April 2010

CELEBRATING 50 YEARS in 2010

FORMER WASTE CONTROL SITE BELLEVUE WA

Annual Groundwater Monitoring Programme 2009

Submitted to:
Department of Environment and Conservation
The Atrium
168 St Georges Terrace
PERTH WA 6000

REPORT

Report Number. 087643011 053 R Rev1

Distribution:

1 Copy - Department of Environment and Conservation (1 electronic)
1 Copy - Golder Associates Pty Ltd

A world of capabilities delivered locally

Golder Associates

Executive Summary

The Department of Environment and Conservation (DEC) engaged Golder Associates Pty Ltd (Golder) to undertake the 2009 Annual Groundwater Monitoring Programme at the Former Waste Control Site in Bellevue, WA (the site).

The monitoring objectives for the 2009 Annual Monitoring were as follows:

- Evaluate the direction and velocity of groundwater flow across the site.
- Monitor changes in contaminant distribution (if any), with a particular focus on:
  - the leading downgradient edges of the hydrocarbon and both chlorinated hydrocarbon plumes; and
  - possible impacts on the Leederville aquifer or the Helena River.
- Monitor groundwater contamination in the vicinity of the source area.
- Provide a second set of groundwater quality data for the newly installed PRB monitoring wells.

The scope of work for the 2009 annual monitoring programme to meet these objectives comprised the following activities:

- The collection of a round of groundwater measurements.
- Collection of 58 groundwater samples from monitoring wells at the site, Hanson, Southwest Industrial Area, Lot 2 and Damplands.
- Collection of four water samples from surface water locations in the Damplands and Helena River. However, due to the dry conditions only two water samples were collected from standing / stagnant water in the Helena River channel. The Helena River samples were subsequently re-sampled on the 13 May 2009.
- Slug tests on the four newly installed multi-level monitoring wells in the Damplands. This was undertaken to better characterise the hydraulic conductivity of the transitional geology between the Guildford and the Alluvium for the purpose of designing a permeable reactive barrier.

The 2009 annual sampling programme was conducted between 24 March 2009 and 8 April 2009 and was based on recommendations from Golder (2006c). Samples were collected from 58 monitoring wells and 2 surface water locations.

The results from this annual monitoring programme are in general agreement with the results of previous programmes. When comparing the 2009 results to those from the 2008 annual monitoring concentrations have generally decreased. However, locations above RBC in 2008 are still above RBC in 2009 and newly installed multi-level monitoring wells in 2009 have resulted in an increase in the number of sample locations with TCE concentrations above RBC. In comparison to results from the 2008 monitoring, results from the 2009 annual programme indicated TCE concentrations decreased to below LOR in MW22i (site, Regional Watertable) and MWG83 (Lot 2, Base of Guildford) whereas they have increased above LOR at MWG66 (Damplands, Alluvium), MWG68 (Damplands, Alluvium) and SG05 (River, downstream). In comparison to historical results, the following notable differences in chlorinated compounds have been identified:

- Concentrations of TCE along the propose PRB have decreased in comparison to results from the delineation programme undertaken in January 2009.
- TCE was detected in MWG68 for the first time. This is closer to the Helena River than previous monitoring rounds have detected.

- TCE and cis-1,2-DCE were detected above the LOR in the Helena River. Re-sampling of the Helena River did not detect concentrations of TCE above LOR.

As the PRB delineation wells (MWG88 to MWG90) have only been sampled twice and the concentrations of TCE (the main contaminant) varied by approximately 50% between the sampling events it is proposed that a third round of groundwater sampling be completed at these wells in winter 2009.

The Helena River has not historically been sampled at this time of the year due to the reduced flow present during summer. It is currently unknown if the chlorinated solvents detected in samples from the Helena River are related to the former Waste Control site, as these chemicals have not previously been identified in monitoring wells closest to the Helena River (e.g. MW36 and MWG60, MWG67 or MWG68). However, the 2009 annual results suggest that the front edge of the secondary off-site TCE plume has possibly advanced enough over the summer to discharge to the Helena River. The presence of chlorinated solvents in the Helena River may be due to seasonal variations, as groundwater modelling (Golder, 2009b) has indicated that recharge from the Damplands Pond can reduce the rate of plume advancement in the Damplands towards the Helena River. This leads to temporary advancement of the plume following periods of no/low recharge such as the summer months. As precipitation during the year (March 2008 to March 2009) was below average and recharge from the Damplands Pond was therefore reduced, the plume may have advanced further than in an average recharge year. Recharge during the winter of 2009 may result in a retreat of the front edge of the off-site TCE plume.

It is therefore recommended that the water quality in the Helena River be tested on a semi-annual basis (March and September). Semi-annual sampling should allow for the identification of any seasonal variation in chlorinated concentrations in surface waters. It should be noted that the concentrations of TCE which were detected in both the Helena River and in the monitoring wells nearest the Helena River were well below the health RBC and Aquatic Ecosystem Screening Criteria and therefore pose little risk to the aquatic environment of the Helena River.

TCE was detected in monitoring well MWG68 (Damplands, Alluvium) for the first time in 2009; this well is located approximately 70 m up gradient of the Helena River and was the closest monitoring well to the Helena River in which TCE has been detected. Therefore, it is also recommended that MWG68 (Damplands, Alluvium), which has only been sampled twice previously, should be included in the additional winter monitoring round.

Interpretation of previous monitoring data identified that it was likely that the mixed organics plume from the Waste Control Site merges with the downgradient TCE plume beneath the escarpment and into the Damplands. The results from the recent monitoring have further supported this interpretation. The mixture of contaminants identified at the MWG89 multi-level monitoring wells and MWG75, MWG78 and MWG79 was a combination of TCE concentrations (above RBC) presumably from the TCE plume with much lower concentrations of PCE, 1,1 DCE, cis 1,2-DCE, 1,2-DCA, chloromethane, cis- and trans- 1,2-DBE, and vinyl bromide at concentrations below site-specific RBC (as applicable).

The concentration of benzene in MW25 (site, Base of Guildford) has been relatively consistent over the last year indicating that the vertical distribution of benzene may have reached steady state. However, the increase in total TPH fractions C_6-C_{36} (0.07 mg/L to 0.46 mg/L) indicates that downward migration of other hydrocarbons is likely still occurring. Due to benzene's higher solubility and lower adsorption it is often the most mobile petroleum hydrocarbon in groundwater; hence its breakthrough at the Base of Guildford ahead of TPH parameters is consistent with its expected behaviour in groundwater.

Table of Contents

TABLES

TABLES FOLLOWING REPORT TEXT

FIGURES

APPENDICES

1.0 INTRODUCTION

The Department of Environment and Conservation (DEC) engaged Golder Associates Pty Ltd (Golder) to undertake the 2009 Annual Groundwater Monitoring Programme at the Former Waste Control Site in Bellevue, WA (the site). A location plan showing the regional setting of the site is included as Figure 1. Groundwater and surface water sampling locations are shown in Figure 2.

2.0 BACKGROUND

A chemical/oil recycling and waste treatment facility operated at the site between 1987 and 2001. In February 2001 a large fire broke out at the site, destroying the treatment and recycling plant and a stockpile of drummed waste chemicals. Several investigations of the site and surrounds have identified groundwater contamination. Numerous groundwater monitoring wells have been installed, including the WCT Series (HRS, 2000), the WCB Series (DoE, 2001-2004), the MW Series (URS, 2002 & 2003), the MWG Series (Golder Associates, 2008a). Additionally, four nests of four multi-level monitoring wells were installed near the location of a proposed permeable reactive barrier (PRB) near the base of the escarpment leading into the Damplands Area (Golder, 2009a).

Golder Associates (2006a, 2008b and 2008c) conducted a health and ecological risk assessment of the groundwater and soil at the site and surrounds. Concentrations exceeding human health risk-based criteria (RBC) were identified at the site and Lot 2. In addition, several potential exceedences of health criteria were also identified beneath the Hanson property, the Southwest Industrial Area and in the Damplands/Helena River. Concentrations exceeding ecological screening criteria and, where available, RBC, were identified in groundwater entering the Damplands and in groundwater currently in the Damplands.

Groundwater monitoring of the site is undertaken annually and the purpose of this report is to present the results from the 2009 annual monitoring programme undertaken in March/April 2009.

2.1 Site Description

The former Waste Control site comprises Lots 88 and 99, in the suburb of Bellevue WA. However, previous investigations have identified that off-site groundwater is also impacted. Bellevue is a semi-industrial suburb that contains both light industrial and residential properties. The lots where monitoring was undertaken during the 2009 annual monitoring are as follows:

- Lot 88 and 99 – the former Waste Control site;
- Lot 5 and 9 Oliver Street – Hanson Property;
- Lot 1 (commonly referred to as the Damplands);
- Lot 2 (Main Roads);
- Lot 84 and 87 – Stanley Street: A&P Transport;
- Lot 80 – Stanley Street: Connect Source;
- Lot 82 – Street Address: 3 Stanley Street;
- Portion of Oliver Street Road Reserve; and
- Portion of Stanley Street Road Reserve.

A location plan showing the regional setting of the study area is included as Figure 1. Current monitoring wells at the site are presented in Figure 2. For further detail on the site description refer to Golder 2008a and 2008d.

2.2 Hydrogeological Setting

Regionally, Perth is underlain by a series of aquifers separated by confining beds. Three main aquifers have been identified (Commander, 2004), however only the upper two aquifers have potential to be impacted beneath the study area:

- The unconfined Superficial Aquifer comprising the permeable units on the Swan Coastal Plain, here the Guildford Formation and alluvial sediments. In the vicinity of the site, groundwater flow towards the Helena River but regionally it was to the west. Elsewhere, this groundwater was used for public water supply but in the vicinity of the site groundwater was more likely to be used for watering parks, irrigation of crops and for garden watering.
- The semi confined Leederville Formation in which groundwater flows generally south southwest from the area of the site. It is a major aquifer used for public water supply, for irrigation and watering of public open space.

It should be noted that, where encountered in the local study area, the upper portion of the Leederville Formation included relatively low permeability clay and clayey sand deposits. This is consistent with the semi confined description of this unit with lower permeability layers marking the interface with the overlying Guildford sediments. Within current assessment programme drilling has only extended into the upper 3-4 metres of Leederville Formation.

Detailed hydrogeological interpretation was presented in *"Geological and Hydrogeological Conditions, Bellevue Waste Control Site"* (Golder, 2005) and *"Hydrogeological Site Assessment*" (Golder, 2006b). Water level data indicate the regional 'true' groundwater table (referred to herein as the 'Regional Watertable') was located between 7 and 9 m AHD, and approximately 8 to 12 m below ground level. Perched groundwater zones have been identified above the Regional Watertable only beneath the former Waste Control site but not in the off-site study area.

2.3 Monitoring Objectives

The monitoring objectives of the 2009 Annual Monitoring were as follows:

- Evaluate the direction and velocity of groundwater across the site.
- Monitor changes in contaminant distribution (if any), with a particular focus on:
  - the leading downgradient edges of the hydrocarbon and both chlorinated hydrocarbon plumes; and
  - impacts on the Leederville aquifer or the Helena River.
- Monitor groundwater contamination in the vicinity of the source area.
- Provide a second set of groundwater quality data for the newly installed PRB monitoring wells.

The scope of work for the 2009 annual monitoring programme to meet these objectives comprised the following activities:

- The collection of a round of groundwater measurements.
- Collection of 58 groundwater samples from monitoring wells at the site, Hanson, Southwest Industrial Area, Lot 2 and Damplands.
- Collection of four water samples from surface water locations in the Damplands and Helena River. However, due to the dry conditions only two water samples were collected from standing / stagnant water in the Helena River channel. The Helena River samples were subsequently re-sampled on the 13 May 2009.

- Slug tests on the four newly installed multi-level monitoring wells in the Damplands. This was undertaken to better characterise the hydraulic conductivity of the transitional geology between the Guildford and the Alluvium for the purpose of designing a permeable reactive barrier.

The 2009 annual sampling programme was conducted between 24 March 2009 and 8 April 2009 and was based on recommendations from Golder (2006c). Samples were collected from 58 monitoring wells and 2 surface water locations. The monitoring well and surface water locations are summarised below based on their hydrogeological unit with the cadastral location of the locations listed in parenthesis. The sampling locations are shown on Figure 2.

Guildford (Regional Watertable)

- MW21i (Waste Control Site)
- MW22i (Waste Control Site)
- MW23i (Waste Control Site)
- MW37 (Lot 2)
- MW42 (Lot 2)
- MW49 (Lot 2)
- MWG51 (Oliver Street)
- MWG54 (Lot 2)
- MWG57 (Lot 2)
- MWG59 (Lot 2)
- MWG62 (Damplands)
- MWG63 (Damplands)
- MWG64 (Hanson)
- MWG65 (A&P Transport)
- MWG70 (Stanley Street)
- MWG72 (A&P Transport)
- MWG81 (Oliver Street)
- MWG82 (Stanley Street)
- MWG84 (Lot 2)
- MWG85 (Connect Source)
- MWG86 (Oliver Street)

Base of Guildford

- MW25 (Waste Control Site)
- MWG46 (Irwin Street)
- MWG53 (Lot 2)
- MWG69 (Stanley Street)
- MWG83 (Lot 2)
- MWG71 (A&P Transport)
- MWG73 (Damplands)
- MWG75 (Damplands)
- MWG78 (Damplands)
- MWG80 (Oliver Street)

Leederville

- MWG45 (Irwin Street)
- MWG76 (Damplands)

Alluvium

- MW36 (Damplands)
- MWG68 (Damplands)

- WCB02 (Damplands)
- MWG60 (Damplands)
- MWG66 (Damplands)
- MWG67 (Damplands)
- MWG74 (Damplands)
- MWG77 (Damplands)
- MWG79 (Damplands)

Helena River

- SG05 (downstream)
- SG06 (midstream)

Multi-Level Wells (A,B & C - Alluvium and D - Base of Guildford)

- MWG87A
- MWG87B
- MWG87C
- MWG87D
- MWG88A
- MWG88B
- MWG88C
- MWG88D
- MWG89A
- MWG89B
- MWG89C
- MWG89D
- MWG90A
- MWG90B
- MWG90C
- MWG90D

The fourteen single well slug tests were conducted in the following multi-level monitoring wells along the proposed PRB locations:

- MWG87A
- MWG87B
- MWG87C
- MWG87D
- MWG88A
- MWG88B
- MWG88C
- MWG88D
- MWG89A
- MWG89B
- MWG89C
- MWG90A
- MWG90B
- MWG90C

3.0 METHODOLOGY

3.1 Groundwater Sampling

Twenty-nine wells on the site, Lot 2 and the Southwest Industrial Area were purged and sampled using a submersible QED micropurge bladder pump operating at a relatively low flow rate of approximately 120 to 320 mL/min. Due to recharge issues, reduced flow rates were used for MW21 (40 mL/min), MW23 (100 mL/min), MW37 (80 mL/min) and MWG54 (110 mL/min) to enable sample collection.

Thirty-two locations in the Damplands and Helena River were purged and sampled using a peristaltic pump. Constant flow rates ranging between 200 to 300 mL/min were used for all of these locations except MWG87A and MWG90A where recharge issues resulted in sporadic pumping.

The peristaltic pump in conjunction with dedicated tubing was used where possible as the pump is external to the well, eliminating a potential source of cross-contamination. As peristaltic pumps only work efficiently up to a depth to groundwater of approximately 4 m when collecting samples for volatile organic compound (VOC) analysis, the submersible pump was required at many locations. A water level was taken prior to pumping at each location using a water level meter and drawdown was monitored when using the submersible pump to ensure that the groundwater level did not fall below the intake valve of the pump. Water levels at the Helena River surface water points were also collected during the surface water sampling event, but no samples or water levels were collected in the Damplands Pond as no water was present at the time of sampling.

The QED bladder pump was used where it was not possible to use the peristaltic pump, generally because the depth of groundwater was greater than 8 m. Sampling was carried out in accordance with standard quality procedures adopted by Golder to minimise the risk of cross contamination. In particular, the QED submersible pump was thoroughly decontaminated prior to use and between each sampling location. The decontamination procedure involved disassembling the pump and washing all components in a water/decon90 mix followed by rinsing them at an initial distilled water station, and again at a second distilled water wash station. The pump was finally sprayed a third time with distilled water using a hand sprayer prior to installation into the well. Nitrile gloves were replaced between each of the three wash stations and hand spray rinse, with the water used to clean the pump changed between each sample location. All non-stainless steel pump components (Teflon bladder and o-rings) were also replaced between locations. Field rinsate wash blanks were also collected as a check on the decontamination process. Due to the laboratory wash water being damaged during transit, commercial distilled water was used for all decontamination procedures up to and including 30 March. A second batch of laboratory supplied nanopure water was supplied and used for the remainder of the programme. A sample of the commercially supplied distilled water was collected and analysed at the start of the programme for quality assurance and quality control purposes.

The monitoring wells sampled using the submersible pump were generally collected in an order from least contaminated to most contaminated based on previous chemical data obtained at the site to further minimise the potential for cross contamination.

Regardless of the pump used, near continuous measurements of field groundwater parameters were made during the purging process, including pH, temperature, conductivity, reduction potential and dissolved oxygen using a pre-calibrated TPS90 FLMV water quality meter. The calibration of the meter (pH and conductivity) was checked twice daily by submersing the probes into two standard pH solutions (pH 4 and pH 7) and a standard conductivity solution (2.76 mS/cm). A groundwater sample was collected once the field parameters stabilised (to within ±10% and 0.1 of a pH unit).

Each groundwater sample and surface water sample was collected using dedicated nitrile gloves, dedicated high density polyethylene tubing and placed into bottles supplied by the laboratory with the relevant preservatives. Samples for ferrous iron analysis were field filtered with a single-use disposable 0.45 micron filter prior to mixing with preservative. Samples were stored under cool conditions in an esky with ice or freezer bricks while in the field and in transit to the laboratory. Each sample, including all quality assurance samples, were given a unique Sample Control Number, which was recorded on a Chain of Custody (CoC) form with all other relevant sampling information. A CoC record was kept for samples from the time of sample collection until delivery to the laboratory. All primary samples were submitted to Leeder Consulting (Leeder), who are NATA accredited for all analyses. Blind duplicate samples were also submitted to Leeder. Blind triplicate samples were submitted to ALS Environmental (ALS), who is NATA accredited for all analyses. The chain of custody forms and the laboratory certificates are included as Appendix A.

All samples collected from the newly installed PRB delineation multi-level monitoring wells were analysed for:

- VOC scan (including chlorinated ethenes, brominated VOCs (Br-VOCs), dichloroethane and BTEX); and
- Nitrate.

The remaining monitoring wells were all tested for the following suite of parameters:

- field parameters: electrical conductivity (EC), dissolved oxygen (DO), temperature, pH, water level and redox potential (Eh);
- major ions (sulphate, chloride, nitrate and alkalinity) and cations (calcium, magnesium, sodium and potassium) and total dissolved solids (TDS);
- total metals (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc) and ferrous iron (surface water samples were analysed for ultra trace metals to achieve lowest available limits of reporting);
- VOC scan (including chlorinated ethenes, Br-VOCs, dichloroethane and BTEX);
- total petroleum hydrocarbons (TPHs) (C_6-C_{36}); and
- phthalates.

In addition to the above suite of parameters the following monitoring wells were also analysed for semi-VOCs (sVOCs). MWG53 (Lot 2, Base of Guildford):

- MWG80 (Southwest Industrial Area, Base of Guildford);
- MW21i (site, Regional Watertable); and
- MW22i (site, Regional Watertable).

The field QA/QC programme adopted for the investigation included the following:

- Equipment wash blank collected each day that the submersible pump that was used. The equipment wash blank were be analysed for TPHs and VOCs to assess quality of decontamination techniques.
- As the sampling included highly volatile compounds, the QA/QC programme included the submission of one trip blank during each day. The trip blank was analysed for VOCs.
- Waste groundwater generated from the sampling programme was collected in 205 L drums provided by Cleanaway and will be temporarily stored on the site. Once the waste has been characterised it will be disposed of by Cleanaway.

3.2 Single Well Recovery Tests

Hydraulic testing was carried out in the PRB delineation wells in the Damplands (16 nested wells MWG87 – MWG90) on 22 April 2009 using rising head tests (Recovery test). An initial water level was collected on all wells prior to start of testing. The recovery test method involved lowering the groundwater level as much as possible by removing approximately 7-10 L of water from the borehole using a peristaltic pump at a rate of approximately 1 L/min. When the wells were pumped dry or an equilibrium was reached, a water level (time = 0) was collected and the pump shut off to allow water level recovery to begin.

Manual water levels were collected at 10 second intervals for the first minute of the test, followed by 15 second intervals for the second minute, 30 second intervals for the next 3 minutes, and 1 minute intervals for the following 5 minutes. Water levels were then collected at irregular intervals for the remainder of the day based on judgement of the observed rate of recovery. Water levels were measured until approximately 90% of recovery was reached at which time the test was ended. The above time schedule was modified for wells with reduced drawdown and rapid recovery including MWG88C & D. Recovery tests were not completed at MWG89D and MWG90D due to drawdown of less than 5 cm and nearly instantaneous recovery was observed. Field data sheets are presented in Appendix B.

Slug test recovery data were analysed using the KGS (Hyder et al. 1994) solution in Aqtesolve. The KGS solution can be used to interpret hydraulic conductivity for a partially penetrating well and under confined or unconfined conditions. A hydraulic conductivity value was derived by selecting the curve that provides the best fit to the observed data. In general solutions were obtained by first allowing the software to provide an automated best fit based on least a squares method. The solution was then adjusted to see if an improved fit could be obtained using a visual matching approach.

For all tests, aquifer saturated thickness was estimated based on the local depth of groundwater and an assumed depth of 9 m to the underlying Leederville formation encountered at nearby well MWG74. The Aqtesolve solutions are presented in Appendix C.

4.0 EVALUATION CRITERIA

Results from the 2009 annual monitoring programme are provided in Tables 1 to 6. Groundwater results from monitoring wells on-site, Lot 2, the Southwest Industrial Area and up-gradient were compared against updated site-specific RBC for the site and Lot 2 (Golder 2008b). These site-specific RBC cover potential indoor air inhalation pathways for environmental works and exposure of a worker performing irrigation. The inclusion of the exposure of a worker performing irrigation is based on hypothetical future land use as currently no groundwater abstraction is permitted. The results of the 2009 groundwater results for the site, Lot 2, Southwest Industrial Area and upgradient wells are presented in Tables 1, 2, 3 and 4 respectively.

Results from the Hanson property sample were compared against both the health RBC (Golder 2008b) for the Hanson property and the site and Lot 2 RBC (Golder 2008b). The site-specific RBC cover outdoor workers conducting outdoor activities on the property that do not involve irrigation, which is current with the current site activities and lack of buildings above affected areas. Results from the Hanson property were also compared against site and Lot 2 RBC for evaluation purposes in case the land use changes in the future. The latter RBC accommodates potential land use changes including future commercial/industrial indoor workers (in a hypothetical future building) and future outdoor maintenance workers, conducting irrigation activities during normal weekly work. It should be noted that as no buildings are currently located over the plume the use of the indoor worker scenario is only hypothetical. The results of the 2009 groundwater results for the Hanson Property are presented in Table 5.

Results from the Damplands samples were compared against both health RBC (Golder, 2008b) for the Damplands and recently updated Aquatic Ecological Screening Criteria (Golder, 2008c). Discussion with WAPC who own the Damplands lot has confirmed that irrigation is not necessary for the planned revegetation scheme. Therefore, the health RBC for the Damplands no longer includes the potential exposure of outdoor workers performing irrigation. The Damplands RBC also does not include a swimmer or recreational bather in the Damplands Pond. However, it does include exposure scenarios for outdoor vapours for park users and outdoor workers. The ecological screening criteria were used to evaluate potential risks to aquatic life associate with the potential migration of contaminants to the Helena River via groundwater. The aquatic ecological screening criteria are intended strictly for application at the point of discharge of the groundwater (i.e. criteria need to be achieved immediately before groundwater enters the River). Application of these screening criteria to Damplands monitoring wells upgradient of the River provides a conservative assessment of risks to the aquatic ecosystems as some attenuation of chemical concentrations is expected prior to discharge into the River. The results of the 2009 groundwater sampling for sampling points in the Damplands are presented in Table 6.

Results from the Helena River samples were compared against both the health RBC (Golder, 2008b) for the Helena River and the recently updated Aquatic Ecological Screening Criteria (previously discussed) (Golder, 2008c). The recreational swimmer was the only health risk exposure pathway considered for the Helena River and is presented in Table 7.

5.0 2009 ANNUAL MONITORING RESULTS

The following discussion summarises the results from both the water levels monitoring and the groundwater chemistry analysis.

5.1 Single Well Recovery Test Results

The single well recovery tests were undertaken in monitoring wells located along the proposed PRB alignment near the base of the escarpment. At this location, more recent alluvial deposits have been deposited on an erosional surface incised through the older Guildford and into the underlying Leederville Formation. There is a lateral transition near the base of the escarpment where groundwater discharges from the Base of Guildford Formation into the Alluvium. (Details on the recent investigation and multi-level monitoring well installation programme at this location are provided in Golder 2009a.) The single well recovery tests were undertaken to better characterise this transitional area for the purpose of designing a permeable reactive barrier for plume remediation purposes.

The results from the single well recovery tests are presented in Table C. Hydraulic conductivity values obtained from monitoring wells MWG73, MWG74, MWG79 and MWG78 in 2008 were also included in Table C in order to present a more complete understanding of the hydrogeology of the transitional area.

Results obtained from the slug tests in the shallowest A series of the multi-level monitoring wells were not included in calculating the overall geometric mean hydraulic conductivity as they were considered unreliable due to insufficient available drawdown to perform the test. The results from the slug tests indicate that the hydraulic conductivity values at the B and C series multi-level monitoring wells, which are screened in alluvial sediments, are similar.

In comparison, the hydraulic conductivity in the deeper D series had a geometric mean hydraulic conductivity approximately double that assessed at the B and C wells. The Base of Guildford was difficult to distinguish from the overlying alluvial sediments due to the transitional boundary. However, the D series wells were inferred from soil logs as having been completed in the remnant of the Base of Guildford Formation at the base of the escarpment.

The results from monitoring wells with 3m long screens were found to have hydraulic conductivities greater than those from multi-level monitoring wells. The large variation in values in the conductivity data is likely due to the heterogeneities identified in the lithology at site. Geometric means calculations are less affected by extreme values than the arithmetic mean and therefore Golder considers that the geometric mean approach is valid for determining the large scale average conductivity.

Table A: Hydraulic Conductivity of PRB Delineation Wells

Hydraulic Conductivity (approx screen depth bgl)	**MWG87**	**MWG73#**	**MWG74#**	**MWG88**	**MWG89**	**MWG79#**	**MWG78#**	**MWG90**	**Geometric Mean (m/day)**
A (2 m)	0.012	-	-	0.019	0.00478	-	-	0.024	0.01
B (4 m)	0.18	-	7.83	0.722	1.25	56.16	-	0.26	1.63
C (6 m)	17.9	-	-	0.73	0.44	-	-	1.34	1.67
D (8 m)	1.34	1.27	-	2.24	-	-	44.06	-	3.60
Geometric Mean (m/day)	0.48	-	-	0.39	0.14	-	-	0.20	2.06*

*does not include results from the A series

#indicates the well tests were undertaken in 2008. The information was presented here in order to present a more complete picture of the hydraulic conductivities of transitional area.

5.2 Water Levels

Water levels collected during the 2009 sampling programme have been included in Table 8 along with historical measurements, and presence of non aqueous phase liquid (NAPL) for each monitoring location.

5.2.1 Groundwater Movement

Groundwater surface elevations at March 2009 for each of the four groundwater bearing zones (Regional Watertable and Alluvium, Base of Guildford, Leederville) are presented in Figures 3 to 5. Groundwater surface elevations at the Regional Watertable in the Guildford Formation and in the Damplands Alluvial aquifers have been interpreted as a single continuous unit. Groundwater contours within a single hydrogeologic unit are generally indicative of lateral groundwater gradients and resultant flow patterns. However, groundwater elevations contours across the escarpment (the transition zone between the Guildford and Alluvial units) also incorporate a significant component of vertical hydraulic gradients associated with topographic relief across this feature.

Table B presents interpreted groundwater flow directions and gradients for the four groundwater bearing zones under the site (Regional Watertable, Base of Guildford Formation, Leederville Formation and Alluvial Aquifer).

Table B: Groundwater Flow Direction and Gradient

Groundwater Bearing Zone	Flow Direction	Gradient (m/m)	Comment
Regional Watertable (Guildford Formation)	SW	5.3×10^{-3}	Average flow direction from site to top of Escarpment
Base of Guildford Formation	SW	5.5×10^{-3}	Average flow direction from site to MWG73
Leederville Formation	SSW	7.2×10^{-3}	Average flow direction from site to MWG76
Alluvial Aquifer	SSW	5.0×10^{-3}	Bottom of Escarpment to Helena River

Lateral gradients and flow directions in the Regional Watertable, Base of Guildford and Leederville groundwater bearing zones are similar. The overall direction of groundwater flow in the four groundwater bearing zones between the site and the Helena River is in a southwest or south-southwest direction.

Calculated lateral gradients for the Regional, Base of Guildford, Alluvium and Leederville Formations are similar to those previously calculated for these units from 2008 annual monitoring programme data (Golder 2008a).

Table C outlines trends in groundwater flow direction by formation between 2005 and 2009. The 2009 results were generally consistent with these historical interpretations. However, there are changes to note over this time period within each formation. In April 2005 the Guildford Formation was examined as a single unit. From June 2007 onward the Guildford Formation was divided into two areas of interest: Base of Guildford Formation and Regional Watertable which essentially describes the free groundwater surface within the Guildford Formation. In 2007 and 2008 the groundwater flow direction in the Regional Watertable and at the Base of the Guildford was interpreted as southwest, whereas in 2005 it was interpreted as south-southwest.

By June 2007, new monitoring wells installed in the Alluvial aquifer bordering the Helena River allowed interpretation of the groundwater flow in this unit beneath the Damplands.

Table C: Groundwater Flow Directions by Formation Between 2005 and 2009

Formation	Reporting Year and Groundwater Flow Direction			
	2005	2007	2008	2009
Guildford	SSW			
Regional		SW	SW	SW
Base of Guildford		SW	SW	SW
Leederville	SSW	SSW	SSW	SSW
Alluvial		S	SSW	SSW

5.2.2 Groundwater Velocities

Approximate groundwater velocities can be obtained from the Darcy equation:

where

$$v = \frac{Ki}{n_e}$$

v = linear particle velocity (LT^{-1})

K = hydraulic conductivity (LT^{-1})

i = hydraulic gradient (LL^{-1})

n_e = effective porosity (L^3L^{-3})

Lateral hydraulic gradients are presented in Table A.

Representative hydraulic conductivity values were selected using the geometric mean, for each groundwater bearing zone, of slug tests conducted between 2005 and 2009. In 2005, hydraulic conductivity tests were undertaken at 29 monitoring wells (Golder, 2005) including two wells previously tested by URS. In 2008, hydraulic conductivity tests were conducted on an additional 14 new monitoring wells (Golder 2008a). The four hydraulic conductivity tests conducted in the Regional and Base of Guildford prior to 2005 were not considered in the calculations. The more recent tests provided a sufficiently large database of values and as a result, due to the limited data set collected prior to 2005, its exclusion does not alter the geometric mean hydraulic conductivities by more than 0.05 m/day.

Consistent with previous historical interpretations, an assumed porosity for the silty sand material which comprises the matrix of the Leederville and Guildford Formation aquifers of 0.3 was used. An effective porosity of 0.25 was assumed for the Alluvial aquifer.

Table D provides estimates for groundwater flow velocities for the four units. The estimates for groundwater flow velocities of Regional Guildford, Base of Guildford, Alluvial and Leederville Formations are based on the results from prior hydraulic conductivity tests as presented in Golder, 2008a.

Table D: Approximate Groundwater Velocities using March 2009 Hydraulic Gradients

Aquifer	Hydraulic Conductivity	Gradient	Effective Porosity	Velocity	
	(m/d)	(m/m)	(-)	(m/day)	(m/year)
Regional Guildford Formation	0.22	5.3×10^{-3}	0.3	3.9×10^{-3}	1.4
Base of Guildford Formation	2.33	5.5×10^{-3}	0.3	4.3×10^{-2}	16

Aquifer	Hydraulic Conductivity	Gradient	Effective Porosity	Velocity	
Alluvial[1]	2.76*	5.00×10^{-3}	0.25	5.5×10^{-2}	20
Leederville Formation	0.44	7.2×10^{-3}	0.3	1.1×10^{-2}	3.9

*does not include results from the A series wells

The above estimates for groundwater flow velocities are indicative only and were averaged over the flow path observed.

5.2.3 Vertical Hydraulic Gradients

Information on vertical hydraulic gradients, including timing of measurements is available for the following inter-aquifer inter-relationships:

- Regional Watertable - Base of Guildford Formation (Table 9a);
- Base of Guildford Formation – Leederville Formation (Table 9b);
- Alluvium – Guildford Formation (Table 9c); and
- Multi-level monitoring wells and paired wells along the proposed PRB location at the base of the escarpment (Table 9d).

Monitoring well locations are shown in Figure 2.

A summary of vertical hydraulic gradient information for the above relationships between May 2005 and March 2009 is presented in Table E below.

Table E: Vertical Hydraulic Gradient Data

Formations	Examined Well Pairs			Gradient Range	Dominant Trend
Regional Watertable to Base of Guildford	MW22i/MW25	MWG49/MWG48	MWG51/MWG50	-0.166 to 0.029	Weak Downward
	MWG57/MWG55	MWG59/MWG58	MWG72/MWG71		
	MWG81/MWG80	MWG84/MWG83			
Base of Guildford to Leederville	MWG46/MWG45	MWG48/MWG47	MWG70/MWG69	-0.128 to 0.009	Moderate Downward
	MWG75/MWG76	MWG82/MW35			
Alluvium to Base of Guildford	MWG74/MWG73	MWG79/MWG78		-0.015 to 0.043	Weak Downward
In the vicinity of the PRB: ■ Regional Watertable to Base of Guildford; and ■ Base of Guildford to Leederville.	MWG87A/MWG87B	MWG87B/MWG87C	MWG87C/MWG87D	-0.028 to 0.274	Moderate Upward
	MWG88A/MWG88B	MWG88B/MWG88C	MWG88C/MWG88D		
	MWG89A/MWG89B	MWG89B/MWG89C	MWG89C/MWG89D		
	MWG90A/MWG90B	MWG90B/MWG90C	MWG90C/MWG90D		
	MWG76/MWG75	MWG78/MWG79	MWG73/MWG74		
Damplands Pond to Alluvium*	SG02/WCB02	SG03/WCB08	SG06/WCB05	-0.009 to 0.928	Moderate Downward
Helena River to Alluvium*	SG06/MW36	SG07/WCB04		-0.091 to 0.042	Moderate Upward

*No data for 2009 as no surface water present, results based on data from (May 2005 to March 2008).

Within the Guildford Formation, between the Regional Watertable and the base of this formation the vertical hydraulic gradients were generally considered weakly downward. In the most recent water level monitoring the following two anomalies were noted:

- A strong upward gradient (0.029) between MWG59 (Regional Watertable) and MWG58 (Base of Guildford). Previously, this location had a weak upward gradient which ranged from 0.002 to 0.003. It is possible that the strong upward gradient in 2009 is a result of water level measurements from the two locations having been collected two days apart.
- A strong downward gradient (-0.02) between MWG57 (Regional Watertable) and MWG55 (Base of Guildford). Previously the gradient at this location varied from weakly upwards (0.004) to weakly downwards (-0.005), consistent with results at other monitoring well pairs between these units. The reason for this change is unclear and may be an anomalous water level measurement.

However, overall the dominant trend was still a weak downward hydraulic gradient which likely reflects drainage towards the Helena River valley and recharge from precipitation. It is likely that groundwater flow is predominantly lateral and unlikely that there is significant vertical groundwater movement within the Guildford Formation.

Generally, moderate downward gradients have been observed between the Base of Guildford and Leederville Formations. This indicates the study area is a potential zone of groundwater recharge. However, relatively lower hydraulic conductivities observed at monitoring wells completed in the Leederville, suggest that the upper part of the formation may be acting as a semi-confining unit.

The vertical hydraulic gradients indicate that between all A and B multi-level wells (MWG87, 88, 89 and 90) there was a strong upward gradient indicating the potential for upward movement of groundwater. This is consistent with the location of these wells at the toe of an escarpment. A classic pattern of upward groundwater circulation and even seepage can occur at the base of escarpments.

In the next deepest of the multi-level pairs (B and C wells), moderate upward gradients were observed at the western multi-level locations MWG87 and MWG88. However, at the eastern multi-levels, MWG89 and MWG90, moderate downward and weak downward gradients were calculated, respectively.

Between the C and D multi-level series the analysis indicated there was a weak to moderate downward gradient at all four multi-level locations, indicating the potential for downward movement of groundwater.

The vertical hydraulic gradients between selected paired monitoring wells were also calculated. It should be noted that unlike the multi-level series these paired wells were used to investigate the gradient between formations as these were spaced further apart vertically. Two of the pairs reflected the hydraulic gradient between the Alluvium and the Base of Guildford (MWG73/MWG74 and MWG78/MWG79). The water level measurements indicated that there is a weak to moderate downward gradient between the Regional Watertable and the Base of Guildford.

The remaining pair (MWG75/MWG76) reflected the vertical hydraulic gradient between the Base of Guildford and the Leederville Formation. The results indicate that there was a strong downward gradient of approximately -0.13 between the Base of Guildford and the Leederville Formation, therefore the potential for downward movement of groundwater exists. However, it is more likely that the strong downward gradient is indicative of a (semi) confining layer near the top of the Leederville, as indicated by the lower hydraulic conductivity values measured at monitoring wells completed in that formation (Table D). This is supported by the bore logs from the pair (MWG75/MWG76) which indicate a clayey sand layer approximately 0.6 m thick separating the two well screens. Because of this low hydraulic conductivity layer, it is unlikely that there is significant vertical groundwater flux between the Guildford and the Leederville.

Due to the lack of precipitation in the previous months so standing water was present at the base of the escarpment and the Helena River was not flowing. Historically a downward hydraulic gradient has been observed between the seasonally standing water at the base of the escarpment (the “Damplands Pond”) and the Alluvial aquifer. This indicates groundwater recharge likely occurs when ponded water is present.

Vertical gradients between the Alluvium and the Helena River have historically been moderately upward, indicating groundwater discharge to the river.

Seasonal changes in groundwater regime appear to have an effect on vertical gradients within the Damplands and Helena River areas. In 2005 it was noted that vertical gradients from the Alluvium to the Helena River were upward during the drier periods of summer and autumn indicating groundwater discharge to the river. However, limited monitoring during the wetter winter period showed a downward gradient indicating flow from the river to the Alluvial aquifer consistent with higher urban runoff expected during this time.

5.3 Water Quality Results

The following discussion summarises locations were key analytes were detected which were above the site-specific RBC and aquatic ecosystem criteria appropriate for each of the main land blocks within the study area.

Monitoring well locations where groundwater concentrations from the 2009 monitoring results exceeded the site-specific RBC are shown on Figure 6. Monitoring well locations where groundwater concentrations from the 2009 monitoring results exceeded the aquatic ecosystem screening criteria are shown in Figure 7.

5.3.1 Field Parameters

Field parameter results collected during the monitoring round for each well sampled are presented in Table 10. This table includes pH, reduction potential, temperature, conductivity and dissolved oxygen. The original field sheets are provided in Appendix B.

The pH of wells ranged between 4.51 (MWG88B, Damplands, Regional Watertable) and 7.39 (SG06, Helena River, Midstream). The pH at 36 of the 60 monitoring locations was found to be below 6 and therefore can be considered slightly acidic. These slightly acidic waters were identified in all four geologic formations and upgradient location MWG46 (Base of Guildford) was also identified as slightly acidic with a pH of 5.77. The greatest variations in pH in comparison to the 2008 annual monitoring results were decreases in pH of 0.5 or greater at locations MWG72, MWG82, MWG85 which are all located in the Regional Watertable in the Southwest Industrial Area.

Sixteen wells had dissolved oxygen (DO) levels above 1mg/L (MW37, MWG54, MWG57, MWG62, MWG63, MWG65, MWG67, MWG70, MWG74, MWG81, MWG82, MWG86, MWG88B, MWG88C, MWG89A and MW90A) with the highest reading at MWG81 (3.94 mg/L, Regional Watertable). In comparison to 2008 annual results, the DO level increased in all locations, except six (MWG51, MWG54, MWG59, MWG63, MWG64 and MWG79). The DO levels decreased in the two surface water samples (SG05 (downstream) and SG06 (midstream)) and were below 1 mg/L. This likely resulted from the fact that samples from surface water locations were collected from stagnant ponded water due to the low water levels, whereas the river was flowing during all previous sampling events.

The conductivity measured ranged from 340 µS/cm (MWG85, Regional Watertable, Southwest Industrial Area) to 2730 µS/cm (MWG90D, Damplands, Base of Guildford). Conductivities less than 500 µS/cm were identified at the following five locations;

- MWG46 (Upgradient, Base of Guildford);
- MWG59 (Lot 2, Regional Watertable);
- MWG68 (Damplands, Alluvium);
- MWG74 (Damplands, Alluvium); and
- MWG85 (Southwest Industrial Area, Regional Watertable).

Generally low conductivities indicate areas of high recharge which mostly agrees with the identified locations with the conductivities below 500 µS/cm. The exception is MWG46, which is located in the Base of Guildford and therefore would be anticipated to not be significantly influenced by recharge. In comparison conductivities greater than 2000 µS/cm where identified at:

- MW21i (site, Regional Watertable);
- MW22i (site, Regional Watertable);
- MWG45 (Upgradient, Leederville);
- MWG76 (Damplands, Leederville);
- MWG77 (Damplands, Alluvium); and
- MWG90D (Damplands, Base of Guildford).

Most of these locations would not be anticipated to be influenced by recent recharge. The two on-site regional watertable wells (MW21i and MW22i) are located below areas which were sealed in order to prevent recharge. However, recent recharge would be expected to influence the groundwater quality at location MWG77 as it is a relatively shallow well located in the Alluvium. MWG77, as well as other Damplands monitoring wells such as WCB02, MWG60 and the A series monitoring wells have elevated conductivity which may be a result of stormwater runoff from the Damplands Pond or Roe Highway.

The redox potential ranged from -108 mV (MWG64, Regional Watertable, Hanson) to 499 mV (MWG89D, Damplands, Base of Guildford). It should be noted that only 11 of 60 sampling locations were noted as being less than 0 mV with all of them being only slightly reducing. Five of these locations MW21i, MW22i, MW23i, MWG51 and MWG64 have been previously identified as within the hydrocarbon plume where reducing conditions would be expected. Slightly reducing conditions within the hydrocarbon plume likely indicate that natural attenuation of the plume is occurring. The remaining six locations with negative redox potential (MWG60, MWG66, MWG67, MWG68, MWG90B and SG07) were all located in the Damplands or the Helena River. In comparison, 29 of the 60 sampling locations had redox potentials greater than 100 mV which indicate oxidising conditions. One of these locations was MW25 in the Base of the Guildformation beneath the former Waste Control site. The positive redox potential indicates some potential capacity for natural attenuation of recently noted downward migration of hydrocarbons at this location.

5.3.2 Upgradient

Two up gradient monitoring wells MWG45 (Leederville) and MWG46 (Base of Guildford) both located on Irwin Street were sampled. Both upgradient samples were analysed for VOCs, Br-VOCs, TPHs, phthalates, major anions and cations, total metals, ferrous iron and TDS. This was undertaken to determine the quality of the groundwater upgradient from the Waste Control Site. The results were compared to RBC developed for the site and Lot 2. These site-specific RBC cover potential indoor air inhalation pathways for environmental works and exposure of a worker performing irrigation. The complete results of the 2009 groundwater sampling for all locations upgradient are presented in Table 4, along with historical groundwater sampling results dating back to 2005.

The results indicated all parameters were below RBC criteria.

5.3.3 On-Site (former Waste Control Site)

Samples were collected from the following four on-site monitoring wells:

- MW21i (Regional Watertable);
- MW22i (Regional Watertable);
- MW23i (Regional Watertable); and
- MW25 (Base of Guildford).

All samples collected from the site were analysed for VOCs, Br-VOCs, TPHs, phthalates, major anions and cations, total metals, ferrous iron and total dissolved solids (TDS). The samples collected from MW23i and MW25 were also analysed for sVOCs. The complete results of the 2009 groundwater sampling for all locations on the site are presented in Table 1, along with historical groundwater sampling results dating back to 2005.

5.3.3.1 RBC Exceedences

Groundwater results on-site were compared against site-specific RBC for the site and Lot 2. These site-specific RBC cover potential indoor air inhalation pathways for environmental works and exposure of a worker performing irrigation. These site-specific RBC cover potential indoor air inhalation pathways for environmental works and exposure of a worker performing irrigation. The inclusion of the exposure of a worker performing irrigation is based on hypothetical future land use as currently no groundwater abstraction is permitted. Table F presents an overall summary of the parameters detected at concentrations above relevant RBC as well as the sample location and relevant monitoring zone.

Table F: Summary of On-Site Results Above Relevant RBC

Location	Monitoring Zone	Parameters	Concentration	Relevant RBC
MW21i	Regional Watertable	Benzene	0.008 mg/L	0.00274 mg/L
		Vinyl Bromide	0.041 mg/L	0.00113 mg/L
MW22i	Regional Watertable	Benzene	0.011 mg/L	0.00274 mg/L
MW23i	Regional Watertable	Arsenic	0.04 mg/L	0.00241 mg/L
		Benzene	0.005 mg/L	0.00274 mg/L
		Vinyl Bromide	0.0036 mg/L	0.00113 mg/L
MW25	Base of Guildford	Benzene	0.027 mg/L	0.00274 mg/L

In most cases the concentration of the parameters identified above the relevant RBC were consistent with previous results. The concentration of benzene in MW25 (Base of Guildford) is consisted with historical results. This suggests that downward migration of benzene may have reached a steady-state.

It is also worth noting that vinyl bromide was last analysed in samples collected from MW23i (Regional Watertable) in 2005 and 2006 when the concentrations were 0.0081 mg/L (above RBC) and 0.0004 mg/L (below RBC), respectively. During the 2009 sampling programme concentrations of vinyl bromide were found to be 0.0036 mg/L which is a significant increase from the 2006 results but still less than 2005 results.

The following contaminants have historically been above the relevant RBC but were identified in 2009 at concentrations below relevant RBC:

- 1,2-dichloroethane (1,2-DCA) at locations MW21i (Regional Watertable), MW22i (Regional Watertable) and MW23i (Regional Watertable) below the LOR;
- arsenic and TPH C_6-C_9 fraction at location MW21i (Regional Watertable) at concentrations of 0.0014 mg/L and 11 mg/L respectively; and
- TCE was detected at MW23i (Regional Watertable) in 2005; however 2009 results indicate the concentration was 0.002 mg/L.

5.3.3.2 Other Results

In addition to the contaminants listed in Table F a number of additional parameters were detected above the laboratory limit of reporting (LOR) but below relevant RBC (where applicable). These additional parameters and their locations are discussed in the following section.

Table G summarises the water quality parameters. The results indicate that nitrate (as N) concentrations in most samples were below LOR with the exception of MW25 (2 mg/L, Base of Guildford). TDS concentrations were generally lower than previously observed values.

Table G: Summary of Water Quality Parameters from On-Site Groundwater

Parameter	Range	Well
Total Alkalinity	40 mg/L to 700 mg/L	MW21i, MW22i, MW23i and MW25
Sodium	130 mg/L to 410 mg/L	MW21i, MW22i, MW23i and MW25
Potassium	1.5 mg/L to 27 mg/L	MW21i, MW22i, MW23i and MW25
Calcium	8.8 mg/L to 54 mg/L	MW21i, MW22i, MW23i and MW25
Magnesium	18 mg/L to 77 mg/L	MW21i, MW22i, MW23i and MW25
Chloride	170 mg/L to 360 mg/L	MW21i, MW22i, MW23i and MW25
Sulphate	<1 mg/L to 89 mg/L	MW22i and MW25
Bicarbonate Alkalinity	40 mg/L to 700 mg/L	MW21i, MW22i, MW23i and MW25
Nitrate (as N)	<1 mg/L to 2 mg/L	MW25
Total Dissolved Solids (TDS)	470 mg/L to 1500 mg/L	MW21i, MW22i, MW23i and MW25

Low concentrations of TDS often indicate areas of recharge. As the site is mostly covered by hardstand it would be anticipated that the shallow groundwater would not be significantly influenced by recharge. Results indicate both MW21i (Regional Watertable) and MW22i (Regional Watertable) had TDS concentrations above 1000 mg/L which indicate low recharge. This is supported by the high conductivity values observed in the field at these locations. However, TDS concentrations from MW23i (Regional Watertable) and MW25 (Base of Guildford) were lower suggesting a greater influence of recharge on groundwater quality, possibly due to lateral migration from areas up gradient, or recharge through the uncapped areas of the site (along the northern and northwestern boundaries such as where MW23i is located). These results are consistent with historical results as these two locations have had lower TDS concentrations than MW21i and MW22i.

A summary of the inorganic results is presented in Table H. Depending on the location, inorganic parameters have not been analysed in samples from the site since 2005 or 2006.

Table H: Summary of Metals Detected in On-Site Groundwater

Analyte	Range	Locations
Aluminium*	0.015 mg/L to 0.58 mg/L	MW21i, MW22i, MW23i and MW25
Arsenic*	0.0014 mg/L to 0.04 mg/L	MW21i and MW22i
Cadmium*	<0.0001 mg/L to 0.0002 mg/L	MW23i
Chromium*	0.0006 mg/L to 0.0015 mg/L	MW21i, MW22i, MW23i and MW25
Copper	<0.0005 mg/L to 0.0013 mg/L	MW21i and MW23i
Ferrous Iron	0.1 mg/L to 24 mg/L	MW21i, MW22i, MW23i and MW25
Iron*	0.21 mg/L to 51 mg/L	MW21i, MW22i, MW23i and MW25
Manganese*	0.027 mg/L to 0.1 mg/L	MW21i, MW22i, MW23i and MW25
Zinc	0.24 mg/L to 2.3 mg/L	MW21i, MW22i, MW23i and MW25

*indicate RBC has been developed for the parameter

Generally the metals results were consistent with historical results except for the following:

- Concentrations of aluminium increased at the following three locations:
  - MW22i (Regional Watertable) from 0.002 mg/L in 2006 to 0.58 mg/L in 2009;
  - MW23i (Regional Watertable) from <0.001 mg/L in 2006 to 0.22 mg/L in 2009; and
  - MW25 (Base of Guildford) from 0.016 mg/L in 2005 to 0.34 mg/L in 2009.

- Cadmium was detected above the laboratory LOR in an on-site sample for the first time.
- Concentrations of iron (0.002 mg/L to 0.21 mg/L) and manganese (0.048 mg/L to 0.1 mg/L) at MW25 (Base of Guildford) increased significantly since 2005.
- Concentrations of zinc increased at all four location as follows:
  - MW21i (Regional Watertable) from 0.065 mg/L in 2005 to 2.3 mg/L in 2009;
  - MW22i (Regional Watertable) from 0.012 mg/L in 2006 to 0.24 mg/L in 2009;
  - MW23i (Regional Watertable) from 0.012 mg/L in 2006 to 0.31 mg/L in 2009; and
  - MW25 (Base of Guildford) from 0.11 mg/L in 2005 to 0.25 mg/L in 2009.

A summary of the organic results in samples collected from site are presented in Table I. Generally the results from the 2009 annual monitoring were consistent with historical results.

Table I: Summary of Organics Detected in On-Site Groundwater

Analyte	Range	Locations
TPHC$_6$-C$_9$	0.19 mg/L to 11 mg/L	MW21i, MW22i, MW23i and MW25
TPH C$_{10}$-C$_{14}$*	0.13 mg/L to 3.6 mg/L	MW21i, MW22i, MW23i and MW25
TPH C$_{15}$-C$_{28}$*	<0.05 mg/L to 0.71 mg/L	MW21i, MW22i, MW23i and MW25
Benzene*	0.005 mg/L to 0.027 mg/L (all above RBC)	MW21i, MW22i, MW23i and MW25
1,2,4-trimethylbenzene*	0.002 mg/L to 0.31 mg/L	MW21i, MW22i, MW23i and MW25
1,3,5-trimethylbenzene*	<0.001 mg/L to 0.13 mg/L	MW21i, MW22i and MW23i
Ethylbenzene*	0.0005 mg/L to 0.91 mg/L	MW21i, MW22i, MW23i and MW25
Isopropylbenzene*	<0.001 mg/L to 0.014 mg/L	MW21i, MW22i and MW23i
n-propylbenzene*	<0.001 mg/L to 0.022 mg/L	MW21i, MW22i and MW23i
p-isopropyltoluene*	<0.001 mg/L to 0.079 mg/L	MW21i, MW22i and MW23i
Toluene*	<0.001 mg/L to 4.6 mg/L	MW21i, MW22i and MW23i
Xylene (m&p)*	0.009 mg/L to 1.6 mg/L	MW21i, MW22i, MW23i and MW25
Xylene (o)*	<0.001 mg/L to 1.3 mg/L	MW21i, MW22i and MW23i
1-methylnaphthalene	0.003 mg/L to 0.004 mg/L	MW21i and MW22i
2-methylnaphthalene*	0.004 mg/L	MW21i and MW22i
Naphthalene*	<0.001 mg/L to 0.036 mg/L	MW21i, MW22i and MW23i
2,4-dimethylphenol*	0.011 mg/L to 0.026 mg/L	MW21i and MW22i
2-methylphenol*	0.014 mg/L to 0.099 mg/L	MW21i and MW22i
Acetophone*	<0.001 mg/L to 0.036 mg/L	MW21i
Isophorone*	<0.001 mg/L to 0.009 mg/L	MW21i
3- &4- methylphenol	<0.001 mg/L to 0.24 mg/L	MW21i
1,1-dichloroethene*	<0.001 mg/L to 0.017 mg/L	MW21i, MW22i and MW23i
1,1-dichloroethane	<0.001 mg/L to 0.059 mg/L	MW21i, MW22i and MW23i
Chloroethane*	<0.001 mg/L to 0.008 mg/L	MW22i and MW23i
Chloroform*	<0.001 mg/L to 0.024 mg/L	MW21i
Cis-1,2-dibromoethene	<0.0001 mg/L to 0.013 mg/L	MW21i and MW23i
Cis-1,2-dichloroethene*	<0.001 mg/L to 0.75 mg/L	MW21i, MW22i and MW23i
TCE*	<0.001 mg/L to 0.009 mg/L	MW21i and MW23i
PCE*	<0.001 mg/L to 0.029 mg/L	MW21i and MW23i

Analyte	Range	Locations
Trichlorofluoromethane	<0.001 mg/L to 0.024 mg/L	MW21i
Vinyl chloride*	<0.001 mg/L to 0.002 mg/L	MW22i and MW23i
1,2-dichlorobenzene*	<0.001 mg/L to 0.011 mg/L	MW21i, MW22i and MW23i
Chlorobenzene*	<0.001 mg/L to 0.005 mg/L	MW21i, MW22i and MW23i

*indicate RBC has been developed for the parameter

Results from the sample collected from MW21i (Regional Watertable) indicated a significant decrease in the concentrations of TPH C_6-C_9 (39 mg/L to 11 mg/L), C_{10}-C_{14} (25 mg/L to 1.3 mg/L) and C_{15}-C_{28} (1.6 mg/L to 0.2 mg/L). A decreased in the concentration of TPH C_{10}-C_{14} at MW23i (Regional Watertable) was also noted (1.1 mg/L to 0.37 mg/L which is below the relevant RBC).

In contrast, results from location MW25 at the Base of Guildford indicated an increase in concentration of TPH C_6-C_9 (0.04-0.19), C_{10}-C_{14} (0.04-0.13) and C_{15}-C_{28} (<0.05-0.14). These results indicate that the downward migration of TPHs is likely occurring on-site. These trends are also consistent with the noted first occurrence of benzene above RBC in this well beginning in 2008 and which remained relatively constant in 2009. Because of its higher solubility and lower adsorption benzene is often the most mobile petroleum hydrocarbon in groundwater; hence its breakthrough at the Base of Guildford ahead of TPH parameters is consistent with its expected behaviour in groundwater.

Concentrations of monocyclic aromatic hydrocarbons (MAHs) results indicate a general decrease in concentrations at location MW21i (Regional Watertable) with benzene (0.014 mg/L to 0.008 mg/L), toluene (6.1 mg/L to 4.6 mg/L) and total xylenes (4.2 mg/L to 2.9 mg/L) decreasing. The concentration of total xylenes at MW23i (Regional Watertable) increased significantly from 0.039 mg/L to 0.45 mg/L. It should be noted that benzene was not listed in Table I as all on-site monitoring locations sampled had concentrations above RBC.

Consistent with historical results, no VOCs were detected in MW25 (Base of Guildford), excluding the previously discussed petroleum hydrocarbons. The only noteworthy increases in VOCs or sVOCs from samples collected on-site were chloroethane in MW23i (Regional Watertable, 0.001 mg/L to 0.008 mg/L), 2,4-dimethylphenol in MW22i (Regional Watertable, <0.001 mg/L to 0.026 mg/) and 2-methylphenol in MW22i (Regional Watertable, <0.0001 mg/L to 0.014 mg/L).

A number of contaminants were noted to have significant decreases in VOC concentrations. The concentration of 1,2-DCA decreased in MW22i (Regional Watertable) and MW23i (Regional Watertable) to below the relevant RBC and the laboratory LOR and the concentration of TCE decreased in 2009 to below the LOR from 0.022 mg/L in 2008. However, the most significant decreases were in the concentrations of the following contaminants at MW21i (Regional Watertable):

- 2,4-dimethylphenol decreased from 0.024 mg/L in 2008 to 0.011 mg/L in 2009;
- 3-4-methylphenol decreased from 0.46 mg/L in 2008 to 0.24 mg/L in 2009;
- 1,2-dichloroethane (DCA) dropped from 0.004 mg/L (above the RBC) in 2008 to <0.001 mg/L which is below the relevant RBC;
- 1,1-DCA decreased from 0.12 mg/L in 2008 to 0.059 mg/L in 2009;
- cis- & trans-1,2-dibromoethene (DBE) which was historically above RBC in 2005 (0.003 mg/L) and 2008 (0.004 mg/L), was in 2009 below the laboratory LOR of 0.001 mg/L;
- chloroethane decreased from 0.008 mg/L in 2008 to <0.001 mg/L in 2009; and
- cis-1,2-dichloroethene (DCE) decreased from 0.79 mg/L in 2008 to 0.41 mg/L in 2009.

5.3.4 Southwest Industrial Area

Samples were collected from the following ten monitoring wells in the Southwest Industrial Area:

- MWG51 (Regional Watertable);
- MWG65 (Regional Watertable);
- MWG69 (Base of Guildford);
- MWG70 (Regional Watertable);
- MWG71 (Base of Guildford);
- MWG72 (Regional Watertable);
- MWG80 (Base of Guildford);
- MWG81 (Regional Watertable);
- MWG82 (Regional Watertable);
- MWG85 (Regional Watertable); and
- MWG86 (Regional Watertable).

All samples collected from the Southwest Industrial Area were analysed for VOCs, Br-VOCs, TPHs, phthalates, major anions and cations, total metals, ferrous iron and TDS. The sample collected from MWG80 (Base of Guildford) was also analysed for sVOCs. The complete results of the 2009 groundwater sampling for all locations on the Southwest Industrial Area are presented in Table 3, along with historical groundwater sampling results dating back to 2005.

5.3.4.1 RBC Exceedences

Results for the Southwest Industrial Area were compared against the site and Lot 2 RBC. These site-specific RBC cover potential indoor air inhalation pathways for environmental works and exposure of a worker performing irrigation. Table J presents an overall summary of the parameters detected at concentrations above relevant RBC as well as the sample location and relevant monitoring zone.

Table J: Summary of Southwest Industrial Area Results Above Relevant RBC

Location	Monitoring Zone	Analyte	Concentration	Relevant RBC
MWG70	Regional Watertable	TCE	0.24 mg/L	0.0351 mg/L

The only contaminant identified at concentrations above the relevant RBC was TCE at location MWG70 (Regional Watertable). The results are consistent with previous concentrations of TCE from the same location.

In the 2008 annual monitoring round bis(2-ethylhexyl) phthalate was above relevant RBC for MWG72 (Regional Watertable) and MWG80 (Base of Guildford). It was thought that these may have been initially anomalous results associated with their recent installation and contact of the PVC with plastic wrap prior to installation. These locations were subsequently re-sampled during the interim monitoring in October 2008 and the results indicated concentrations of bis(2-ethylhexyl) phthalate were below RBC. The most recent results were below LOR at both monitoring wells, confirming the anomalous nature of the initial bis(2-ethylhexyl) phthalate results.

The last time vinyl bromide was analysed for in samples collected from MWG51 (Regional Watertable) was in 2006 and results indicated the concentration was above RBC. The most recent results indicate that the concentration of vinyl bromide at MWG51 (Regional Watertable) was below LOR.

5.3.4.2 Other Results

In addition to the contaminants listed in Table J a number of additional parameters were detected above the laboratory LOR but below relevant RBC (if any). These additional parameters and their locations are discussed in the following section.

Table K summarises the water quality parameters.

Table K: Summary of Water Quality Parameters from the Southwest Industrial Area

Analyte	Range	Locations
Total Alkalinity	10 mg/L to 140 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Sodium	29 mg/L to 200 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Potassium	4.8 mg/L to 11 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Calcium	3.7 mg/L to 28 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Magnesium	4.9 mg/L to 39 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Chloride	50 mg/L to 240 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Sulphate	<1 mg/L to 100 mg/L	MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Bicarbonate Alkalinity	20 mg/L to 140 mg/L	MWG51, MWG65, MWG70, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Nitrate (as N)	1 mg/L to 47 mg/L	MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Total Dissolved Solids	230 mg/L to 680 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86

TDS concentrations in the Southwest Industrial Area were generally identified to be low (< 1000 mg/L). This indicates that the groundwater beneath this area is likely receiving recharged from infiltration and up gradient groundwater.

Table L presents a summary of the metals identified at concentrations above LOR and below the relevant RBC (if any exist).

Table L: Summary of Metals Detected in Southwest Industrial Area Groundwater

Analyte	Range	Locations
Aluminium*	0.011 mg/L to 0.27 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Arsenic*	<0.0005 mg/L to 0.0012 mg/L	MWG82
Chromium*	<0.0002 mg/L to 0.002 mg/L	MWG79, MWG71, MWG72 and MWG81
Copper	<0.0005 mg/L to 0.0042 mg/L	MWG70, MWG80 and MWG86
Ferrous Iron	<0.1 mg/L to 1.9 mg/L	MWG51, MWG70, MWG80, MWG82 and MWG85
Iron*	0.019 mg/L to 24 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Lead	<0.001 mg/L to 0.001 mg/L	MWG71

Analyte	Range	Locations
Nickel*	<0.001 mg/L to 0.004 mg/L	MWG51, MWG80, MWG81, MWG82, MWG85 and MWG86
Manganese*	0.026 mg/L to 0.63 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86
Zinc	0.14 mg/L to 0.34 mg/L	MWG51, MWG65, MWG70, MWG71, MWG72, MWG80, MWG81, MWG82, MWG85 and MWG86

*indicate RBC has been developed for the parameter

Metals results from the 2009 annual monitoring were generally consistent with historical results. However significant increases in aluminium and zinc were noted in all samples collected from the Southwest Industrial Area. One of the most significant increases of aluminium was noted in MWG51 (Regional Watertable) which went from <0.001 mg/L in 2008 to 0.19 mg/L in 2009 and of zinc in MWG72 (Regional Watertable) from 0.0061 mg/L in 2008 to 0.34 mg/L in 2009. It was also identified that nickel decreased all locations except MWG82 (Regional Watertable) and manganese decreased in all locations except MWG72 (Regional Watertable).

Inorganic parameters were not analysed in samples collected during the 2008 annual round for MWG65 (Regional Watertable) and during the interim monitoring round in MWG70 (Regional Watertable), MWG72 (Regional Watertable), MWG80 (Base of Guildford) and MWG81 (Regional Watertable).

A summary of the organic results in samples collected from the Southwest Industrial Area are presented in Table M.

Table M: Summary of Organic Parameters Detected in Southwest Industrial Area Groundwater

Analyte	Range	Locations
TPH C_6-C_9*	<0.01 mg/L to 0.13 mg/L	MWG51, MWG71 and MWG81
TPH C_{10}-C_{14}*	<0.01 mg/L to 0.14 mg/L	MWG51 and MWG81
TPH C_{15}-C_{28}*	<0.05 mg/L to 0.07 mg/L	MWG51 and MWG81
Benzene*	<0.001 mg/L to 0.002 mg/L	MWG51
Chloroform*	<0.001 mg/L to 0.003 mg/L	MWG51, MWG65 and MWG81
Cis-1,2-DBE	<0.0001 mg/L to 0.0013 mg/L	MWG51
Cis-1,2-DCE*	<0.001 mg/L to 0.074 mg/L	MWG51, MWG65 and MWG81
TCE*	<0.001 mg/L to 0.24 mg/L	MWG51, MWG65, MWG70 and MWG81
PCE*	<0.001 mg/L to 0.016 mg/L	MWG51, MWG65, MWG70, MWG81 and MWG86
Trichlorofluoromethane	<0.001 mg/L to 0.004 mg/L	MWG65, MWG81, and MWG86

*indicate RBC has been developed for the parameter

The results from the 2009 annual monitoring are generally consistent with historical results with the following exceptions:

- The concentration of TPH at MWG51 (Regional Watertable) increased as follows:
  - TPH C_6-C_9 from 0.01 mg/L to 0.13 mg/L; and
  - TPH C_{10}-C_{14} from 0.06 mg/L to 0.14 mg/L.
- The concentrations at MWG71 (Base of Guildford) decreased as follows:
  - TPH C_6-$C_{9,}$ from 0.46 mg/L to 0.03 mg/L;
  - TPH C_{10}-C_{14} from 0.46 mg/L to 0.03 mg/L; and
  - TPH C_{15}-C_{28} from 0.15 mg/L to <0.05 mg/L.
- The concentration of cis-1,2-DCE at MWG65 (Regional Watertable) decreased from 0.023 mg/L to 0.006 mg/L.
- The concentration of PCE at MWG51 (Regional Watertable) decreased from 0.034 mg/L to 0.014 mg/L.

The results for TPH from location MWG81 (Regional Watertable) were found to be more consistent with results from the 2008 annual monitoring programme conducted in March, than that of the 2008 interim monitoring programme conducted in October. Concentrations of contaminants (1,1-DCA, chloroform, TCE, PCE, trichlorofluoromethane and TPH fractions C_6-C_9, C_{10},-C_{14} and C_{15}-C_{28}) were lower in samples collected in October 2008 (following winter) in comparison to those collected in March 2008 or 2009. It is possible that MWG81 (Regional Watertable) is located on the southwest edge of the plume emanating from the former Waste Control site. The differences in the contaminant results may indicate a shift southward in the plume during the summer season. This is supported by the particle tracking modelling (Golder, 2009b) which suggested that flowlines, which generally trend southwest, may have a more southerly component during periods of low recharge.

5.3.5 Hanson

Only one sample from MWG64 (Regional Watertable) was collected from the Hanson Property. The sample was analysed for VOCs, Br-VOCs, TPHs, phthalates, major anions and cations, total metals, ferrous iron and TDS. The complete results of the 2009 groundwater sampling for all locations on the Hanson Property are presented in Table 5, along with historical groundwater sampling results dating back to 2005.

5.3.5.1 RBC Exceedences

Results for the Hanson Property sample were compared against the Hanson RBC and site and Lot 2 RBC. The Hanson RBC covers outdoor workers conducting outdoor activities on the property that do not involve irrigation, which is current with the current site activities and lack of buildings above affected areas. The latter RBC accommodates potential land use changes including future commercial/industrial indoor workers (in a hypothetical future building) and future outdoor maintenance workers, conducting irrigation activities during normal weekly work. It should be noted that as no buildings are currently located over the plume the use of the indoor worker scenario is only hypothetical. A summary of the contaminants identified at concentrations above RBC is presented in Table N.

Table N: Summary of Hanson Property Results Above Relevant RBC

Location	Monitoring Zone	Analyte	Concentration	Relevant RBC
MWG64	Regional Watertable	Arsenic	0.049 mg/L	0.00241 mg/L
		Bis(2-ethylhexyl) phthalate	0.003 mg/L	0.0028 mg/L

The relevant RBC exceedences noted at the Hanson Property were for site and Lot 2 RBCs and not Hanson RBCs. It should be noted that no buildings are located over the plume and therefore the use of the indoor worker scenario is only hypothetical. This indicates a risk for potential land use changes and not a risk for the current land use.

Arsenic has historically been above the relevant RBC at MWG64 (Regional Watertable). However, the most recent result of 0.049 mg/L is a significant increase from 0.017 mg/L in 2006.

For the first time bis(2-ethylhexyl) phthalate was detected both above the LOR and above the relevant RBC. It should be noted that a Hanson RBC has not been developed for bis(2-ethylhexyl) phthalate and that the concentration of bis(2-ethylhexyl) phthalate was well below the site and Lot 2 RBC for inhalation which is 35,700 mg/L.

Historical results also had concentrations of TPH C_{10}-C_{14}, benzene and vinyl bromide above relevant RBC. The results from the 2009 annual monitoring round indicate that these contaminants were detected at concentrations below the relevant RBC and vinyl bromide was below LOR.

5.3.5.2 Other Results

In addition to the contaminants listed in Table N a number of additional parameters were detected above the laboratory LOR but below relevant RBC (if any). These additional parameters and their locations are discussed in the following section.

Table O summarises the water quality parameters.

Table O: Summary of Water Quality Parameters from the Hanson Property

Analyte	Result	Locations
Total Alkalinity	240 mg/L	MWG64
Sodium	220 mg/L	MWG64
Potassium	9.4 mg/L	MWG64
Calcium	11 mg/L	MWG64
Magnesium	54 mg/L	MWG64
Chloride	340 mg/L	MWG64
Sulphate	53 mg/L	MWG64
Bicarbonate Alkalinity	240 mg/L	MWG64
Total Dissolved Solids	810 mg/L	MWG64

Table P presents a summary of metals identified at concentrations above LOR and below the relevant RBC (if any exist).

Table P: Summary of Metals Detected in Hanson Property Groundwater

Analyte	Result	Locations
Aluminium*	0.041 mg/L	MWG64
Zinc	0.34 mg/L	MWG64
Ferrous Iron	20 mg/L	MWG64
Iron*	32 mg/L	MWG64
Manganese*	0.1 mg/L	MWG64
Nickel*	0.002 mg/L	MWG64

*indicate RBC has been developed for the parameter

Results for both aluminium and zinc were significantly greater than historical results for MWG64 (Regional Watertable). Aluminium increased to 0.41 mg/L from 0.013 and zinc to 0.34 mg/L from 0.018 mg/L. In comparison results of ferrous iron, iron, manganese and nickel all decreased.

Table Q presents a summary of the organic parameters identified at concentrations above LOR and below the relevant RBC (if any exist).

Table Q: Summary of Organic Parameters Detected in Hanson Property Groundwater

Analyte	Result	Locations
TPHC_6-C_9	0.08 mg/L	MWG64
TPH C_{10}-C_{14}*	0.15 mg/L	MWG64
TPH C_{15}-C_{28}*	0.1 mg/L	MWG64
Benzene*	0.001 mg/L	MWG64
Ethylbenzene*	0.001 mg/L	MWG64
1,2,4-trimethylbenzene*	0.001 mg/L	MWG64
1,1-dichloroethene*	0.007 mg/L	MWG64
1,1-dichloroethane	0.032 mg/L	MWG64
Cis-1,2-dichloroethene*	0.13 mg/L	MWG64
TCE*	0.003 mg/L	MWG64
PCE*	0.003 mg/L	MWG64
1,2-dichlorobenzene*	0.003 mg/L	MWG64

*indicate RBC has been developed for the parameter

Overall the results indicate a decrease in the concentration of hydrocarbons with the lighter TPH fractions, benzene, ethylbenzene, and 1,2,4-trimethylbenzene all decreasing significantly in comparison to historical results. In comparison, concentrations of chlorinated compounds were mostly consistent with historical results with the exception of TCE which decreased from 0.011 in 2008 mg/L to 0.003 mg/L in 2009.

5.3.6 Lot 2

Nine monitoring wells on Lot 2 were included as part of the 2009 annual monitoring programme:

- MW37 (Regional Watertable);
- MW42 (Regional Watertable);
- MWG49 (Regional Watertable);
- MWG53 (Base of Guildford);

- MWG54 (Regional Watertable);
- MWG57 (Regional Watertable);
- MWG59 (Regional Watertable);
- MWG83 (Base of Guildford); and
- MWG84 (Regional Watertable).

All samples collected from Lot 2 were analysed for VOCs, Br-VOCs, TPHs, phthalates, major anions and cations, total metals, ferrous iron and TDS. The sample collected from MWG53 (Base of Guildford) was also analysed for sVOCs. The complete results of the 2009 groundwater sampling for all locations on Lot 2 are presented in Table 2, along with historical groundwater sampling results dating back to 2005.

5.3.6.1 RBC Exceedences

Results for Lot 2 were compared against the site and Lot 2 RBC. As stated in Section 4, these site-specific RBC address potential exposures to indoor workers and workers performing irrigation.

Table R presents a summary of the locations where contaminants were detected above relevant RBC.

Table R: Summary of Lot 2 Results Above Relevant RBC

Location	Monitoring Zone	Analyte	Concentration	Relevant RBC
MW42	Regional Watertable	TCE	0.085 mg/L	0.0351 mg/L
MWG49	Regional Watertable	TCE	0.049 mg/L	0.0351 mg/L
MWG57	Regional Watertable	TCE	0.77 mg/L	0.0351 mg/L
MWG59	Regional Watertable	1,2-Dichloroethane	0.003 mg/L	0.00126 mg/L
		TCE	0.056 mg/L	0.0351 mg/L
		Vinyl Bromide	0.0059 mg/L	0.00113 mg/L
MWG83	Base of Guildford	Vinyl Bromide	0.015 mg/L	0.00113 mg/L
MWG84	Regional Watertable	TPH C_{10}-C_{14}	0.74 mg/L	0.655 mg/L
		Benzene	0.003 mg/L	0.00274 mg/
		1,2-Dichloroethane	0.007 mg/L	0.00126 mg/L
		Vinyl Bromide	0.052 mg/L	0.00113 mg/L
		1,4-dichlorobenzene	0.004 mg/L	0.00373 mg/L

The concentration of TCE at MW42 (Regional Watertable) decreased from 0.17 mg/L to 0.067 mg/L. The concentration of TCE at MWG49 (Regional Watertable) was not significantly lower this year in comparison to last year. However, the results do indicate a generally downward trend in the concentration of TCE at this location as the 2005 concentration was 0.44 mg/L and in March 2009 the concentration was 0.049 mg/L.

The last time (October 2006) vinyl bromide was analysed in samples collected from MWG59 (Regional Watertable) the concentration was 0.0006 mg/L. The 2009 results indicate that the concentration of vinyl bromide at MWG59 (Regional Watertable) increased to 0.0059 mg/L which is above the relevant RBC.

In March 2008 the concentration of vinyl bromide at MWG83 (Base of Guildford) was 0.0016, in October 2008 it was 0.001, the most recent results indicate the concentration has now increased to 0.015 mg/L. Hence an overall increasing trend in vinyl bromide concentrations is apparent at MWG83.

The concentration of benzene at MWG84 (Regional Watertable) was above the relevant RBC for the first time in March 2009. However the concentration only marginally increased from the historical value of 0.002 mg/L to 0.003 mg/L. Though MWG84 (Regional Watertable) has a number of halogenated compounds above RBC, the 2009 results indicate a general decrease in their concentrations since

October 2008, with 1,2-DCA, vinyl bromide, 1,2-dichlorobenzene and TCE all decreasing. In particular, the concentrations of TCE dropped significantly from above the RBC (0.037 mg/L) in October 2008 to below RBC (0.006 mg/L).

5.3.6.2 Other Results

Table S presents the analytes which were detected above the laboratory LOR but below relevant RBC criteria.

Table S: Summary of Water Quality Parameters from Lot 2

Analyte	Range	Locations
Total Alkalinity	<1 mg/L to 120 mg/L	MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Sodium	58 mg/L to 200 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Potassium	4.3 mg/L to 8.6 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Calcium	2.4 mg/L to 27 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Magnesium	8.2 mg/L to 58 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Sulphate	16 mg/L to 330 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Chloride	68 mg/L to 320 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Bicarbonate Alkalinity	<1 mg/L to 120 mg/L	MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Total Dissolved Solids	320 mg/L to 900 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84

TDS results beneath Lot 2 were generally low (< 1000 mg/L) suggesting somerecharge occurs over this area which is consistent with its undeveloped status.

A summary of the results of inorganic parameters in the samples collected from Lot 2 are presented in Table T.

Table T: Summary of Metals Detected in Lot 2 Groundwater

Analyte	Range	Locations
Aluminium*	0.059 mg/L to 0.47 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Cadmium*	<0.0001 mg/L to 0.0017 mg/L	MW42 and MWG57
Chromium*	<0.0002 mg/L to 0.0063 mg/L	MWG53, MWG54, MWG57, MWG59 and MWG83
Copper	<0.0005 mg/L to 0.0013 mg/L	MW42, MWG54 and MWG83
Ferrous Iron	<0.1 mg/L to 0.4 mg/L	MW37, MW42 and MWG83
Iron*	0.022 mg/L to 1.1 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84
Lead	<0.001 mg/L to 0.001 mg/L	MWG53 and MWG54
Manganese*	0.013 mg/L to 0.41 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84

Analyte	Range	Locations
Nickel*	<0.001 mg/L to 0.003 mg/L	MW37, MW42, MWG49, MWG54, MWG59, MWG83 and MWG84
Zinc	0.019 mg/L to 0.47 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG57, MWG59, MWG83 and MWG84

*indicate RBC has been developed for the parameter

Analysis of metals was not undertaken on samples collected from MW42, MWG49, MWG53 and MWG54 in 2008. Hence, there are no historical data from 2008 upon which to base a comparison.

The concentration of aluminium has increased significantly in comparison to previous results (in most cases March 2008; however for MW42, MWG49, MWG53 and MWG54 it was October 2006) at all locations except MW37 (Regional Watertable) were it remained relatively consistent. The greatest increase was noted at MWG54 (Regional Watertable) where the concentration increased from 0.005 mg/L in 2006 to 0.47 mg/L in 2009.

Arsenic was historically detected in monitoring wells on Lot 2 where is has been tested. However, concentrations of arsenic decreased in MWG49 (Regional Watertable), MWG53 (Base of Guildford), MWG54 (Regional Watertable), MWG59 (Regional Watertable), MWG84 (Regional Watertable) and MWG83 (Base of Guildford) to below the LOR.

The concentration in cadmium in MWG57 (Regional Watertable) increased from below the LOR in 2008 to 0.0002 mg/L in 2009. Cadmium has previously been detected in MWG57 (Regional Watertable) at a concentration of 0.00006 mg/L in 2006.

The concentration of copper decreased below LOR for the first time in MW37 (Regional Watertable), MW42 (Regional Watertable), MWG49 (Regional Watertable), MWG59 (Base of Guildford) and MWG84 (Regional Watertable) and decreased from 0.0026 mg/L to 0.0013 mg/L in MWG54 (Regional Watertable). Copper increased only in MWG83 (Base of Guildford) with the concentration (0.0006 mg/L) above LOR for the first time in the March 2009 monitoring programme.

The concentration of chromium decreased below LOR for the first time in MW37 (Regional Watertable) and increased in MWG83 (Base of Guildford, 0.0009 mg/L) above LOR for the first time. The concentration of chromium also increased in MWG53 (Base of Guildford) from 0.0003 mg/L in 2006 to 0.0063 mg/L in 2009.

In comparison to results from March 2008, results from the 2009 annual results indicated that the ferrous iron concentration decreased from 1.1 mg/L to 0.1 mg/L at MWG83 (Base of Guildford).

The concentration of lead in groundwater from Lot 2 increased in both MWG54 (Regional Watertable) and MWG53 (Base of Guildford) from <0.001 mg/L in 2006 to 0.001 mg/L. The lead concentration in MW37 (Regional Watertable) decreased below LOR (<0.001 mg/L) from 0.0016 mg/L in 2008.

Nickel decreased in all monitoring wells except MWG49 (Regional Watertable) where the concentration was increased from <0.0002 mg/L in 2008 to 0.001 mg/L in 2009.

Concentrations of manganese decreased in all monitoring wells, most significantly MWG83 (Base of Guildford, 2.3 mg/L in 2008 to 0.12 mg/L in 2009), except MWG54 where an increase was noted (0.004 mg/L to 0.013 mg/L).

Concentrations of zinc increased in all locations except MW37 (Regional Watertable), where the concentration decreased from 0.46 mg/L in 2008 to 0.019 mg/L in 2009. The most increase significant was noted at MWG53 (Base of Guildford), which went from <0.0005 mg/L in 2006 to 0.22 mg/L in 2009.

A summary of results of organic parameters in the samples collected from Lot 2 are presented in Table U.

Table U: Summary of Detected Analytes Below Relevant RBC

Analyte	Range	Locations
TPH C_6-C_9	<0.01 mg/L to 0.28 mg/L	MW42, MWG49, MWG57, MWG59, MWG83 and MWG84
TPH C_{10}-C_{14}*	<0.01 mg/L to 0.74 mg/L	MWG83 and MWG84
TPH C_{15}-C_{28}*	<0.05 mg/L to 0.38 mg/L	MW42 and MWG84
Isopropylbenzene*	<0.001 mg/L to 0.003 mg/L	MWG84
Xylenes (o,m &p) *	<0.002 mg/L to 0.011 mg/L	MWG84
1,1,1-TCA	<0.001 mg/L to 0.003 mg/L	MWG59
1,1-DCA	<0.002 mg/L to 0.039 mg/L	MW42, MWG49, MWG59, and MWG84
1,1-DCE*	<0.001 mg/L to 0.064 mg/L	MWG49, MWG53, MWG59, and MWG84
Chloroform*	<0.001 mg/L to 0.11 mg/L	MWG49, MWG53, MWG59, and MWG84
Cis-1,2-DBE	<0.0001 mg/L to 0.061 mg/L	MW42, MWG49, MWG54, MWG59 and MWG84
Cis-1,2-DCE*	<0.001 mg/L to 0.26 mg/L	MW42, MWG49, MWG53, MWG59, MWG83 and MWG84
TCE*	<0.001 mg/L to 0.77 mg/L	MW37, MWG54, and MWG84
PCE*	<0.001 mg/L to 0.026 mg/L	MW37, MW42, MWG49, MWG53, MWG54, MWG59, MWG83 and MWG84
Trans-1,2-DBE	<0.0001 mg/L to 0.013 mg/L	MWG54, MWG59 and MWG84
Trans-1,2-DCE	<0.001 mg/L to 0.015 mg/L	MW42
trichlorofluoromethane	<0.001 mg/L to 0.005 mg/L	MWG49, MWG59 and MWG84
Vinyl Bromide*	<0.0001 mg/L to 0.052 mg/L	MW42
1,2-dichlorobenzene*	<0.001 mg/L to 0.016 mg/L	MWG83 and MWG84
1,3-dichlorobenzene*	<0.001 mg/L to 0.004 mg/L	MWG84
1,4-dichlorobenzene*	<0.001 mg/L to 0.004 mg/L	MWG83
Chlorobenzene*	<0.001 mg/L to 0.001 mg/L	MWG84

*indicate RBC has been developed for the parameter

The 2009 results were generally consistent with historical results. Concentrations of 1,1-DCA and 1,1-DCE appear to have decreased in MWG49 (Regional Watertable) and increased in MWG59 (Regional Watertable) since October 2006 and March 2008. Concentrations of chloroform and cis-1,2- DBE at locations have decreased in comparison to historical results.

The concentration of cis-1,2-DCE decreased in MWG84 (Regional Watertable) from 1 mg/L in October 2008 to 0.24 mg/L. However, the March 2009 results are consistent with the March 2008 monitoring results for cis-1,2 DCE at MWG84 of 0.22 mg/L. In contrast, the concentration of cis-1,2-DCE at MWG59 (Regional Watertable) increased from 0.033 mg/L to 0.072 mg/L (March 2008 to March 2009, respectively) and decreased at MWG53 Base of Guildford) from 0.021 mg/L to 0.007 mg/L (October 2006 to March 2009, respectively).

Two of Base of Guildford monitoring wells MWG53 and MWG83 have historically had low concentrations of TCE detected (0.003 mg/L and 0.004 mg/L, respectively). However, 2009 results indicate that concentrations of TCE in both monitoring wells were below the LOR. The concentration of TCE at MW42 (Regional Watertable) decreased to 0.067 mg/L from 0.17 mg/L during both the 2006 and 2008 annual monitoring rounds. PCE has also significantly decreased in MW42 (Regional Watertable) from 0.064 mg/L in March 2008 to 0.021 mg/L in March 2009.

The concentration of PCE decreased in MWG49 (Regional Watertable, 0.046 mg/L to 0.026 mg/L), MWG53 (Base of Guildford, 0.011 mg/L to 0.001 mg/L), MWG54 (Regional Watertable, 0.021 mg/L to 0.12 mg/L), MWG83 (Base of Guildford, 0.007 mg/L to 0.001 mg/L) and MWG84 (Regional Watertable, 0.075 mg/L to

0.018 mg/L). PCE was detected for the first time at location MW37 (Regional Watertable) at a concentration of 0.002 mg/L.

Vinyl bromide was detected (0.00049 mg/L) for the first time since 2005 at location MW42 (Regional Watertable). 1,4-dichlorobenzene was also detected for the first time at MWG83 as a concentration of 0.001 mg/L.

1,2-dichlorobenzene was first detected at low concentrations during the 2008 annual monitoring in MWG83 (Regional Watertable) but was not detected during the interim monitoring. The results from the 2009 annual monitoring indicate 1,2-dichlorobenzene was once again detected at a low concentration of 0.004 mg/L in MWG83. The concentration of chlorobenzene at MWG84 decreased from 0.055 mg/L from the interim monitoring in October 2008 to 0.004 mg/L. However the 2009 results were consistent with results from the 2008 annual monitoring.

Over all the 2009 annual results for organic contaminants from monitoring locations MWG83 (Regional Watertable) and MWG84 (base of Guildford) are more consistent with results from the 2008 annual results (March 2008) and those of the interim monitoring (October 2008). This may be due to seasonal variations in recharge or shifts in the plume due to small changes in the lateral groundwater flow direction.

5.3.7 Damplands

Samples were collected from 31 locations in the Damplands which included the 16 multi-level monitoring wells near the proposed alignment of the PRB.

- MW36 (Alluvium);
- MWG60 (Alluvium);
- MWG62 (Regional Watertable);
- MWG63 (Regional Watertable);
- MWG66 (Alluvium);
- MWG67 (Alluvium);
- MWG68 (Alluvium);
- MWG73 (Base of Guildford);
- MWG74 (Alluvium);
- MWG75 (Base of Guildford);
- MWG76 (Leederville);
- MWG77 (Alluvium);
- MWG78 (Base of Guildford);
- MWG79 (Alluvium);
- WCB02 (Alluvium);
- MWG87A (Alluvium), B (Alluvium), C (Alluvium) and D (Base of Guildford);
- MWG88A (Alluvium), B (Alluvium), C (Alluvium) and D (Base of Guildford);
- MWG89A (Alluvium), B (Alluvium), C (Alluvium) and D (Base of Guildford); and

- MWG90A (Alluvium), B (Alluvium), C (Alluvium) and D (Base of Guildford).

The multi-level wells were analysed for VOCs, Br-VOCs and nitrate. All other samples collected from the Damplands monitoring wells were analysed for VOCs, Br-VOCs, TPHs, phthalates, major anions and cations, total metals, ferrous iron and TDS. The complete results of the 2009 groundwater sampling for all locations in the Damplands are presented in Table 6, along with historical groundwater sampling results dating back to 2005.

5.3.7.1 RBC Exceedences

Results for the Damplands were compared against both health RBC for the Damplands and Aquatic Ecosystem Screening Criteria as discussed in Section 4.

The Damplands RBC includes exposure scenarios for outdoor vapours for park users and outdoor workers. The ecological screening criteria were used to evaluate potential risks to aquatic life associated with the potential migration of contaminants to the Helena River via groundwater. Additional information is included in Section 4.

Table V presents a summary of the locations where contaminants were detected above relevant RBC.

Table V: Summary of Damplands Results Above Relevant RBC

Location	Monitoring Zone	Analyte	Conc	Relevant RBC or Screening Criteria
MW36	Alluvium	Copper	0.0019 mg/L	0.0014 mg/L - Aquatic Screening Criteria
		Iron	17 mg/L	0.3 mg/L - Aquatic Screening Criteria
MWG60	Alluvium	Iron	2 mg/L	0.3 mg/L - Aquatic Screening Criteria
MWG62	Regional Watertable	Nitrate (as N)	10 mg/L	7 mg/L - Aquatic Screening Criteria
		Aluminium	0.51 mg/L	0.055 mg/L - Aquatic Screening Criteria
		Iron	0.43 mg/L	0.3 mg/L - Aquatic Screening Criteria
		Zinc	0.29 mg/L	0.008 mg/L - Aquatic Screening Criteria
MWG63	Regional Watertable	Nitrate (as N)	17 mg/L	7 mg/L - Aquatic Screening Criteria
		Aluminium	0.43 mg/L	0.055 mg/L - Aquatic Screening Criteria
		Copper	0.0014 mg/L	0.0014 mg/L - Aquatic Screening Criteria
		Iron	0.48 mg/L	0.3 mg/L - Aquatic Screening Criteria
		Zinc	0.27 mg/L	0.008 mg/L - Aquatic Screening Criteria
MWG66	Alluvium	Iron	1.4 mg/L	0.3 mg/L - Aquatic Screening Criteria
MWG67	Alluvium	Iron	43 mg/L	0.3 mg/L - Aquatic Screening Criteria
MWG68	Alluvium	Iron	1.2 mg/L	0.3 mg/L - Aquatic Screening Criteria
MWG73	Base of Guildford	Nitrate (as N)	9 mg/L	7 mg/L - Aquatic Screening Criteria
MWG74	Alluvium	Nitrate (as N)	8 mg/L	7 mg/L - Aquatic Screening Criteria
MWG75	Base of Guildford	Zinc	0.008 mg/L	0.008 mg/L - Aquatic Screening Criteria
MWG76	Leederville	Zinc	0.015 mg/L	0.008 mg/L - Aquatic Screening Criteria
MWG77	Alluvium	Iron	13 mg/L	0.3 mg/L - Aquatic Screening Criteria
MWG78	Base of Guildford	Iron	0.83 mg/L	0.3 mg/L - Aquatic Screening Criteria
WCB02	Alluvium	Iron	0.69 mg/L	0.3 mg/L - Aquatic Screening Criteria
MWG88A	Alluvium	Nitrate (as N)	7 mg/L	7 mg/L - Aquatic Screening Criteria
		TCE	0.52 mg/L	0.33 mg/L - Aquatic Screening Criteria

Location	Monitoring Zone	Analyte	Conc	Relevant RBC or Screening Criteria
MWG88B	Alluvium	Nitrate (as N)	14 mg/L	7 mg/L - Aquatic Screening Criteria
		TCE	0.54 mg/L	0.33 mg/L - Aquatic Screening Criteria
MWG88C	Alluvium	Nitrate (as N)	16 mg/L	7 mg/L - Aquatic Screening Criteria
		TCE	0.58 mg/L	0.33 mg/L - Aquatic Screening Criteria
MWG88D	Base of Guildford	Nitrate (as N)	17 mg/L	7 mg/L - Aquatic Screening Criteria
MWG89A	Alluvium	TCE	0.67 mg/L	0.33 mg/L - Aquatic Screening Criteria
MWG89B	Alluvium	Nitrate (as N)	10 mg/L	7 mg/L - Aquatic Screening Criteria
		TCE	0.87 mg/L	0.33 mg/L - Aquatic Screening Criteria
MWG89C	Alluvium	Nitrate (as N)	10 mg/L	7 mg/L - Aquatic Screening Criteria
		TCE	0.73 mg/L	0.33 mg/L - Aquatic Screening Criteria
MWG87B	Alluvium	Nitrate (as N)	8 mg/L	7 mg/L - Aquatic Screening Criteria
MWG87C	Alluvium	Nitrate (as N)	7 mg/L	7 mg/L - Aquatic Screening Criteria
MWG87D	Base of Guildford	Nitrate (as N)	11 mg/L	7 mg/L - Aquatic Screening Criteria
MWG90C	Alluvium	Nitrate (as N)	7 mg/L	7 mg/L - Aquatic Screening Criteria

Concentrations of nitrate and the inorganic parameters which were detected above criteria are generally consistent with previous results excluding the following results:

- The concentration of copper in MW36 (Alluvium) was above aquatic screening criteria for the first time.
- Comparing 2009 results from MWG62 (Regional Watertable) to those from 2008 the following was noted:
  - the concentration of iron increased from 0.068 mg/L (below criteria) to 0.43 mg/L (above criteria);
  - aluminium increased from 0.088 mg/L to 0.51 mg/L; and
  - nickel decreased from 0.012 mg/L (above criteria) to 0.004 mg/L (below criteria).
- Comparing 2009 results from MWG63 (Regional Watertable) to those from 2008 the following was noted:
  - concentration of iron increased from 0.085 mg/L (below criteria) to 0.48 mg/L (above criteria);
  - aluminium increased from 0.013 mg/L (below criteria) to 0.43 mg/L (above criteria); and
  - zinc increased from 0.008 mg/L to 0.27 mg/L.
- The concentration of manganese in MWG67 (Alluvium) decreased from 4.3 mg/L in 2008, which was above the screening criteria to 0.33 mg/L which is below the screening criteria.
- The concentration of zinc in MWG76 (Leederville) increased from 0.0079 mg/L in 2008, which was below the screening criteria to 0.015 mg/L which is above the screening criteria.

TCE was the only organic contaminant detected at sample locations within the Damplands at concentrations above RBC. TCE was detected at concentrations above aquatic ecosystem screening criteria (0.33 mg/L) in six samples. The current results were compared to previous results and the following differences were identified:

- The concentration of TCE at MWG63 (Regional Watertable) has historically been above the aquatic ecosystem screening criteria (0.35 mg/L in 2006 and 0.76 mg/L in 2008). However recent monitoring results indicate the concentration has decreased to 0.056 mg/L which is below the criteria.
- The concentration of TCE at MWG74 (Alluvial) was noted to have increased from 0.061 mg/L to 0.096 mg/L.
- In general the concentrations of TCE at the multi-level monitoring wells (MWG88 and MWG89 series) have decreased from the initial sampling of these wells in January 2009. One of the most significant decreases was noted at MWG88B (Alluvium) where the concentration of TCE decreased from 1.1 mg/L to 0.54 mg/L between January and March 2009.

5.3.7.2 Other Results

Table W presents the water quality parameters which were detected above the laboratory LOR but below relevant RBC criteria.

Table W: Summary of Water Quality Parameters from the Damplands

Analyte	Range	Locations
Total Alkalinity	80 mg/L to 10 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Sodium	350 mg/L to 68 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Potassium	4.3 mg/L to 12 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Calcium	0.48 mg/L to 21 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Magnesium*	7.6 mg/L to 70 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Sulphate	<1 mg/L to 120 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Bicarbonate Alkalinity	10 mg/L to 80 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Nitrate (as N)*	<1 mg/L to 6 mg/L	MWG75, MWG76, MWG78, MWG79, WCB02, MWG89A, MWG89D, MWG90B and MWG90D
Total Dissolved Solids	260 mg/L to 1100 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02

*indicate RBC or screening criteria has been developed for the parameter

Results for TDS in the Damplands would be anticipated to be relatively low as the area has been identified as an area of recharge. However, three monitoring locations were found to have TDS of 1000 mg/L or greater. One of the locations MWG76 is a deeper well located in the Leederville which would not be expected to be significantly influenced by recharge. However, the other two MW36 and MWG77 are located in the alluvium with MW36 being only 10 m from the Helena River.

Table X presents metals which were detected above the laboratory LOR but below relevant RBC criteria.

Table X: Summary of Metals Detected in Dampland Waters

Analyte	Range	Locations
Aluminium*	<0.001 mg/L to 0.038 mg/L	MWG60, MWG66, MWG68, MWG73, MWG74, MWG76, MWG77, MWG78, MWG79 and WCB02
Chromium*	<0.002 mg/L to 0.0013 mg/L	MWG62, MWG63, MWG73, MWG74, MWG75, MWG78 and MWG79
Copper*	<0.0005 mg/L to 0.0013 mg/L	MWG62 and MWG68
Ferrous Iron	<0.1 mg/L to 14 mg/L	MW36, MWG60, MWG66, MWG67, MWG68, MWG73, MWG74, MWG77, and WCB02
Iron*	0.1 mg/L to -0.26 mg/L	MWG74, MWG75, MWG76 and MWG79
Lead*	<0.001 mg/L to 0.001 mg/L	MWG63
Manganese*	0.014 mg/L to 0.35 mg/L	MW36, MWG60, MWG62, MWG63, MWG66, MWG67, MWG68, MWG73, MWG74, MWG75, MWG76, MWG77, MWG78, MWG79 and WCB02
Nickel*	<0.001 mg/L to 0.004 mg/L	MWG62, MWG63, MWG75, MWG76 and MWG78
Zinc*	0.001 mg/L to 0.007 mg/L	MW36, MWG60, MWG66, MWG67, MWG68, MWG73, MWG74, MWG77, MWG78, MWG79 and WCB02

*indicate RBC or screening criteria has been developed for the parameter

The concentration of aluminium increased in MWG62 (Regional Watertable), MWG63 (Regional Watertable), MWG66 (Alluvium), MWG68 (Alluvium), MWG73 (Base of Guildford), MWG74 (Alluvium), MWG78 (Base of Guildford), MWG79 (Alluvium) and WCB02 (Alluvium). The most significant increase occurred in WCB02 (Alluvium) from 0.002 mg/L in 2008 to 0.13 mg/L in 2009.

Chromium results were relatively consistent with previous results. In some locations, the concentration decreased below the LOR, whereas in other locations the concentration has increased. The most significant increase was noted at MWG75 (Base of Guildford) from <0.0002 mg/L in March 2008 to 0.0013 mg/L in March 2009.

Copper concentrations exceeded the aquatic ecosystem screening criteria in 2008 for location MWG76 (Leederville), MWG74 (Alluvium), MWG75 (Base of Guildford) and MWG79 (Alluvium). The 2009 results indicated that the concentration of copper at these locations was below laboratory LOR. The copper concentrations also decreased to below LOR at MWG66 (Alluvium), MWG67 (Alluvium), MWG73 (Base of Guildford), MWG78 (Base of Guildford) and WCB02 (Alluvium).

Iron and ferrous iron results were generally consistent with historical results.

The concentration of lead increased at MWG63 (Regional Watertable) from <0.0001 in 2008 to 0.001 in 2009.

Manganese concentrations decreased at all locations except MWG78 (Base of Guildford) where an I increase occurred (0.2 mg/L to 0.35 mg/L) at MWG67. The most significant decrease was in MWG73 (Base of Guildford) as discussed section 5.7.2.1 where manganese decreased from 4.3 mg/L to 0.33 mg/L.

Nickel concentrations exceeded the aquatic ecosystem screening criteria in 2008 for location MWG62 (Regional Watertable) and MWG67 (Alluvium). The 2009 recent results indicated that the concentration of nickel had decreased to below the aquatic ecosystem screening criteria at both of these locations. The nickel concentrations had also decreased to below LOR at MWG66 (Alluvium), MWG68 (Alluvium), MWG73 (Base of Guildford), MWG74 (Alluvium) and MWG77 (Alluvium).

In general the concentrations of zinc were consistent with historical results with the following exception:

- MWG76 (Leederville) had increased from 0.0079 mg/L in 2008 to 0.015 mg/L, which is above the screening criteria; and

- MWG63 (Regional Watertable) had increased from 0.008 mg/L in 2008 to 0.27 mg/L.

A summary of results of organic parameters in the samples collected from the Damplands are presented in Table Y.

Table Y: Summary of Detected Organics in Damplands Monitoring Wells

Analyte	Range	Locations
TPH C_6-C_9	<0.01 mg/L to 0.13 mg/L	MWG63
Benzene*	<0.001 to 0.044 mg/L	MWG89D
Isopropylbenzene*	<0.001 mg/L to 0.001 mg/L	MWG89D
1,1,1-TCA*	<0.001 mg/L to 0.003 mg/L	MWG79, MWG89A and MWG89B
1,1-DCA*	<0.001 mg/L to 0.017 mg/L	MWG75, MWG78, MWG79, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
1,1-DCE*	<0.001 mg/L to 0.034 mg/L	MWG75, MWG78, MWG79, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
1,2-DCA*	<0.001 mg/L to 0.005 mg/L	MWG79, MWG89D and WCB02
Cis-1,2-DBE	<0.0001 mg/L to 0.0096 mg/L	MWG78, MWG79, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
Cis-1,2-DCE*	<0.001 mg/L to 0.056 mg/L	MWG60, MWG75, MWG78, MWG79, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
PCE*	<0.001 mg/L to 0.05 mg/L	MWG63, MWG75, MWG78, MWG79, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
TCE*	<0.001 mg/L to 0.079 mg/L	MWG62, MWG63, MWG66, MWG68, MWG73, MWG75, MWG78, MWG79, MWG87B, MWG87C, MWG87D, MWG88D, MWG89A, MWG89D and WCB02
Trans-1,2-DBE	<0.0001 mg/L to 0.0029 mg/L	MWG78, MWG79, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
trichlorofluoromethane	<0.0013 mg/L to 0.18075 mg/L	MWG75, MWG78, MWG79, MWG87B, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
Vinyl Bromide	<0.0001 mg/L to 0.0077 mg/L	MWG78, MWG79, MWG89A, MWG89B, MWG89C, MWG89D and WCB02
1,2-Dichlorobenzene*	<0.001 mg/L to 0.003 mg/L	MWG78 and MWG79
1,3-Dichlorobenzene*	<0.001 mg/L to 0.002 mg/L	MWG79
1,4-Dichlorobenzene*	<0.001 mg/L to 0.001 mg/L	MWG78 and MWG79

*indicate RBC or screening criteria has been developed for the parameter

The concentration of TPH C_6-C_9 at MWG63 (Regional Watertable) increased in comparison to historical results (0.01 mg/L in 2008 to 0.13 in 2009). It is unclear what this increase may be attributed to as the results in the MAHs were below LOR and PAH analysis was not undertaken.

Isopropylbenzene and 1,1,1-TCA concentrations were consistent with previous groundwater monitoring results. The concentrations of 1,1-DCA were consistent with previous results at most locations. However, a significant change in 1,1-DCA was noted at MWG79 (Alluvium) where the concentrations increased from 0.001 mg/L in 2008 to 0.017 mg/L in 2009.

At MWG89D (Base of Guildford) a benzene concentration of 0.044 mg/L was detected in March 2009, this is an increase from 0.009 mg/L initially reported in January 2009, shortly after the multi-level was installed.

1,2-DCA was detected for the first time at MWG89D (0.002 mg/L, Base of Guildford) and WCB02 (0.001 mg/L, Alluvium). However, 1,2-DCA was previously detected at a concentration of 0.001 mg/L in MWG79 (Alluvium) and the 2009 results indicate the concentration had increased to 0.005 mg/L.

Previously, samples collected during the PRB delineation programme and from WCB02 were not analysed for Br-VOCs. Results indicate that Br-VOCs such as cis-1,2-DBE, trans-1,2-DBE and vinyl bromide were detected at MWG89A (Alluvium), MWG89B (Alluvium), MWG89C (Alluvium), MWG89D (Base of Guildford).

Samples previously collected from MWG78 (Base of Guildford) and MWG79 (Alluvium) had been analysed for Br-VOCs and results indicate that the concentrations of cis-1,2-DBE, trans-1,2-DBE and vinyl bromide have increased at these wells between March 2008 and March 2009.

The following has been noted for concentrations of cis-1,2-DCE:

- concentrations have increased at MWG79 (Alluvium) from 0.003 mg/L in 2008 to 0.049 mg/L in 2009; and
- in 2006 the concentration at WCB02 (Alluvium) was 0.005 mg/L; it subsequently increased in 2008 to 0.039 and 0.056 mg/L in 2009.

Generally the concentration of PCE was consistent with previous results. However, at MWG79 (Alluvium) the concentration of PCE increased from 0.008 mg/L in October 2008 to 0.05 mg/L in March 2009.

TCE was detected in 24 of the 31 sampling locations, making it the most widely detected organic contaminant in the Damplands Area. At 15 of the 24 locations TCE concentrations were below RBC, while the remaining 9 were above as discussed in Section 5.2.7.1. TCE was detected in monitoring well MWG68 (Alluvium) for first time in 2009 with a concentration of 0.006 mg/L. The TCE concentration increased in MWG79 (Alluvium) from 0.036 mg/L to 0.072 mg/L and in MWG89D (Base of Guildford) from 0.041 mg/L to 0.079 mg/L.

The 2009 concentrations of dichlorobenzenes were not consistent with previous results. Samples from the 2008 annual monitoring for dichlorobenzenes had a lower LOR of 0.0001 mg/L in comparison to the 0.001 mg/L LOR from the 2009 annual monitoring. Previously, concentrations of dichlorobenzenes were below 0.001 mg/L with the exception of 1,2-dichlorobenzene at MWG78 (Base of Guildford) which was 0.003 mg/L and 0.005 mg/L (from two different analytical methods). Results indicate that concentrations of 1,2-dichlorobenzene, 1,3-dichlorobenzene and 1,4-dichlorobenzene have in general increased in comparison to 2008 annual results for MWG78 (Base of Guildford) and MWG79 (Alluvium) as they were detected above the LOR of 0.001 mg/L.

5.3.8 Surface Water

Due to the lack of precipitation in the months prior to the 2009 annual monitoring programme the Damplands Pond was completely and the Helena River bed was largely dry and not flowing at the time of sampling (8 April 2009) . Only two surface water samples were collected, both from stagnant ponded water in the Helena River bed: SG05 (downstream) and SG06 (midstream). The two locations were re-sampled on 13 May 2009 to re-assess the initial results.

Surface water samples collected during the 2009 annual monitoring programme from the Helena River were analysed for VOCs, Br-VOCs, TPHs, phthalates, major anions and cations, ultra-trace total metals, ferrous iron and TDS. The samples collected during the May re-sampling event were analysed only for VOCs and Br-VOCs. The complete results of the 2009 groundwater sampling for all surface water locations are presented in Table 7, along with historical results dating back to 2005.

5.3.8.1 RBC Exceedences

Results for surface water locations were compared against both health RBC (Golder 2008b) for the Helena River and recently updated Aquatic Ecological Screening Criteria (Golder, 2008c). The recreational swimmer was the only health risk exposure pathway considered for the Helena River RBC.

A summary of the contaminants identified at concentrations above RBC (from the initial round of sampling) is presented in Table Z.

Table Z: Summary of Surface Water Results Above Relevant RBC and Ecological Screening Criteria

Location	Monitoring Zone	Analyte	Concentration	Relevant RBC
SG05	downstream	Iron	21 mg/L	Aquatic Ecosystem Screening Criteria
		Zinc	0.055 mg/L	Aquatic Ecosystem Screening Criteria
SG06	midstream	Iron	38 mg/L	Aquatic Ecosystem Screening Criteria

The results are consistent with historical results as both iron and zinc have previously been identified in concentrations above RBC for samples collected from the Helena River (including upstream river sampling SG07). However, the concentrations of metals have increased significantly as follows:

- iron from 1.9 mg/L in 2008 to 21 mg/L in 2009 at location SG05;
- iron from 1.8 mg/L in 2008 to 38 mg/L in 2009 at location SG06; and
- zinc from 0.007 in 2008 to 0.055 mg/L in 2009 at location SG05.

5.3.8.2 Results

Table AA presents the analytes which were detected above the laboratory LOR but below relevant RBC and ecological screening criteria.

Table AA: Summary of Water Quality Parameters from Surface Waters

Analyte	Range	Locations
Total Alkalinity	120 mg/L to 240 mg/L	SG05 and SG06
Sodium	300 mg/L to 240 mg/L	SG05 and SG06
Potassium	9.8 mg/L to 8.7 mg/L	SG05 and SG06
Calcium	38 mg/L to 27 mg/L	SG05 and SG06
Magnesium*	34 mg/L to 36 mg/L	SG05 and SG06
Chloride	490 mg/L to 310 mg/L	SG05 and SG06
Sulphate	<1 mg/L to 11 mg/L	SG05 and SG06
Bicarbonate Alkalinity	120 mg/L to 240 mg/L	SG05 and SG06
Total Dissolved Solids	1000 mg/L to 870 mg/L	SG05 and SG06

*indicate RBC or screening criteria has been developed for the parameter

A summary of the results of metals in the samples collected from surface water samples are presented in Table BB.

Table BB: Summary of Metals Detected in Surface Waters

Analyte	Range	Locations
Aluminium*	0.0025 mg/L to 0.04 mg/L	SG05 and SG06
Arsenic*	0.0014 mg/L	SG06
Chromium*	0.0002 mg/L to 0.0003 mg/L	SG05 and SG06
Copper*	0.0005 mg/L to 0.0007 mg/L	SG05 and SG06
Ferrous Iron	0.1 mg/L to 8.9 mg/L	SG05 and SG06
Manganese*	0.886 mg/L to 1.2 mg/L	SG05 and SG06
Zinc*	0.004 mg/L	SG06

*indicate RBC or screening criteria has been developed for the parameter

The concentration of the metals detected in surface water samples is relatively consistent with previous results with the following exceptions:

- Arsenic was not detected at SG06 (midstream) or SG07 (upstream) in 2008. It was however detected from samples collected at different river locations in 2006.
- Chromium was not detected at SG05 (downstream), SG06 (midstream) and SG07 (upstream) in 2008. It was however detected from samples collected at different river locations in 2006.
- The concentration of ferrous iron at SG05 (downstream) increased significantly from 0.1 mg/L to 8.9 mg/L.

A summary of results of organic parameters in the samples collected from the Helena River are presented in Table CC.

Table CC: Summary of Organic Parameters Detected in Surface Waters

Analyte	Value	Locations
TCE*	0.002 mg/L	SG05
Cis-1,2-DCE	0.001 mg/L	SG05

*indicate RBC or screening criteria has been developed for the parameter

The results from SG05 (downstream) were not consistent with historical results as concentrations of chlorinated hydrocarbons have never been detected in the Helena River before. As a result the Helena River was re-sampled on 13 May 2009. In the second sampling event TCE was not detected in any of the samples; however, cis-1,2-DCE was again detected in SG05 at a concentration of 0.001 mg/L.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

6.1 Field Testing

Water quality meters used for field parameter measurement during the 2009 sampling round were calibrated by the supplier (Allara Instrument Hire Equipment Pty Ltd) prior to shipment and at least weekly during the sampling programme. The calibration certificates are included at the end of Appendix D. The calibration (pH and conductivity) of the water quality meter was checked twice-daily (before commencing work and at the end of the day) during the field programme to ensure the calibrations were accurate. These results are presented in Table 11.

Golder considers a range of pH 3.7-4.3 for pH 4 and a range of 6.58-7.18 for pH 6.88 as indicating acceptable meter calibration. The greatest pH deviation from both the pH 4 and 6.88 calibration solution occurred on 8 April 2009 (readings of 4.62 and 7.5, respectively). These reading may have been affected by the reusing of pH solution and possible contamination after several uses. Samples collected on 8 April 2009 were surface samples from the Helena River. pH readings from this sampling event were consistent with previous sampling events, therefore the high pH readings during the calibration check are not considered to affect the outcomes of the investigation. In addition, readings were just outside the acceptable range on 24 April 2009. The following morning, pH readings using the same probe with no calibration resulted in acceptable pH readings. During the calibration checks following sampling on 6 April and 7 April 2009, pH readings were outside of the acceptable range. The pH probes were allowed to sit overnight in pH solution to see if results would stabilise. pH readings the following morning were acceptable and used as the final pH reading for the previous evening. Overall, the pH calibration was considered satisfactory for the purpose of this investigation.

A range of 2.48 to 3.04 mS/cm is considered acceptable for the 2.76 ms standard conductivity solution used during this investigation based on 10% deviation from the standard concentration. All conductivity readings were noted to be within this acceptable range.

6.2 Holding Times

6.2.1 Primary Laboratory (Leeder)

Analytical reports were reviewed to assess whether holding times were met for the analytes reported. Samples were shipped overnight to Leeder in Melbourne and data associated with Leeder analytical reports indicated that all samples were extracted and analysed the day they arrived at the laboratory. Therefore, samples were extracted and/or analysed within 24 hours of sampling, complying with acceptable holding times for the various analytes.

6.2.2 Secondary Laboratory (ALS)

One holding time breach (4 days) was noted for Nitrate & Nitrite as N (NOX as N) for SG06 (Helena River surface sample). This sample was analysed 4 days past the required analysis date. These results were not considered necessary for the investigation and were not analysed by the primary laboratory, therefore a breach in holding time was not of concern. Nevertheless, ALS reported a result of 0.03 mg/L for Nitrate & Nitrite as N at SG06, a result only marginally above the LOR (0.01 mg/L).

6.3 Field Duplicates

Seven field duplicates were taken during groundwater sampling. Four of these duplicates were sent to the primary laboratory (Leeder), with the remaining going to a secondary laboratory (ALS). The duplicates were taken from four locations; a well on the site which is known to be contaminated (MW22i), a well on the adjacent Lot 2 property (MW42), a Damplands well within the co-mingled plume (MWG89B) and a surface water sample collected from the Helena River in the Damplands (SG06). The field duplicate results are presented in Table 12.

A comparison between duplicate sample results can be conducted using a Relative Percentage Difference (RPD) to analyse the duplicate samples. This is a measure of the difference between the primary and duplicate samples as a percentage of their average value. RPDs are calculated according to the following formula:

$$\%\,\mathrm{RPD} = \left|\frac{\mathrm{A}-\mathrm{B}}{\mathrm{A}+\mathrm{B}}\right| \mathrm{x}\ 200$$

Where:

A is the concentration of the primary laboratory analyte, and

B is the corresponding duplicate result.

In calculating RPD values, the following protocols have been adopted:

- Where both concentrations are below limits of reporting (LOR), no RPD is calculated and a nominal value of less than 50% is assigned.
- Where one laboratory concentration is below the LOR and one is above, a value of one half of the detection limit is substituted for the non-detect sample.
- Where both concentrations were above laboratory LOR, the RPD was calculated as per the formula above.

The Australian Standard (AS 4482.1) indicates RPDs of less than 50% are considered to be satisfactory for soil analyses. RPDs greater than 50% may be acceptable for a) organic analyses and b) low concentrations where the difference in concentrations was <10 times the method LOR. This standard has also been adopted in the review of groundwater samples for this investigation.

6.3.1 Primary Laboratory (Leeder)

Field duplicates sent for analyses at the same laboratory were submitted as ‘blind’ duplicates, i.e. the laboratory were not aware that the two samples came from the same location. This provides a measure of the reproducibility of results received from the laboratory.

Comparison of the primary and duplicate samples from MW42 (Lot 2) shows that RPDs greater than 50% occurred for four analytes (chromium, TPH C_6-C_9, TPH C_{10}-C_{14}, and TPH C_{15}-C_{28}). All four sample exceedances indicated that the difference in results was less than ten times the applicable laboratory LOR and results were below the relevant criteria (site-specific RBC). Thus Golder considers these results acceptable for the purposes of this investigation.

Comparison of the primary and duplicate samples from MW22i (on-site well) showed that RPDs greater than 50% occurred for three analytes (copper, TPH C_{15}-C_{28}, and PCE). Of these exceedances, only one, TPH C_{15}-C_{28}, had a difference between results above ten times the laboratory LOR. Results were well below the site-specific RBC. Concentrations of other parameters (copper and PCE) were less than ten times the applicable LOR. Therefore, Golder has considered these results acceptable for the purposes of the investigation.

No RPDs greater than 50% were noted during the comparison of the primary and duplicate samples from MW89B (Damplands).

Comparison of the primary and duplicate samples from SG06 (midstream) revealed that RPDs greater than 50% occurred for five analytes (sulphate as SO_4, zinc, TPH C_6-C_{36}, TPH C_{10}-C_{14}, and TPH C_{15}-C_{28}). The differences between results were generally below ten times difference the respective LOR with the exception of sulphate as SO_4 (RPD = 183%), where the difference (10 mg/L versus < 1 mg/L) in results was marginally above ten times the LOR (1 mg/L). In this case, the sulphate results were well below the relevant site-specific RBC of 500 mg/L. Therefore, this RPD exceedance was not considered to affect the outcomes of this investigation.

In general, intra-laboratory testing did not highlight any significant issues with the quality of the data.

6.3.2 Secondary Laboratory (ALS)

Three field triplicate samples (MW42, MWG89B and SG06) were submitted to both Leeder and the secondary laboratory, ALS. The primary sample was sent to Leeder and the secondary sample was sent to ALS. The results from these samples were compared to assess the variability in results between laboratories.

Several analytes had RPDs greater than 50% due to the differences in the limits of reporting between the primary and secondary laboratories. As the LORs were generally below the relevant criteria, these results were not considered to affect the outcomes of this investigation. In some cases, the criteria were below the LORs and this is discussed in Section 6.9.

At MW42 (Lot 2, Regional Watertable), six analytes were found to have RPDs greater than 50% and differences between results more than ten times the more conservative lower laboratory LOR associated with the respective analyte. Analytes included nitrate as N (RPD=103%), chromium (RPD=190%), copper (RPD=186%), iron (RPD=52%), nickel (RPD=176%), and TPH C_6-C_9 (RPD=143%). Generally, these elevated RPDs arise from either one result being close to or below the laboratory LOR and the other above, or both results being marginally above the LOR. The concentrations of each of the pairs of results were low, yet small differences in concentrations, close to the laboratory LOR, can yield high RPDs. Furthermore, the differences between results were less than ten times the laboratory LOR. It should also be noted that Leeder and ALS have different methods of analysis for TPH. Leeder includes fewer analytes in their TPH analysis which tends to result in lower reported concentrations compared to analytical results from ALS. It is considered that these results have not adversely affected the outcomes of the investigation.

Nine other analytes were noted at MW42 (Lot 2, Regional Watertable) with RPDs greater than 50%, but the difference between the results were less than ten times the conservative LOR. Therefore, the data quality was not considered to adversely affect the outcomes of this investigation.

Comparison of primary and triplicate samples at MWG89B (Regional Waterable, Damplands) revealed that three analytes had RPDs greater than 50% (trichlorofluoromethane, trans-1,2-DBE, and vinyl bromide). Of these, only one, trichlorofluoromethane, had a difference between results ten times the LOR. This was due to one result being below the LOR and one result being marginally above the LOR. As Golder takes half the

LOR while performing calculations, high RPDs can emerge. Therefore the data quality of these results has not adversely affected the outcomes of this investigation.

Seven analytes were noted to have RPDs greater than 50% at SG06 (midstream, Helena River). These analytes include aluminium, chromium, sulphate as SO_4, nitrate as N, nickel, TPH C_{15}-C_{28}, and TPH C_{29}-C_{36}. Of these, only two (aluminium and sulphate as SO_4) were noted to have a difference of results greater than ten times the LOR. In both cases the results were well below the site-specific RBC and were both close to the LOR. Therefore, they are not considered to have adversely affected the results of this investigation.

In general, inter-laboratory testing did not highlight any significant issues with the quality of the data.

6.4 Laboratory Duplicates

6.4.1 Primary Laboratory (Leeder)

A total of sixteen laboratory duplicates were analysed by Leeder over the duration of the investigation. The laboratory duplicates were analysed for a range of analytes. The comparison between duplicate sample results has been assessed by using a RPD calculation as described in Section 6.3.

The laboratory duplicate samples were randomly spread across the study area and across the different aquifers. Two of the laboratory duplicates was located on the site (MW22i (Regional Watertable) and MW21i (Regional Watertable)), three were located on Lot 2 (MWG54 (Regional Watertable), MWG59 (Regional Watertable) and MWG84 (Regional Watertable)), seven came from the Damplands (MWG62 (Regional Watertable), MWG68 (Alluvium), MWG73 (Base of Guildford), MWG78 (Base of Guildford), MWG89B (Regional Watertable), MWG89C (Alluvium), and MWG90A (Alluvium)), one came from an upgradient monitoring well, MWG46 (Base of Guildford), one came from the Southwest Industrial Area (MWG69 (Base of Guildford)), and one came from the Helena River during the re-sampling event on 13 May 2009 (SG06 (midstream)).

Thirteen of the sixteen laboratory duplicates did not have RPDs greater than 50%, indicating satisfactory agreement between results and acceptable internal laboratory reproducibility of results. Samples which reported laboratory duplicate RPDs greater than 50% were collected from MWG46 (up gradient, Base of Guildford), MWG59 (Lot 2, Regional Watertable), and MWG22i (site, Regional Watertable).

The laboratory duplicate for MWG46 (up gradient, Base of Guildford) reported one RPD which exceeded the acceptable range of between 0% and 50%. Nickel had an RPD of 120% based on a primary result of 0.002 mg/L and a laboratory duplicate result below the LOR (0.001 mg/L). This elevated RPD resulted from one result being marginally above the LOR and the other result being below the LOR. This result is not considered to have adversely affected the outcomes of the investigation.

Comparison of primary sample results to laboratory duplicate results from MWG59 (Lot 2, Regional Watertable) indicated one RPD outside the acceptable range of 0% to 50% for TPH C_6-C_{36} (RPD=67%). The primary result was 0.05 mg/L and the duplicate result was below the LOR (0.05 mg/L). The RPD exceedance was considered an artefact due to one result being at the LOR and the other below the LOR. Golder does not consider this result to have adversely affected the outcomes of the investigation.

Two results were noted to be outside the acceptable RPD range at MW22i (site, Regional Watertable) for PCE and TCE (the RPD for both analytes was 67%). These marginal exceedances were due to one result being below the LOR and the other being on or just above the LOR. Therefore, these results were not considered to have adversely affected the outcomes of the investigation.

Laboratory duplicates were also run on spike recoveries as part of the laboratories internal QA/QC testing regime. None of these duplicate results had RPDs exceeding 50%.

6.4.2 Secondary Laboratory (ALS)

The acceptable range that is adopted by ALS states that for samples with concentrations less than 10 times the LOR no acceptable RPD range is applied, for samples with concentrations between 10 and 20 times the LOR an acceptable range of 0 to 50% is applied and for samples with concentrations greater than 20 times the LOR an acceptable range of 0 to 20% is applied.

All ALS laboratory duplicates were within the acceptable range set by the laboratory as well as within Golder's acceptable RPD limit (50%).

6.5 Blank Samples

Results of the laboratory blanks from the primary laboratory, the field wash blanks and trip blank samples are presented in Table 13.

6.5.1 Laboratory Blanks

6.5.1.1 Primary Laboratory (Leeder)

Leeder reported eight laboratory blanks throughout the sampling and analysis programme (one per batch). Laboratory blanks were conducted on all analytes which were part of the analytical suite for that batch.

The results of the laboratory blank analyses indicate that no analytes were detected above the laboratory LOR in any of the laboratory blanks.

6.5.1.2 Secondary Laboratory (ALS)

The results of the laboratory blank analyses by ALS indicate that no analytes were detected above the laboratory LOR in any of the laboratory blanks.

6.5.2 Trip Blanks

Eleven trip blanks (1 per day + 1 per batch to secondary laboratory) were analysed for VOCs and Br-VOCs to assess whether cross contamination of volatiles may be occurring in transit. Trip blanks were provided by Leeder and ALS and were sent to the corresponding laboratory.

Review of trip blanks submitted to both Leeder and ALS revealed that all samples were below the respective LOR for VOCs and brominated VOCs.

6.6 Wash Blanks

Wash blanks were samples consisting of store-bought distilled water due to unavailability of laboratory provided water at the time of sample. The bottles for each wash blank were filled with the rinse water by rinsing the decontaminated parts of the sampling equipment, which had had contact with the groundwater. The wash blank tests for cross-contamination between wells according to which, if any, analytes are still present on the pump after decontamination. As store-bought rinse water was being used for the wash blanks, a representative sample of un-used rinse water was also submitted to the laboratory to facilitate a comparison with wash blank analytical results. Detections of copper, zinc, dibromochloromethane, and tribromomethane were noted in the un-used rinse water, as such these were considered baseline results for review of the wash blanks. Table DD provides a summary of rinse water detections.

Table DD: Detections in Un-Used Rinse Water

Analyte	Concentration (mg/L)
Copper	0.003
Zinc	0.002
Dibromochloromethane	0.002
Tribromomethane	0.003

Eight wash blanks were collected during the investigation. Wash blanks were collected only on days when the submersible pump was used to collect groundwater samples. All wash blanks were analysed for metals (excluding ferrous iron), TPH and VOCs.

The results of the wash blank testing indicate that some metals, TPH, and some VOCs were detected in some wash blank samples. However, a review of the wash blank data indicates that there are no apparent trends to signify data integrity issues or problems with the decontamination procedure. Table EE provides a summary of the detected analytes in the wash blanks. Further discussion of the wash blank results is provided below.

Table EE: Detections in Wash Blanks

Analyte	Limit of Reporting (LOR) (mg/L)	Number of Wash Blanks Detected In	Maximum Concentration (mg/L)	Site and Lot 2 RBC (mg/L)
Aluminium	0.001	1	0.002	309
Copper	0.0005	7	0.0067	
Iron	0.001	1	0.003	217
Nickel	0.001	1	0.002	3.86
Zinc	0.001	7	0.009	
TPH C_6-C_9	0.01	1	0.05	22.9
TPH C_{10}-C_{14}	0.01	2	0.02	0.655
TPH C_{15}-C_{28}	0.05	2	0.09	9.82
TPH C_{29}-C_{36}	0.05	1	0.05	13.1
TPH C_6-C_{36}	0.05	2	0.21	
Bromodichloromethane	0.001	3	0.001	0.25
Dibromochloromethane (chlorodibromomethane)	0.001	6	0.003	
Tribromomethane (bromoform)	0.001	6	0.004	0.25

Metals detected in the wash blanks were not detected regularly and when they were detected, the concentrations were negligible in comparison to the site and Lot 2 RBC. Copper and zinc were detected in seven of the eight samples and appears to be associated with the store-bought rinse water, which also had similar concentrations copper and zinc. Aluminium, iron, and nickel were only detected in one sample (wash blank collected from the washed submersible pump at MWG57 (Lot 2, Regional Watertable)), though results were only marginally above the LOR and significantly below the site and Lot 2 RBC. It appears that the decontamination procedures adopted were sufficient to minimise cross contamination between wells and to allow for meaningful interpretation of the results.

TPH (C_6-C_9, C_{10}-C_{14}, C_{15}-C_{28} and C_6-C_{36}) were detected in two (of eight) wash blanks. The wash blanks in question were taken from the washed submersible pump at MWG45 (Upgradient, Leederville) and MWG83 (Lot 2, Base of Guildford). The concentrations of TPH recorded in both wash blanks were on or just above the LOR and are all were under the RBC for site and Lot 2 by a large margin. The presence of these TPH fractions may have been related to residue on the equipment after decontamination or to the quality of the store-bought water or a combination of both. Regardless, it appears that the decontamination procedures adopted were sufficient to minimise cross contamination between wells and to allow for meaningful interpretation of the results.

Three VOCs were also detected in six of the eight wash blanks, bromodichloromethane, dibromochloromethane, and tribromomethane. Maximum results were on or just above the LOR and two of the three analytes were also detected in the baseline wash water sample (dibromochloromethane and tribromomethane) at similar concentrations. Detectable levels of these analytes are most likely due to the quality of the store-bought water and the presence of these VOCs is not considered to affect the results of the investigation.

6.7 Surrogate Recoveries

The results of the surrogate analyses from the primary and secondary laboratories are presented in the laboratory certificates of analysis, presented in Appendix A.

6.7.1 Primary Laboratory (Leeder)

The surrogate recoveries are a measure of the amount of a chemical the laboratory has actually retrieved during a sample analysis. A known quantity of a similar chemical that is not present in the groundwater sample is added to the sample, and then the percentage retrieved during analysis is measured and used as a base measure for the expected percentage of similar analytes retrieved, as opposed to how much is actually present. NATA and Leeder have established a standard of 60% to 130% as the acceptable range for surrogate recoveries and Golder considers this range acceptable for the requirements of the 2009 groundwater monitoring programme.

For two samples (MWG66 (Damplands, Alluvium) and MWG73 (Damplands, Base of Guildford)), surrogate recoveries were not reported by Leeder due to sample matrix interferences for one VOC surrogate, toluene-d8. In addition, two phenolic compounds (fluorophenol and phenol-D6) were not reported due to high levels of compounds in the sample (MWG21i (site, Regional Watertable)). As these interferences only occurred in three instances during the sampling programme, they are not expected to affect the results of the investigation.

Obtaining 100% recovery for many organic compounds in a variable matrix is often not possible with existing technologies and methodologies. The surrogate recoveries reported by Leeder during this monitoring round were taken into consideration when assessing the groundwater results and in all cases the low recoveries do not appear to have any significant implications with regards to the outcomes of the investigation.

6.7.2 Secondary Laboratory (ALS)

Surrogate recoveries performed by ALS were within the acceptable range (70-130%) with the exception of a number of sVOCs where surrogate recoveries were less than 70%. For these surrogates, ALS has adopted "dynamic recovery limits" which is covered by their NATA accreditation. The dynamic recovery limits are based on instrument history over a set of 20 quality control lots, and generally cover a much wider range than 70% to 130%. It is noted that several surrogate recoveries were outside the Golder's acceptable range, yet within the "dynamic recovery limits" set by ALS.

Also, as stated above, obtaining 100% recovery for many organic compounds in a variable matrix is often not possible with existing technologies and methodologies. Hence, in Golder's opinion these results have not adversely affected the outcomes of the investigation

6.8 Spike Recoveries

The results of spike recoveries from the primary and secondary laboratories are presented in the laboratory certificates of analysis, presented in Appendix A.

6.8.1 Primary Laboratory (Leeder)

Spike recoveries are samples (either blank samples or actual samples) to which a known amount of the analytes being tested for have been added and then recovered through the same process as the actual samples to provide an indication of how efficient the recovery process is. As with surrogates, Leeder have a general acceptance limit of 60% to 130%.

All spike recoveries were generally within Leeder's acceptable limits (60-130%). Therefore, in Golder's opinion is these results do not adversely affect the outcome of the investigation.

Spike recoveries were not reported in some instances due to high levels of compounds in the sample interfering with spike recovery. In particular, lack of reporting was noted for phenolic compounds and aluminium at MW21i (Regional Watertable, site), aluminium and iron at MW22i (Regional Watertable, site), and iron at SG06 (midstream, Helena River). Primary sample results indicated elevated levels of these analytes, therefore the lack of a spike recovery result is acceptable.

Spike duplicates were also performed for all of the spike recoveries. No sample duplicates were found to be outside of the acceptable RPD limit of 50%.

6.8.2 Secondary Laboratory (ALS)

One internal ALS laboratory spike sample was outside the dynamic control limits adopted by ALS. This was iodomethane (49.7%), with a dynamic control range of 59-137%. As the spike sample was performed was on a laboratory control sample and no detections of iodomethane were noted during the investigation, this result was not considered to have adversely affected the outcomes of the investigation.

No matrix spike was determined for manganese and nitrate & nitrite as N in ALS batch EP0901889. ALS stated that this was due to the background level in the sample being greater than or equal to 4 times the spike level. Golder considers this explanation adequate, given that a manganese spike was determined in the laboratory control sample for this batch.

In addition, no matrix spike was determined for TCE in ALS batch EP090173 due to background level in the sample being greater than or equal to 4 times the spike level. The TCE result for the primary sample MW42 (Regional Watertable, Lot 2) was 0.085 mg/L, over two times the site-specific RBC of 0.0351 mg/L. TCE concentrations at this monitoring historically have also been above the RBC. Therefore, Golder does not consider these results to have adversely affected the outcomes of this investigation.

All other spike recoveries were within the acceptable range set by the laboratory.

6.9 Quality Assurance/Quality Control Summary

A summary of the QA/QC assessments undertaken as part of the investigation is provided below.

Fieldwork was undertaken using procedures to minimise the risk of cross contamination which included:

- collection of samples using new disposable nitrile gloves for each sample collected;
- collection of groundwater samples using dedicated sampling equipment (tubing, pump bladders and o-rings) at each location;
- decontamination of sampling equipment prior to sample collection at each location;
- groundwater samples for ferrous iron were field filtered using a disposable, one-use 0.45 µm filter; and
- samples were collected into clean laboratory provided sample containers with appropriate preservatives where required.

Based on this, the risk of cross-contamination was considered to have been successfully minimised. Additionally, the QA/QC programme included:

- The calibration (pH and conductivity) of the water quality meter used to measure field parameters was checked during the investigation and considered to be satisfactorily calibrated.
- The laboratory LOR for contaminants of concern were targeted at being below the adopted screening criteria and site-specific RBC allowing satisfactory interpretation of results. In some cases, laboratory LORs were above the relevant criteria. Table FF identifies the analytes that had screening criteria below the LOR for this sampling event. Discussions undertaken with the laboratory since the 2009 sampling programme indicates that it is possible to further lower the LOR for these contaminants of concern. Golder therefore recommends that in future monitoring programmes analysis for these contaminants of concern use the lower LORs.

Table FF: Analytes with LORs Above Relevant Guideline

Analyte	Location(s)	Relevant Guideline	Guideline Value (mg/L)	LOR (mg/L)
Mercury	River, Damplands	Risk Based Criteria May 2008 Aquatic Ecosystem Screening Criteria	0.00006	0.0001

Analyte	Location(s)	Relevant Guideline	Guideline Value (mg/L)	LOR (mg/L)
Phthalates	River	Risk Based Criteria May 2008 Aquatic Ecosystem Screening Criteria	0.0002-0.0099	0.001
Carbon tetrachloride	SW Industrial, Hanson, Lot 2, Site, Upgradient	Site & Lot 2 RBC Inhalation Only	0.00075	0.001
Carbon tetrachloride	SW Industrial, Hanson, Lot 2, Site, Upgradient	Site & Lot 2 RBC	0.00075	0.001
Benzo(a)-pyrene	SW Industrial, Site	Site & Lot 2 RBC Inhalation Only	0.000366	0.001

- Field blind and field split duplicate groundwater samples were collected and analysed at an acceptable rate (i.e. greater than 10% for contaminants of concern).
- The RPDs calculated for the field blind and field split duplicates were generally within the acceptable range of 0% to 50%. All of the duplicates with RPDs exceeding 50% were related to differences in concentration on or close to laboratory LOR. This indicates that the analytical results may be considered to be precise. The results were all below relevant screening criteria.
- The results of the internal laboratory QA/QC assessment involving duplicate, spike, surrogate and laboratory blank analyses were judged to produce accurate results for the purposes of this investigation.
- Wash blank samples were collected and analysed as a check on decontamination procedures and data quality. A review of the wash blank results indicated that some analytes were detected; however there does not appear to be any data quality issues associated with their presence.
- Trip blank samples were analysed as part of the field QA programme and no detections were present.

Overall, the quality assurance objectives for the investigation have been met and that the data integrity was acceptable to produce precise and accurate analytical data for the purposes of the 2009 groundwater monitoring programme.

7.0 SUMMARY AND CONCLUSIONS

This report has presented the results of the 2009 annual groundwater monitoring round undertaken at the former Waste Control site and its surrounds. The programme included the collection of groundwater measurements, the collection of samples from 60 locations and single well recovery tests at 4 new multi-level monitoring wells. The results from this annual monitoring programme are in general agreement with the results of previous programmes.

The TCE distribution over the study area is presented in Figure 8. When comparing the 2009 results to those from the 2008 annual monitoring concentrations have generally decreased. However, locations above RBC in 2008 are still above RBC in 2009 and newly installed multi-level monitoring wells in 2009, have resulted in an increase in the number of sample locations with TCE concentrations above RBC. In comparison to results from the 2008 monitoring, results the 2009 annual programme indicated TCE concentrations decreased to below LOR in MW22i (site, Regional Watertable) and MWG83 (Lot 2, Base of Guildford) whereas they have increased above LOR at MWG66 (Damplands, Alluvium), MWG68 (Damplands, Alluvium) and SG05 (River, downstream). However, in comparison to historical results the following significant differences in chlorinated compounds have been identified:

- Concentrations of TCE along the propose PRB have decreased significantly in comparison to results from the delineation programme undertaken in January 2009.
- TCE was detected in MWG68 for the first time. This is significant as it is closer to the River than previously monitoring rounds have detected.
- TCE and cis-1,2-DCE were detected above the LOR in the Helena River. Re-sampling of the Helena River did not detected concentrations of TCE above LOR.

As the PRB delineation wells (MWG88 to MWG90) have only been sampled twice and the concentrations of TCE (the main contaminant) varied by approximately 50% between the sampling events it is proposed that a third round of groundwater sampling be completed at these wells in winter 2009.

The Helena River has never been sampled at this time of the year due to the reduced flow in the Helena River. It is currently unknown if the chlorinated solvents in the Helena River are related to the former Waste Control site as these chemicals have not previously been identified in monitoring wells closest to the Helena River (e.g. MW36 and MWG60, MWG67 or MWG68). However, the 2009 annual results suggest that the front edge of the secondary off-site TCE plume has possibly advanced enough over the summer to discharge to the Helena River. The presence of chlorinated solvents in the Helena River may be due to seasonal variations, as groundwater modelling (Golder, 2009b) has indicated that recharge from the Damplands Pond can reduce the rate of plume advancement in the Damplands towards the Helena River. This leads to temporary advancement of the plume following periods of no/low recharge such as the summer months. As precipitation during the year (March 2008 to March 2009) was below average and recharge from the Damplands Pond was therefore reduced, the plume may have advanced further than anticipated. Recharge during the winter of 2009 may result in a retreat of the front edge of the off-site TCE plume.

It is therefore recommended that the water quality in the Helena River be tested on a semi-annual basis (March and September). Semi-annual sampling should allow for the identification of any seasonal variation in chlorinated concentrations in surface waters. It should be noted that the concentrations of TCE which were detected in both the Helena River and in the monitoring wells nearest the Helena River were significantly below the health RBC and Aquatic Ecosystem Screening Criteria and therefore should not pose a risk to the aquatic environment of the Helena River.

TCE was detected in monitoring well MWG68 (Damplands, Alluvium) for the first time in 2009; this well is located approximately 70 m up gradient of the Helena River and was the closest monitoring well to the Helena River in which TCE had been detected. Therefore, it also recommended that MWG68 (Damplands, Alluvium), which has only been sampled twice previously, should be included in the additional winter monitoring round.

Interpretation of previous monitoring data identified that it was likely that the mixed organics plume from the Waste Control Site merges with the downgradient TCE plume beneath the escarpment and into the Damplands. The results from the recent monitoring have further supported this hypothesis. The mixture of contaminants identified at the MWG89 multi-level monitoring wells and MWG75, MWG78 and MWG79 was a combination of high TCE concentrations (above RBC) presumably from the TCE plume with much lower concentrations of PCE, 1,1 DCE, cis 1,2-DCE, 1,2-DCA, chloromethane, cis- and trans- 1,2-DBE, and vinyl bromide at concentrations below site-specific RBC (as applicable).

The concentration of benzene in MW25 (site, Base of Guildford) has been relatively consistent over the last year indicating that downward migration of benzenes has potentially reached steady state. However, the increase in total TPH fractions C_6-C_{36} (0.07 mg/L to 0.46 mg/L) indicates that downward migration of other hydrocarbons is likely occurring. Due to benzene's higher solubility and lower adsorption it is often the most mobile petroleum hydrocarbon in groundwater; hence its breakthrough at the Base of Guildford ahead of TPH parameters is consistent with its expected behaviour in groundwater.

REFERENCES

DoE (2001-2004). Western Australian Department of Environment. Quarterly Monitoring Data and Reports. March 2001, May 2001, November 2001, March 2002, June 2002, August 2002, October 2002, March 2003, July 2003, October 2003, February 2004, June 2004, October 2004.

Commander, P, (2004). Outline of the Hydrogeology of the Hydrogeology of the Perth Region. Australia Geomechanics, Vol. 38, No. 3, September 2003.

Golder Associates, (2005), Geological and Hydrogeological Conditions, Bellevue Waste Control Site, April 2005. 04643336-R05.

Golder Associates, (2006a). Human Health and Ecological Risk Assessment Former Waste Control Site, Bellevue WA, November 2006, 04643336-R08.

Golder Associates (2006b), Hydrogeological Site Assessment, Former Bellevue Waste Control Site Bellevue, WA, June 2007, 04643336-R10.

Golder Associates (2006c), Proposed Monitoring Schedule, Former Waste Control Site Bellevue, WA, September 2006, 0464336-R13.

Golder Associates (2008a). Summary of Completed Work for Off-Site Contamination at the Former Waste Control Site Bellevue, July 2008, 087643011 011R Rev 0.

Golder Associates (2008b). Review of Risk-Based Criteria Former Waste Control Site, Bellevue, June 2008, 087643011 012 R.

Golder Associates (2008c). Review of Ecological Screening Criteria for Groundwater, Former Waste Control Site, Bellevue, 17 September 2008, 087643011 031 L DRAFT Rev0.

Golder Associates (2008d). Summary of Completed Work for On-Site Contamination at the Former Waste Control Site Bellevue, June 2008, 087643011 004 Rev0.

Golder Associates (2009a). Off-Site Groundwater Remediation Plan and Permeable Reactive Barrier Design, Draft, 087643011 050R DRAFT Rev1.

Golder Associates, (2009b). Updated Modelling of Groundwater Flow and Contaminant Transport, Former Waste Control Site, Bellevue, WA February 2009 087643011 029 R Rev0.

HRS (2000). Preliminary Environmental Site Assessment for Subsurface Contamination for Waste Control Pty. Ltd., Hydrocarbon Remedial Services, May 2000.

Hyder, Z, J.J. Butler, Jr., C.D. McElwee and W. Liu, 1994. Slug tests in partially penetrating wells, Water Resources Research, vol. 30, no. 11, pp. 2945-2957.

URS (2002). Detailed Site Investigation. Waste Control Site, Bellevue. February 2002.

URS (2003). Further Site Investigation, Waste Control Site, Bellevue. August 2003.

Report Signature Page

GOLDER ASSOCIATES PTY LTD

Keely Mundle	
Keely Mundle Environmental Engineer	David Reynolds Associate

KM/DAR/ajm

A.B.N. 64 006 107 857

Golder, Golder Associates and the GA globe design are trademarks of Golder Associates Corporation.

j:\jobs408\environ\087643011 - bellevue - further work\corres out\087643011 053 r annual\087643011 053 r rev1.docx