

* Trigger values not corrected for hardness, ID = insufficient data to have ANZECC water quality guideline

Guideline	Pb* mg/L	Sn	Sr mg/L	Ti mg/L	V mg/L	Zn* mg/L
ANZECC Water Quality Guidelines – Recreational (2000)	0.05	ID	ID	ID	ID	5
ANZECC Water Quality Trigger Values Freshwater 99% (2000)	0.001	ID	ID	ID	ID	0.0024
ANZECC Water Quality Trigger Values Freshwater 95% (2000)	0.0034	ID	ID	ID	ID	0.008
ANZECC Water Quality Trigger Values Freshwater 90% (2000)	0.0056	ID	ID	ID	ID	0.015
ANZECC Water Quality Trigger Values Freshwater 80% (2000)	0.0094	ID	ID	ID	ID	0.031
ANZECC Water Quality Guidelines – Freshwater (1992)	0.001-0.005	ID	ID	ID	ID	0.005-0.05
Limit of reporting	0.001	0.05	0.001	0.01	0.002	0.001

Appendix C – Salinity measurements and tolerance limits

Salt Measurement Conversions

mS/cm	mS/m	ppm,mg/L	ppt	gr/gal		
0	0	0	0	0		distilled water
0.1	10	55	0.06	4		
0.2	20	110	0.11	8		
0.3	30	165	0.17	12		
0.4	40	220	0.22	15	FRESH	
0.5	50	275	0.28	19		
0.6	60	330	0.33	23		
0.7	70	385	0.39	27		
0.8	80	440	0.44	31		maximum stonefruit, citrus, peas, onion, carrot
0.9	90	495	0.50	35		
1.0	100	550	0.55	39		
1.5	150	825	0.83	58		maximum for hot water systems
2.0	200	1100	1.10	77	MARGINAL	
2.5	250	1375	1.38	96		maximum for people, grapes,tomato, lettuce
2.7	273	1500	1.50	105		
3.0	300	1650	1.65	116		
3.5	350	1925	1.93	135		
4.0	400	2200	2.20	154		
4.5	450	2475	2.48	173		
5.0	500	2750	2.75	193		
5.5	550	3025	3.03	212		maximum for milk cows and poultry,olives, figs
6.0	600	3300	3.30	231		
6.5	650	3575	3.58	250	BRACKISH	
7.0	700	3850	3.85	270		
7.5	750	4125	4.13	289		maximum for pigs
8.0	800	4400	4.40	308		
8.5	850	4675	4.68	327		
9.0	900	4950	4.95	347		
9.1	910	5005	5.01	350		
9.5	950	5225	5.23	366		
10.0	1000	5500	5.50	385		maximum for horses
10.5	1050	5775	5.78	404		
11.0	1100	6050	6.05	424		maximum lambs, weaners & breeder ewes
11.5	1150	6325	6.33	443		
12.0	1200	6600	6.60	462		
12.5	1250	6875	6.88	481		
13.0	1300	7150	7.15	501		
13.5	1350	7425	7.43	520		
14.0	1400	7700	7.70	539		
14.5	1450	7975	7.98	558	SALINE	
15.0	1500	8250	8.25	578		
15.5	1550	8525	8.53	597		maximum septic Tanks
16.0	1600	8800	8.80	616		
16.5	1650	9075	9.08	635		maximum beef cattle
17.0	1700	9350	9.35	655		
17.5	1750	9625	9.63	674		
18.0	1800	9900	9.90	693		
18.5	1850	10175	10.18	712		
19.0	1900	10450	10.45	732		
19.5	1950	10725	10.73	751		
20.0	2000	11000	11.00	770		
20.5	2050	11275	11.28	789		
21	2100	11550	11.55	809		
21.5	2150	11825	11.83	828		
22	2200	12100	12.10	847		
22.5	2250	12375	12.38	866		
23	2300	12650	12.65	886		maximum sheep
23.5	2350	12925	12.93	905		
24	2400	13200	13.20	924		
24.5	2450	13475	13.48	943		
25	2500	13750	13.75	963		
30	3000	16500	16.50	1155		
53	5300	29150	29.15	2041		sea water
64	6400	35200	35.20	2464		sea water
11.97	1197	6584	6.58	461		

Measurement Units

mS/cm = millisiemens per cm
mS/m = millisiemens per metre
ppm = parts per mllion
mg/L = milligrams per litre
gr/gal = grains per gallor

Conversion Factors

mS/m	x 100 = mS/cm
mS/m	x 5.5 = mg/L
mS/m	x 0.385 = gr/gallon
mS/m	x 10 = EC uS/cm
gr/gall	x 14.25 = mg/L

Appendix D - Hardness-Modified Trigger Value calculations based on varying water hardness (Table 3.4.4. ANZECC & ARMCANZ, 2000).

Hardness category (mg/L as CaCO3)	Water Hardness (mg/L as CaCO3)	Cd (mg/L)	Cr(III) (mg/L)	Cu (mg/L)	Pb (mg/L)	Ni (mg/L)	Zn (mg/L)
Soft (0-59)	30	TV	TV	TV	TV	TV	TV
Moderate (60-119)	90	*2.7	*2.5	*2.5	*4	*2.5	*2.5
Hard (120-179)	150	*4.2	*3.7	*3.9	*7.6	*3.9	*3.9
Very Hard (180-240)	210	*5.7	*4.9	*5.2	*11.8	*5.2	*5.2
Extremely Hard (>400)	400	*10	*8.4	*9	*26.7	*9	*9