Pesticides and nutrients in groundwater of the Darwin region

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Cover Photograph: Rodney Metcalfe sampling a bore in the Darwin rural area. (Photo: Liza Schenkel)

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1. Summary

This study is the second in a series of surveys of baseline groundwater quality in water allocation plan areas of the Top End.

In particular, this study aimed to:

1. investigate whether any pesticides are currently present in groundwater of the Darwin region
2. investigate current nutrient concentrations in groundwater of the region
3. compare historical pesticide and nutrient data to current results where available

The survey examined 24 bores in the Howard East and Berry Springs water planning regions. The bores were selected to be spread across the aquifer and included both private equipped bores used for domestic or irrigation purposes and NT Government monitoring bores. Sites included bores on uncleared, agricultural, and rural domestic blocks.

Traces of 8 different pesticides were detected in this study. Six of the 24 bores contained at least one herbicide or insecticide while the remaining 18 bores had no detections at all. No more than three different chemicals were found at any one site.

Guideline values were only available for 2 of the chemicals and the detected concentrations were well below these. All other chemicals were detected at very low concentrations close to their respective limits of detection.

Nitrate concentrations were low in comparison to other regions of Australia but variable across the sampling region. Significantly higher nitrate concentrations were found under agricultural land use than other land use categories. All concentrations were well below the Australian drinking water guideline value.

Overall, the current levels of groundwater contamination of the Darwin rural area with pesticides and nitrate are very low and are not a cause for concern. However, the detection of any aquifer contamination should serve as a reminder to apply best practice in the storage, application and disposal of chemicals and fertilisers.

2. Introduction

2.1. Background and study aims

Dry season surface water monitoring of streams in the Darwin, Katherine and Douglas-Daly regions between 2011 and 2015 detected small traces of herbicides and insecticides ((Schult 2012, Schult 2014, Schult 2016)). Since dry season flows in these regions are almost entirely supplied by groundwater, the Department of Environment and Natural Resources commenced a series of baseline studies of selected aquifers of the Top End in 2015 to examine groundwater quality with a focus on chemical contaminants. The first groundwater quality survey covered the Tindal aquifer in the Katherine region (Schult 2016). This current study is the second in the series and focussed on groundwater resources in the Darwin rural area.

In particular, this study aimed to:

1. investigate whether any pesticide residues are currently present in groundwater of the Darwin region
2. investigate current nutrient concentrations, particularly nitrate (NO_3), in groundwater of the region
3. where available, compare historical pesticide and nitrate data to current results to detect any trends

Recently, contamination of ground and surface water with chemicals from fire-fighting foams, (per- and polyfluoroalkyl substances or PFAS) has emerged as an issue of concern in the Northern Territory. The work reported here was unrelated to this issue and did not test samples for PFAS chemicals.

2.2. Definition of terms

The term “pesticide” means a chemical substance that is used to destroy or deter any pest. This can include weeds, insects, fungi and other pests. The term pesticide as used in this report therefore encompasses both herbicides and insecticides as well as other substances including fungicides, rodenticides and insect repellents.

2.3. Groundwater in the Darwin Region

The aquifers of the region have been well studied since the 1980s and there is much information available on their characteristics (e.g.Jolly 1983, Jolly and Yin Foo 1988, Verma 1995, Hatton et al. 1998, Radke et al. 1998, Tien 2002, Fell-Smith and Sumner 2011, Schult 2014).

Most of the groundwater in the Darwin rural area is sourced from two karst aquifers: the Koolpinyah dolomite in the Howard Springs area and the Berry Springs Dolostone. These cavernous fractured limestone formations have a porous texture and act like sponges to hold large amounts of water. In the wet season, the aquifers in the Darwin region are recharged from rainwater that infiltrates the soil and unconfined shallower aquifers until it reaches the karstic layers; or by direct recharge through areas where the karst formations reach the surface.

The Koolpinyah dolomite and Berry Springs dolostone aquifers are subject to water allocation planning which resulted in the recent declaration of the Berry Springs Water

Allocation Plan (WRD 2016) and is continuing with the current development of a Howard East Water Allocation Plan. Other aquifers also exist in the region but are not currently subject to water allocation planning.

The geology of an aquifer naturally influences the water quality of groundwater. The minerals dissolved in the water reflect the type of rock water is stored in.

Changes to groundwater quality can occur when chemicals used at the surface reach the water table by leaching through the soil or more directly through contamination of bores and sinkholes. Because it takes time for these substances to move through the soil and the aquifer, shallow, unconfined areas are most at risk from surface contamination since there is no physical barrier of impervious rock. Processes that generate a change in groundwater quality can be natural or caused by human activities.

Human-made chemicals, including pesticides, can enter aquifers and contaminate groundwater. Pesticides are used widely in the community with uses ranging from small scale applications around the home and garden, termite control around buildings, larger scale herbicide spraying around infrastructure and roads to the control of noxious weeds on rural blocks and applications of pesticides to crops and livestock by farmers and the agricultural industry.

Where these chemicals are stored or applied incorrectly, they can enter the groundwater, for example via backflow through faulty valves of fertigation systems or when excessive amounts of chemicals or fertilisers are applied to crops and leach through the soil into the aquifer below. Chemicals that are highly water-soluble pose a higher risk to groundwater because they are easily carried from the soil surface into the aquifer by rain or irrigation. In Australia, the Australian Pesticides and Veterinary Medicines Authority (APVMA) regulates the registration and use of pesticides.

Similarly, excess nutrients can also reach the water table. The most common anthropogenic (human-generated) contaminant of groundwater is the nutrient nitrate. Nitrate occurs naturally and is produced from the decomposition of organic material and the fixation of atmospheric nitrogen by bacteria and its subsequent oxidation. These processes occur in soils and plants. The main anthropogenic sources of nitrate are sewerage discharge, animal waste and the agricultural application of industrial fertilisers which usually contain nitrogen in the form of ammonia or nitrate. Another source of nitrate is atmospheric deposition of nitrogen from burning fossil fuels.

While other nutrients, such as phosphorus or organically bound nitrogen adsorb to soil particles and are therefore filtered out as water passes through the soil, nitrate is easily dissolved in water and can be carried deep into the aquifer.

The removal of nitrate from soils only occurs if nitrate is taken up by plants for further growth, or through the process of denitrification, the biological reduction of nitrate to molecular N_2 (a gas, which is released back into the atmosphere). This can only occur under certain anaerobic soil conditions, however, these conditions are not common in the unsaturated zone above the water table, so that once nitrate moves below the root zone of plants, it is likely to persist and reach the aquifer below.

Nitrate contamination of groundwater can potentially lead to the eutrophication of aquatic ecosystems and cause algal blooms and other changes to the aquatic flora, when contaminated groundwater is discharged to rivers and streams.

2.4. Current knowledge of groundwater quality

The NT Government's Water Resources Division carries out regular sampling for general water quality in selected monitoring bores but this does not routinely include pesticides or nutrients.

Newly established bores are routinely sampled for a number of parameters to establish their aquifer source and to determine if water is suitable for drinking. This analysis includes sampling for nitrate, however, it is generally done to a detection limit that is unsuitable for environmental applications. Prior to the early 2000s the results of this analysis were provided to the NT government and stored in the Water Resources database, however, this requirement has been removed for more recently established bores, so that the data is not publicly available.

A comprehensive survey of groundwater quality in the Darwin region was conducted by Geoscience Australia (formerly the Australian Geological Survey Organisation) in 1995 (Radke et al. 1998). The survey investigated a large number of bores in the Darwin rural area with the aim of providing baseline information on groundwater quality including the presence of pesticides. At the time, no pesticides were detected in any of the sampled bores at detection limits of 0.1 -0.01 µg/L depending on the individual chemical.

In 2004 a review of pesticide sampling in the Darwin region was undertaken (Waugh and Padovan 2004) which concluded that there had been only a small amount of small scale, project-specific sampling in surface and groundwater, and that pesticide monitoring had often not been the primary objective of the studies. The report list one study in which 24 bores in the Darwin rural area were tested in 1992/93. Three pesticides (*atrazine, prometryn* and *heptoachlor epoxide*) were detected in 2 bores at concentrations of 0.04-0.07 µg/L. The study itself has not been published and detection limits and results cannot be verified.

3. Methods

Site selection

The survey examined 24 bores in the Darwin region, 15 of these were located in the Howard Springs and 9 in the Berry Springs area (Figure 1). Sites were selected to be spread across the aquifer and included both private bores equipped with pumps and used for domestic or irrigation purposes and NT Government monitoring bores. Bores were situated within different land uses including agricultural, rural domestic, and uncleared blocks. Each site was allocated one of four land use categories (agricultural (mangoes), agricultural (vegetables), rural/domestic or natural environment) according to the immediate surrounding area using Google Earth imagery.

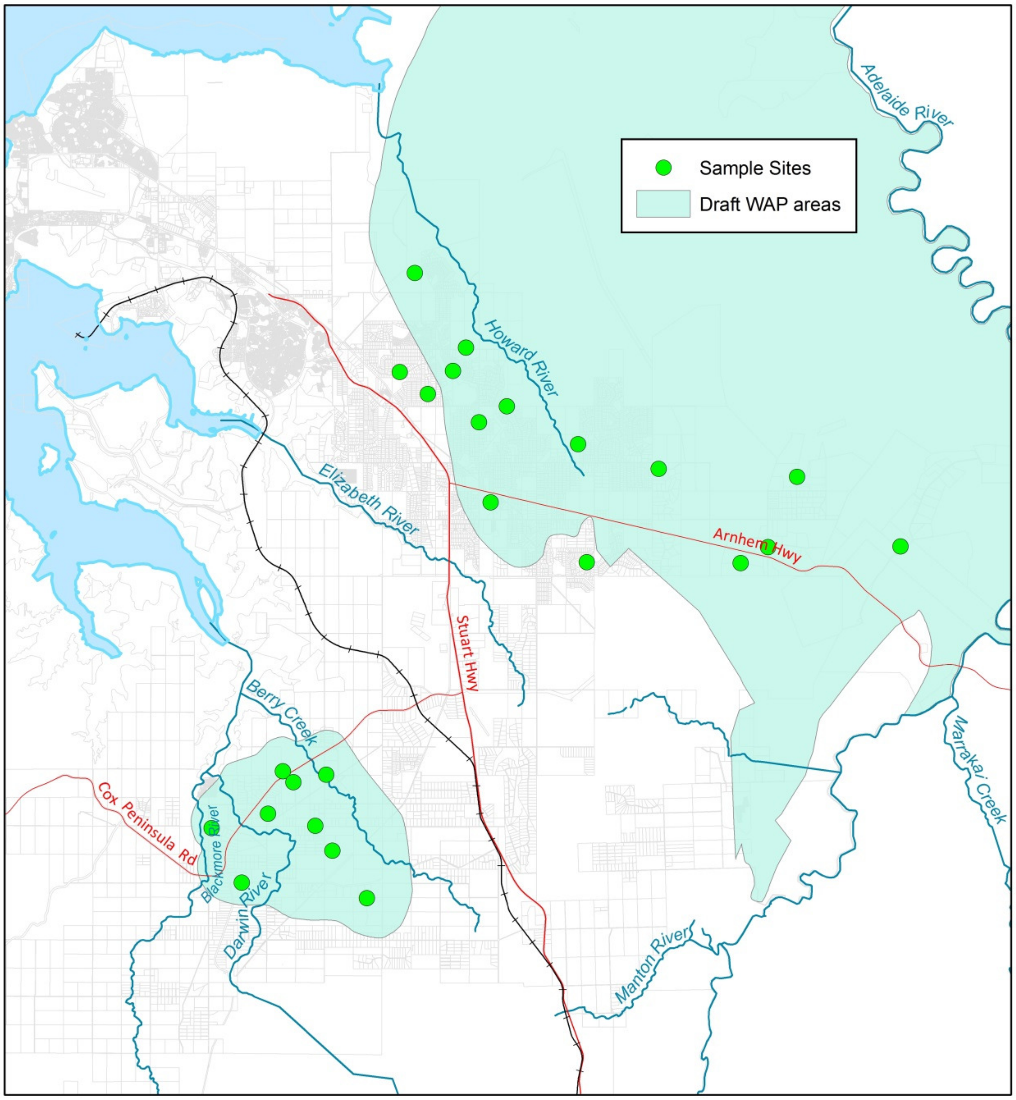

Figure 1. Location of sample sites in the Darwin region.

Bore sampling

Field measurements and water samples were collected from all bores.

Where bores were equipped with a pump and used for production, samples were collected from a tap as close to the bore head as possible. Unequipped bores were purged to remove stagnant water in the bore using a mobile pump and samples taken when field measurements of water quality were stable. Field measurements from bores were made using bore water collected in a bucket.

Field measurements of temperature, pH, electrical conductivity (EC), dissolved oxygen (DO) were measured with a Hydrolab Quanta multi-parameter probe (Ott Hydromet GmbH). Turbidity measurements were taken using a portable Hach 2100Q turbidimeter. Pesticide and herbicide samples were collected in three separate glass bottles for pesticide, herbicide and glyphosate analysis. All herbicide and pesticide samples were refrigerated in the field and upon return to the laboratory. Samples were analysed by the Queensland Department of Health's Forensic and Scientific Services for a large range of pesticides and some other common contaminants. A total of 180 substances were tested for, including organochlorine pesticides (e.g. *DDT, Dieldrin*), organophosphate pesticides (e.g. *chlorpyrifos*), synthetic pyrethroids, triazine herbicides, *glyophosate* ("Roundup") and other common herbicides. A full list of analytes and their Limits of Reporting (LOR) is provided in Appendix A. The LOR is currently used by many laboratories in place of a limit of detection.

Nutrient samples were collected in polyethylene sample bottles for total and soluble nutrients. Soluble nutrient samples were filtered in the field using through Minisart 0.45 µm PES a syringe filters. All nutrient samples were stored on ice in the field and frozen on return to the laboratory. Samples were analysed by the Northern Territory Environmental Laboratories (NTEL Intertek) for total nitrogen and total phosphorus, nitrite (NO_2), nitrate (NO_3), ammonia (NH_3) and filterable phosphorus (FRP). Samples for general water quality parameters (alkalinity, hardness, pH, conductivity) and major cations (K^+, Na^{2+}, Ca^{2+}, Mg^{2+}) and anions (Cl^-, HCO_3^-, SO_4^-) were collected in polyethylene bottles and kept refrigerated until they were analysed by NTEL Intertek, Darwin. All samples were analysed according to APHA (2005) standard methods.

Historical data

For comparison of historical nitrate concentrations with current results, data from the DENR water quality database was used where available. Bore water quality is routinely tested when a bore is first established and the data is held in the DENR database. Historical NO_3 data were available for most of the sites and were collected between 1968 and 2000.

Some of the bores that were sampled in this survey were included in a previous assessment of pesticides in Darwin region groundwater in 1995 (Radke et al. 1998).

4. Results

4.1. General water quality

The ionic composition of groundwater samples depends on the geology of their source aquifer. Samples from the same aquifer are expected to have similar proportions of anions and cations. The Piper diagram (Figure 2) shows the clusters of different water types. Similar samples plot close together on the diagram. The ionic composition of samples from this survey shows that not all the bores that were sampled accessed the same water type.

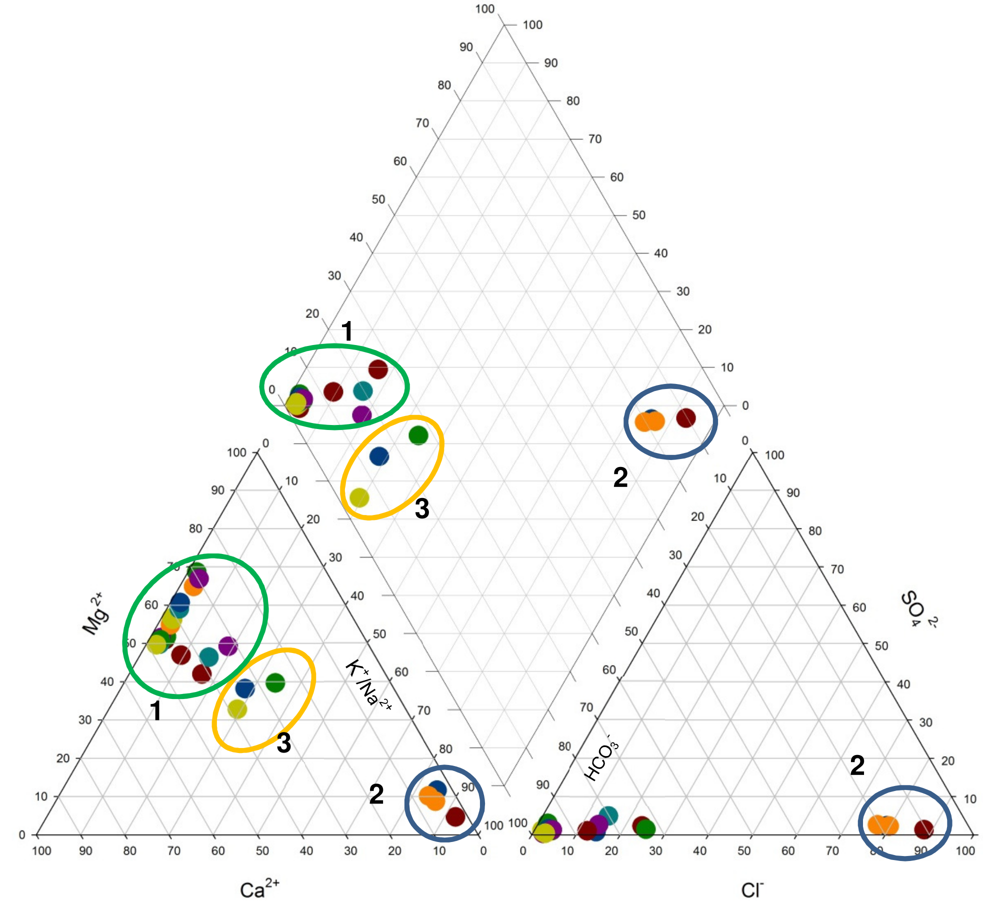

Figure 2. Piper plot of ionic composition of sampled bores. Samples with similar water types plot close together. Each dot represents one sample.

The majority of samples were dominated by calcium and magnesium bicarbonate ions indicative of the Koolpinyah dolomite and Berry Springs dolostone aquifers (Figure 2, Group 1). These waters typically have an electrical conductivity of 200-350 µS/cm. Four of the bores were sodium chloride dominated with low pH and low electrical conductivity (<50 µS/cm) (Figure 2, Group 2). Another group of three samples was very low in electrical conductivity but contained higher proportions of calcium bicarbonate (Figure 2, Group 3).

For the summary of field and general parameter data provided in Table 1 samples from groups 2 and 3 were combined. Raw results for each bore are presented in Appendix B.

Table 1. Summary statistics of general water quality parameters in bores and springs in the Darwin region. SE: standard error of the mean.

	Karst (n=17)					Other (n=7)				
Parameter (unit)	Mean	(SE)	Median	Max	Min	Mean	(SE)	Median	Max	Min
Field Measurements										
Temperature (deg C)	30.7	(0.06)	30.5	34.1	29.6	30.73	(0.16)	30.40	32.80	29.50
Field pH* (units)	na	na	7.31	7.76	6.51	na	na	4.60	6.12	4.37
DO (mg/L)	3.1	(0.20)	3.4	6.3	0.2	3.40	(1.14)	2.79	7.08	0.34
EC (µS/cm)	303	(2.20)	301	360	205	54.54	(6.59)	38.30	144.00	18.00
Turbidity (NTU)	0.4	(0.02)	0.2	1.35	0.1	25.83	(6.12)	4.98	120.00	0.70
Major ions										
Lab pH*	na	na	7.7	8.2	7	na	na	5.1	6.4	4.6
Lab EC (µS/cm)	281.9	(2)	283	331	192	43.9	(3.97)	31	85	18
Alkalinity (mg $CaCO_3$/L)	154.3	(1.55)	156	189	77	12.8	(2.42)	1	40	0.5
CO_3 (mg/L)	<1	na	<1	na	na	<1	na	<1	na	na
HCO_3 (mg/L)	154.3	(1.55)	156	189	77	14.8	(2.93)	7	40	1
OH (mg/L)	<1	na	<1	na	na	<1	na	<1	na	na
TDS (mg/L)	176.5	(1.28)	170	210	130	32.9	(2.82)	30	60	10
Cl (mg/L)	4.1	(0.19)	3.15	14.5	2.1	3.2	(0.14)	2.6	4.9	2.2
Si (mg/L)	9.3	(0.15)	8.84	13.6	6.2	5.9	(0.23)	5.5	8.9	3.5
Hardness	153.8	(1.65)	159	192	84.4	9.0	(1.88)	0.7	35.2	0.3
Ca (mg/L)	26.2	(0.27)	26.8	32.2	16.8	1.6	(0.34)	0.05	6.3	0.05
K (mg/L)	0.4	(0.04)	0.2	2.8	0.05	0.2	(0.04)	0.05	0.8	0.05
Mg (mg/L)	21.4	(0.34)	21.2	32.6	10.3	1.2	(0.25)	0.2	4.7	0.05
Na (mg/L)	3.5	(0.24)	2.1	18.3	1.6	2.4	(0.11)	2.6	3.7	1.5
SO_4 (mg/L)	1.5	(0.06)	1.25	4.6	0.5	0.3	(0.08)	0.05	1.6	0.05

*pH data unsuitable for calculation of mean due to log_{10} scale of pH units
na: not applicable

4.2. Pesticides

Traces of 8 different pesticides were detected during this study. Six of the 24 bores tested contained at least one herbicide or insecticide while the remaining 18 bores had no detections at all. No more than three different chemicals were found at any one site (Figure 3).

The most commonly detected chemical was the herbicide *2,4-DB*, which was found in three of the bores. The herbicide *MCPB* was found at 2 sites while the herbicides *tebuthiuron, diuron*, *bromacil, mecoprop* and *desisopropyl atrazine*, a breakdown product of *atrazine*, were detected once each. *Imidacloprid,* an insecticide, was also found at only one site (Table 2). Raw results for individual bores are presented in Appendix C.

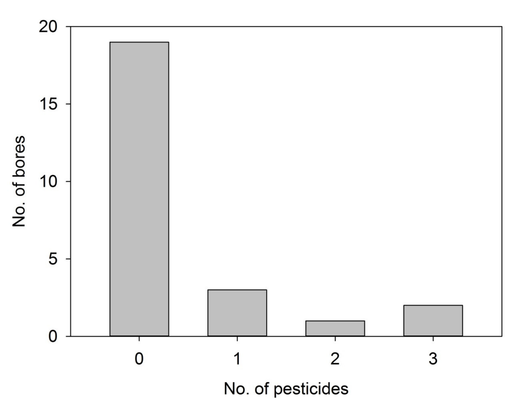

Figure 3. Frequency of pesticide detection.

Environmental guideline values are currently only available for one of the detected pesticides, *tebuthiuron*. The detected concentrations of this herbicide were several orders of magnitude below the trigger values (ANZECC and ARMCANZ 2000) for moderately disturbed ecosystems (Table 2). The concentrations of all the pesticides without available guidelines were very low and close to their respective reporting limits of 0.001 µg/L (herbicides) or 0.003 µg/L (*imidacloprid*).

Table 2. Results of pesticide analysis for the Darwin region, 2016. Only detected pesticides are listed. For a complete list of analytes see Appendix A.

Analyte	ANZECC Guideline (µg/L)	Reporting Limit (µg/L)	% detection (No. of sites)	Max Concentration (µg/L)
Herbicides				
2,4-DB		0.001	12 (3)	0.002
Bromacil	-	0.001	4 (1)	0.009
Desisopropyl atrazine	-	0.001	4 (1)	0.002
Diuron	-	0.001	4 (1)	0.002
MCPB	-	0.001	8 (2)	0.002
Mecoprop	-	0.001	4 (1)	0.002
Tebuthiuron	2.2	0.001	4 (1)	0.016
Insecticides				
Total Imidacloprid	-	0.003	4 (1)	0.005

Pesticides were associated with both of the agricultural land use categories (mangoes and other agriculture) as well as sites with native vegetation. No pesticides were found in the rural residential category. An uncategorised site adjacent to the former Howard Springs Waste management facility also contained pesticide residues (Figure 4).

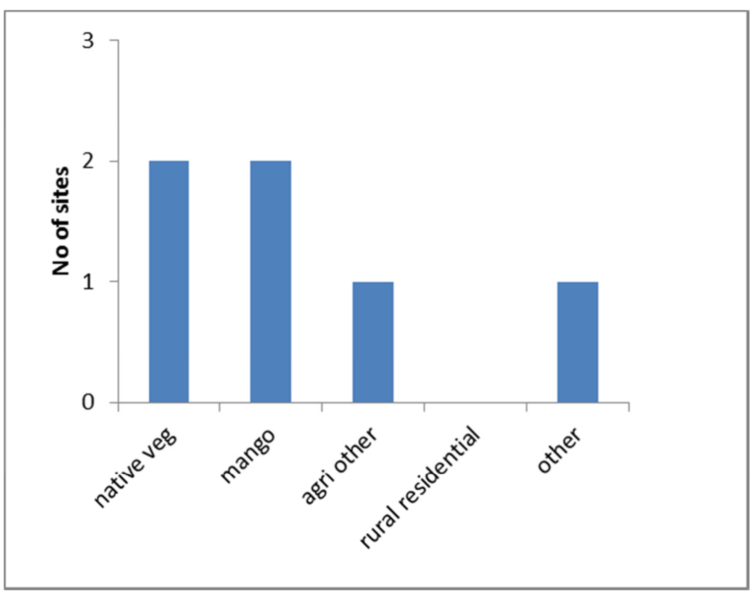

Figure 4. No. of sites where pesticide residues were detected by land use category.

4.1. Nutrients

Soluble nutrient concentrations were low for nitrite (NO_2), ammonia (NH_3) and filterable reactive phosphorus (FRP), with medians of <0.001, 0.002 and 0.011mg/L respectively. . Nitrate concentrations were more variable across the aquifer and much higher with a mean of 0.350 mg/L and values ranging from <0.001 mg/L to 1.85 mg/L (Table 3).

Table 3. Summary statistics for nutrient concentrations in bores and springs of the Darwin region (n=25). SE: standard error of the mean.

Parameter (unit)	Mean	SE	Median	Max	Min
NO_2_N (mg/L)	<0.001	na	<0.001	0.010	<0.001
NO_3_N (mg/L)	0.230	(0.011)	0.128	0.840	0.002
FRP (mg/L)	0.014	(0.001)	0.011	0.050	<0.001
NH_3_N (mg/L)	0.023	(0.002)	0.002	0.250	<0.001

Mean nitrate concentrations by land use ranged from 0.07 mg/L under native vegetation to 0.55 mg/L in non-mango agricultural areas (Table 4). Mean nitrate concentrations were significantly higher under non-mango agricultural areas than under all other land uses ($p<0.005$, one-way ANOVA).

Table 4. Mean NO_3 (mg N/L) concentrations by land use category

Land Use Category	n	Mean	(SD)	Max	Min
Horticulture (mangoes)	8	0.19	0.18	0.59	0.002
Agriculture (other)	4	0.55	0.32	0.818	0.091
Natural environments	6	0.07	0.06	0.139	0.002
Rural/domestic	4	0.10	0.12	0.261	0.010

A comparison of historical and current NO_3 concentrations in groundwater of the Darwin region is confounded by the fact that although historical bore samples were routinely tested for NO_3, the detection limit that applied to those samples prior to the year 1995 is much higher than that used for the current survey (1 mg NO_3/L or 0.26 mg NO_3-N/L vs. 0.001 mg NO_3-N/L). In addition, water quality results are no longer routinely provided to the NT Government for newly drilled bores, so that baseline NO_3 data are not available for some bores.

The comparison of current results with historical data shows that NO_3 concentrations appear to have increased 2-3 fold compared to historical levels in four of the bores (Figure 5, bores 5,6,10 and 20). Three of these are located on agricultural land while the fourth is adjacent to the former Howard Springs waste disposal facility. This comparison should only be considered an indication since in most cases only one single historical and one current measurement are available.

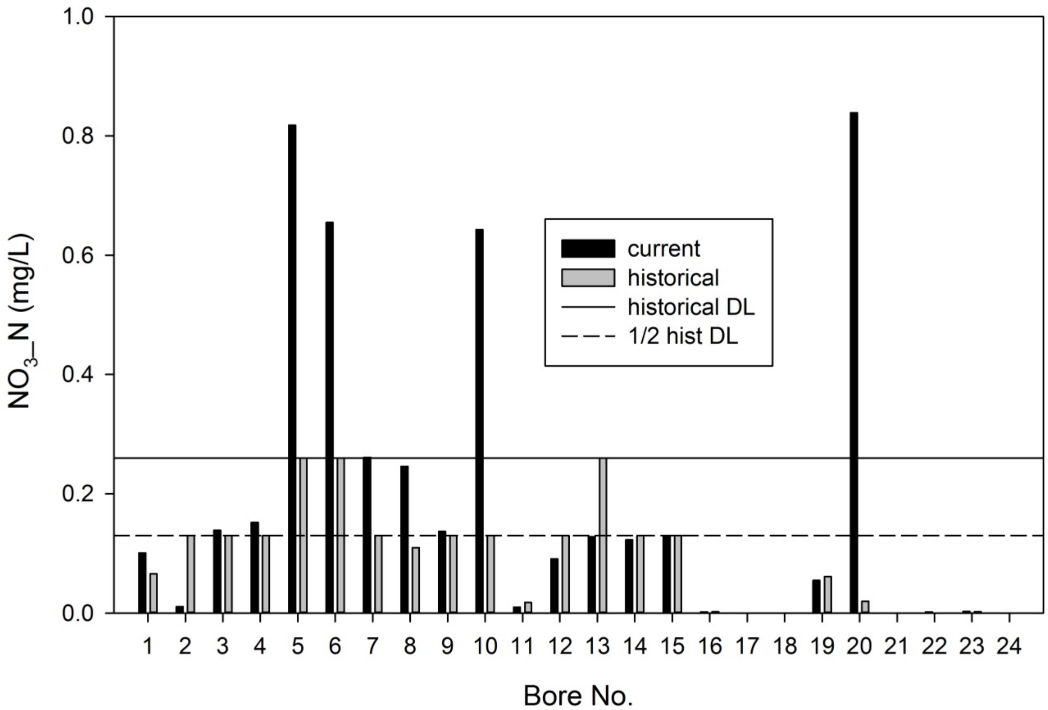

Figure 5. Comparison of historical (1968-2014) and current NO_3 concentrations in Darwin region bores. Where concentrations were below the detection limit, half the detection limit is shown**.**

5. Discussion

5.1. Pesticides and herbicides

The results of this survey show that there is currently very little contamination of groundwater in the Darwin rural area with herbicides or insecticides. Only eight different herbicides, insecticides or their derivatives were detected out of a total of approximately 180 substances that were tested for. All of the detected chemicals were found at very low concentrations that would have been undetectable prior to recent improvements to analytical methods. None of the samples exceeded environmental or drinking water quality guidelines where such guidelines exist.

The substances that were detected were highly mobile pesticides that are associated with a relatively high risk of leaching into groundwater because of their chemical properties. They are commonly found in groundwater in other regions of Australia, often in higher concentrations than those detected in this study (e.g. (Wightwick and Allinson 2007, Shaw et al. 2012))

Table 5 provides a brief description of some of the uses and properties of the chemicals that were detected in this study.

Table 5. Description of chemicals detected in Darwin rural bores

Chemical name	Description and main uses	Examples of trade names*
2,4-D	Common herbicide for the control of broadleaf weeds. It is also a breakdown product of 2,4-DB (see below)	Surefire Vortex Nufarm
2,4-DB	Common herbicide used to control broadleaf weeds	Relyon Empress
Bromacil	Herbicide used mainly to control perennial grasses. Often used in roadside weed control.	Uragan HYVAR
Desisopropyl Atrazine	Breakdown product of atrazine. Atrazine used to be one of the main herbicides used in Australia. Used before and after planting of crops to control broad-leaved weeds and grasses in crops such as sorghum, sugar cane, maize and canola. Also used in turf and non-agricultural sites such as lawns, industrial areas, rights-of-way and in orchards (APVMA 2008, US EPA 2014). Atrazine is a common contaminant of surface and groundwater in Eastern Australia (Shaw and Muller 2005) and has been banned in Europe after persistent contamination of groundwater was found (EC 2014)	Farmozine Nutrazine Gesaprim
Diuron	Broad-spectrum herbicide and algaecide used to control broadleaved and grass weeds in agriculture, around buildings and roads and to control weeds around waterbodies. A component of marine antifouling paint. Use has been restricted since a 2011 review to protect aquatic environments.	Di-RON Kenso Aqua One Algae Eliminator
Imidacloprid	Very widely used insecticide. Registered for use on a variety of crops to control aphis, mites, thrips and other insects in agriculture and gardening. Also used to control fleas and worms in pets. Highly water soluble with a high risk of leaching. Persistent in water in the absence of light. Can persist in groundwater for extended periods.	Confidor Advantage Kenso Agcare savage 350
MCPB	Herbicide to control broadleaf weeds in pastures	Nufarm MCPB-400
Mecoprop	Herbicide to control broadleaf weeds. Often used in combination with 2,4-D and other herbicides.	Nufarm Miracle-grow lawn food BARMAC
Tebuthiuron	A general herbicide that is commonly used to control weeds. It is slightly toxic to aquatic vertebrates and invertebrates at higher concentrations but has little potential to accumulate in the environment.	Farmalinx Graslan Tebulan

All herbicides and pesticides that were detected in this study were found in very few samples (3 or less). No spatial patterns of contamination could be discerned due to the small number of detections. The low concentrations and isolated occurrence of pesticides in groundwater of the Darwin region indicate that the low level contamination is only localised.

The exact source of the contamination cannot be determined by a survey of this kind. Pesticides and herbicides are an integral part of modern agricultural practices and are also widely used for infrastructure maintenance such as weed control around buildings and roads. With the widespread use of these chemicals it is almost inevitable that traces of them will make their way into the environment.

Two springs in the Howard East area (Howard Springs and Whitewood Jungle) were included in a study of Darwin springs that were tested for pesticides in 2014 (Schult 2014). Of the pesticides found in the groundwater, only diuron was detected in this previous study at an extremely low level.

The springs provide an integrated sample of groundwater from different areas. Since pesticides are not present throughout the entire aquifer, concentrations in the springs are expected to be lower due to a dilution effect.

5.2. Nitrate

Intensive agricultural land use and the application of fertilisers and manures is one of the most common sources of nitrate in groundwater throughout the world (Bolger and Stevens 1999). A review by Geoscience Australia (Sundaram and Coram 2009) found that elevated nitrate concentrations in Australia were generally found in areas surrounded by intensive agriculture.

Nitrate concentrations in the Darwin region are low in comparison to other regions of Australia where concentrations of up to 50 mg NO_3_N/L have been found in groundwater (Bolger and Stevens 1999). However, there was a high variability in nitrate concentrations in the Darwin rural area with levels ranging from 0.002 mg NO_3_N/L to 0.8 mg NO_3_N/L. This variability in indicates that nitrate concentrations are influenced by local surface processes.

There are natural sources of elevated nitrate in groundwater. For instance, nitrogen-fixing bacteria associated with termites have been identified as a major potential natural source of nitrate to groundwater in the Australian arid zone (Barnes et al. 1992)

However, significantly higher nitrate concentrations in the “non-mango” agricultural land use category indicate that the use of fertilisers may be having an impact on the local groundwater in these areas.

A comparison with historical data is confounded by the fact that historical detection limits were based on human health concerns and were much higher than the current standard for environmental purposes. Nevertheless, the fact that several agricultural sites had substantially increased NO_3 levels compared to historical measurements is another indication that agricultural practices may be having an impact on groundwater resources.

6. Conclusion

This survey was the first comprehensive study of groundwater quality in the Darwin rural area since the study by the Australian Geographical and Survey Organisation in 1995, which found no pesticides, though the survey used a higher detection limit.

Development and human activities in the region currently have a very small impact on groundwater quality. There is some localised low level contamination of groundwater with some pesticides and nitrate. The increased detection of pesticides compared to the previous survey in 1995 is entirely due to improvements in detection limits for pesticides since that time. These chemicals can now be detected at lower concentrations, which has increased the likelihood of detection.

The low level nitrate contamination of the groundwater is likely to be caused at least in part to human activities, including agricultural land use in the region.

The concentrations of both nitrate and pesticide contaminants are currently well below guidelines for health (nitrate) and environmental protection and are low in comparison with many other regions of Australia. However, any detection of aquifer contamination should serve as a reminder to apply best practice in the storage, application and disposal of any domestic and agricultural chemicals.

7. References

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Appendix A: List of analytes for pesticide/herbicide analysis.

Highlighted chemicals were detected in the Darwin rural area. LOR: Limit of Reporting

ID	Description	LoR (µg/L)	ANZECC	ADWG
	Herbs GCMS All			
KE34DA	3,4-Dichloroaniline	0.1		--
KEAM1	Ametryn (HBG)	0.1		70
KEAMIT	Amitraz (HBG)	0.1		9
KEATR1	Atrazine (HBG)	0.1		20
KEBROM	Bromacil (HBG)	0.1		400
KEDZ1	Desethyl Atrazine (HBG)	0.1		--
KEDOZ1	Desisopropyl Atrazine (HBG)	0.1		--
KEDICM	Diclofop-methyl (HBG)	0.1		5
KEFLZF	Fluazifop-butyl (HBG)	0.1		--
KEFLM1	Fluometuron (HBG)	0.1		70
KEHO2E	Haloxyfop-2-etotyl (HBG)	0.1		1
KEHOM	Haloxyfop-methyl (HBG)	0.1		1
KEHZ1	Hexazinone (HBG)	0.1		400
KEMETC	Metolachlor (HBG)	0.1		300
KEMRB	Metribuzin (HBG)	0.1		70
KEMOLN	Molinate (HBG)	0.1		4
	Organics Env. Lab #			--
KEOXYF	Oxyfluorfen (HBG)	0.1		--
KEPDM	Pendimethalin (HBG)	0.1		400
KEPM1	Prometryn (HBG)	0.1		--
KEPPNL	Propanil (HBG)	0.1		700
KEPPZN	Propazine (HBG)	0.1		50
KESM1	Simazine (HBG)	0.1		20
KETB1	Tebuthiuron (HBG)	0.1		--
KETBTZ	Terbuthylazine (HBG)	0.1		10
KETBTY	Terbutryn (HBG)	0.1		400
KETRIA	Triallate (HBG)	0.1		--
KETRIF	Trifluralin (HBG)	0.1		90
	Organochlorine Pesticides			
KEALD	Aldrin (OC)	0.1		0.3
KECLDC	Chlordane cis (OC)	0.1		2
KECLT	Chlordane Total (OC)	0.2		2
KECLDT	Chlordane trans (OC)	0.1		2
KECHL	Chlordene (OC)	0.1		--
KECHLE	Chlordene epoxide (OC)	0.1		--
KEC1H	Chlordene-1-hydroxy (OC)	0.1		--
KEC1H2	Chlordene-1-hydroxy-2,3-epoxide (OC)	0.1		--
KEDIC	Dicofol (OC)	1.5		4

ID	Description	LoR (µg/L)	ANZECC	ADWG
KEDIEL	Dieldrin (OC) new	0.1		0.3
KEENDA	Endosulfan Alpha (OC)	0.2		20
KEENDB	Endosulfan Beta (OC)	0.2		20
KEENDE	Endosulfan ether (OC)	0.1		--
KEENDL	Endosulfan lactone (OC)	0.5		--
KEENDS	Endosulfan sulfate (OC)	0.1		20
KEERIN	Endrin (OC)	0.2		--
KEERIA	Endrin aldehyde (OC)	0.1		--
KEHCB	HCB (OC)	0.2		--
KEHCHA	HCH alpha (OC)	0.1		--
KEHCHB	HCH beta (OC)	0.1		--
KEHCHD	HCH delta (OC)	0.1		--
KECBH	Heptachlor (OC)	0.1		0.3
KECBHE	Heptachlor epoxide (OC)	0.1		0.3
KEELD	Lindane (OC)	0.1		10
KEMET	Methoxychlor (OC)	0.1		300
KENONC	Nonachlor cis (OC)	0.1		--
KENONT	Nonachlor trans (OC)	0.1		--
KEODDD	o-p DDD (OC)	0.1		--
KEODDE	o-p DDE (OC)	0.1		--
KEODDT	o-p DDT (OC)	0.1		9
KELN	Organics Env. Lab #			--
KEOXC	Oxychlordane (OC)	0.1		2
KEPDDD	p-p DDD (OC)	0.1		9
KEPDDE	p-p DDE (OC)	0.1		9
KEPDDT	p-p DDT (OC)	0.1		9
KETAD	Total Aldrin & Dieldrin (OC)	0.2		0.3
KEDDT	Total DDT (OC)	0.4		9
KEEND	Total Endosulfan (OC)	0.6		20
KETHC	Total Heptachlor (OC)	0.2		0.3
	Organophosphate Pesticides			
KEAZPE	Azinphos-ethyl (OP)	0.1		--
KEAZPM	Azinphos-methyl (OP)	0.1		30
KEBMPE	Bromophos-ethyl (OP)	0.1		10
KECADS	Cadusafos (OP)	0.1		--
KECARP	Carbophenothion (OP)	0.1		0.5
KECHFV	Chlorfenvinphos (OP)	0.1		2
KECHP	Chlorpyrifos (OP)	0.1		10
KECHPO	Chlorpyrifos oxon (OP)	0.1		--
KECHPM	Chlorpyrifos-methyl (OP)	0.1		--
KECOUM	Coumaphos (OP)	0.1		--

ID	Description	LoR (µg/L)	ANZECC	ADWG
KEDEOM	Demeton-O-methyl	0.1		--
KEDEMT	Demeton-S 16315	0.1		--
KEDESM	Demeton-S-methyl (OP)	0.1		--
KEDIAZ	Diazinon (OP)	0.1		4
KEDICH	Dichlorvos (OP)	0.1		5
KEDIME	Dimethoate (OP)	0.1		7
KEDIOX	Dioxathion (OP)	0.1		--
KEDIS	Disulfoton (OP)	0.1		4
KEETHI	Ethion (OP)	0.1		4
KEETHP	Ethoprophos (OP)	0.1		1
KEETRI	Etrimphos (OP)	0.1		--
KEFAMP	Famphur (OP)	0.1		--
KEFENA	Fenamiphos (OP)	0.1		0.5
KEFENC	Fenchlorphos (OP)	0.1		30
KEFENI	Fenitrothion (OP)	0.1		7
KEFENM	Fenthion (methly) (OP)	0.1		7
KEFENE	Fenthion-ethyl (OP)	0.1		--
KEISOP	Isofenphos (OP)	0.1		--
KEMALA	Malathion (OP)	0.1		70
KEMETD	Methidathion (OP)	0.1		6
KEMEVI	Mevinphos (OP)	0.1		5
KEMCP	Monocrotophos (OP)	0.1		2
KEOME	Omethoate (OP)	0.2		1
KEOXDM	Oxydemeton-methyl (OP)	0.1		--
KEPARE	Parathion (ethyl) (OP)	0.1		--
KEPARM	Parathion-methyl (OP)	0.1		20
KEPHOR	Phorate (OP)	0.1		0.7
KEPHOS	Phosmet (OP)	0.1		--
KEPHOP	Phosphamidon (OP)	0.1		--
KEPIRM	Piromiphos-methyl (OP)	0.1		--
KEPROF	Profenofos (OP)	0.1		90
KEPROT	Prothiofos (OP)	0.1		0.3
KEPYRZ	Pyrazophos (OP)	0.1		--
KESUL	Sulprofos (OP)	0.1		20
KETEME	Temephos (OP)	0.1		10
KETERB	Terbufos (OP)	0.1		400
KETCVP	Tetrachlorvinphos (OP)	0.1		1
KEDIMT	Total Dimethoate (OP)	0.3		100
KEOTCG	**Other Compounds GCMS**			7
KE1HBZ	1H-Benzotriazole (OTCG)	0.7		
KE1HB1	1H-Benzotriazole, 1-methyl (OTCG)	0.1		--
KE1HB5	1H-Benzotriazole, 5-methyl (OTCG)	0.2		--
KE24DT	2,4-Di-t-butylphenol	0.1		--
KEDTBC	2,6-Di-t-butyl-p-cresol (OTCG)	0.1		--
KEDTBP	2,6-Di-t-butylphenol (OTCG)	0.3		--

ID	Description	LoR (µg/L)	ANZECC	ADWG
KE2B4C	2-Benzyl-4-chlorophenol	0.2		--
KECDMP	4-Chloro-3,5-dimethylphenol (OTCG)	0.1		--
KEBESA	Benzenesulfonanilide	0.2		--
KEGALA	Galaxolide (OTCG)	0.1		--
KEICAD	Icaridin	0.1		--
KEMOCL	Moclobemide (OTCG)	1		--
KEMSKK	Musk Ketone (OTCG)	0.1		--
KEMSKX	Musk Xylene (OTCG)	0.1		--
KENBBS	N-Butylbenzenesulfonamide (OTCG)	0.1		--
KENBTS	N-Butyltoluenesulfonamide (OTCG)	0.1		--
	Organics Env. Lab #			--
KETONL	Tonalid (OTCG)	0.1		--
KETNBP	Tri-n-butyl phosphate (OTCG)	0.1		--
KETRIC	Triclosan (OTCG)	0.1		--
KETCME	Triclosan methyl ether (OTCG)	0.1		--
KETEP	Triethyl phosphate (OTCG)	0.1		--
KETCEP	Tris(chloroethyl) phosphate (OTCG)	0.1		--
KETCPP	Tris(chloropropyl) phosphate isomersOTCG	0.1		--
KETDCP	Tris(dichloropropyl) phosphate (OTCG)	0.1		--
	Other Pesticides 1			--
KEBENA	Benalaxyl (OTP)	0.1		
KEBENC	Bendiocarb (OTP)	0.1		--
KEBITE	Bitertanol (OTP)	0.1		--
KECAPT	Captan (OTP)	0.1		--
KECARB	Carbaryl (OTP)	0.1		400
KEDEET	DEET (OTP)	0.1		30
KEDIMM	Dimethomorph (OTP)	0.2		--
KEWFIP	Fipronil (OTP)	0.1		--
KEFLTF	Flutriafol	0.1		0.7
KEFURA	Furalaxyl (OTP)	0.1		--
KEMLAX	Metalaxyl (OTP)	0.1		--
KEMETP	Methoprene (OTP)	0.1		--
	Organics Env. Lab #			--
KEOXAD	Oxadiazon (OTP)	0.1		--
KEPIPB	Piperonyl butoxide (OTP)	0.1		--
KEPIMC	Pirimicarb (OTP)	0.2		600
KEPRAQ	Praziquantel	0.1		7
KEPCYM	Procymidone (OTP)	0.1		--
KEPROG	Propargite (OTP)	0.1		--
KEPPIC	Propiconazole (OTP)	0.1		7
KEPROX	Propoxur (OTP)	0.1		100
KEROTN	Rotenone (OTP)	0.1		--
KETEBU	Tebuconazole (OTP)	0.1		--
KETDIF	Tetradifon (OTP)	0.1		--

ID	Description	LoR (µg/L)	ANZECC	ADWG
KETHIB	Thiabendazole (OTP)	0.2		--
KETTRM	Total Triadimefon (OTP)	0.3		--
KETRIM	Triadimefon (OTP)	0.1		90
KETRIN	Triadimenol (OTP)	0.1		90
KEVINC	Vinclozolin (OTP)	0.1		--
	Synthetic Pyrethroids 1			--
KEBIFN	Bifenthrin (SP)	0.1		
KEBIRM	Bioresmethrin (SP)	0.1		--
KECYFL	Cyfluthrin (SP)	0.1		100
KELAMC	Cyhalothrin (SP)	0.1		50
KECYPM	Cypermethrin (SP)	0.1		--
KEDELM	Deltamethrin (SP)	0.1		200
KEFENV	Fenvalerate (SP)	0.1		40
KEFLUV	Fluvalinate (SP)	0.1		60
	Organics Env. Lab #			--
KEPERM	Permethrin (SP)	0.1		**--**
KEPHEN	Phenothrin (SP)	0.1		200
KETETM	Tetramethrin (SP)	0.1		--
KETRAF	Transfluthrin (SP)	0.1		--
				--
	Water Glyphosate LCMS			
KEAMPL	Aminomethylphosphonic Acid (AMPA) LL	0.5		
KEGLUF	Glufosinate LL	0.5		--
KEGLYL	Glyphosate LL	0.5		--
KELN	**Organics Env. Lab #**			--
KETGLY	Total Glyphosate	1	370	--
				--
	Herbicides (low level)			
KHSP59	2,4-D (low)	0.004		
KHSP60	2,4-DB (low)	0.004		--
KHSP49	3,4-Dichloroaniline (low)	0.001		--
KHSP1J	Acetamiprid (Low)	0.001		--
KHSP61	Acifluorfen (low)	0.004		--
KHSP43	Ametryn (low)	0.001		--
KHSP44	Atrazine (low)	0.001	13	--
KHSP45	Bromacil (low)	0.001		--
KHSP62	Clomazone (low)	0.001		--
KHSP91	Clothianidin (low)	0.001		--
KHSP63	Cyanazine (low)	0.001		--
KHSP46	Desethyl Atrazine (low)	0.001		--
KHSP47	Desisopropyl Atrazine (low)	0.001		--
KHSP48	Diuron (low)	0.001		--
KHSP64	Ethametsulfuron methyl (low)	0.001		--
KHSP50	Fluometuron (low)	0.001		--

ID	Description	LoR (µg/L)	ANZECC	ADWG
KHSP65	Fluroxypyr (low)	0.01		--
KHSP66	Flusilazole (low)	0.001		--
KHSP67	Haloxyfop (acid) (low)	0.004		--
KHSP51	Hexazinone (low)	0.001		--
KHSP1C	Imazapic (Low)	0.001		--
KHSP1D	Imazapyr (Low)	0.001		--
KHSP68	Imazethapyr (low)	0.001		--
KHSP52	Imidacloprid (low)	0.001		--
KHSP89	Imidacloprid metabolites (low)	0.001		--
KHSP70	MCPA (low)	0.004		--
KHSP71	MCPB (low)	0.004		--
KHSP72	Mecoprop (low)	0.004		--
KHSP73	Mesosulfuron methyl (low)	0.001		--
KHSP1I	Methoxyfenozide (Low)	0.001		--
KHSP53	Metolachlor (low)	0.001		--
KHSP58	Metribuzin (Low)	0.001		--
KHSP74	Metsulfuron methyl (low)	0.001		--
KHSP1F	N-Demethyl Acetamiprid (Low)	0.001		--
KHSP75	Napropamide (low)	0.001		--
	Organics Env. Lab #			**--**
KHSP54	Prometryn (low)	0.001		--
KHSP76	Propachlor (low)	0.001		--
KHSP77	Propazin-2-hydroxy (low)	0.001		--
KHSP78	Sethoxydim (including Clethodim) (low)	0.008		--
KHSP55	Simazine (low)	0.001	3.2	--
KHSP79	Sulfosulfuron (low)	0.001		--
KHSP56	Tebuthiuron (low)	0.001	2.2	--
KHSP80	Terbuthylazine (low)	0.001		--
KHSP81	Terbuthylazine desethyl (low)	0.001		--
KHSP57	Terbutryn (low)	0.001		--
KHSP1G	Thiacloprid (Low)	0.001		--
KHSP92	Thiamethoxam (low)	0.001		--
KHSP1H	Total Acetamiprid (Low)	0.003		--
KHSP94	Total Diuron (low)	0.0		--
KHSP82	Total Imazapic (low)	0.05		--
KHSP90	Total Imidacloprid (low)	0.003		--
KHSP69	Total Isoxaflutole (low)	0.004		--
KHSP83	Triclopyr (low)	0.004		--
KHSP84	Trifloxysulfuron (low)	0.004		--

Appendix B: Raw field and lab results (nutrients and major ions)

Table 6. Field measurements of physico-chemical parameters. Ns: not measured

Site	Date	Time	Temp (deg C)	pH	DO (mg/L)	EC (uS/cm)	Tur (NTU)
RN006310	31/08/2016	14:49	29.6	7.59	ns	282	0.14
RN006962	31/08/2016	16:40	30.91	6.51	0.58	264	1.34
RN007048	30/08/2016	15:38	29.6	7.2	ns	273	0.1
RN007071	31/08/2016	15:40	29.9	7.46	ns	295	0.22
RN008803	29/08/2016	12:55	29.76	4.6	7.08	21	3.92
RN031410	30/08/2016	14:15	30.42	7.28	2.93	320	0.44
RN021390	30/08/2016	9:45	29.81	6.79	5.81	205	0.29
RN025232	30/08/2016	11:55	30.69	7.08	4.12	317	0.82
RN026686	29/08/2016	11:05	30.81	7.31	3.77	314	0.12
RN026767	31/08/2016	15:15	30.38	7.23	1.86	306	0.55
RN028032	1/09/2016	10:18	29.5	5.92	ns	89.8	21
RN029043	29/08/2016	9:50	31.48	6.12	0.34	144	28
RN029733	31/08/2016	10:00	31.23	7.53	6.3	283	0.16
RN030218	31/08/2016	18:37	30.17	4.5	2.79	18	0.7
RN031419	30/08/2016	11:20	30.9	7.32	ns	357	0.4
RN032300	1/09/2016	9:55	34.1	7.4	0.21	360	0.35
RN032490	31/08/2016	11:52	30.7	7.26	3.84	338	1.35
RN033786	1/09/2016	10:45	30.97	7.3	2.01	334	0.11
RN035313	31/08/2016	10:18	30.3	7.76	ns	313	0.27
RN035867	30/08/2016	14:47	31	4.38	ns	40.7	2.19
RN036488	30/08/2016	10:05	30.4	4.37	ns	30	4.98
RN036531	31/08/2016	12:32	30.4	7.33	ns	288	0.2
RN037417	29/08/2016	13:35	30.5	7.61	ns	295	0.22
RN037419	29/08/2016	15:36	32.8	5.45	ns	38.3	120

Table 7. Nutrient concentrations

Gcode	Date	Time	NH3_N (mg/L)	NO2_N (mg/L)	NO3_N (mg/L)	PO4_P (mg/L)
RN006310	31/08/2016	14:49	0.002	< 0.001	0.101	0.029
RN006962	31/08/2016	16:40	0.01	< 0.001	0.011	0.026
RN007048	30/08/2016	15:38	< 0.001	< 0.001	0.139	0.026
RN007071	31/08/2016	15:40	0.002	0.002	0.152	0.017
RN008803	29/08/2016	12:55	< 0.001	< 0.001	0.818	< 0.001
RN031410	30/08/2016	14:15	0.001	< 0.001	0.123	0.020
RN021390	30/08/2016	9:45	0.002	0.002	0.655	0.011
RN025232	30/08/2016	11:55	0.002	0.002	0.261	0.006
RN026686	29/08/2016	11:05	0.001	0.002	0.246	0.012
RN026767	31/08/2016	15:15	0.004	0.001	0.137	0.007
RN028032	1/09/2016	10:18	0.009	< 0.001	0.643	0.002
RN029043	29/08/2016	9:50	0.037	0.006	0.010	0.011
RN029733	31/08/2016	10:00	< 0.001	< 0.001	0.091	0.03
RN030218	31/08/2016	18:37	0.002	0.002	0.128	< 0.001
RN031419	30/08/2016	11:20	0.004	0.002	0.128	0.008
RN032300	1/09/2016	9:55	0.001	< 0.001	0.002	0.045
RN032490	31/08/2016	11:52	0.004	0.003	0.151	0.025
RN033786	1/09/2016	10:45	0.002	< 0.001	0.112	0.03
RN035313	31/08/2016	10:18	0.04	0.002	0.055	0.019
RN035867	30/08/2016	14:47	0.016	< 0.001	0.839	< 0.001
RN036488	30/08/2016	10:05	< 0.001	0.004	0.592	< 0.001
RN036531	31/08/2016	12:32	0.053	< 0.001	0.002	0.007
RN037417	29/08/2016	13:35	0.115	< 0.001	0.003	0.009
RN037419	29/08/2016	15:36	0.254	< 0.001	0.11	0.003

Table 8. Major cations and anions and general parameters

Site	Date	Time	pH	EC (µS/cm)	Alkali-nity	CO3 (mg/L)	HCO3 (mg/L)	OH (mg/L)	TDS (mg/L)	Cl (mg/L)	Si (mg/L)	Hard-ness	Ca_F (mg/L)	K_F (mg/L)	Mg_F (mg/L)	Na_F (mg/L)	SO4_F (mg/L)
RN006310	31/08/2016	14:49	7.8	266	148	<1	148	<1	170	3	8.8	148	19.6	0.2	24.1	2.1	1.3
RN006962	31/08/2016	16:40	7	266	143	<1	143	<1	170	3.6	13.6	106	22.8	2.8	11.9	18.3	1.2
RN007048	30/08/2016	15:38	7.6	244	132	<1	132	<1	150	3.3	9.6	134	24.9	0.3	17.5	2.1	1.2
RN007071	31/08/2016	15:40	7.7	278	153	<1	153	<1	180	3.4	11.1	155	30.2	0.3	19.3	2	1.5
RN008803	29/08/2016	12:55	5.1	30	1	<1	1	<1	20	2.5	5.5	0.7	<0.1	<0.1	0.2	2.7	<0.1
RN031410	30/08/2016	14:15	7.7	301	171	<1	171	<1	180	2.6	6.9	171	32.2	0.2	21.9	1.9	0.5
RN021390	30/08/2016	9:45	7.4	192	77	<1	77	<1	130	14.5	7.5	84.4	16.8	0.4	10.3	7.4	1.9
RN025232	30/08/2016	11:55	7.6	297	167	<1	167	<1	170	2.9	6.2	168	29.2	0.2	23	2.2	1
RN026686	29/08/2016	11:05	7.7	292	165	<1	165	<1	190	2.4	6.5	165	27.9	0.2	23.2	2	0.9
RN026767	31/08/2016	15:15	7.7	288	159	<1	159	<1	170	2.8	11.3	162	30.8	0.2	20.5	1.9	1.4
RN028032	1/09/2016	10:18	6.4	82	33	<1	33	<1	60	3.6	6.5	35.2	6.3	0.4	4.7	2.8	1.6
RN029043	29/08/2016	9:50	6.4	85	40	<1	40	<1	60	3.9	3.5	17.1	3.2	0.8	2.2	2.6	0.3
RN029733	31/08/2016	10:00	8	265	128	<1	128	<1	160	10.4	7.5	133	25.7	0.1	16.7	6.2	1.2
RN030218	31/08/2016	18:37	5	18	<1	<1	<1	<1	10	2.6	5.4	0.3	<0.1	<0.1	<0.1	1.8	<0.1
RN031419	30/08/2016	11:20	7.8	330	189	<1	189	<1	200	2.1	7.3	189	31.8	0.2	26.6	1.9	1.8
RN032300	1/09/2016	9:55	8	331	186	<1	186	<1	210	2.6	12.7	192	23	0.3	32.6	1.6	4.6
RN032490	31/08/2016	11:52	7.9	317	179	<1	179	<1	210	3.3	12.5	178	28	0.3	26.3	2.2	1.5
RN033786	1/09/2016	10:45	7.9	307	172	<1	172	<1	200	3.3	13.2	174	26.5	0.2	26.3	1.7	2.2
RN035313	31/08/2016	10:18	8.2	292	158	<1	158	<1	190	4	8.9	162	20	0.5	27.3	2.3	1.7
RN035867	30/08/2016	14:47	4.9	31	1	<1	1	<1	30	4.9	8.9	0.7	<0.1	0.1	0.1	3.7	<0.1
RN036488	30/08/2016	10:05	4.6	23	1	<1	1	<1	20	2.2	5.5	0.5	<0.1	<0.1	0.1	1.5	<0.1
RN036531	31/08/2016	12:32	7.9	268	150	<1	150	<1	160	2.7	6.6	150	29.5	<0.1	18.5	1.6	0.5
RN037417	29/08/2016	13:35	7.7	259	146	<1	146	<1	160	2.5	7.6	143	27	0.2	18.4	2.4	0.5
RN037419	29/08/2016	15:36	6.3	38	13	<1	13	<1	30	2.6	5.9	8.2	1.3	<0.1	1.2	1.9	0.2

Appendix C: Herbicide and pesticide concentrations in Darwin region bores and springs.

Table 9. Herbicide and pesticide concentrations in Darwin region bores.
Only chemicals that were detected at a minimum of one site are shown. For a full list of analytes see Appendix A.

		Pesticide concentrations (µg/L)							
Bore number	**NO3_N (mg/L)**	2,4-DB	Bromacil	Desisopropyl Atrazine (low)	Diuron	MCPB (low)	Mecoprop (low)	Tebuthiuron	Imidacloprid
DL	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003
Guideline value	11.4							2.2	
RN008803	0.818	ND	ND	ND	ND	ND	ND	ND	ND
RN021390	0.655	ND	ND	ND	ND	ND	ND	ND	ND
RN028032	0.643	ND	ND	ND	ND	ND	ND	ND	ND
RN029733	0.091	ND	ND	ND	ND	ND	ND	ND	**0.005**
RN007071	0.152	ND	ND	ND	ND	ND	ND	ND	ND
RN026686	0.246	**0.002**	ND	ND	ND	**0.002**	**0.002**	ND	ND
RN031410	0.123	ND	ND	ND	ND	ND	ND	ND	ND
RN031419	0.128	ND	ND	ND	ND	ND	ND	ND	ND
RN032300	0.002	ND	ND	ND	ND	ND	ND	ND	ND
RN032490	0.151	ND	ND	ND	ND	ND	ND	ND	ND
RN033786	0.112	ND	ND	**0.002**	ND	ND	ND	ND	ND
RN036488	0.592	ND	ND	ND	ND	ND	ND	ND	ND
RN006310	0.101	**0.001**	ND	ND	ND	**0.002**	ND	ND	ND
RN007048	0.139	ND	ND	ND	ND	ND	ND	ND	ND
RN035313	0.055	ND	ND	ND	ND	ND	ND	ND	ND
RN036531	0.002	ND	ND	ND	ND	ND	ND	ND	ND
RN037417	0.003	**0.001**	ND	ND	ND	ND	ND	ND	ND
RN037419	0.110	ND	ND	ND	ND	ND	ND	ND	ND
RN026767	0.137	ND	ND	ND	ND	ND	ND	ND	ND
RN035867	0.839	ND	**0.009**	ND	**0.004**	ND	ND	**0.016**	ND
RN006962	0.011	ND	ND	ND	ND	ND	ND	ND	ND
RN025232	0.261	ND	ND	ND	ND	ND	ND	ND	ND
RN029043	0.01	ND	ND	ND	ND	ND	ND	ND	ND
RN030218	0.128	ND	ND	ND	ND	ND	ND	ND	ND