NSW DEPARTMENT OF PRIMARY INDUSTRIES

AUGUST 2018

SITE SUMMARY STATUS REPORT

WARATAH ROAD, MANGROVE MOUNTAIN, NSW

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Site summary status report
Waratah Road, Mangrove Mountain, NSW

NSW Department of Primary Industries

WSP
Level 27, 680 George Street
Sydney NSW 2000
GPO Box 5394
Sydney NSW 2001

Tel: +61 2 9272 5100
Fax: +61 2 9272 5101
wsp.com

REV	DATE	DETAILS
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	NAME	DATE	SIGNATURE
Prepared by:	Davide Menozzi	16/08/2018	
Reviewed by:	Colin McKay	16/08/2018	
Approved by:	Colin McKay	16/08/2018	

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ABBREVIATIONS

ANZECC	Australian & New Zealand Environment & Conservation Council
BOD	Biochemical oxygen demand
BTEX	Benzene, toluene, ethyl benzene, xylene
DP	Deposited Plan
DPI	Department of Primary Industries
DQO	Data Quality Objectives
EPA	Environment Protection Authority
GCL	Geo-composite clay liner
GME	Groundwater monitoring event
LEP	Local Environmental Plan
mAHD	Metres Australian Height Datum
mBTOC	Metres below top of casing
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NHMRC	National Health & Medical Research Council
PAH	Polycyclic aromatic hydrocarbons
PPM	Parts per million
PQL	Practical quantitation limit (of chemical concentration)
QA/QC	Quality assurance & quality control
RPD	Relative percentage difference
SAQP	Sampling analysis and quality plan
SWL	Standing water level
TOC	Total organic carbon
TDS	Total dissolved solids
TKN	Total Kjeldahl Nitrogen

1 INTRODUCTION

1.1 BACKGROUND

An outbreak of a poultry disease, known as Newcastle Disease, occurred at Mangrove Mountain on the Central Coast Plateau in 1999. Approximately two million carcasses of slaughtered poultry and associated shed litter and wastes were buried to contain the potential spread of the disease. The poultry carcasses were placed inside tar-lined shipping containers, which were placed into engineered burial pits at George Downes Drive (on the former Hymix Kulnura Quarry site) and Bloodtree Road (on Gosford City Council's Mangrove Mountain Works Depot site). Shed litter, manure and other potentially virus-contaminated materials were buried at a third site located at Waratah Road, Mangrove Mountain.

Subsequently, NSW Department of Primary Industries (DPI, Agriculture), working in collaboration with DPI Water, NSW Environment Protection Authority, the Central Coast Public Health Unit of the Central Coast Area Health Service, and contracted environmental consultants (Robert Carr & Associates Pty Ltd) developed a groundwater monitoring program to monitor any potential environmental impacts resulting from the presence of the burial pits. The groundwater monitoring program commenced in January 2001, following "baseline" groundwater monitoring events undertaken in 1999. Groundwater monitoring events (GMEs) were conducted by various consultants between 2001 and 2018. Presently, there are 19 groundwater monitoring wells located across the three sites.

DPI Agriculture commissioned WSP Australia Pty Limited (formerly WSP | Parsons Brinckerhoff Australia Pty Ltd) to undertake the bi-annual groundwater monitoring program at the three sites for three years (2015 to 2018).

This report presents a summary of results for key groundwater indicators from all GMEs undertaken at the Waratah Road site by WSP Australia Pty Limited (WSP) since 2015, which comprise:

- WSP | Parsons Brinckerhoff (2017a) Groundwater monitoring event 18, Mangrove Mountain poultry burial sites, dated 4 January 2017 – November 2015 GME – Rev. C
- WSP | Parsons Brinckerhoff (2017b) Groundwater monitoring event 19, Mangrove Mountain poultry burial sites, dated 20 February 2017 – June 2016 GME
- WSP | Parsons Brinckerhoff (2017c) Groundwater monitoring event 20, Mangrove Mountain poultry burial sites, dated 20 February 2017 – October 2016 GME
- WSP (2017 d) Groundwater monitoring event 21, Mangrove Mountain poultry burial sites, dated September 2017 – March 2017 GME
- WSP (2018a) Groundwater monitoring event 22, Mangrove Mountain poultry burial sites, dated March 2018 – November 2017 GME
- WSP (2018b) Groundwater monitoring event 23, Mangrove Mountain poultry burial sites, dated July 2018 (draft) – March 2018 GME

This report presents information and data specifically for the Waratah Road site. Separate reports have been produced for the George Downes Drive and Bloodtree Road landfills.

1.2 PURPOSE OF THIS REPORT

The purpose of this summary report is to document the condition of the groundwater in the vicinity of the containment cell and the physical condition of the cell, particularly with respect to any impacts that may have arisen from possible breaches of the containment of poultry wastes.

1.3 OBJECTIVES

The objectives of the regular groundwater monitoring events (GMEs) and visual inspections were to:

- determine the present occurrence, nature and extent of contamination.
- determine the existence of or potential for off-site transport of contaminants and the associated environmental risks; and, should contamination and/or associated off-site risks exist.
- identify and recommend appropriate mitigation/remedial measures, or otherwise provide a monitoring strategy.

1.4 LIMITATIONS AND INTELLECTUAL PROPERTY

SCOPE OF SERVICES

This site summary report (the report) has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client and WSP (scope of services). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

RELIANCE ON DATA

In preparing the report, WSP has relied upon data, surveys, analyses, designs, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, WSP has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. WSP will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP.

ENVIRONMENTAL CONCLUSIONS

In accordance with the scope of services, WSP has relied upon the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants or emissions.

Also, it should be recognised that site conditions, including the extent and concentration of contaminants, can change with time.

Within the limitations imposed by the scope of services, the monitoring, testing, sampling and preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, expressed or implied, is made.

REPORT FOR BENEFIT OF CLIENT

The report has been prepared for the benefit of the client and no other party. WSP assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of WSP or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

OTHER LIMITATIONS

WSP will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

The scope of services did not include any assessment of the title to or ownership of the properties, buildings and structures referred to in the report nor the application or interpretation of laws in the jurisdiction in which those properties, buildings and structures are located.

2 SITE BACKGROUND

2.1 SITE IDENTIFICATION AND DESCRIPTION

The Mangrove Mountain region is located in the municipality of Gosford City Council (Council), approximately 85 km north of Sydney. This report presented information and data specifically for the burial site at the Waratah Road site which was a former piggery effluent dam site. The identification details for the site are provided in Table 2.1and the location is indicated in Figure 1 and Figure 2 (Appendix A).

Table 2.1 Site identification details

IDENTIFICATION	WARATAH ROAD
Council	Gosford
County	Northumberland
Parish	Kooree
Title identification	Lot 12 DP 860200
MGA co-ordinates (zone 56)	329350 E, 6315165 N

The area surrounding the site comprises well-developed agricultural and horticultural industries, including intensive poultry farms, the quarry, orchards, vegetable market gardens and more recently groundwater extraction for bottling. The established agricultural areas are surrounded by native bushland areas including the Dharug, Popran and Brisbane Water National Parks, McPherson, Olney and Ourimbah State Forests and other Crown Land.

The Waratah Road site is located on a rural lot owned by NSW DPI. The site backs onto McPherson State Forest and is constructed at the site of a former intensive piggery effluent containment dam. The burial pit has horizontal dimensions of 60 m by 70 m, with an average depth of 5 m. Like the other pits, it is excavated into sandstone bedrock. It was lined with two layers of geo-composite clay liner (GCL) and capped with one layer of GCL and 1-metre-deep clay. This burial pit was filled with poultry shed litter and may also contain a relatively small number of incidental carcasses. The layout of the site, and monitoring locations are shown in Figures 3 and 4 in Appendix A.

2.2 TOPOGRAPHY

The site is located near Mangrove Mountain on a sandstone plateau which drains into the Warre Warren Creek, Wyong River, Ourimbah Creek and Brisbane Water catchments. Several small creeks and tributaries of the Hawkesbury River, including Mangrove, Mooney Mooney and Popran Creeks drain the area. Mangrove Creek has an urban water supply dam in its upper catchment and provides drinking water to the Gosford-Wyong local government areas. The site topography features undulating sandstone ridge-tops, vegetated by temperate sclerophyll woodland.

2.3 GEOLOGY

A review of the Gosford-Lake Macquarie 1:100,000 (1994) geological map indicates that the sites are generally underlain by Hawkesbury Sandstone. The Hawkesbury Sandstone consists of inter-bedded layers of sandstone (massive and sheet facies), siltstone and shale.

The parent material overlying the sandstone bedrock in the vicinity of the Waratah Road burial pit is described as a gravelly lateric colluvium from sandstone according to a more comprehensive map of soils of the central coast plateau (Hawkins and Haddad, 2011). The soils are dominated by a non-calcareous gradational texture profile, an earthy fabric in the B horizon and a moderate amount of loose gravel in the upper part of the profile.

The available borehole logs indicated subsurface profiles at the sites generally correspond with the regional geology identified above; a natural, sandy clay topsoil extends to approximately 0.8 m below ground level, and is underlain by sandstone.

2.4 HYDROGEOLOGY

The aquifer in the Hawkesbury Sandstone has both porous and fractured flow. It is recharged by rainfall and discharges as springs and to surface water systems that flow from the Mangrove Mountain plateau.

Perched aquifers are common across the area in the weathered material, with the more productive aquifers, commonly used for commercial and domestic purposes, located at depths below 20 metres. There is potentially a hydraulic connection between the perched and upper sandstone aquifer, however the degree of connection at the site is not well known.

2.5 REGISTERED GROUNDWATER BORES

A search of the NSW Office of Water groundwater database (www.nratlas.nsw.gov.au) indicated that several groundwater bores are registered within 500 m of the site. The recent review of the database (http://allwaterdata.water.nsw.gov.au/water.stm) (on 3 July 2018) did not identify any new bores in the vicinity of the site. A summary of the registered bores and their distance from the Waratah Road site is provided in Table 2.2 and shown in Figure 2 in Appendix A. The table does not include bores in which license has been cancelled, namely GW018952, GW027773, GW018811, GW018810 and GW104203.

Table 2.2 Summary of registered bores with 500 m radius of the site

SITE	BORE ID	PURPOSE	APPROXIMATE DISTANCE AND DIRECTION FROM SITE(1)	SCREEN DEPTH INTERVAL (m)	STANDING WATER LEVEL (mBTOC)	TOTAL DEPTH (M)
Waratah Road	GW101979(2)	Domestic/stock	DPI - 240m south	5.5 – 48	14.0	48.0
	GW104330	Domestic/stock Farm/Industrial	427m south-south-east	0 – 33	Unknown	33.0
	BLR(3)	Domestic	434m south-south-east	N/A	N/A	N/A
	GW103472	Farm/Industrial	482m south	0 – 47.0	Unknown	47.0
	GW102510	Irrigation	346m west-south-west	20.0 – 30.5	6.5	30.5
	20WA203515	Irrigation	408m west-south-west	N/A	N/A	N/A

(1) Distances are approximate only –calculated based on best judgement.

(2) Information provided by NSW DPI indicated this bore (GW101979) is inactive at the time of investigation. The bore may be re-activated, if required.

(3) The term “BLR” refers to Basic Landholder Rights (domestic and stock) bore, where the work has not been allocated a Groundwater Work number (GW prefix) on the public database.

3 CONTAMINANTS OF CONCERN AND APPLICABLE CRITERIA

3.1 CONTAMINANTS OF CONCERN

The contaminants of concern for the GMEs at Waratah Road, as identified in the SAQP (Parsons Brinckerhoff, 2013), are presented in Table 3.1.

Table 3.1 Contaminants of potential concern

CONTAMINANT	JUSTIFICATION
Total dissolved solids (TDS) Major anion and cation concentrations (chloride, sulphate, bicarbonate, magnesium, calcium, potassium and sodium) Biochemical oxygen demand (BOD) Electrical conductivity (EC) Dissolved oxygen Alkalinity (bicarbonate, carbonate, hydroxide and total) Chemical oxygen demand (COD) – in six monitoring wells Total organic carbon (TOC) – in six monitoring wells	Assessment of general water quality.
Nutrients (ammonia, nitrate and nitrite, total Kjeldahl nitrogen (TKN), total nitrogen and total phosphorus	Assessment of breakdown of organic matter placed within the burial pits and maturing of the waste material over time.
Metal concentrations (arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc)	Assessment of potential corrosion of the metal containers containing the carcasses and waste.

3.2 GROUNDWATER INVESTIGATION LEVELS

With reference to the National Environmental Protection (Assessment of Site Contamination) Measure as amended in 2013 (NEPM, 2013), the groundwater investigation levels adopted for assessing the quality of groundwater for the Waratah Road site are summarised in Table 3.2. These investigation levels were selected to assess the potential risks to human and freshwater aquatic ecosystems. The environmental and human receptors identified on-site and off-site include:

- Workers conducting monitoring or maintenance works at the sites.
- Users of the groundwater in the vicinity of the site. Groundwater quality at the site indicated possible the beneficial uses of groundwater at the site include irrigation, stock, domestic and potable use. Groundwater in the surrounding area is also used for bottling and sale as mineral spring water.
- Aquatic ecosystems in the surface waters down gradient of the site (Ourimbah Creek, Warre Warren Creek, Bull Gully and Broula Gully). In addition, spring-fed streams were previously identified in the area.
- Surface water users, including Gosford-Wyong Councils Water Supply Authority, on the catchment streams of Warre Warren Creek and Mangrove Creek downstream of Warre Warren Creek.

The rationale for selecting the investigation levels presented in Table 3.2 was detailed in the SAQP (Parsons Brinckerhoff, 2013). When the guidance values are not provided in the NEPM 2013, the parent guidelines were referenced. Where there is more than one guideline value, the most conservative guidelines is used.

Table 3.2 Groundwater investigation levels

ANALYTE	UNIT	DRINKING WATER GUIDELINES(1),(2)	PROTECTION OF FRESHWATER ECOSYSTEM (1),(3)	LIVESTOCK DRINKING WATER(4)	IRRIGATION USE(5)
Indicators					
pH	-	6.5 – 8.5	6.5 – 8.0	-	6.5 – 8.5
Total dissolved solids	mg/L	600	-	2,000 – 10,000	-
Biochemical oxygen demand	mg/L	-	-	-	-
Chemical oxygen demand	mg/L	-	-	-	-
Anion					
Total alkalinity	mg/L	-	-	-	-
Hydroxide	mg/L	-	-	-	-
Carbonate	mg/L	-	-	-	-
Bicarbonate	mg/L	-	-	-	-
Chloride	mg/L	250	-	-	-
Sulfate	mg/L	500	-	2,000	-
Cations					
Calcium	mg/L	-	-	1,000	-
Magnesium	mg/L	-	-	-	-
Potassium	mg/L	-	-	-	-
Sodium	mg/L	180	-	-	-
Nutrients					
Ammonia (as NH_3-N) (6)	mg/L	0.41(7)	2.57(8)	-	-
Nitrate (as N) (6)	mg/L	11.3(7)	0.16 (9)	338	-
Nitrite (as N) (6)	mg/L	0.91(7)	-	9.12	-
Nitrate + nitrite (as N)	mg/L	-	0.04	-	-
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	-	-
Total nitrogen	mg/L	-	0.35	-	5
Phosphorus	mg/L	-	0.025	-	0.05
Metals					
Aluminium	µg/L	200(11)	55(10)	5,000	-
Arsenic	µg/L	10	-	500 – 5,000	100
Arsenic (as AsIII)	µg/L	-	24	-	-
Arsenic (as AsV)	µg/L	-	13	-	-
Barium	µg/L	2,000	-	-	-
Boron	µg/L	4,000	370	5,000	500

ANALYTE	UNIT	DRINKING WATER GUIDELINES(1),(2)	PROTECTION OF FRESHWATER ECOSYSTEM (1),(3)	LIVESTOCK DRINKING WATER(4)	IRRIGATION USE(5)
Cadmium	µg/L	2	0.2	10	10
Chromium (CrVI)	µg/L	50	1.0	1,000	100
Cobalt	µg/L	-	-	1,000	50
Copper	µg/L	2,000	1.4	400 – 5,000	200
Iron	µg/L	300	-	-	200
Lead	µg/L	10	3.4	100	2,000
Manganese	µg/L	500	1,900	-	200
Mercury	µg/L	1	0.06	2	2
Nickel	µg/L	20	11	1,000	200
Zinc	µg/L	3,000	8	20,000	2,000

(1) NEPM (2013) Schedule B1 – Investigation levels for soil and groundwater

(2) NHMRC/NRMMC (2011) Australian Drinking Water Guidelines. (Note: Human health values are provided as priority, aesthetic values are only provided in the absence of a human health value)

(3) ANZECC/ARMCANZ (2000) – trigger values for the protection of 95% of freshwater ecosystem

(4) ANZECC/ARMCANZ (2000) – recommended water quality trigger values for livestock drinking water

(5) ANZECC/ARMCANZ (2000) – Agricultural irrigation water long term trigger values

(6) 1 mg/L of NH_3-N = 1.21 mg/L of NH_3; 1 mg/L of NO_3-N = 4.43 mg/L of NO_3; and 1 mg/L of NO_2-N = 3.29 mg/L of NO_2.

(7) The guideline values for drinking water are: 0.5 mg/L ammonia (as NH_3), 50 mg/L nitrate (as NO_3) and 3 mg/L (as NO_2).

(8) Ammonia/ammonium equilibrium concentration is highly dependent on pH and temperature. In the ANZECC/ARMCANZ (2000) guidelines, the trigger values for ammonia were derived for pH 6 to 9; extrapolation outside this range is not advisable. On account that the groundwater at the three burial sites is generally of acidic conditions, ammonia concentration for pH 6 is adopted here.

(9) The guideline value for the protection of 95% of freshwater ecosystem is: 0.7 mg/L nitrate (as NO_3).

(10) ANZECC (2000) only provide criteria for Aluminium where the pH of the groundwater is >6.5

(11) NHMRC/NRMMC (2011) values for Aluminium are aesthetic criteria in the absence of health-based criteria.

4 REVIEW OF STANDING WATER LEVELS AND GROUNDWATER FLOW DIRECTION

4.1 GROUNDWATER LEVELS

The relative difference in the standing water level (SWL) in the groundwater monitoring bores is used to calculate the direction of groundwater flow.

The shed litter burial pit is located in the catchment area of Warren Creek, which flows through the McPherson state Forest and into Mangrove Creek.

Table 4.1presents the location, elevation and last recorded SWL (March 2018) of the groundwater monitoring bores on the site.

Table 4.1 Gauging results for March 2018 – Waratah Road site

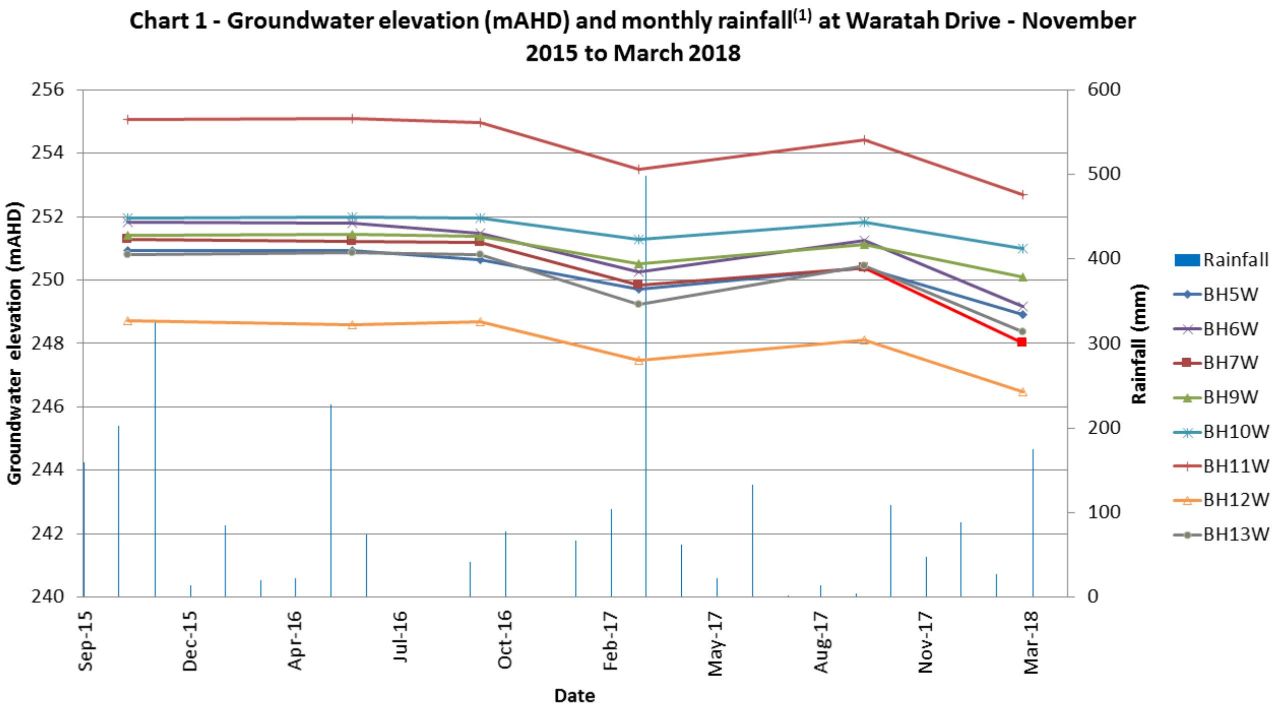
BOREHOLE ID	EASTING	NORTHING	T.O.C. ELEVATION (mAHD)	SWL (mBTOC)	GROUNDWATER ELEVATION (mAHD)
BH5W	329409	6315171	268.865	19.955	248.910
BH6W	329352	6315115	266.910	17.735	249.175
BH7W	329290	6315134	265.560	17.560	248.000
BH9W	329409	6315194	269.545	19.440	250.105
BH10W	329406	6315214	270.565	19.590	250.975
BH11W	329274	6315182	267.845	15.160	252.685
BH12W	329409	6315147	268.165	21.680	246.485
BH13W	329411	6315116	268.025	19.655	248.370
BH14W	-	-	267.125(2)	16.750	250.375(2)
BH15W	-	-	235.000(2)	8.538	226.462(2)

(1) Abbreviations: T.O.C. – top of casing; mBTOC – metres below top of casing, mAHD – metres Australian Height Datum, mBGL – metres below ground level

(2) The elevations (T.O.C. in mAHD) of BH14W and BH15W are estimate only. These data were not represented in Figure 3 in Appendix A.

Monitoring well BH11W is considered to be the up gradient well, and BH5W, BH12W and BH13W is considered to be the main down gradient wells.

Chart 1 shows groundwater elevations from November 2015 to March 2018 in the ten groundwater monitoring wells located at Waratah Road. The SWLs at the Waratah Road site ranged from 226.462 mAHD (in BH15W) to 252.685 mAHD (in BH11W) over the three-year period. Groundwater elevations in the up gradient monitoring well (BH11W) are consistently higher in elevation than groundwater levels in the nine other wells. Groundwater elevation in each monitoring well followed a similar trend of fluctuation over time and was slightly influenced by rainfall as recharge occurred, particularly after heavy rainfall in March 2017. Groundwater elevations in down gradient well BH12W have been consistently lower than the other wells on the site throughout the reporting period, at around 246 mAHD. Two new downgradient groundwater monitoring wells, BH14W and BH15W, were installed in July 2017 and SWL data are available only for November 2016 and March 2017 groundwater monitoring events, as these two wells have not yet been surveyed their standing water levels cannot be accurately compared to the Australian Height Datum. Long-term trends in groundwater elevation and rainfall are presented in Appendix A (Figure 5).



(1) The monthly rainfall data were obtained from the Mangrove Mountain AWS (Bureau of Meteorology Automated Weather Station 061375).

4.2 GROUNDWATER FLOW DIRECTION

Despite groundwater level fluctuations over time, the inferred groundwater flow direction was similar during the six gauging events occurred between November 2015 and March 2018. The gauging data presented in Table 4.1showed that groundwater is anticipated to flow towards the south-east. The groundwater flow direction is presented on Figure 3 (Appendix A).

The information shown in Figure 3 indicates that the cell is having some effect on the groundwater flow in the local area as evidenced by some flattening of the gradient in the vicinity of the mound.

5 GROUNDWATER QUALITY

Trends in groundwater quality changes and exceedances of adopted assessment criteria (where applicable) are presented below. This report focuses upon the trends and exceedances in the down gradient monitoring well BH5W, because monitoring the quality of groundwater leaving the pit is a major focus of the program. Data for key contaminants is presented for all groundwater monitoring wells and groundwater assessment levels (see Table 3.2) are also presented, where relevant. Two groundwater monitoring wells, BH14W and BH15W, were installed in July 2017. Because only two rounds of data were collected for these two wells (November 2017 and March 2018), no substantial trend observations could be made in this report.

5.1 TOTAL DISSOLVED SOLIDS

5.1.1 TRENDS

The total dissolved solids (TDS) concentration in groundwater is a measure of all dissolved substances in groundwater, including inorganic and organic substances dissolved in either a molecular, ionised or fine colloidal form. TDS is not a contaminant of concern but it is an indicator of aesthetic characteristics of drinking water, and an indicator of the potential presence of contaminants of concern. TDS data provides a broad indication of fluctuations in the chemical composition of groundwater.

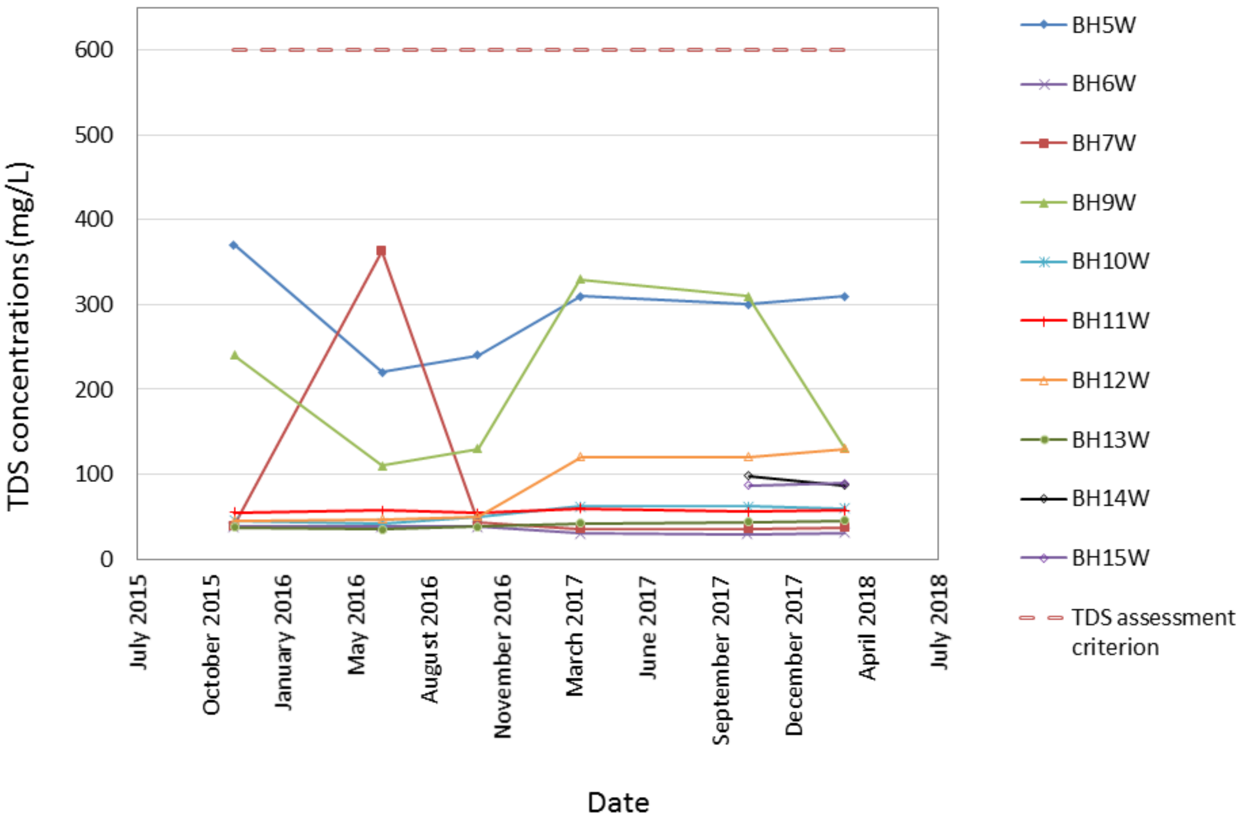
As shown on Chart 2, concentrations of TDS were generally consistent in each well throughout the monitoring period and lower than 100 mg/L, except for down gradient wells BH5W, BH9W and BH12W (since March 2017) which showed variable TDS concentrations ranging from 110 mg/L to 370 mg/L. The elevated TDS in BH5W, BH9W and BH12W are likely to be a consequence of leachate presence downgradient of the cell interreacting with solid phase exchange surfaces.

Cross gradient well BH7W generally presented TDS concentrations below 100 mg/L during the six monitoring events, similar to the other wells, except for the groundwater sample collected in June 2016 which showed a TDS concentration of 363 mg/L. In the absence of other leachate indicators this isolated event is less likely to represent leachate impact.

5.1.2 EXCEEDANCES

TDS concentrations were consistently reported below the adopted assessment criteria of 600 mg/L for drinking water use from November 2015 to March 2018.

Chart 2 - Trends in TDS concentrations at Waratah Road

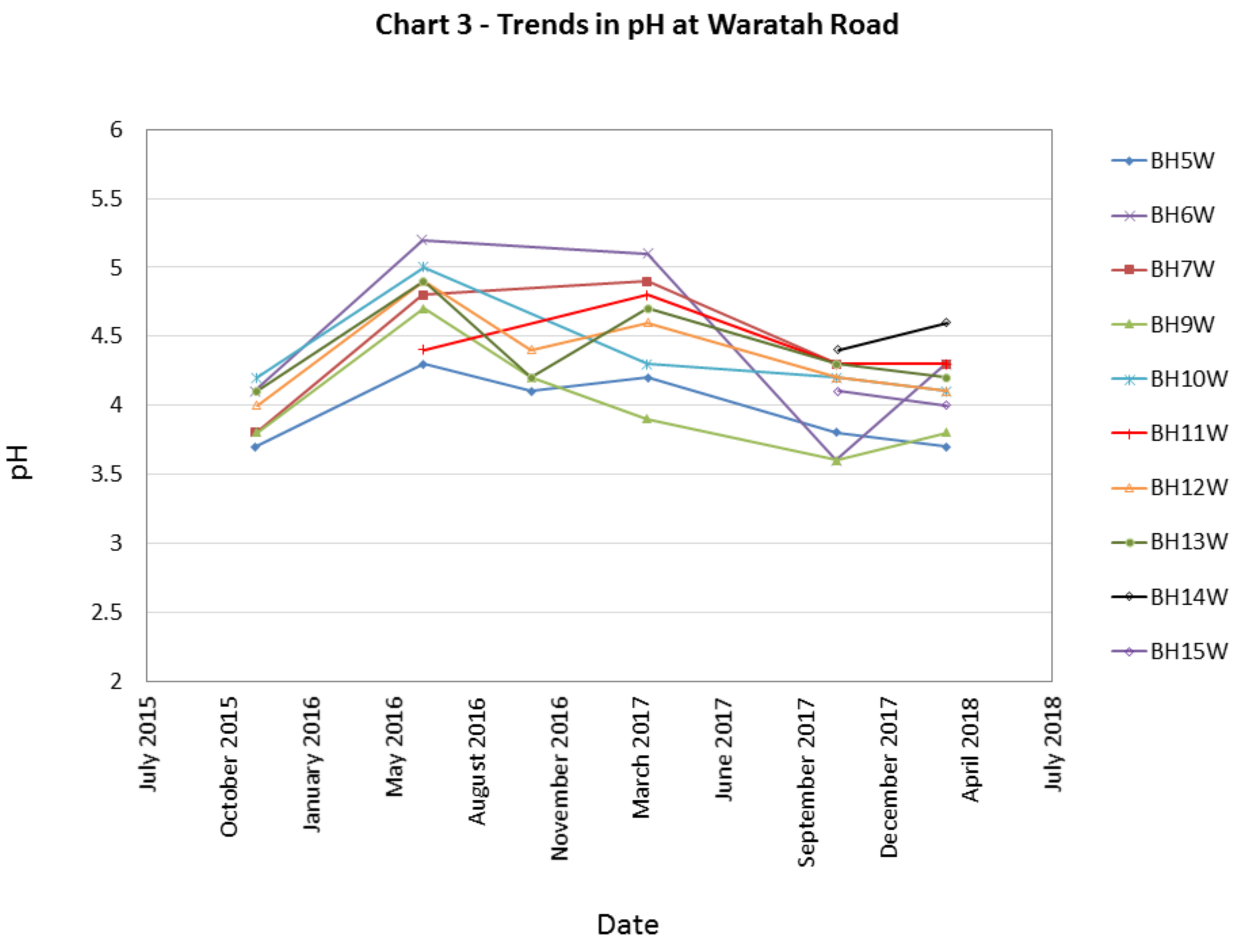


5.2 pH

5.2.1 TRENDS

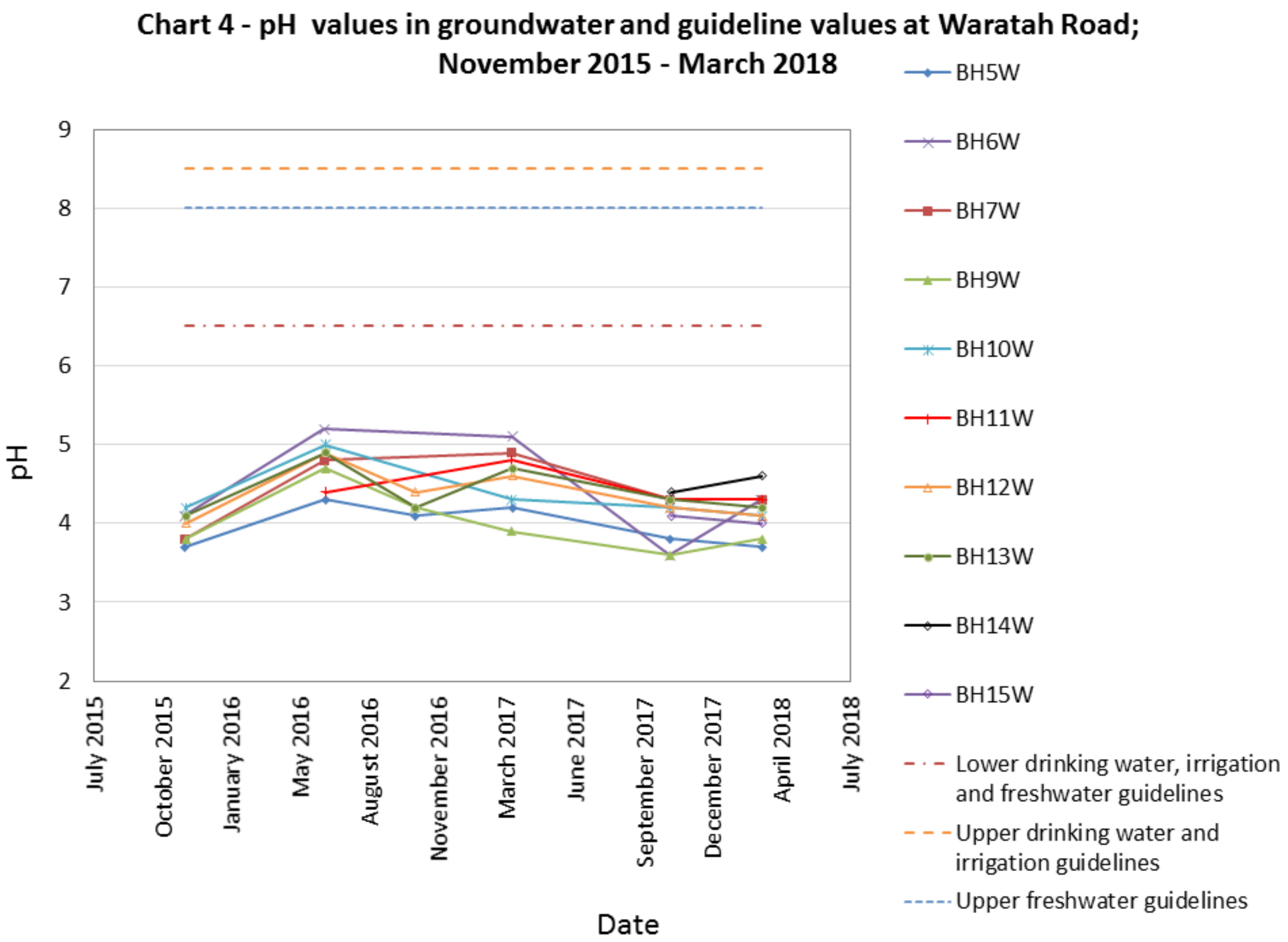
Groundwater at Waratah Road and in the vicinity of Mangrove Mountain is generally acidic, which is common in groundwater associated with the Hawkesbury Sandstone formation. Chart 3 presents pH values measured in the field in each well on the site from November 2015 to March 2018. The pH values varied from 3.6 in BH9W to 5.2 in BH6W confirming the acidic nature of the local aquifer.

There was some fluctuation in the pH values in each well over the 3-year period; variations were less than 2 pH unit in each well over that period.



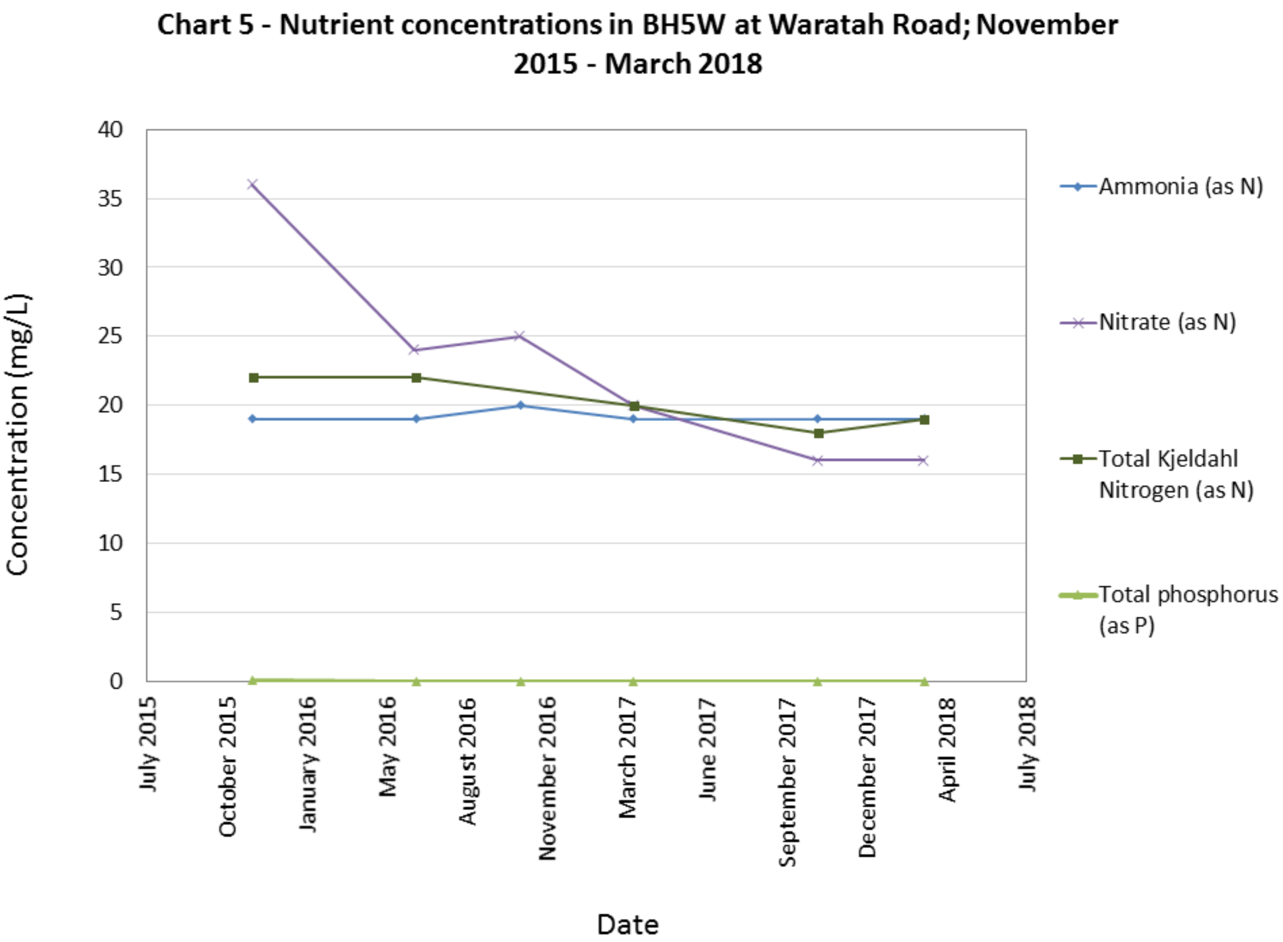
5.2.2 EXCEEDANCES

The pH values detected in groundwater from all monitoring wells at Waratah Road were consistently reported outside of the adopted assessment criteria for drinking water and irrigation use (6.5 to 8.5 pH value) and for protection of freshwater aquatic ecosystems (6.5 to 8.0 pH value) between November 2015 to March 2018. The bands of acceptance (between the lower threshold and upper threshold) for acceptable pH and the groundwater pH values are presented on Chart 4.



5.3 NUTRIENTS

Nitrogen and phosphorus are released during the decomposition of organic material, including animal carcasses, they are also agricultural fertilisers. Their presence in groundwater downgradient of the burial pit could potentially indicate migration of leachate. Chart 5 presents the trends in key nutrients in down gradient well BH5W.



5.3.1 *NITRATE*

5.3.1.1 TRENDS

Common sources of nitrate in the environment include fertilisers, animal wastes, septic tanks, municipal sewage treatment systems and decaying plant debris. Excess nitrogen within the environment can contribute to eutrophication and algal blooms, leading to oxygen depletion in water. Nitrate can also be an important contaminant in drinking water.

The highest nitrate (as N) concentrations were shown by down gradient wells BH5W and BH9W, as presented on Charts 5 and 6. While nitrate concentrations in groundwater have progressively decreased in BH5W between November 2015 and March 2018, they showed high variability in BH9W without apparent trend. Nitrate levels in other downgradient wells BH12W, BH14W and BH15W also appear to be above background levels.

Nitrate concentrations in groundwater samples collected in the other wells remained relatively stable throughout the monitoring period, with concentrations ranging from 7.7 mg/L and 0.076 mg/L. The lowest nitrate (as N) concentrations reported on the site were encountered in up gradient well BH11H and BH6W, BH7W and BH13W, all located south of the site.

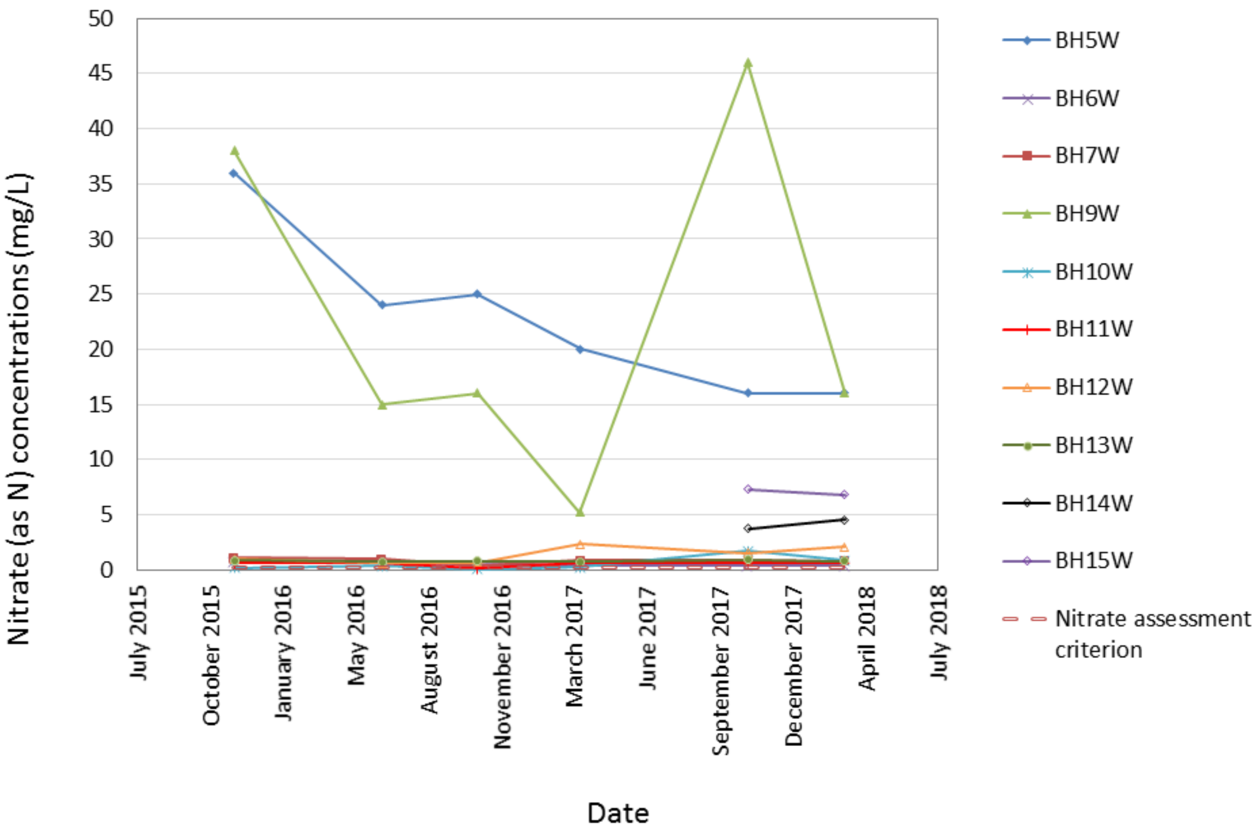
Nitrate presence downgradient of the cell suggests leakage from the cell, however, it is noted that because the Waratah Road site was previously used as an effluent dam for the piggery operation, the elevated nitrogen concentrations downgradient of the cell may well be attributed to previous land use.

5.3.1.2 EXCEEDANCES

Concentrations of nitrate (as N) in groundwater consistently remained above the adopted assessment criterion for the protection of freshwater aquatic ecosystems in all wells on the site, as presented on Chart 6. The only exceptions were wells MW10W and MW11W, which presented nitrate concentrations below the assessment criterion in three cases, in total.

As previously noted the concentrations of nitrate (as N) have significantly decreased in down gradient well BH5W, while fluctuated in BH9W; however, in both cases they remain high and exceeded the *Australian Drinking Water Guideline (2011)* level of 11.3 mg/L in most groundwater monitoring events.

Chart 6 - Nitrate (as N) concentrations and adopted assessment criterion at Waratah Road; November 2015 - March 2018



5.3.2 *AMMONIA*

Ammonia is produced during the decay processes of animal and vegetable matter and by anthropogenic sources such as livestock farming practices and sewage (including septic systems). Ammonia can be toxic to aquatic organisms at varying concentrations, depending on pH conditions. Ammonia is a nutrient and oxidises to nitrate in surface water which can contribute to algal blooms.

5.3.2.1 TRENDS

Concentrations of ammonia (as N) in all groundwater monitoring wells on the site showed little variation between November 2015 and March 2018. The only exception was down gradient well BH12W, which showed a sharp increase in ammonia concentrations between November 2015 and March 2017, followed by stable levels between March 2017 and March 2018.

Low ammonia (as N) concentrations, close to or below the laboratory limit of reporting (LOR = 0.01 mg/L), were detected in wells BH6W, BH7W, BH9W, BH10W, BH11W, BH13W and BH15W.

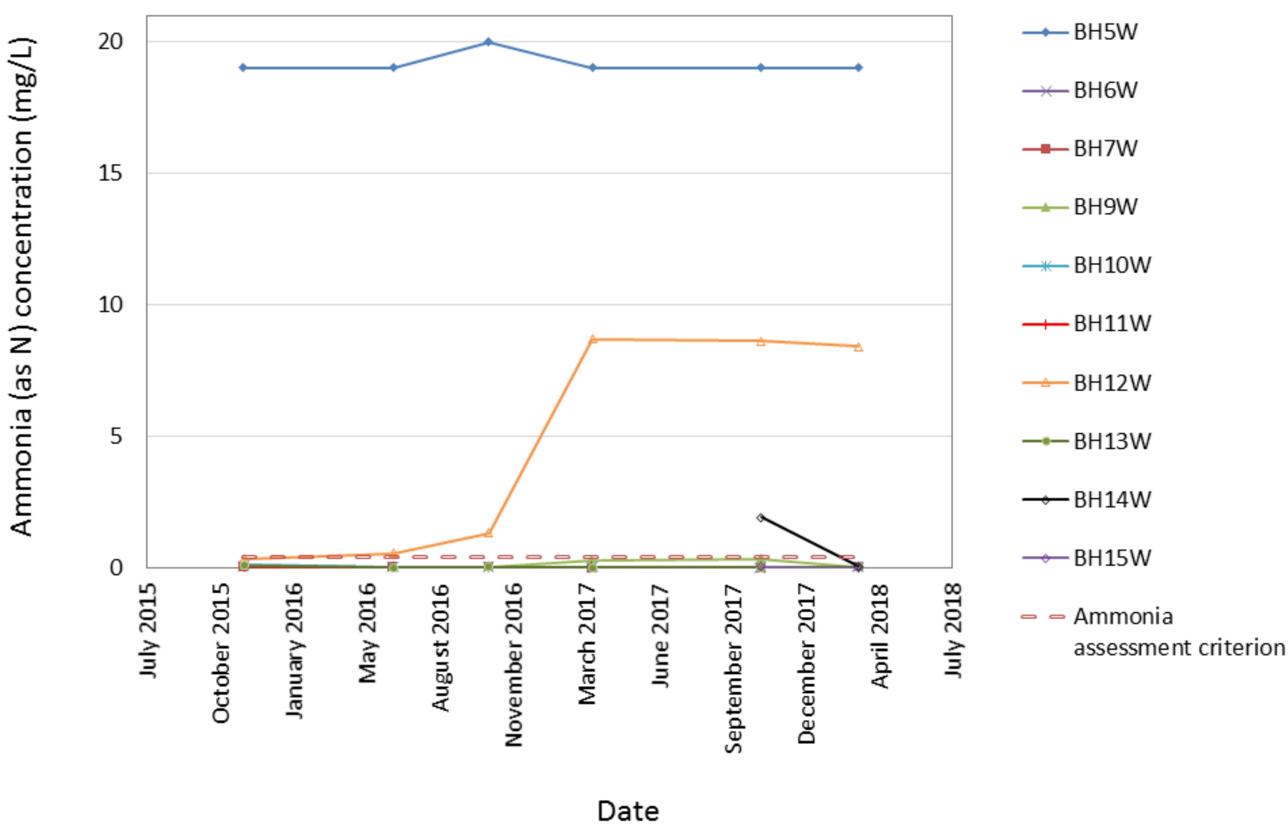
Elevated ammonia (as N) concentrations have consistently been observed in down gradient wells BH5W and BH12W, and in one case in BH14W, which may be indicative of nutrient leakage from the containment cell (or surrounds). Concentration trends in down gradient well BH5W are presented on Chart 5.

5.3.2.2 EXCEEDANCES

Concentrations of ammonia (as N) in groundwater remained above the adopted assessment criterion for drinking water (aesthetic; Australian Drinking Water Guidelines (2011)) of 0.41 mg/L, in down gradient bores BH5W and BH12W, as presented on Chart 7. In most cases, they also exceeded the criterion for protection of aquatic ecosystems (2.57 mg/L). In addition, the groundwater sample collected from down gradient well BH14W during the November 2017 monitoring event showed an ammonia concentration above the adopted assessment criterion, but this declined by April 2018 to less than the threshold.

In all other wells, ammonia (as N) concentrations have consistently been reported below the adopted assessment criterion for drinking water use.

Chart 7 - Ammonia (as N) concentrations and adopted assessment criterion at Waratah Road; November 2015 - March 2018



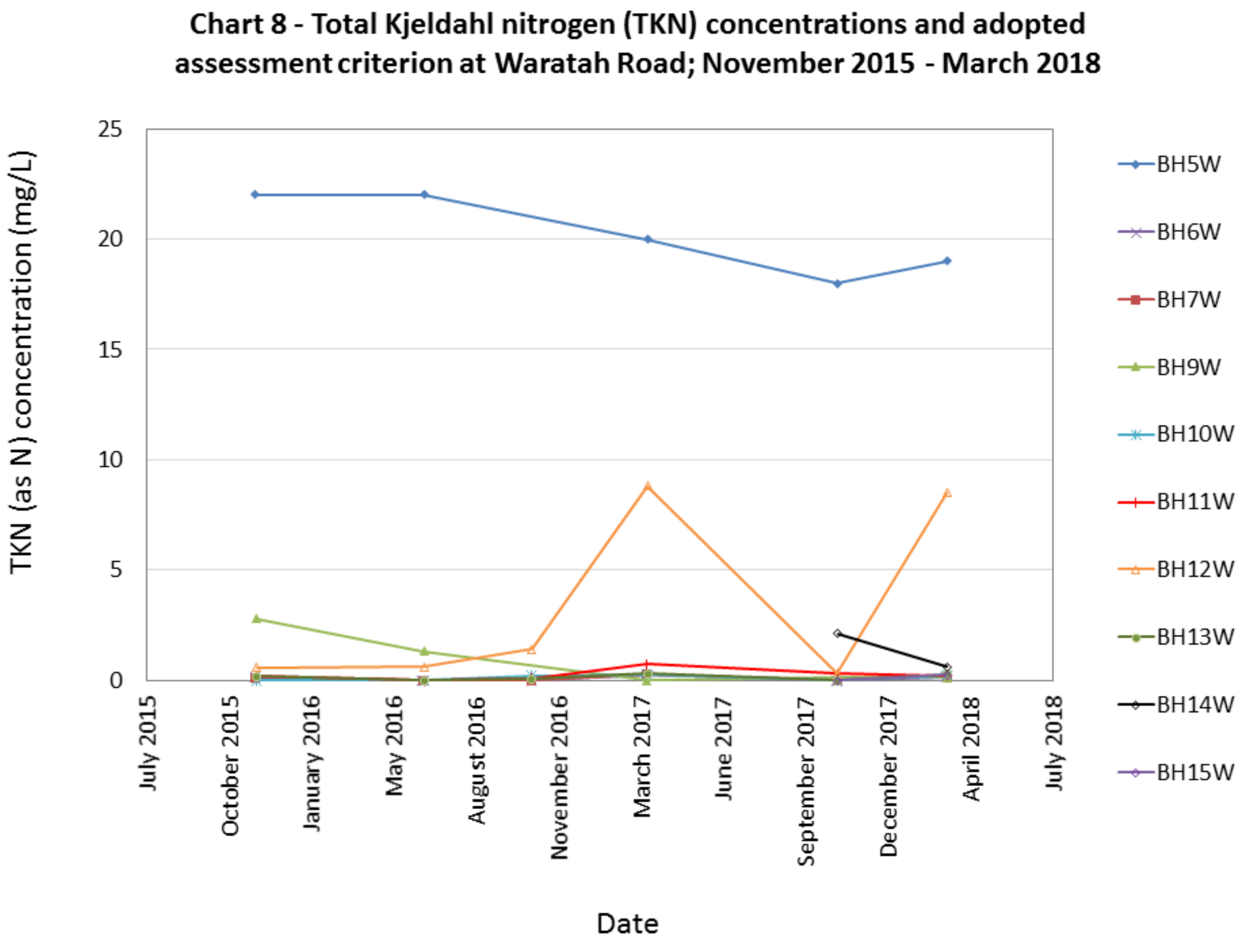
5.3.3 *TOTAL KJELDAHL NITROGEN*

TKN is the sum of all organic nitrogen and ammonia in a given groundwater sample.

5.3.3.1 TRENDS

TKN concentrations were similar and relatively low, ranging from the laboratory LOR (i.e. 0.1 mg/L) to 2.8 mg/L, in all wells on the site except for down gradient monitoring wells BH5W and BH12W, as presented on Chart 8. Higher TKN concentrations were reported for BH5W and BH12W ranging from 0.3 mg/L to 22 mg/L.

TKN concentrations remained overall stable during the monitoring period in all wells, except for BH5W and BH9W, which showed a gradual decrease over time, and BH12W which presented variable concentrations ranging from 0.3 mg/L to 8.8 mg/L.



5.3.3.2 EXCEEDANCES

There are no applicable adopted assessment criteria for TKN.

5.3.4 PHOSPHOROUS

Phosphorus is a key fertiliser used in agricultural and horticultural industries. An excess of phosphorus in surface water can contribute to algal blooms. Phosphorus binds strongly to iron compounds in soil, and is not generally as mobile as nitrogen in groundwater.

Phosphorus is commonly analysed as soluble reactive phosphorus (which is predominantly orthophosphate) or total phosphorus, which includes organic phosphorus and particulate phosphorus, as well as soluble reactive phosphorus. Total phosphorus has been analysed during this monitoring program.

5.3.4.1 TRENDS

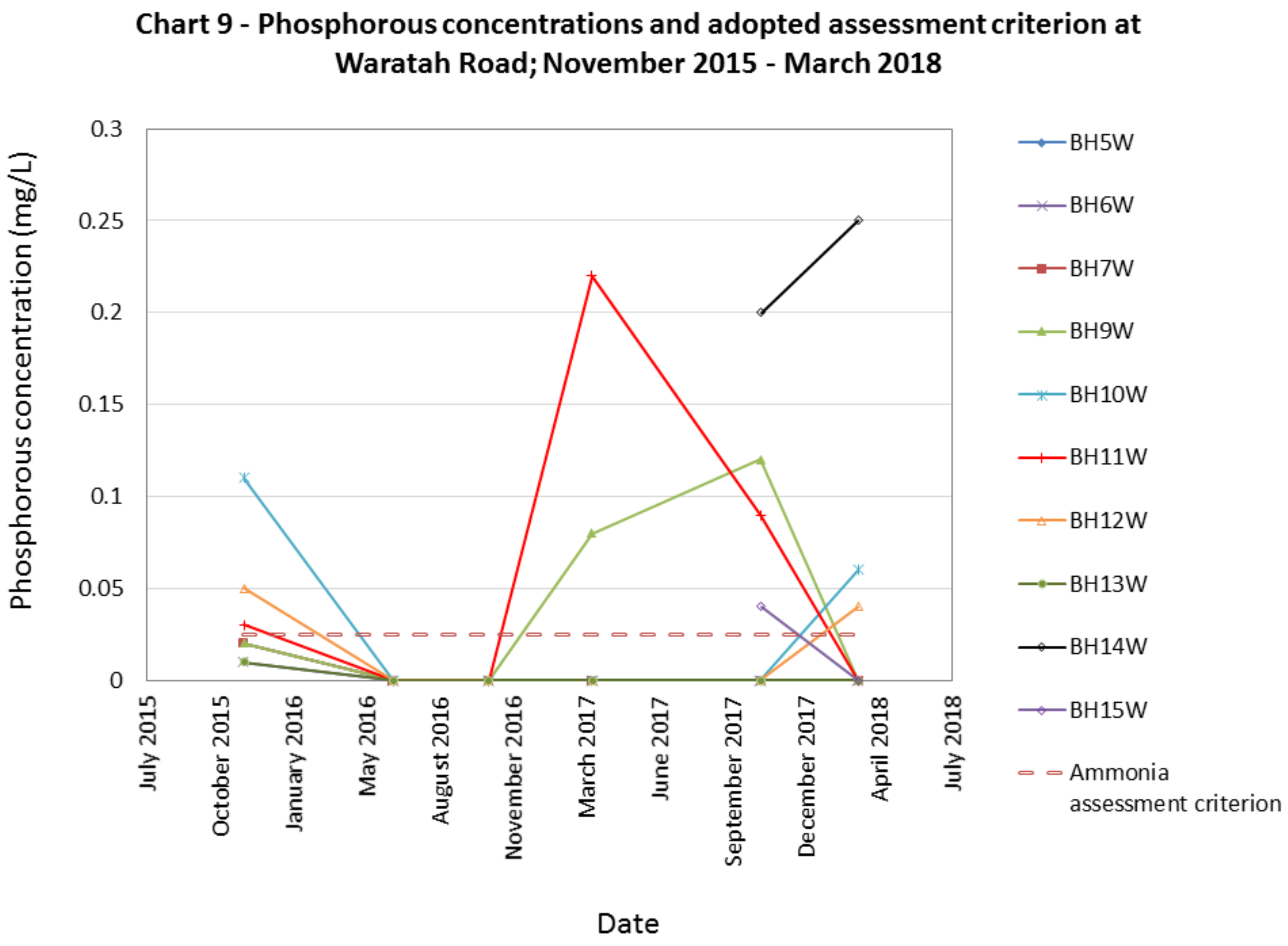
Phosphorous concentrations in groundwater collected from up gradient well BH11W, and down and cross gradient wells BH5W, BH9W, BH10 and BH12W showed high variability in most monitoring wells, with concentrations fluctuating between values above and below the adopted assessment criterion (0.025 mg/L, Chart 9). In contrast, groundwater samples collected from cross gradient wells BH6W, BH7W and BH13W presented more stable phosphorous concentrations during the monitoring period, below the adopted assessment criterion.

The highest total phosphorus concentrations were reported in up gradient well BH11W, and downgradient gradient wells BH10W and BH14W during each GME.

5.3.4.2 EXCEEDANCES

Out of the ten groundwater monitoring wells present on site, six, (BH9W, BH10W, BH11W, BH12W, BH14W and BH15W), presented total phosphorus concentrations above the adopted assessment criterion for the protection of freshwater aquatic ecosystems. Up gradient well BH11W showed total phosphorous concentrations above the criterion in three occasions between November 2015 and March 2018. There are no guidelines established for phosphorus for the protection of human health or aesthetic criteria.

Based on these results, WSP considers the phosphate impact at the site is unlikely to be significant and may be largely attributed to background conditions not associated with the burial pit.



5.4 METALS

Analysis of heavy metals and metalloids (aluminium, arsenic, barium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc) was undertaken to assess the potential leakage of soluble metals from the poultry shed litter contained in the pit at the Waratah Road site, and from potential mobilisation of metals due to interaction between any fluid leakage from the pit and the surrounding geology.

The trends for the metals and metalloids reported above the laboratory limit of reporting (LOR) are presented below.

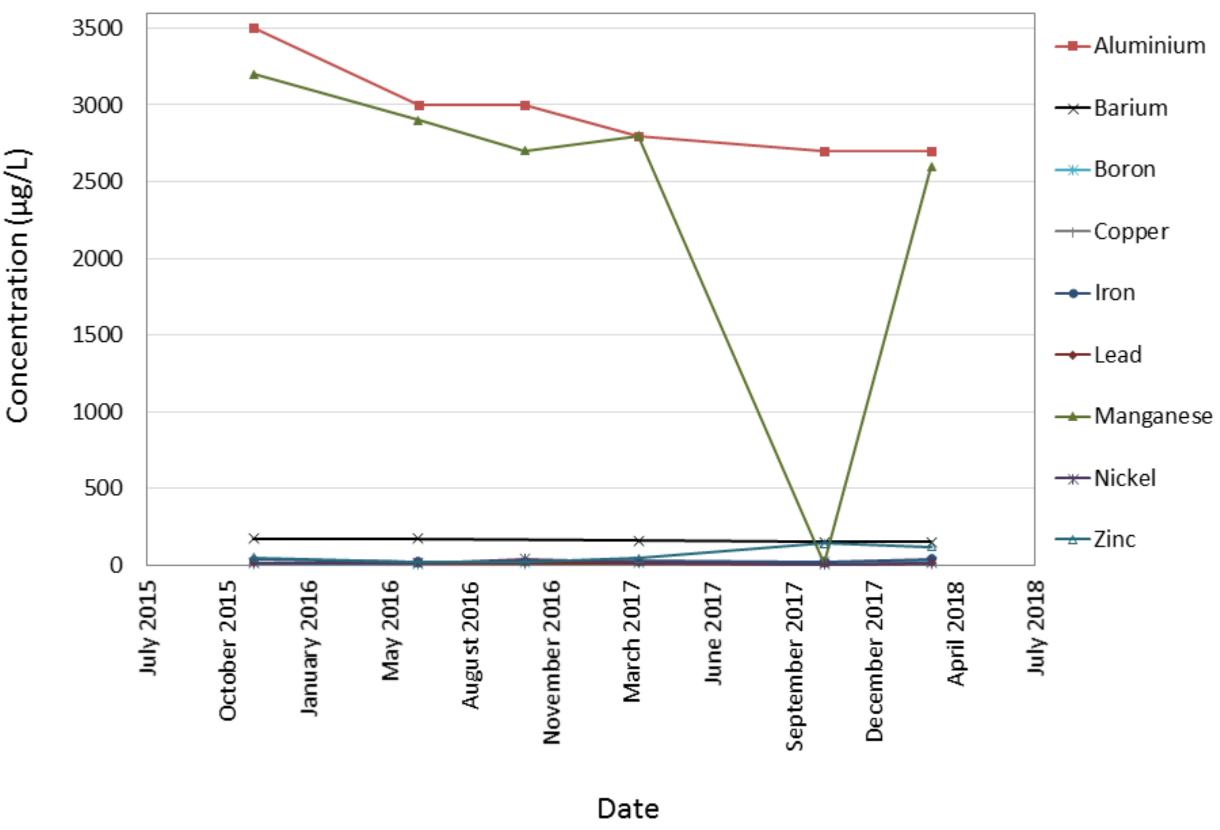
5.4.1 TRENDS

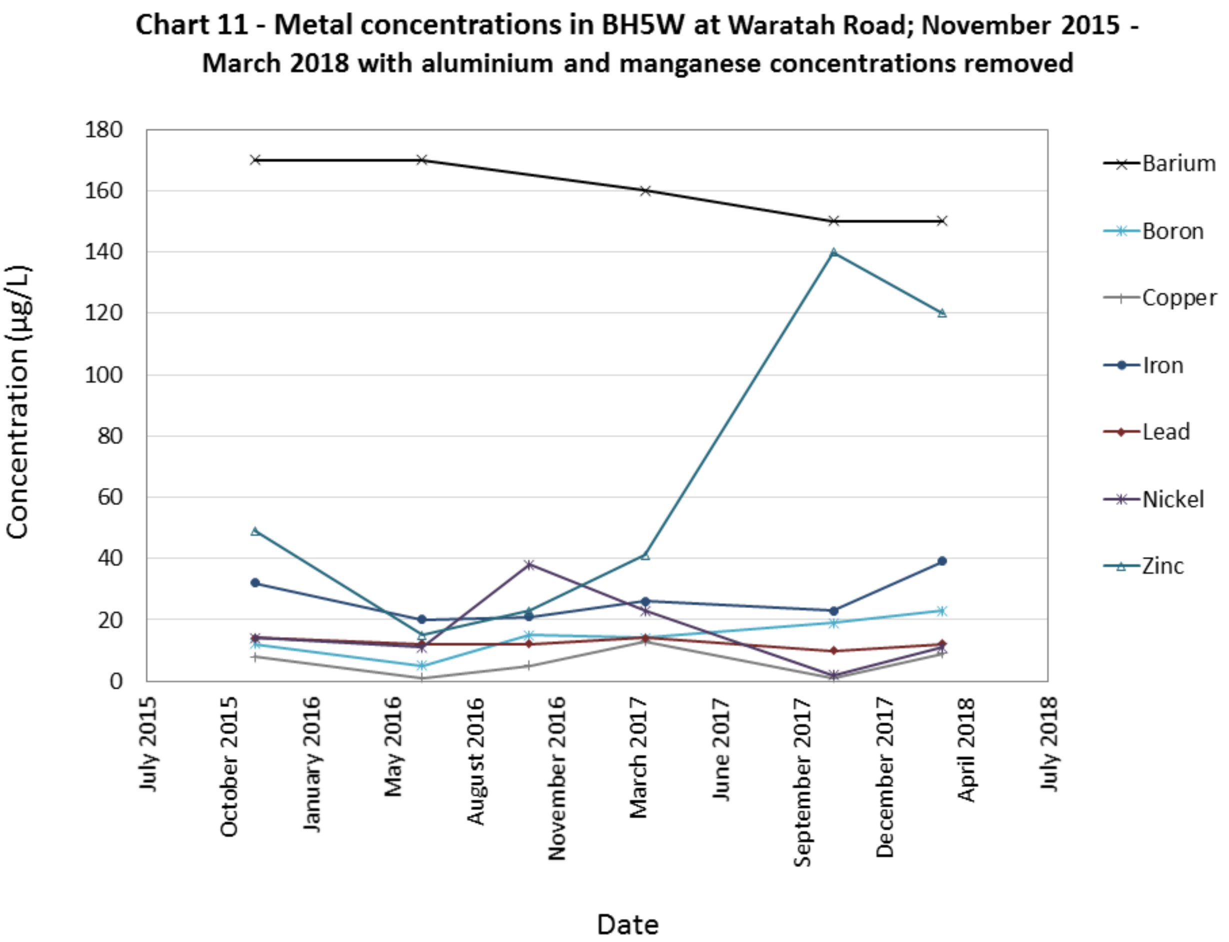
Concentrations of boron, copper, nickel, iron and lead fluctuated slightly between November 2015 and March 2018, remaining below 50 µg/L in down gradient well BH5W, as presented on Charts 10 and 11. Concentrations of zinc rose from 15 µg/L in November 2015 to 140 µg/L in March 2018 (Chart 11). Very high concentrations of aluminium and manganese were reported in BH5W ranging from 2,600 µg/L to 3,500 µg/L, showing a slight decrease over time. Arsenic, cadmium, chromium and mercury concentrations were consistently below the laboratory LOR in groundwater samples collected from down gradient well BH5W and are not reported in Charts 10 and 11.

Across all the groundwater monitoring bores, aluminium, barium, boron, copper, iron, lead, manganese, nickel and zinc were detected in the majority of the groundwater samples analysed. Arsenic was only detected once, in well BH9W and at the LOR of 1 µg/L. Cadmium, chromium and mercury were not detected in any of the wells on the site over the three-year monitoring program.

Metal concentrations were generally higher in down gradient monitoring wells BH5W and BH9W.

Chart 10 - Metal concentrations in BH5W at Waratah Road; November 2015 - March 2018



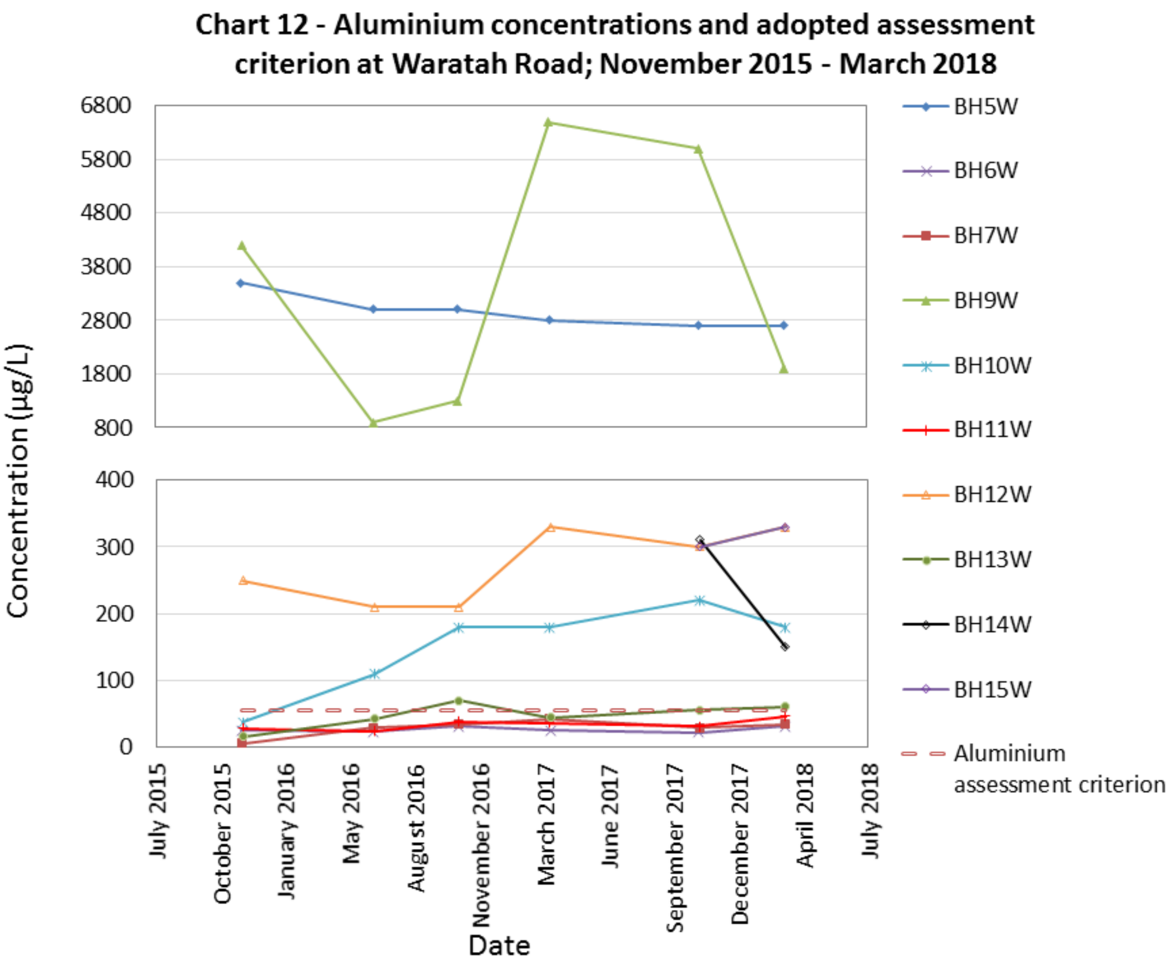


5.4.2 EXCEEDANCES

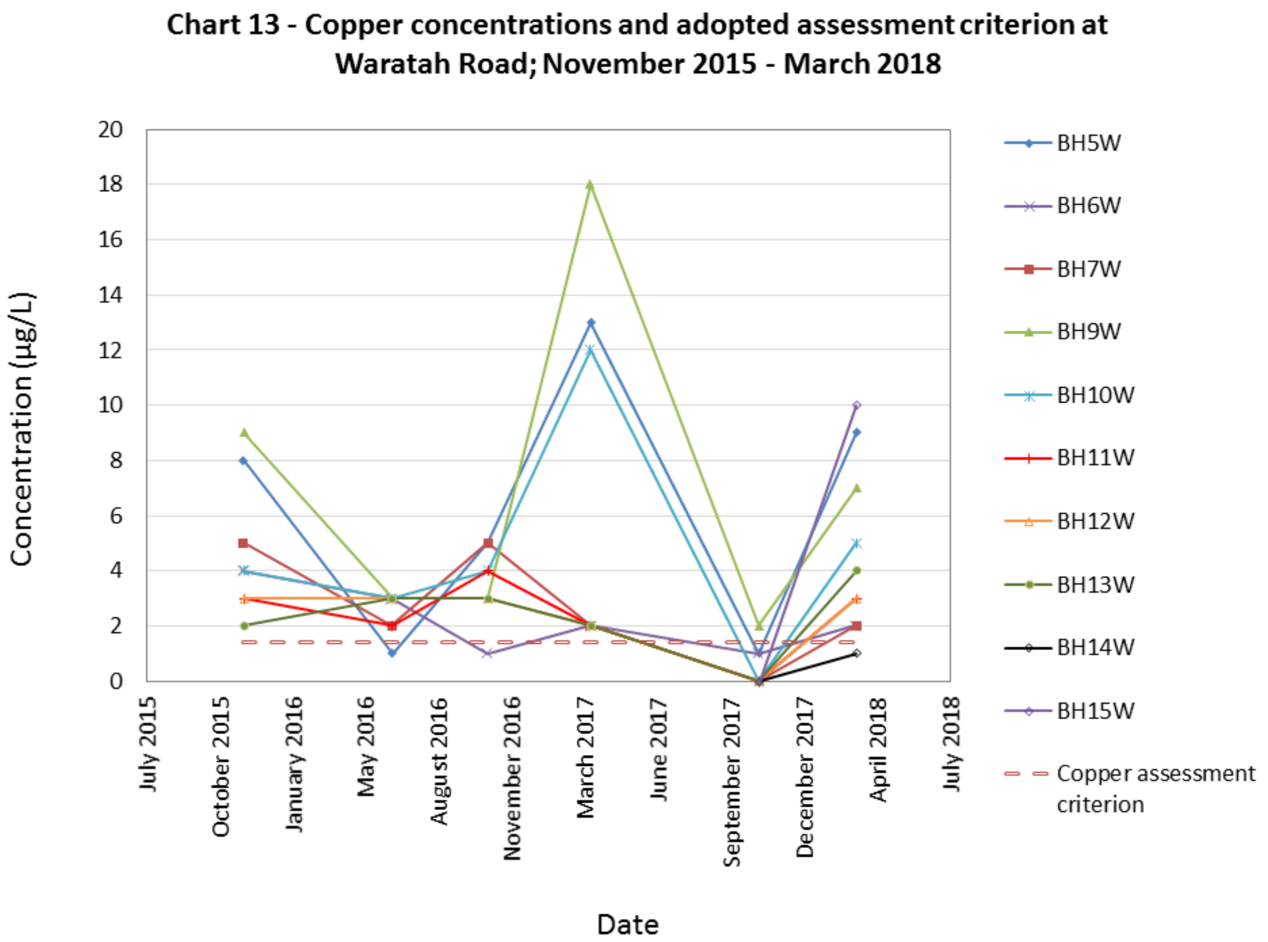
Aluminium, copper, lead, manganese, nickel and zinc were detected exceeding the site investigation levels in one or more of the groundwater samples collected at the Waratah Road site between November 2015 and March 2018. The adopted investigation level (or assessment criterion) for each metal was the threshold value for the protection of freshwater aquatic ecosystems with the exception of arsenic, barium, iron and manganese for which the recreational or drinking water guideline were applied.

Aluminium concentrations, presented in Chart 12, remained above the adopted assessment criterion for freshwater aquatic ecosystems (55 µg/L) in down-gradient monitoring wells BH5W, BH9W, BH12W, BH14W and BH15W, and in cross gradient well BH10W, throughout the monitoring period. The highest concentrations were presented in down gradient wells BH5W and BH9W. Aluminium concentrations detected in cross gradient wells BH6W, BH7W and up gradient well BH11W were lower than the assessment criterion, while in BH13W they exceeded only in October 2016.

The exceedances reported in groundwater on the site, particularly downgradient of the burial pit, may be indicative of a leakage from the burial cell, interacting with sub-surface geology resulting in increased exchange of metals from mineral surfaces. Note that aluminium solubility increases with decreasing pH, particularly below pH 4 (Hem, 1989). Hence, high aluminium concentrations in groundwater are a characteristic of the local aquifer. The ANZECC (2000) only provides an aluminium criterion for groundwater with a pH greater than 6.5 as there are insufficient data for groundwater with a pH lower than 6.5. Groundwater samples collected at the Waratah Road site during the monitoring period presented pH values generally lower than 5.5. Therefore, the aluminium assessment criterion should be used only as a reference value.



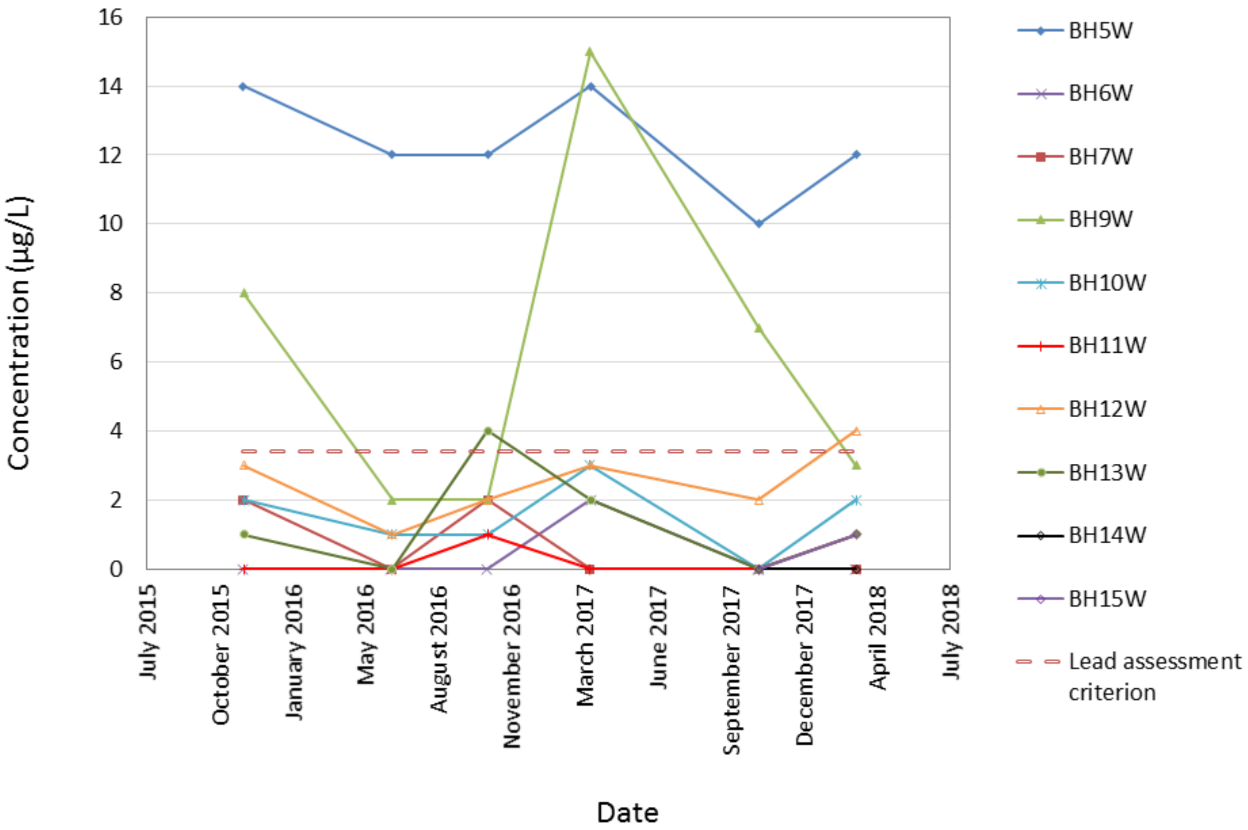
Concentrations of copper, presented on Chart 13, generally remained above the adopted assessment criteria for freshwater aquatic ecosystems in both up and down gradient monitoring wells on the site. A concentrations peak occurred in March 2017 affecting BH5W, BH9W and BH10W. Although two of these locations are leachate affected the third (BH10W) is not. Therefore, these exceedances are considered to be most likely representative of regional groundwater fluctuations, though interaction of leachate chemistry in the aquifer may have liberated some additional copper in BH5W and BH9W. The reported levels remain well-below the *Australian Drinking Water Guideline (2011)* for copper concentration of 2,000 µg/L.



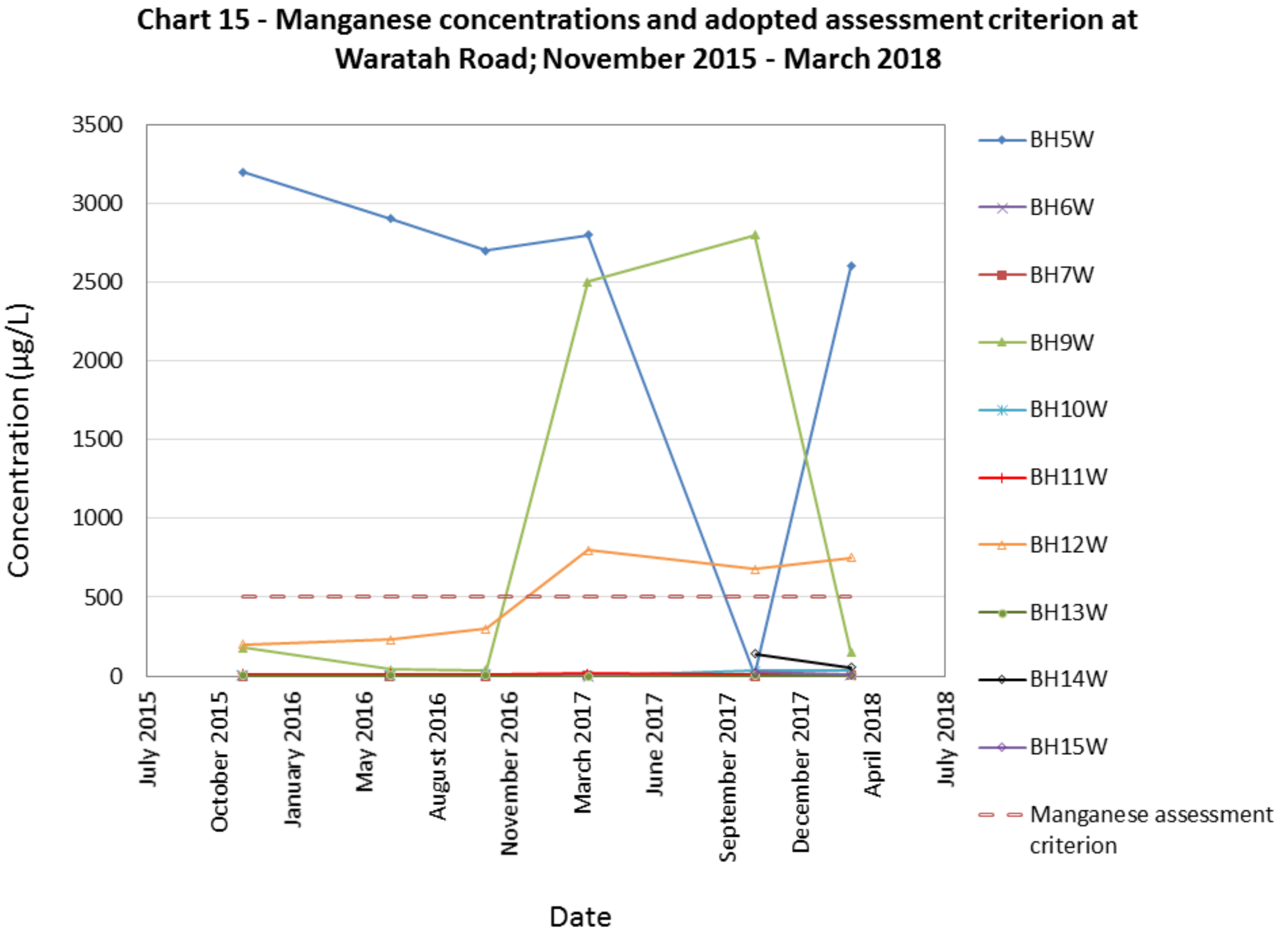
Lead concentrations were generally below the adopted assessment criteria in most wells on the site, with the exception of down gradient wells BH5W and BH9W, as presented in Chart 14. The levels reported in down gradient bore BH5W and, in one case, BH9W also exceeded the *Australian Drinking Water Guideline (2011)* level for lead of 10 µg/L. The distribution of dissolved lead concentrations is similar to that of nitrate (as N) where the two impacted monitoring wells BH5W and BH9W, which are located along the eastern boundary of the burial pit, recorded elevated concentrations.

The exceedances reported in groundwater on the site, east of the burial pit, tend to indicate an association with leachate emanating from the vicinity of the burial cell. This may be due to dissolution from waste in the cell (either the poultry litter or more likely lead based paints on the shipping containers used to entomb the waste). Alternatively, the low pH, more reducing conditions and increased ion activity (particularly cations) would all contribute to liberation of heavy metals from the mineral phase into the dissolved phase within the plume. Therefore, the presence of elevated metals in the plume may be due to geochemical interactions with the natural aquifer sediments.

Chart 14 - Lead concentrations and adopted assessment criterion at Waratah Road; November 2015 - March 2018

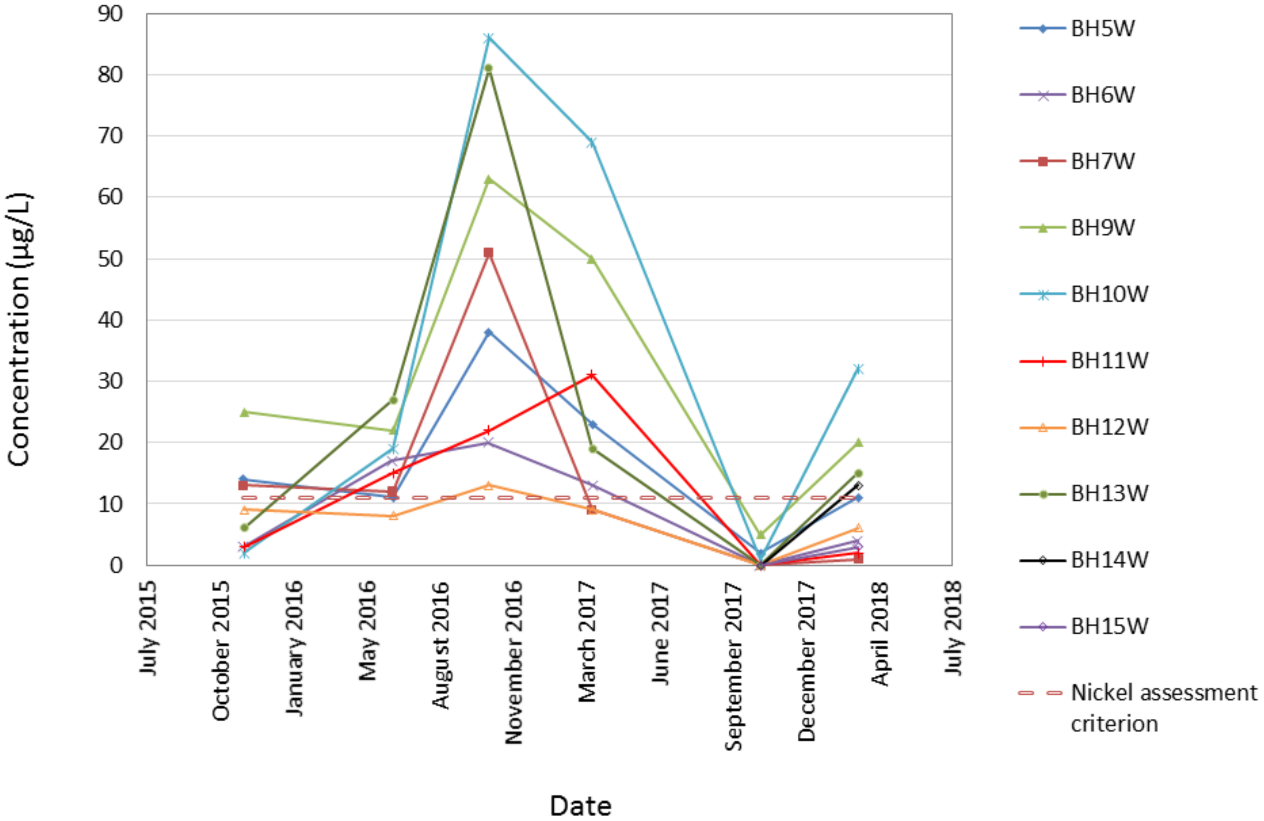


Manganese concentrations exceeded the adopted assessment criterion in several cases in monitoring well BH5W, BH9W and BH12W, as presented in Chart 15. The distribution of elevated dissolved manganese concentrations in these monitoring wells is similar to that of nitrate (as N) and lead. Higher concentrations were evident in wells BH5W, BH9W and BH12W which are located down gradient of the poultry shed litter burial pit. Similar to the lead, the elevated manganese may be attributed to the waste itself but could also be due to geochemical reactions within the lower pH and lower redox conditions downgradient of the cell resulting in increased the solubility.

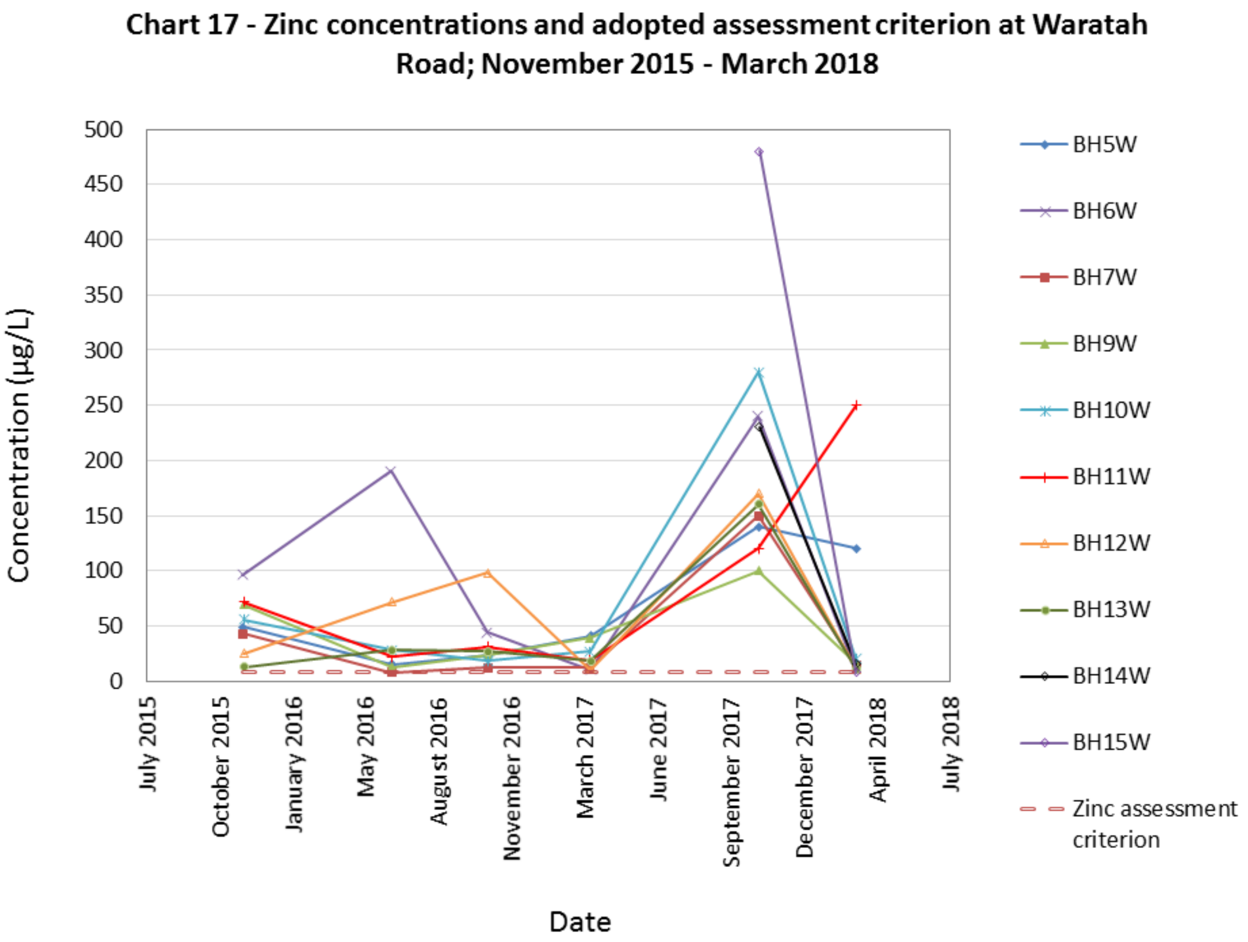


Nickel concentrations above the adopted assessment criterion of 11 µg/L were detected in almost all wells, including up gradient well BH11W, between June 2016 and March 2017 as presented in Chart 16. The highest nickel concentration was detected in a groundwater sample collected from well BH10W (October 2016), whereas up gradient well BH11W presented levels in line with down gradient and cross gradient wells. The concentrations of nickel on the site were therefore considered to be representative of the background levels. It should be noted that levels reported on occasion in a number of the bores including up gradient bore BH11W, and wells BH5W, BH7W, BH9W, BH10W, BH12W and BH13W, exceeded the *Australian Drinking Water Guideline (2011)* level for nickel (20 µg/L).

Chart 16 - Nickel concentrations and adopted assessment criterion at Waratah Road; November 2015 - March 2018



Zinc concentrations consistently remained above the adopted assessment criterion for freshwater aquatic ecosystems in both up and down gradient monitoring wells on the site. It is noted that the highest exceedances were reported for down gradient well BH15W, up gradient well BH11W and cross gradient well BH10W. The zinc concentrations detected on the site were considered representative of the background levels. There is no established health guideline level for zinc in the *Australian Drinking Water Guidelines (2000)*.



5.4.3 SUMMARY OF TRENDS IN METAL CONCENTRATIONS

The monitoring of metals showed considerable variability in concentrations and several exceedances of the adopted water quality criteria. It should be noted that natural background concentrations of heavy metals are often elevated in acidic aquifers in the Sydney and Central Coast regions. With pH ranging from 3.5 to 5.5, some metals in the geological profile tend to be dissolved and mobilised by groundwater.

The distribution of dissolved manganese and lead concentrations in monitoring wells located down gradient of the burial pit suggests either:

- Direct dissolution from the waste (or the shipping containers used to entomb the waste) may be increasing the concentrations of the metals downgradient of the cell, or
- Interactions of leachate with the natural geology are leading to increased solubility of these metals in the plume. This may be due to more reducing conditions caused by increased microbiological activity, and additional cation exchange from mineral surfaces due to the increased ion activity in the leachate.

It should also be recognised that, as discussed in Section 5.3, the leachate observed may well be due to historical piggery effluent activities rather than the poultry cell leaking.

5.5 SUMMARY EVALUATION OF TRENDS IN CONTAMINANT CONCENTRATIONS

The distribution of dissolved heavy metals, particularly manganese and lead, was similar to that of nitrate, all being present at the highest concentrations downgradient of the burial cell. These results could point to the cell liner being compromised resulting in a leachate plume downgradient of the cell. However, it is noted that the cell was constructed in a former effluent dam historically used for pig production. It is therefore possible that residues from that activity may be the primary source of the detected nutrient plume.

The monitoring program has demonstrated that the plume concentrations reduce with distance from the cell, though nutrients remain elevated above background levels at the most downgradient monitoring point, BH15W.

6 SITE MAINTENANCE WORK SUMMARY

At the Waratah Road, poultry litter containment pit site, an automated and telemetered continuous extraction pumping system for liquid waste-water and bunded above-ground storage tank system was installed in October 2017. This improves the efficiency of liquid removal, for transport off-site for treatment and recycling, to reduce the hydraulic load from rainfall infiltrating at the site.

An environmental service provider completed a detailed site investigation at the Waratah Road site in September - October 2017, including sampling, field measures and laboratory analysis of physical, chemical and microbiological features of buried materials. The investigation allowed characterisation/classification of buried waste and quantity survey to establish material mass, density and composition to guide analysis of long-term site management options.

Two new down-gradient groundwater monitoring bores, BH14W and BH15W, were installed at the Waratah Road site to further investigate the flow direction, chemical features and environmental fate of groundwater moving to the east of the poultry litter containment pit site.

7 CONCLUSIONS

Monitoring of total dissolved solids (TDS), nutrients and metals in groundwater from event 18 to event 23 showed elevated concentrations of nutrients (in particularly nitrate), and also lead and manganese, downgrading of the poultry litter containment cell. Given that nitrate is a common constituent of poultry shed litter, the elevated concentrations downgradient of the cell indicates the burial pit may be leaking. The presence of elevated lead and manganese may relate to the litter or the shipping containers entombed in the cell but may also be a feature of the lower pH, lower redox and increased ion activity in the plume, all of which would contribute to increased solubility and exchange of these metals from the solid phase into the groundwater.

Prior to the use of the Waratah Road site as an effluent dam for an intensive piggery operation is a significant confounding factor. It is possible that the nutrient loads observed relate primarily to residues from that activity rather than leakage from the cell. The scope of the GMEs is not sufficient to differentiate between these possible sources.

Groundwater at the Waratah Road site is anticipated to flow towards the south-east. Historic assessment data provided by DPI indicated that groundwater flow velocity in monitoring wells BH5W, BH7W and BH8W ranged from 7 to 28 m/year. The closest down-gradient registered borehole is located 227 m south-south-east of the site. Based on the results of this study it is considered unlikely that contaminants of concern are migrating at significant concentration in this direction. Moreover, concentrations of leachate indicators appear to reduce with distance from the cell, however, ongoing monitoring is warranted.

REFERENCES

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- WSP (2017 d) Groundwater monitoring event 21, Mangrove Mountain poultry burial sites, dated September 2017 – March 2017 GME.
- WSP (2018a) Groundwater monitoring event 22, Mangrove Mountain poultry burial sites, dated March 2018 – November 2017 GME.
- WSP (2018b) Groundwater monitoring event 23, Mangrove Mountain poultry burial sites, dated July 2018 (draft) – March 2018 GME.
- WSP | Parsons Brinckerhoff (2017a) Groundwater monitoring event 18, Mangrove Mountain poultry burial sites, dated 4 January 2017 – November 2015 GME – Rev. C.
- WSP | Parsons Brinckerhoff (2017b) Groundwater monitoring event 19, Mangrove Mountain poultry burial sites, dated 20 February 2017 – June 2016 GME.
- WSP | Parsons Brinckerhoff (2017c) Groundwater monitoring event 20, Mangrove Mountain poultry burial sites, dated 20 February 2017 – October 2016 GME.

APPENDIX A

FIGURES

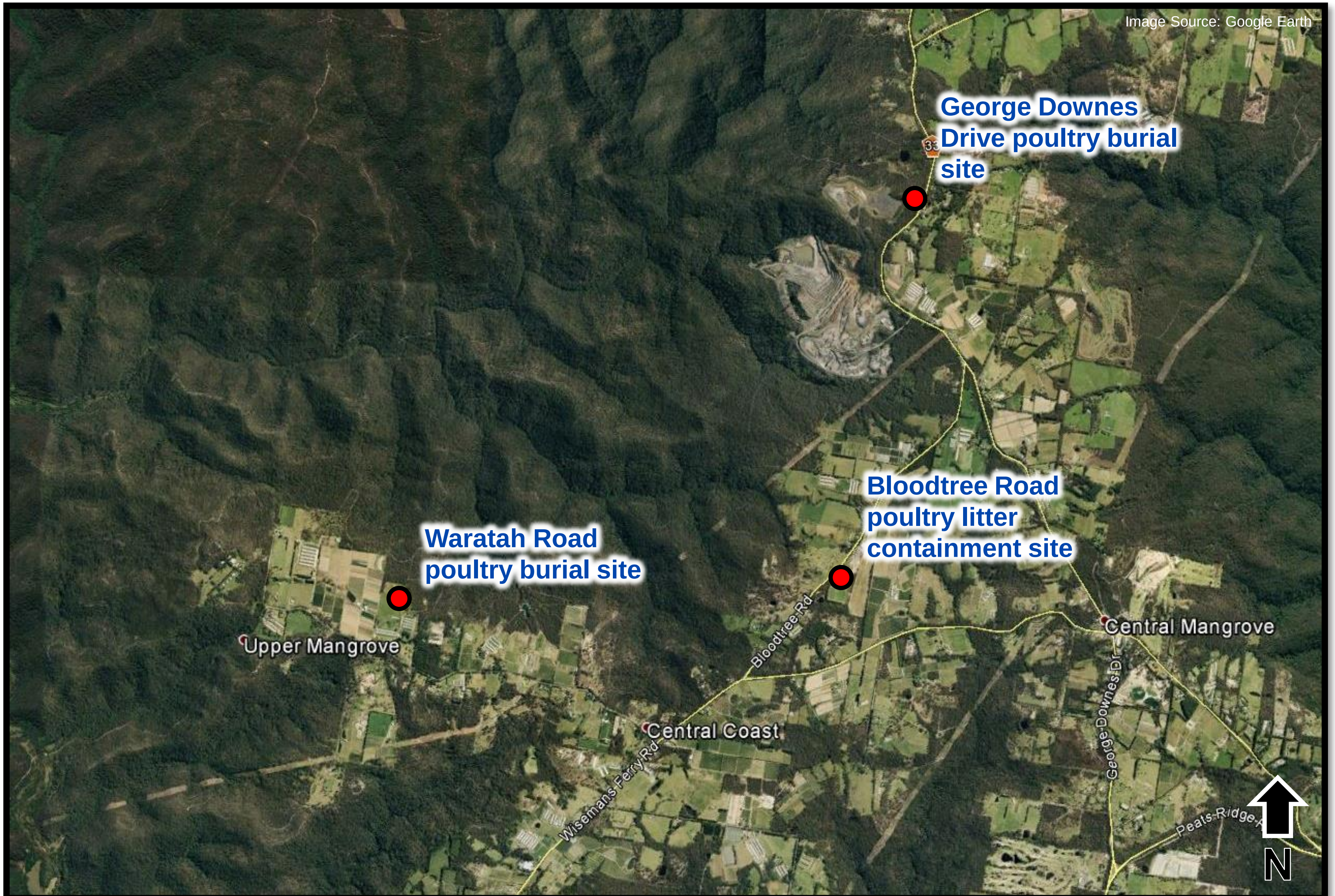

Figure 1

Mangrove Mountain Groundwater Monitoring Locations

0 km 1

Approximate site location

Mangrove Mountain Groundwater Monitoring Project
Site summary status – Waratah Road

Figure 2

Registered Groundwater Bores-Waratah Road, Mangrove Mountain

Mangrove Mountain Groundwater Monitoring Project
Site summary status – Waratah Road

Poultry litter containment site

Registered groundwater bore

500 m buffer

0 500

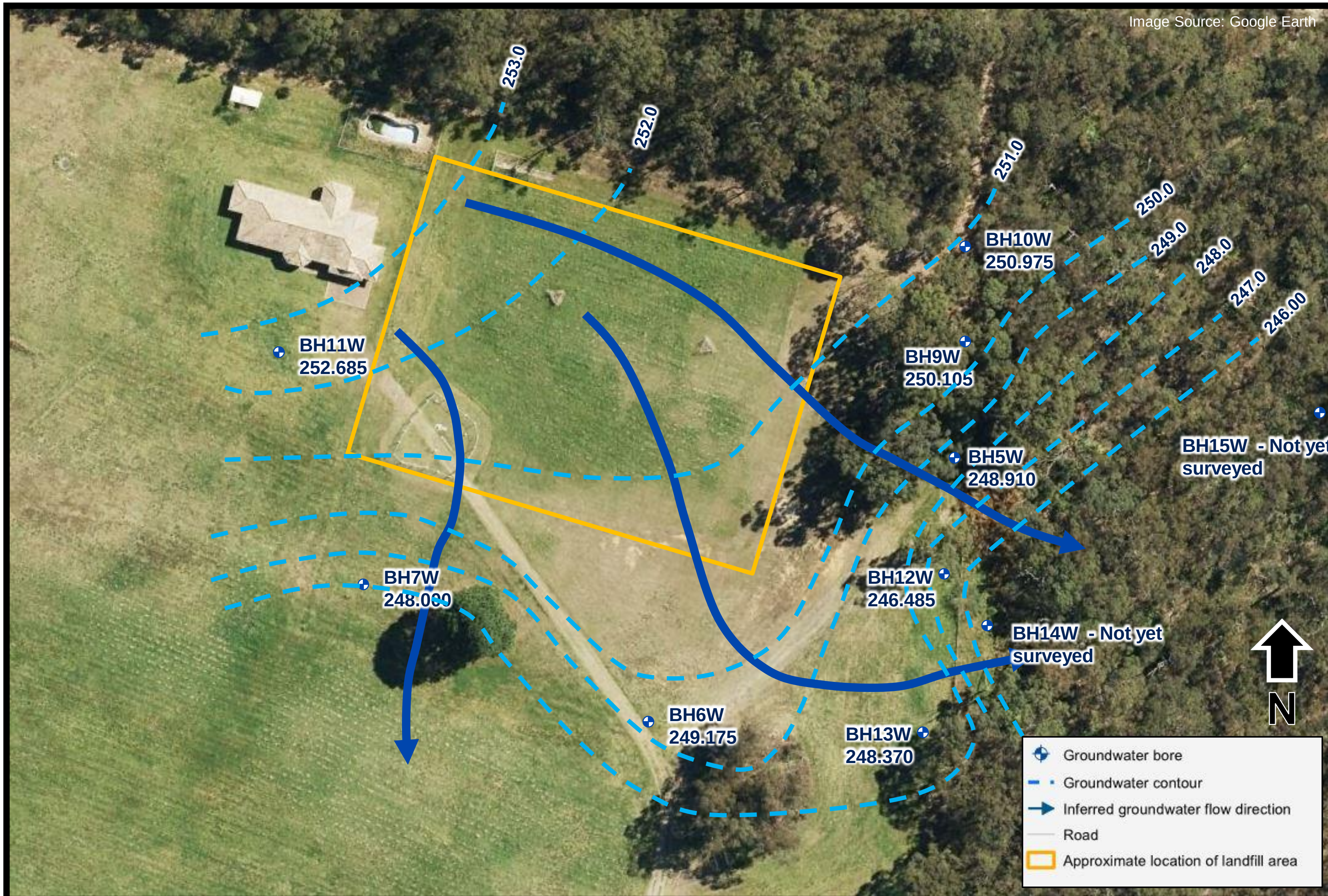

Figure 3

Site layout and groundwater elevation contours
Waratah Road, Mangrove Mountain

m
0 20

Groundwater Monitoring Well

Mangrove Mountain Groundwater Monitoring Project
Site summary status – Waratah Road

wsp

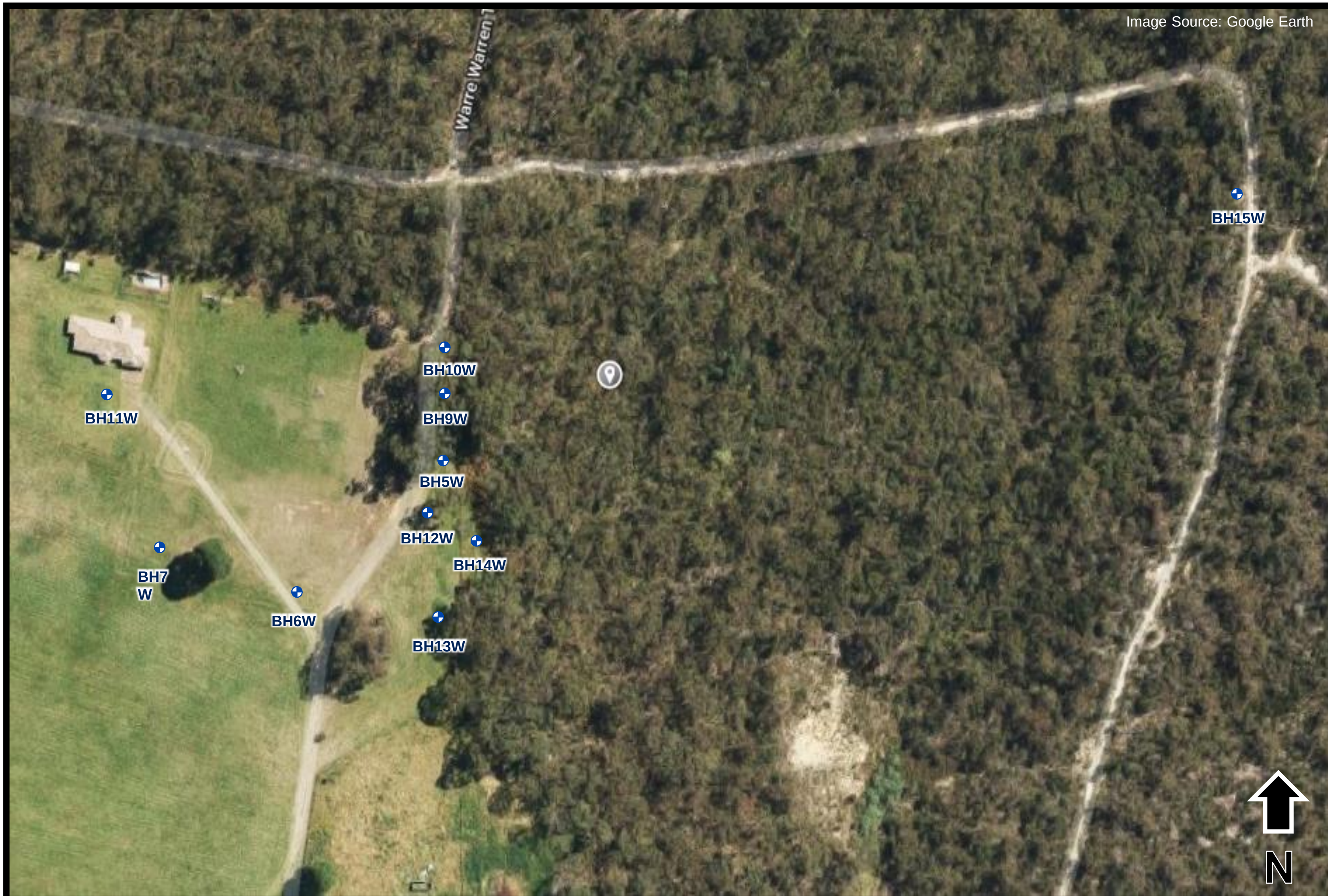

Figure 4

Site layout – including the BH15W.
Waratah Road, Mangrove Mountain

m
0 50

Groundwater Monitoring Well

Mangrove Mountain Groundwater Monitoring Project
Groundwater Monitoring Event 22 (October 2017)

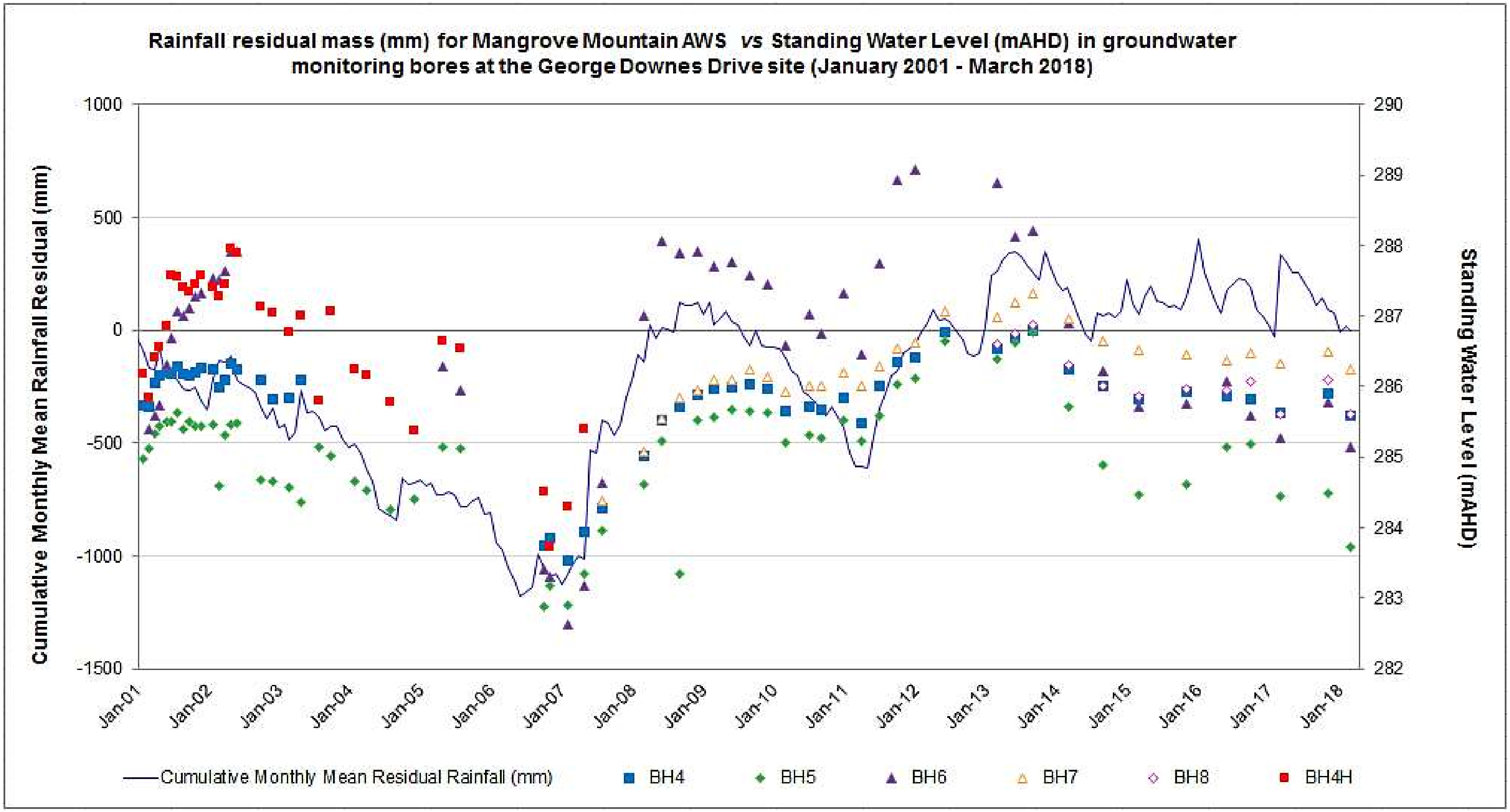

Figure 5: Rainfall residual mass (mm; Jan 2001 – Mar 2018) *vs* Standing Water Level (mAHD) in groundwater monitoring bores at the George Downes Drive poultry burial site (January 2001 – March 2018) (1) (Average monthly rainfall (mm) = Jan 2001 – Mar 2018 @ Mangrove Mountain AWS

(1)David, K., Liu, T., and David, V. (2014) Use of several different methods for characterising a fractured rock aquifer, case study Kempfield, New South Wales, Australia, pages 307-328, in *Fractured Rock Hydrogeology, International Association of Hydrogeologists Selected Papers* ***20***, J.M. Sharp (ed.)(2014) CRC Press, Taylor & Francis Group, LLC, Boca Raton, Florida.