Status Report

George Downes Drive, Mangrove Mountain

for Department of Trade and Investment, Regional Infrastructure and Services

Ref. SR_GeorgeDownesDr-rev1
May 2012

CMJA
C. M. Jewell & Associates Pty Ltd

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LIMITATIONS AND INTELLECTUAL PROPERTY

This report has been prepared by C. M. Jewell & Associates Pty Limited (CMJA) for the use of Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS), for the specific purpose described in the scope of works provided to CMJA by DTIRIS on 1 July 2010. The project objectives and scope of work were developed for that purpose, taking into consideration client requirements.

The work has been carried out, and this report prepared, utilising the standards of skill and care normally expected of professional scientists practising in the fields of hydrogeology and contaminated land management in Australia. The level of confidence of the conclusions reached is governed, as in all such work, by the scope of the investigation carried out and by the availability and quality of existing data. Where limitations or uncertainties in conclusions are known, they are identified in this report. However, no liability can be accepted for failure to identify conditions or issues which arise in the future and which could not reasonably have been assessed or predicted using the adopted scope of investigation and the data derived from that investigation.

Where data collected by others have been used to support the conclusions of this report, those data have been subjected to reasonable scrutiny but have essentially, and necessarily, been used in good faith. Liability cannot be accepted for errors in data collected by others.

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1.0 INTRODUCTION

In 1999, there was an outbreak of Newcastle Disease in the Mangrove Mountain region of NSW. To prevent the disease spreading, approximately two million chickens were destroyed, and their carcasses and shed litter were buried in three landfill pits, located at:

1. Bloodtree Road;
2. George Downes Drive; and
3. Waratah Road.

At Bloodtree Road and George Downes Drive, the chicken carcasses were placed in tar-lined shipping containers, which were then placed into the pits. There were some loose carcasses buried between the containers.

At Waratah Road, poultry shed litter and manure from the chickens were buried in the pit.

Between October 1998 and June 2000, in order to obtain information about baseline water quality (specifically for drinking water) and groundwater levels, Environmental Health Officers from the Central Coast Public Health Unit sampled a number of boreholes owned and operated by the Department of Land and Water Conservation (DLWC). These boreholes were part of the DLWC's monitoring borehole network in the Kulnura/Mangrove Mountain area, and had previously been used to monitor water levels.

Additionally, in 1999, Robert Carr & Associates Pty Ltd installed three monitoring boreholes at each landfill site so that baseline groundwater quality could be assessed prior to any possible impact of the chicken and shed litter burials. The three boreholes were generally positioned so that one was upgradient of the pit and two were downgradient.

From January 2001 to August 2005, groundwater investigations were conducted by Brink & Associates at the three landfill sites to determine whether any contaminants were leaching out of the pits. Works included standing water level monitoring, assessment of groundwater flow direction, and analysis of groundwater quality. Reports for these investigations showed that some analytical results exceeded the relevant standards and concentrations of contaminants fluctuated.

In 2006, the NSW Department of Primary Industries, now trading as the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) commissioned C. M. Jewell & Associates Pty Ltd (CMJA) to conduct the monitoring program at these sites for the next five years. Four sampling events were scheduled for the twelve months between September 2006 and August 2007, and two during the following twelve-month period. While groundwater monitoring was scheduled to reduce to an annual event, more frequent monitoring (quarterly) was maintained for a selected number of boreholes. These included the defined downgradient bore at each site and any additional bores where recent results required confirmation or further investigation.

By bringing together key groundwater and landfill gas information, this Status Report establishes a baseline against which future results can be compared. Moreover, it provides an assessment to assist in the interpretation of groundwater monitoring data.

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

2.0 BACKGROUND

2.1 George Downes Drive

The George Downes Drive pit is located on zoned rural land identified as Lot 2 in Deposited Plan 233808; and lies within Gosford City Council jurisdiction, in the parish of Kooree, in the county of Northumberland. It is positioned along the eastern boundary of the basalt or 'blue metal' quarry operated by Hymix, and is slightly west of George Downes Drive. Approximate Map Grid of Australia (MGA) Zone 56 co-ordinates for the centre of this location are 333922 m E and 6318807 m N.

2.2 Pit Excavation and Construction Details

As reported by Robert Carr & Associates Pty Ltd, the George Downes Drive carcass disposal pit was constructed by excavating a 50 metre long trench, which varied in depth between 6 and 8 metres. The excavation was unlined but natural clays were observed at the base of the excavation.

An estimated one million chickens were placed in the pit, predominantly in shipping containers; some chickens were also placed between the containers. A total of 45 tar-lined steel shipping containers were used. The pit was then capped with 3 metres of clay, which was then covered with basalt aggregate up to boulder size.

2.3 Installation of Boreholes

As identified in Section 1.0, Robert Carr & Associates Pty Ltd installed three boreholes (BH4, BH5 and BH6) around the pit at depths between 34 and 36 metres. Monitoring bore BH4H was later installed close to the western edge of the pit, to act as an 'early warning' bore.

Standing water levels (SWLs) in BH4, BH5 and BH6 were measured by Robert Carr & Associates Pty Ltd and by Brink & Associates Pty Ltd on thirty occasions between May 1999 and April 2004. The reports prepared by these companies also included an assessment of groundwater flow direction based on survey and standing water level data and groundwater quality.

The location of monitoring bore BH5 is downgradient of the pit, while BH4 and BH6 are considered to be upgradient given the RWL data and location of the pit. In 2007, monitoring bore BH7 was installed upgradient of the pit to replace the poorly designed bore BH4H (see Section 8.1 for further discussion).

2.4 Geology

The site and surrounding districts lie on the Hornsby Plateau, which is underlain by flat-lying sedimentary rocks belonging to the Middle Triassic Hawkesbury Sandstone. This formation consists predominantly of medium to coarse grained quartz sandstone with numerous thin interbedded mudstone and shale units. Interbeds of very fine to medium grained sandstone also occur in some units.

2.5 Hydrogeology - Regional

Some zones that allow groundwater flow (aquifers) are present within the Hawkesbury Sandstone in the Mangrove Mountain area, mostly at depths of between 10 and 50 metres. Water quality in these aquifers is generally good, with low salinity and hardness, although the water is often slightly acidic. A natural high iron content is also often present, and there has been some diffuse regional contamination by nitrates due to agricultural land use.

2.6 Hydrogeology - Local

Local groundwater flow is largely controlled by the topography and by the location of more permeable and porous sandstone horizons, which constitute the major water storage units. Enhanced hydraulic conductivity is, however, dependent on the occurrence of both vertical and horizontal structural discontinuities such as joints and bedding plane fractures. Fracturing, which may be present on a regional scale, is a major component of the aquifer's transmissivity, and a minor component of the aquifer's storage. The occurrence of structural discontinuities suggests that variable hydrogeological conditions exist in the Mangrove Mountain area; this can make the analysis of groundwater flow more difficult.

Numerous springs in the area feed the local creeks.

3.0 CONTAMINANTS OF CONCERN AND APPLICABLE CRITERIA

3.1 Contaminants of Concern

For the assessment of general water quality at George Downes Drive, DTIRIS selected the following suite of analytes.

- pH
- total dissolved solids (TDS)
- major cations (sodium, potassium, magnesium and calcium)
- major anions (sulphate, chloride and bicarbonate)
- redox potential
- biological oxygen demand (BOD)
- dissolved oxygen
- electrical conductivity (EC)

For the assessment of nutrient load resulting from the decomposition of the carcasses and litter, the following analytes were selected:

- nitrate
- nitrite
- ammonia
- Total Kjeldahl Nitrogen (TKN)
- Total nitrogen as N
- Total phosphorus as P

In order to assess whether the metal containers containing the carcasses had corroded, the following metals were identified as suitable analytes:

- copper
- cadmium
- chromium
- lead
- nickel
- zinc
- iron

3.2 Criteria for Groundwater Quality Assessment

For the assessment of potential environmental impacts arising from the interaction of groundwater with freshwater aquatic ecosystems (a relevant issue at Mangrove Mountain), the appropriate criteria are those trigger values set for the protection of 95 per cent of species in fresh water and listed in Table 3.4.1 of ANZECC's *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000).

Note: The ANZECC (2000) **Trigger Values for the Protection of Freshwater Aquatic Ecosystems (95% level of protection)** were developed for surface waters, not groundwater. However, the NSW Environment Protection Authority (EPA) Guidelines for the Assessment and Management of Groundwater Contamination indicate that these triggers should be used as Groundwater Investigation Levels (GILs). The EPA guidelines also state that exceedances of GILs only indicate a need for detailed assessment. This is because natural background concentrations, diffuse regional contamination, the fate and transport of contaminants in groundwater, and potential exposure pathways must all be considered. For example, there is diffuse regional contamination by nitrates from other sources in the Mangrove Mountain area.

For the assessment of potential human health issues relating to the consumption of bore water in the area, the appropriate criteria are found within the Health Guidelines in *Australian Drinking Water Guidelines* (ADWG) (2004), prepared by the National Health and Medical Research Council (NHMRC) in collaboration with the Natural Resource Management Ministerial Council (NRMMC). These levels relate specifically to water that is to be used for human consumption, and although they do not represent mandatory standards for the quality of water for human consumption, they do offer a framework for identifying acceptable water quality.

The relevant criteria for both human health and environmental concerns are presented in Table 1.

Trigger values included in Table 1 are the values applying to slightly–moderately disturbed systems, and have been derived for use in assessing surface waters. In the absence of specific levels for groundwater, the surface-water trigger values have been used.

TABLE 1
Criteria for Groundwater Quality Assessment

Analyte	Drinking Water Health Guidelines ‡‡ (mg/L)	Trigger Values for the Protection of Freshwater Aquatic Ecosystems ‡ (mg/L)
pH (field + laboratory)	6.5 – 8.5	6.5 – 7.5
TDS	500+	-
Sodium	180+	-
Chloride	250+	-
Sulphate	500	-
Ammonia (as nitrogen)	0.4+#	0.9
Nitrate (as nitrogen)	11#	0.158#
Nitrite (as nitrogen)	0.9#	-
Arsenic (total)	0.007	
Arsenic (As III)	-	0.024
Arsenic (As V)	-	0.013
Cadmium	0.002	0.0002
Chromium (Cr III)	-	0.0033*
Chromium (Cr VI)	0.05	0.001^
Copper	2	0.0014
Iron	0.3+	0.3*
Lead	0.01	0.0034
Nickel	0.02	0.011
Zinc	3+	0.008

Notes:
‡‡ NHMRC 2004
‡ ANZECC 2000
* Low reliability figures which should only be used as indicative interim working levels
\+ Aesthetic value (in the absence of a human health value)
^ Figure may not protect key species from chronic toxicity
\# Trigger value calculated based on atomic weight of nitrogen
\- No criteria currently available

4.0 REVIEW OF GROUNDWATER FLOW AND STANDING WATER LEVELS

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

George Downes Drive traverses a ridge that forms the catchment divide between Ourimbah Creek catchment to the east and the Mangrove Creek catchment to the west. The landfill is located in the drainage line of Mangrove Creek.

Table 2 presents the location, elevation and last recorded SWL (October 2011) of the groundwater monitoring bores on site. *Note:* BH4H was decommissioned in August 2007.

TABLE 2
Borehole Details - October 2011

Borehole ID	Easting	Northing	Elevation of Top of Well Casing (mAHD)	SWL (mTOC)	RWL (mAHD)
BH4	320150	1318760	316.962	30.59	286.37
BH4H	320089	1318781	311.392	-	-
BH5	320088	1318822	309.365	23.32	286.05
BH6	320067	1318767	310.041	21.08	288.96
BH7	320089	1318777	311.700	24.94	286.76

In Table 2 above, the SWL is shown first as metres below the top of the well casing (mTOC), and then as a reduced water level (RWL) in metres above Australian Height Datum (AHD). The RWL (mAHD) is calculated by subtracting the SWL (mTOC) from the elevation of the surveyed point at the top of the well casing.

Based on RWL data, BH7 is considered to be the upgradient well, while BH5 is positioned downgradient.

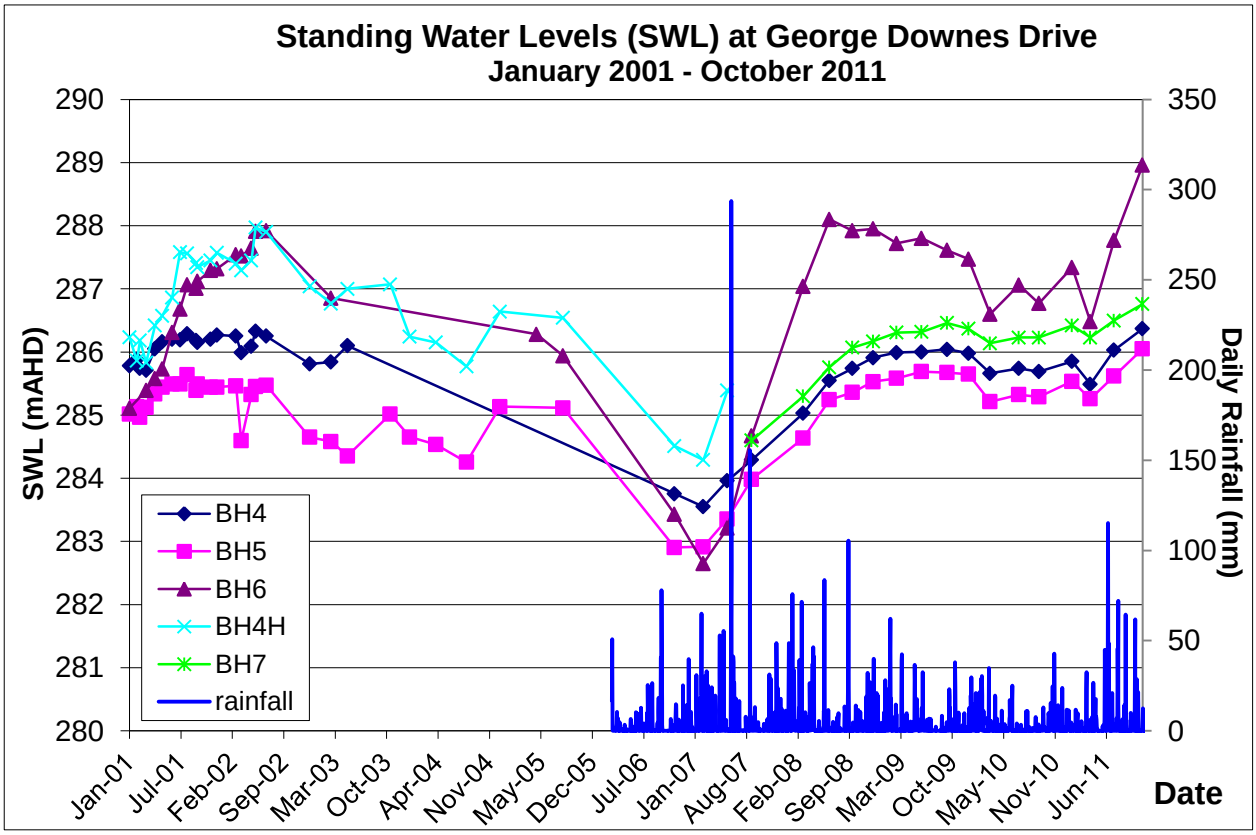

Figure 1: Reduced Water Levels - January 2001 to October 2011

Figure 1 shows long-term reduced water levels (mAHD) trends in the five groundwater monitoring boreholes at George Downes Drive. It confirms that the groundwater level in the upgradient bores, BH6 and BH7 (located west of the landfill) are consistently higher in elevation than groundwater levels in the two downgradient bores (BH4 and BH5).

The RWL in BH6 fluctuates significantly in comparison the other groundwater boreholes on site; however, the reason behind this pattern is not completely understood. Poor borehole construction could be a logical explanation, as was the case with BH4H where perched water was shown to be entering the well at a higher level than the regional aquifer. The bentonite seal or casing in BH6 may not be successfully sealing the annulus of the borehole from perched groundwater. The fluctuation could also be related to the high permeability of the sandstones around BH6, which facilitates more rapid percolation through to the water table.

As previously indicated, the RWL in BH4H was higher as the screen intersects different aquifers.

Figure 2: Groundwater Flow Direction relative to the Burial Pit and Borehole Locations

As shown on Figure 2, the groundwater flow direction at the George Downes Drive landfill is to the north-east, at a hydraulic gradient of 0.02. The hydraulic gradient on site has been relatively consistent throughout the monitoring period.

Note: The groundwater flow direction is perpendicular to the contour lines.

5.0 WATER QUALITY: LONG-TERM TRENDS

The following paragraphs contain a discussion of long-term trends in concentrations of key analytes, identifying concentration fluctuations and any exceedances of the criteria listed in Table 1, with a comparison between upgradient and downgradient bores from 1999 to 2011.

There is a particular focus on the 'downgradient bore' BH5, because the quality of groundwater leaving the pit is of most concern.

5.1 Total Dissolved Solids

The total dissolved solids (TDS) concentration in groundwater is a measure of the combined inorganic and organic substances dissolved in a molecular, ionised or fine colloidal form, it is not therefore directly associated with any one analyte. TDS data thus provides an indication of fluctuations in the chemical composition of groundwater.

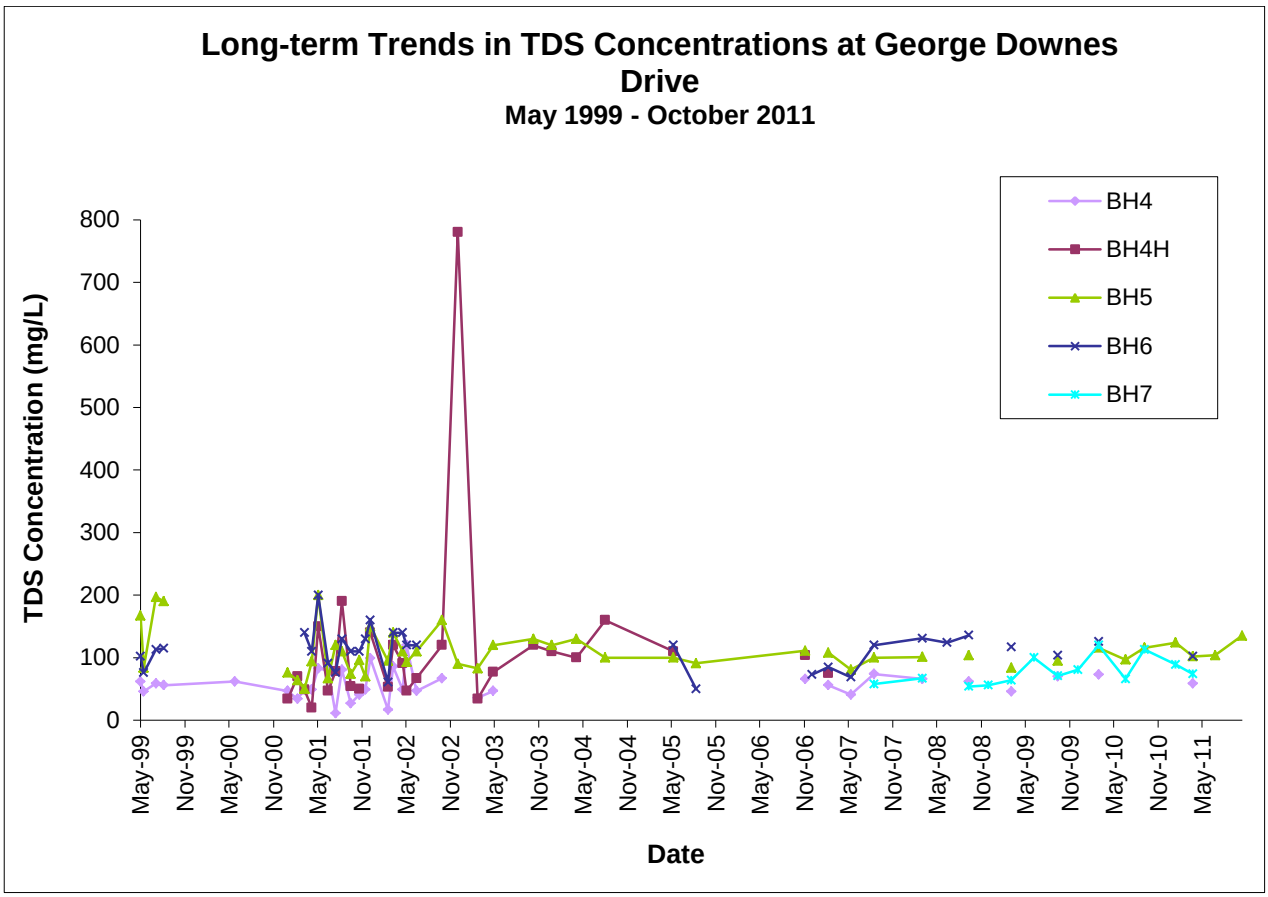

Figure 3: Long-term Trends of TDS - May 1999 to October 2011

As shown in Figure 3, TDS concentrations in groundwater throughout the monitoring period were typically below the ADWG (2004).

The 'spike' in TDS concentration in BH4H exceeded the current ADWG (2004) in the December 2002 monitoring event, for which a concentration of 780 mg/L was reported. This high concentration of TDS appears not to be associated with a significant change in any other analyte, and may reflect an error.
Note: This anomalous exceedance was reported by Brink & Associates Pty Ltd.

5.2 Nutrients

Nitrogen and phosphorus concentrations at the George Downes Drive landfill have been analysed since groundwater monitoring commenced in 1999. An assessment of these concentrations in groundwater is important because nitrogen and phosphorus are released during the decomposition of carcasses; their presence in groundwater could indicate migration of leachate.

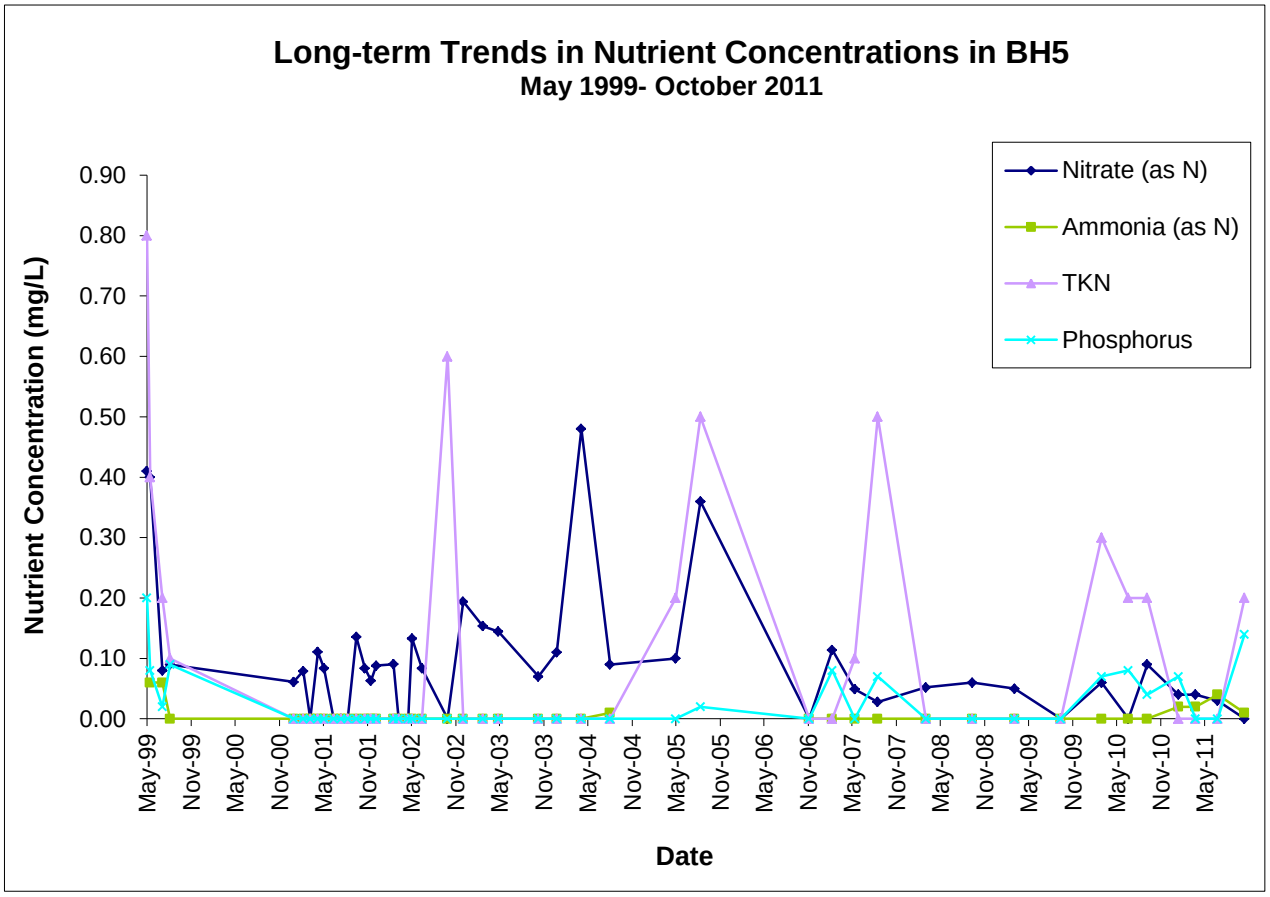

Figure 4: Long-term Trends of Nutrient Concentrations in BH5 – May 1999 to October 2011

Nitrate

Nitrate is a water-soluble molecule made up of nitrogen and oxygen.

Common sources of nitrate in the environment include fertilizers, 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.

Note: Samples taken between January 2001 and August 2005 were analysed for nitrate concentration using Ion Chromatography, while analysis carried out from November 2006 to 2011 was conducted using a Discrete Analyser. When analysing groundwater, most laboratories report nitrate as nitrogen (nitrate as N) because this allows easy comparison with other forms of nitrogen. However, the reporting units from January 2001 to May 2003 are presumed to be nitrate (as nitrate), whilst the units in 1999 and from October 2003 to 2011 are nitrate (as nitrogen). The closure of the laboratory that analysed samples from 2001 to 2003 means that this assumption cannot be confirmed.

To assess the long-term nitrate (as nitrogen) concentration trends, those concentrations reported in samples obtained from January 2001 to May 2003 have been converted to nitrate (as nitrogen), and results presented in Figure 4.

As shown on Figure 4, nitrate concentrations in BH5 ranged from <0.01 to 0.48 mg/L, and concentrations appear to be decreasing from August 2005.

Concentrations of nitrate have exceeded the ANZECC Guidelines (2000) in all four boreholes at George Downes Drive throughout the monitoring period. However, these results are indicative of a regional problem, most probably due to the intensive agricultural land use around Mangrove Mountain. If nitrate were originating from the pit, nitrate concentrations are expected to be higher in boreholes downgradient of the pit given the likely high nitrogen content of material in the pit.

Ammonia

Ammonia is a molecule made up of nitrogen and hydrogen. When analysing groundwater, most laboratories report ammonia as nitrogen (ammonia as N) to allow easy comparison with other forms of nitrogen.

Ammonia is naturally occurring, being produced through the decay processes of animal and vegetable matter. Other sources of ammonia can be anthropogenic e.g. livestock farming practices, sewage (including septic systems). Ammonia can be very toxic to aquatic organisms; this toxicity is pH dependent. Ammonia is also a nutrient and oxidises to nitrate in surface water. Its presence can contribute to eutrophication of natural waters.

As shown in Figure 4, ammonia (as nitrogen) concentrations in BH5 ranged from below the limit of reporting (LOR) to 0.06 mg/L. Ammonia is not considered to be of concern at George Downes Drive, remaining below the appropriate criteria in all groundwater monitoring boreholes.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a sum of all organic nitrogen and ammonia in a given groundwater sample.

Throughout the monitoring period, TKN concentrations in BH5 have ranged from below the LOR to 0.6 mg/L.

Phosphorus

Phosphorus is a non-metal that is a vital plant nutrient and its main use, as phosphate compounds, is in the production of fertilizers.

As it is a plant nutrient, excess phosphorus in surface water can result in excessive algal and water weed growth, and in eutrophication. Phosphorus does tend to bind 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.

The concentration of total phosphorus in BH5 throughout the monitoring period, varied from below the LOR to 0.2 mg/L.

5.3 Heavy Metals

To assess the condition of the metal containers containing the chicken carcasses, heavy metals were incorporated into the suite of analytes. Although some heavy metals are necessary in small amounts for normal biological processes, many become toxic at high concentrations. Heavy metals can enter the environment both naturally (e.g. through rock weathering processes) and anthropogenically (e.g. agricultural practices, transport, industrial activities and waste disposal). Unlike organic wastes, heavy metals are not biodegradable, and some have the ability to accumulate in the environment and in living tissue.

Heavy metals generally occur in very low concentrations and are reported in micrograms per litre (µg/L) as opposed to milligrams per litre (mg/L).

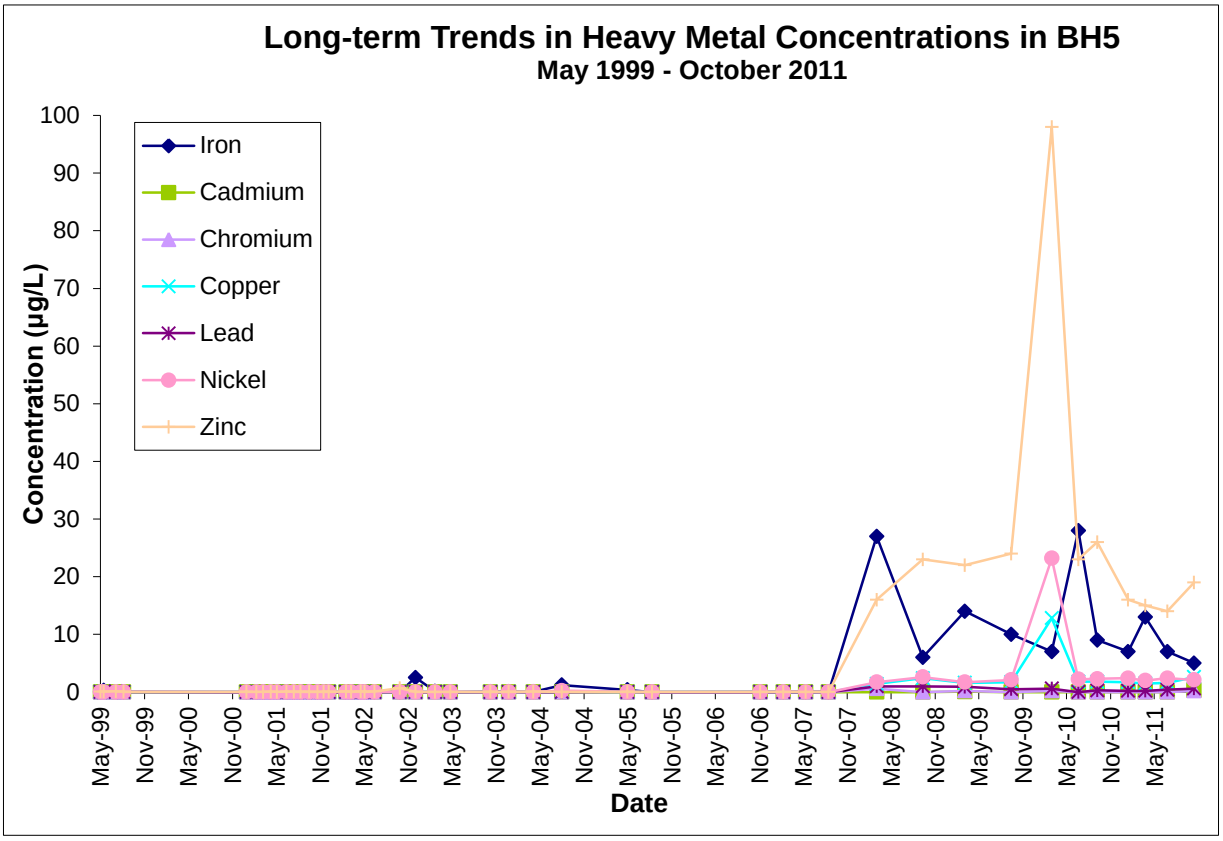

Figure 5: Long-term Trends of Heavy Metals in BH5 - May 1999 to October 2011

As shown in Figure 5, concentrations of zinc in BH5 range from below the LOR to 98 µg/L. However, the concentration of zinc in groundwater at George Downes Drive is typically below the ANZECC (2000) trigger value for the protection of freshwater ecosystems at the 95% species protection level.

However, the concentration of zinc in BH5 has been above the assessment criteria since March 2008, ranging from 15 µg/L to 98 µg/L. This trend in zinc concentrations is consistent across all other monitoring wells on site.

Note: The LOR for iron between 1999 and 2005 was either 50 µg/L or 100 µg/L. If a concentration of iron was reported below the LOR, the value could not be graphed on Figure 5.

Nickel and copper concentrations in BH5 exceeded the ANZECC Guidelines in the March 2010 groundwater monitoring event. These spikes of dissolved metals were considered to be anomalous, as concentrations significantly dropped following that event.

Copper concentrations within groundwater sampled from BH6 have typically been above the criteria throughout the monitoring period, with exceeding concentrations ranging from 1.9 µg/L to 29 µg/L. The maximum concentration reported in BH7 was 9.2 µg/L in August 2007.

Overall, heavy metals in groundwater are not considered to be of concern at the George Downes Drive landfill.

6.0 WATER QUALITY: RECENT TRENDS

The following paragraphs contain a discussion of recent trends in concentrations of key analytes, identifying concentration fluctuations and exceedances of the criteria listed in Table 1, with a comparison between upgradient and downgradient bores from 2006 to 2011.

There is a particular focus on the downgradient bore BH5, as this is most likely to reflect the influence of the burial pit.

6.1 Total Dissolved Solids

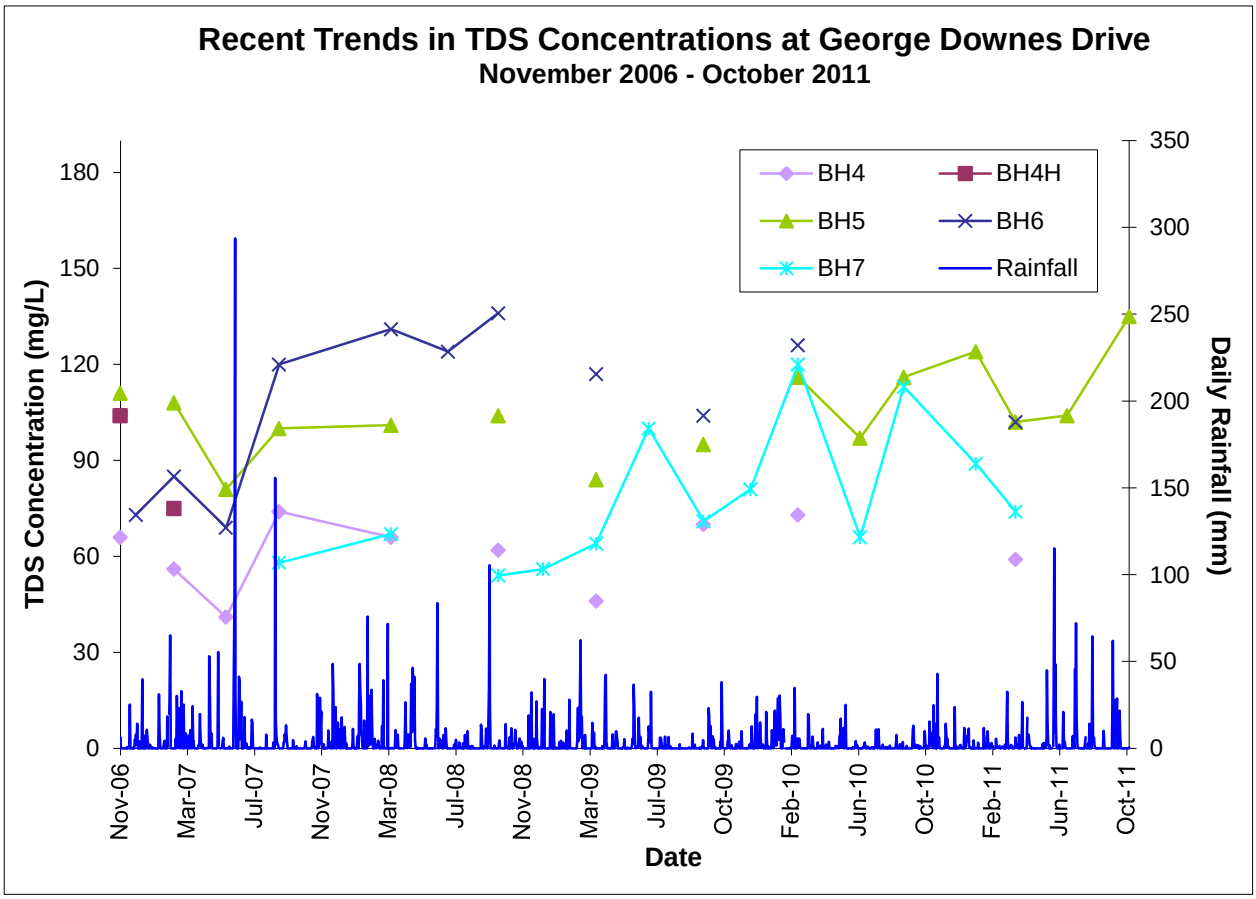

Figure 6: Recent Trends of TDS - November 2006 to October 2011

As presented in Figure 6, TDS concentrations in groundwater from all four boreholes on site have been below the ADWG (2004) from November 2006 to October 2011.

Recent TDS concentrations ranged from 41 mg/L in BH4 to 136 mg/L in BH6. From the analytical results shown on Figure 6, it is considered that there is no correlation between borehole location (upgradient or downgradient) and TDS concentration.

6.2 Nutrients

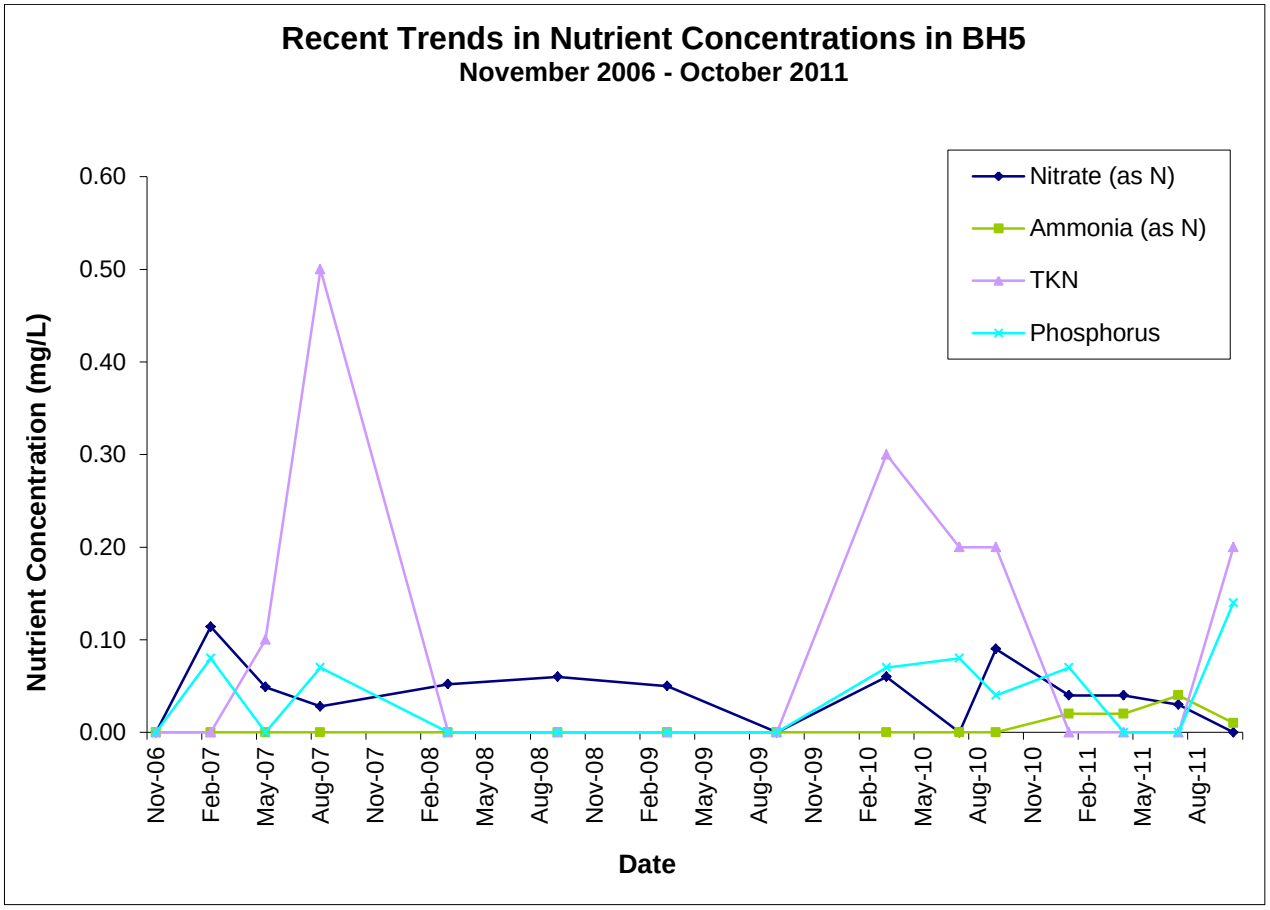

Figure 7: Recent Trends in Nutrient Concentrations in BH5 - November 2006 to October 2011

As shown on Figure 7, recent concentrations of nitrate in BH5 are below the guidelines for the protection of freshwater ecosystems at the 95% species protection level, ranging from below the LOR to 0.11 mg/L.

Ammonia in groundwater is largely undetected at George Downes Drive; where it has been detected, concentrations are within the adopted criteria.

Recent concentrations of TKN ranged from below the LOR to 0.5 mg/L, while concentrations of phosphorus ranged from below the LOR to 0.14 mg/L.

6.3 Heavy Metals

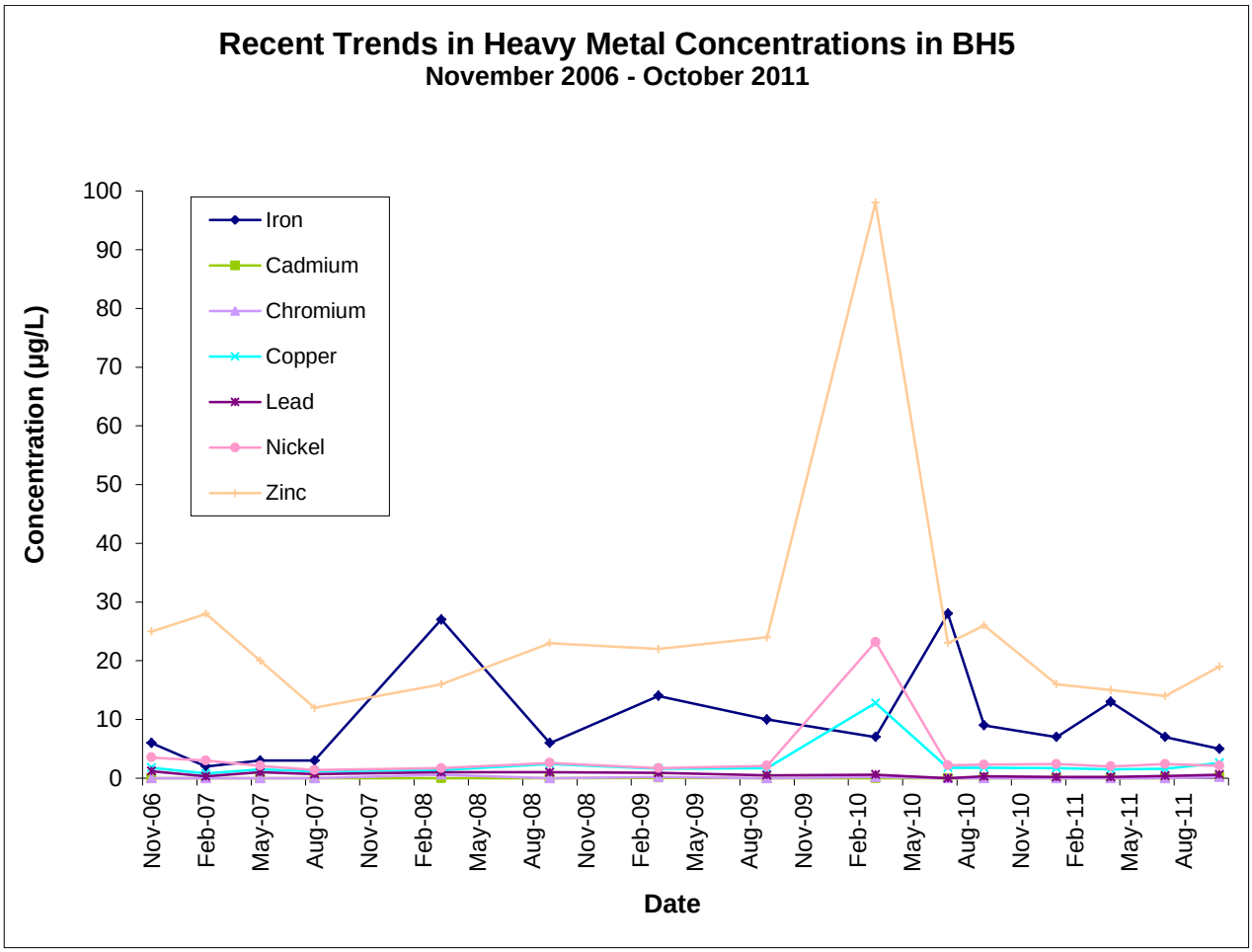

Figure 8: Recent Trends of Heavy Metals in BH5 – November 2006 to October 2011

As shown on Figure 8, zinc concentrations in BH5 have exceeded the freshwater ecosystem guidelines at the 95% species protection level since November 2006. Over this period, concentrations of zinc in BH5 have ranged from 12 µg/L to 98 µg/L.

The highest concentrations of zinc reported in BH6 and BH7 were 166 µg/L and 158 µg/L, respectively.

All other heavy metals (i.e. nickel, copper and iron) have been measured in BH5 at concentrations typically below the criteria.

7.0 SUMMARY OF EXCEEDANCES IN RECENT AND LONG-TERM MONITORING EVENTS

As previously discussed in Section 3.0, all analytical results are compared to relevant criteria to assess groundwater quality. Specifically, the ANZECC Guidelines are used as a decision-making tool to guide further sampling, while the ADWG are used to assess risk to down-gradient human receptors.

Although the ANZECC (2000) Trigger Values for the Protection of Freshwater Aquatic Ecosystems were developed for surface waters, not groundwater, they are used as a benchmark in the analysis of groundwater quality, because groundwater discharges to surface water systems.

7.1 pH

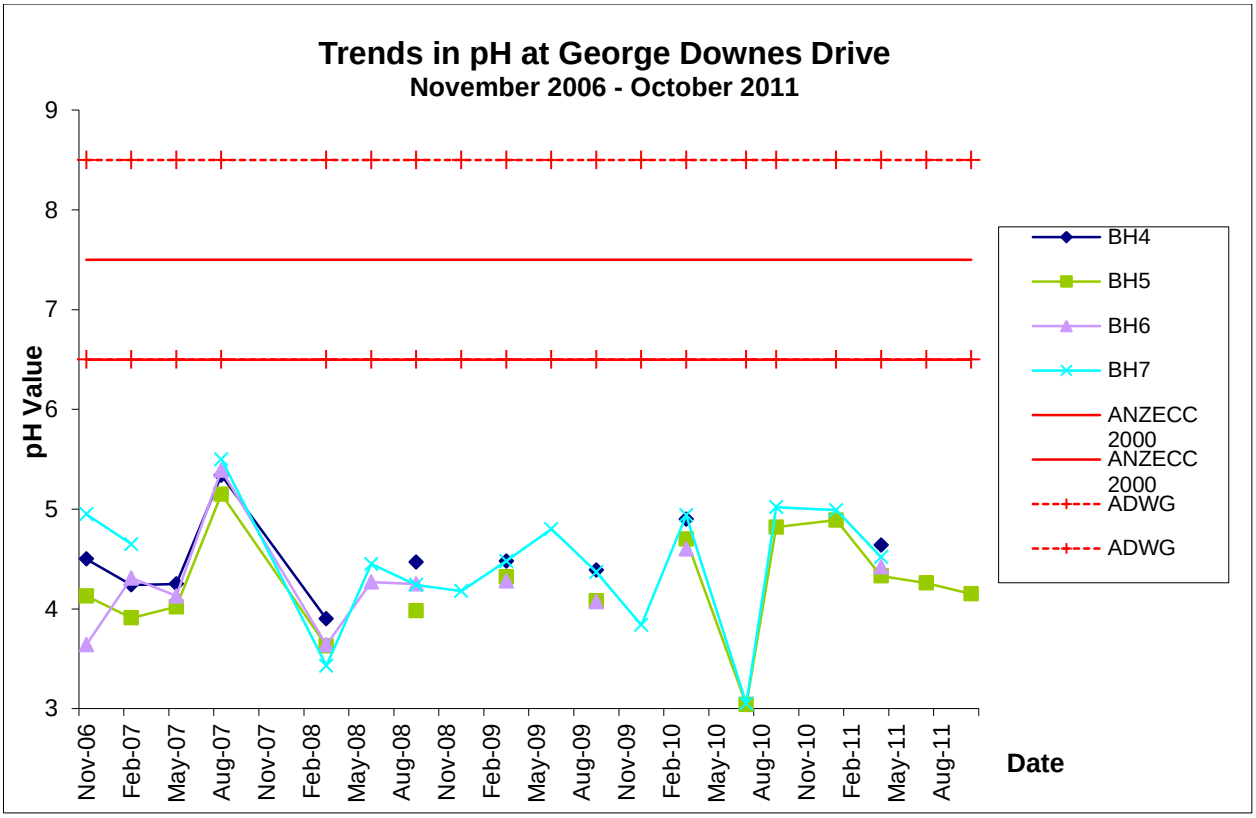

Figure 9: Trends in pH - November 2006 to October 2011

Groundwater at George Downes Drive and at Mangrove Mountain, is generally considered to be slightly acidic, which is common in groundwater associated with the Hawkesbury Sandstone formation.

As seen in Figure 9, in all four groundwater monitoring boreholes, pH values have continuously remained outside the guideline values set by the ADWG (2004) and the ANZECC 2000 Fresh Water Guidelines at the 95% species protection level. The pH of groundwater between 2006 and 2011 has ranged from 3.04 (BH5) to 5.5 (BH7).

It has been noted that pH increases slightly following periods of heavy rainfall, as an influx of fresh water mixes with the groundwater.

7.2 Nitrate as Nitrogen

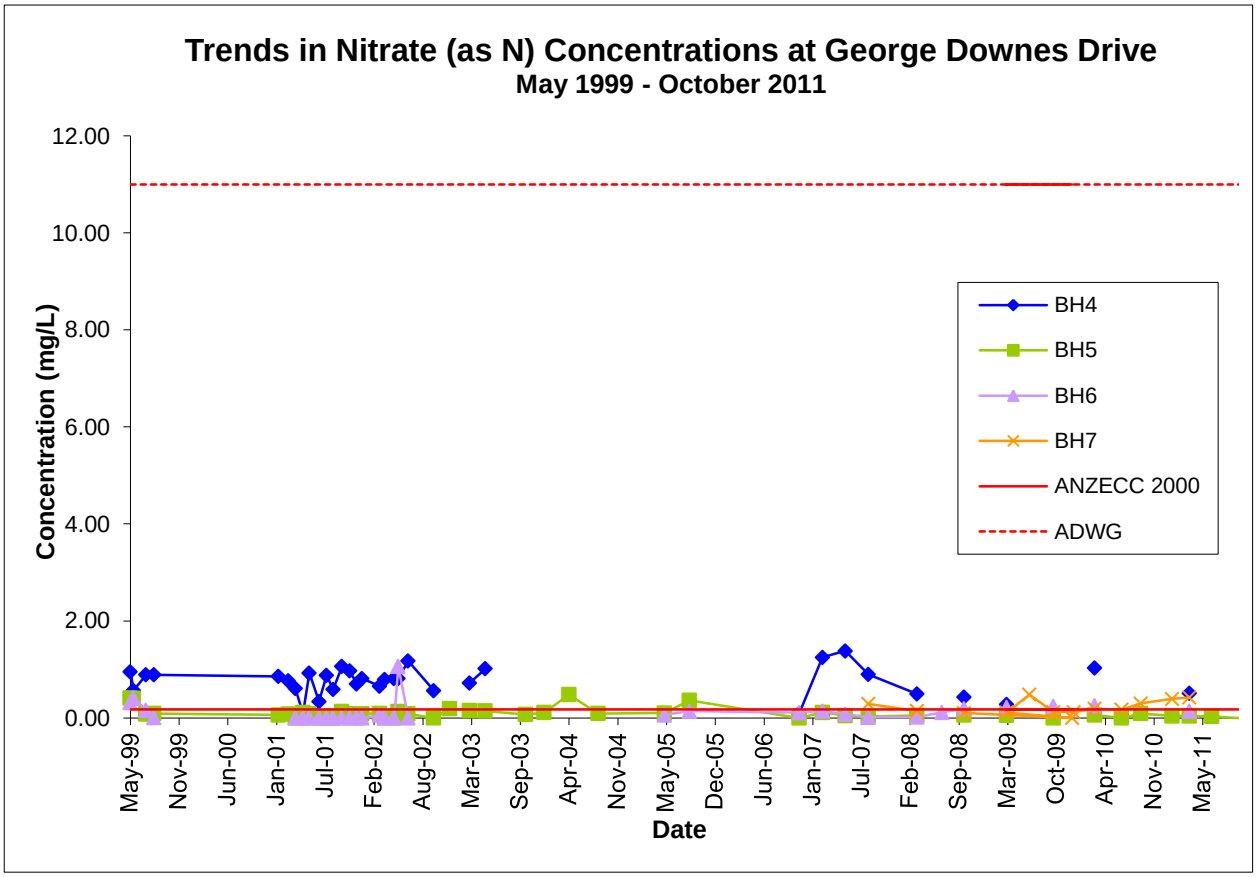

Figure 10: Trends in Nitrate (as N) Concentrations – May 1999 to October 2011

Since monitoring began in 1999, detected concentrations of nitrate in groundwater have remained below the ADWG (2004) value of 11 mg/L in all four monitoring boreholes at George Downes Drive.

However, the recorded concentrations of nitrate in all boreholes at George Downes Drive have exceeded the ANZECC 2000 fresh water guideline value of 0.158 mg/L (95% species protection level). The highest concentration of nitrate reported throughout the monitoring period is 1.38 mg/L, reported in the upgradient well BH4. As seen in Figure 10, concentrations of nitrate in groundwater at BH4 are typically higher than those boreholes downgradient.

These results are indicative of regional levels, and not associated with the landfill. The elevated nitrate concentration is likely due to the intensive agricultural land use around Mangrove Mountain.

Concentrations of nitrate in BH5, BH6 and BH7 are typically below the ANZECC (2000) guidelines.

7.3 Zinc

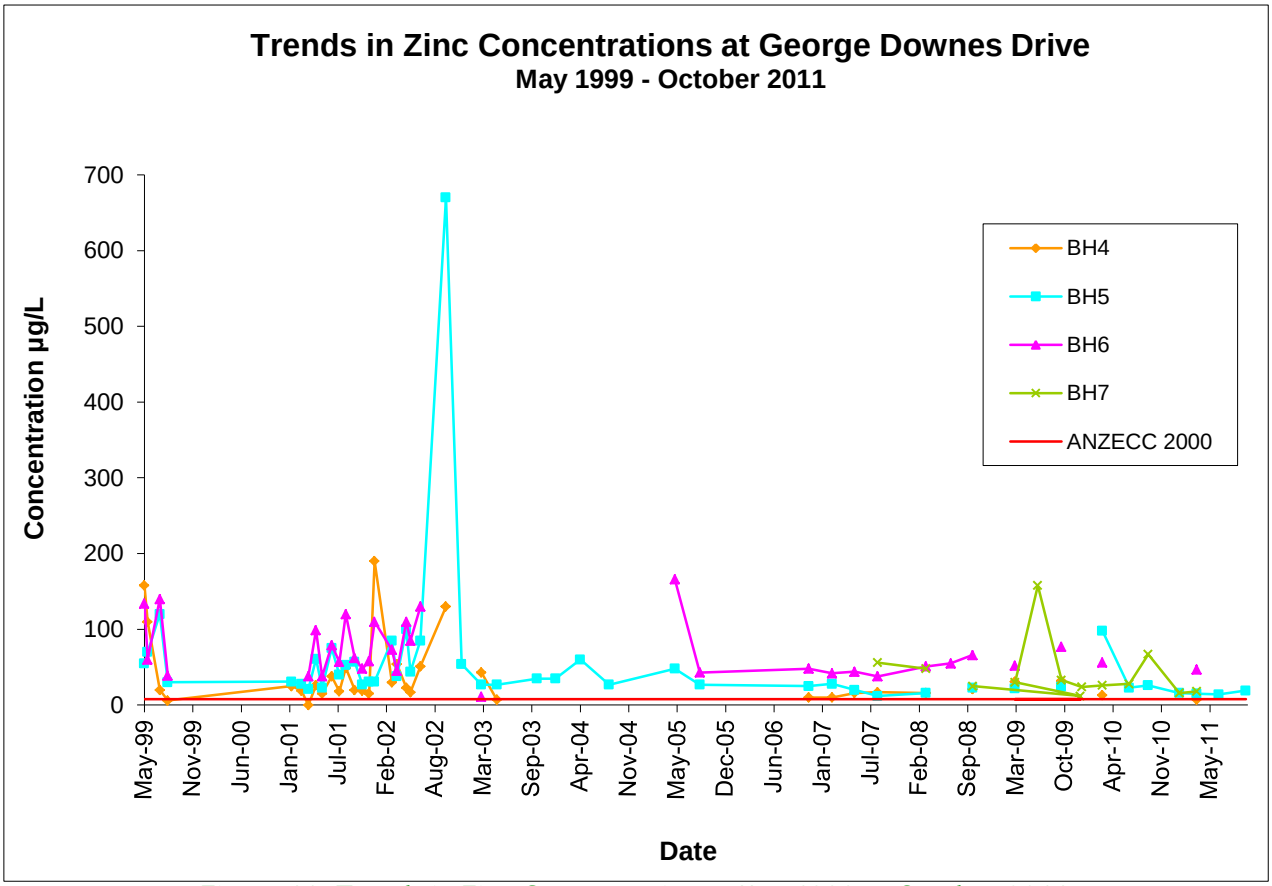

Figure 11: Trends in Zinc Concentrations - May 1999 to October 2011

Exceedances of the ANZECC 2000 trigger value for zinc (8 µg/L) have recently been reported in all groundwater monitoring bores at George Downes Drive, as shown on Figure 11. The highest reported concentration of zinc to date is 670 µg/L from BH5 in the October 2002 monitoring event.

The toxicity of zinc to plants and animals varies with hardness and pH; the acute toxicity of zinc is lower in water with higher hardness and lower pH.

Acute toxicity for Australian species range from 140 to 9600 µg/L (Bacher and O'Brien (1990), Skidmore and Firth (1983)).

7.4 Copper

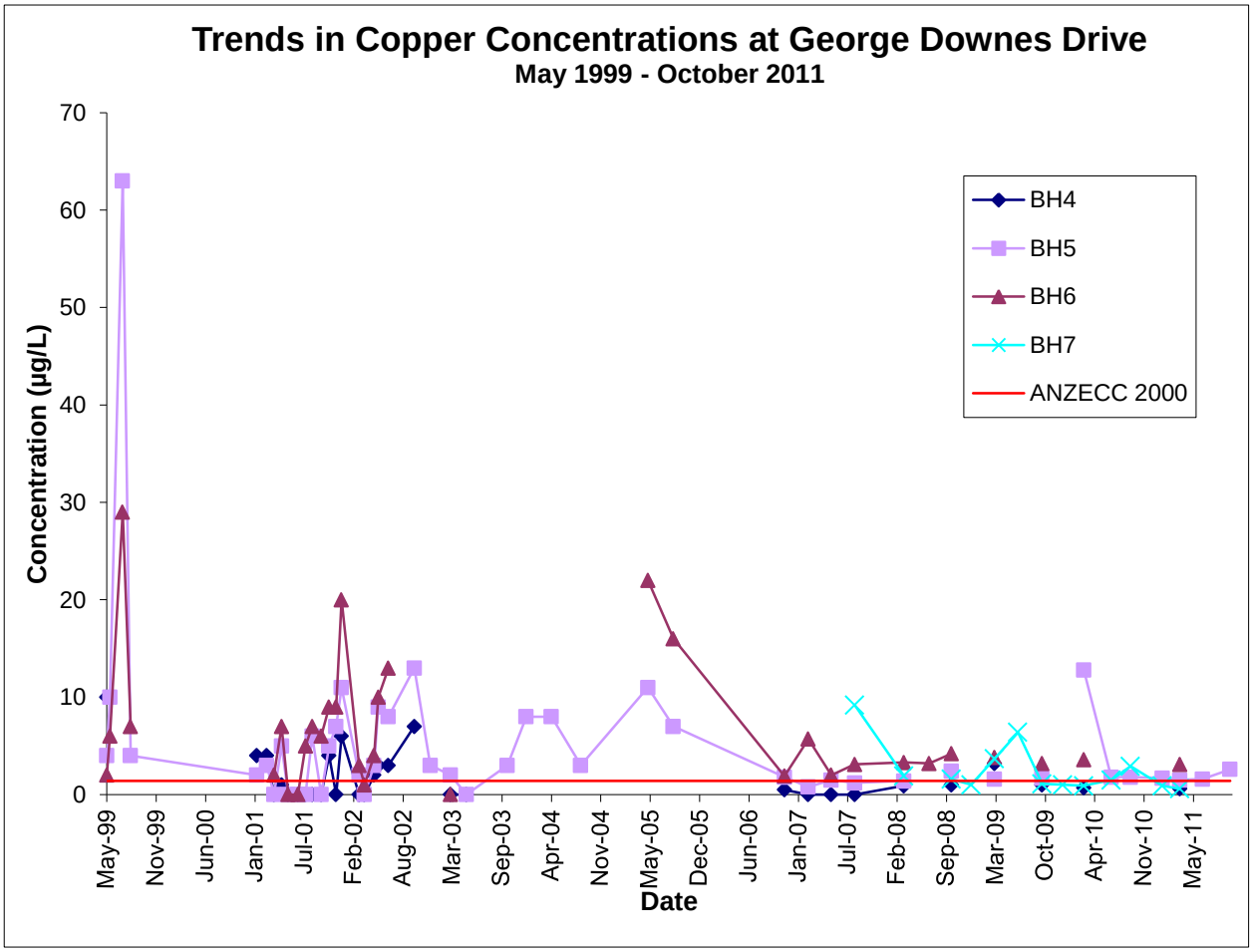

Figure 12: Trends in Copper Concentrations – May 1999 to October 2011

As shown on Figure 12, all bores at George Downes Drive have exceeded the ANZECC 2000 Fresh Water Trigger Value of 1.4 µg/L since May 1999. Concentrations of copper have ranged from below the LOR to 63 µg/L (BH5).

Typically, BH5 located downgradient of the pit, reported higher concentrations of copper when compared to all other wells on site.

Copper is an essential element that is readily accumulated by plants and animals. Bioconcentration factors between 100 and 26,000 µg/L have been recorded. Copper is toxic to many plants; this toxicity increases with water hardness and pH, and decreases if humic acids are present. Thus lower toxicity would generally be expected in sandstone waters.

The acute toxicity levels for copper to Australian species ranges widely, from 40 to 21,000 µg/L (Bacher and O'Brien (1990), Skidmore and Firth (1983)).

8.0 MAINTENANCE WORK AND RESPONSES TO SITE ISSUES

8.1 Decommissioning of Groundwater Monitoring Bores

It was recommended by CMJA that borehole BH4H be decommissioned. BH4H was located approximately 5 metres from the current location of monitoring bore BH7. It had been constructed with a long screen extending from 6 metres below ground surface down to 39 metres below ground surface, i.e. a length of 33 metres. Ideally, monitoring wells should have the shortest screen possible as the shorter the screen, the more precisely one can identify the horizon from which water is drawn during sampling.

The water level in this bore was higher than water levels in neighbouring bores, as the long screen allowed perched water from a higher horizon to enter the well and flow to the deeper aquifer. It was noted that the perched water was entering the well from the 13 to 17-metre interval.

Monitoring well BH4H was decommissioned in August 2007. A 'tremmie' pipe was lowered to the base of the hole and approximately 200 litres of grout was pumped into the bore as the pipe was lifted out. The grout was made as thin as possible in order for the cement to penetrate the screen and seal off the annulus from the formation. As the grout was pumped in, it forced the groundwater above the tremmie pipe to rise up and out of the bore. Concrete pumping continued until grout overflowed from the well. The cement had set within 24 hours.

8.2 Installation of Groundwater Monitoring Bores

Monitoring Bore – BH7

In August 2007, a replacement groundwater monitoring bore (BH7) was installed at an appropriate location approximately 5 metres from the decommissioned borehole BH4H. This bore was installed to enable the groundwater flow direction to be accurately assessed and to further assess the impact of the landfill on water quality.

The borehole was advanced using the air-percussion hammer technique. The upper 6 metres were drilled with a solid flight auger, and the air-hammer was used below that depth. Once the borehole had been drilled to the depth of the water table, a claw drill bit was used (as wet sand caused the air-hammer to clog). All drill bits were 100 millimetres in diameter.

The well was completed with class 18 PVC casing and a 3-metre 0.40 millimetre machine-slotted screen, with a short sump at the base. The annulus around the screened zone was filled with 2-millimetre clean quartz gravel, and a bentonite seal was formed above the gravel pack. The upper portion of the annulus was backfilled with crushed sandstone from the drilling, and a surface cement seal was installed.

Due to the ongoing water level fluctuation in BH6 and concerns over the resulting utility of analysis results and influence on groundwater flow prediction, it is proposed to decommission BH6 and replace with a new down-gradient bore to the north of the pit in 2012.

8.3 Landfill Gas Monitoring

Detection of landfill gases at Mangrove Mountain would be expected, given the volume of organic material that has been buried in the landfills. Landfill gases are produced by the decomposition of organic waste in a landfill. Waste is broken down by bacteria that are naturally present both in the waste itself, and also in the soil that has been used to cover the landfill. The major components of landfill gas are methane, carbon dioxide and nitrogen, but many other gases may be present at trace concentrations.

Landfill gas (LFG) monitoring was conducted at George Downes Drive on 21 August 2007 using a GA2000 infrared gas analyser.

The monitoring work targeted:

- cracks in the pit surface,
- cracks within the monitoring well casing, and
- potential gas pockets beneath the cap.

No methane was detected at the George Downes Drive site, but in the past a sulphide odour had been noted at BH4H.

8.4 Site Maintenance Work

It was identified by CMJA that surface of the landfill cap at the George Downes Drive site was cracking and subsiding in places. To address this problem, maintenance work was conducted in April 2009 as outlined below.

Fill material was placed on the landfill to create a mounded landform, directing runoff away from the surface of the pit. The fill material included crusher dust, sourced from the Hansen Quarry, and clayey sand overburden that was stockpiled in the north-western portion of the landfill area.

Once the filling and levelling had been completed, the surface was covered with black polyethylene sheeting to prevent rainwater infiltration. The plastic sheets were taped along the joins and overlapped.

For wind protection, the plastic sheeting was anchored by:

- tent pegs,
- basalt boulders,
- old car and truck tyres, and
- hay bales.

As part of the recapping works, a silt fence was erected at the base of the landfill's western batter. This fence was installed:

- to prevent erosion of any crusher dust material remaining in this area after completion of the maintenance work; and
- to protect non-vegetated areas of the landfill batter which could otherwise be eroded by runoff from the impermeable plastic sheeting.

During the September 2009 groundwater monitoring event, it was noted that the plastic sheeting over the landfill had not withstood the windy conditions. However, the underlying crusher dust used to cap the landfill had formed a crust, similar to an asphalted cap. It is considered that this cap directs rainfall off the surface of the landfill and adequately reduces infiltration, despite the absence of the plastic membrane.

The car and trucks tyres were removed from the site in November 2010 and disposed of appropriately.

The surface of the landfill is currently well vegetated with a number of grass species.

9.0 ADDITIONAL WORKS REQUIRED

Recent and long-term groundwater analytical results from the George Downes Drive site indicate that the groundwater continues to be of relatively good quality.

The maintenance work conducted continues to successfully address the subsidence issue and the final mounded form appears to be adequately directing water away from the surface.

To continue to maintain the integrity of the landfill liners and cap, vegetation growth must be controlled (through lawn mowing and removal of deep rooted vegetation).

The chicken carcasses within the George Downes Drive landfill will continue to decompose and the landfill liner may weaken over time. As a result, DTIRIS intends to continually monitor groundwater quality and conduct maintenance works on site, as required.

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