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FORMER WASTE CONTROL SITE BELLEVUE WA

Annual Groundwater Monitoring Programme 2010

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REPORT

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1.0 INTRODUCTION

The Department of Environment and Conservation (DEC) engaged Golder Associates Pty Ltd (Golder) to undertake the 2010 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. This report presents the results and conclusions from the 2010 Annual Monitoring Programme. It does not present the results from monitoring wells located in the area of the recently installed Permeable Reactive Barrier (PRB), these results are located in Permeable Reactive Barrier Groundwater Monitoring – July 2010 Quarterly Results (Golder, 2010a).

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 hydrocarbon and halogenated hydrocarbon groundwater contamination associated with the former chemical/oil recycling and waste treatment facility. Numerous groundwater monitoring wells have been installed, including the WCT Series (HRS, 2000), the WCB Series (DoE, 2001-2004), the MW Series (URS, 2002 and 2003), the MWG Series (Golder, 2008a) and a long-term permeable reactive barrier (PRB) monitoring system (Golder, 2009a).

Furthermore, results from investigations in 2008 and 2009 (Golder, 2009b) indicated that a separate off-site plume originated from a local source near the east end of Stanley Street containing TCE as the only organic contaminant. Potential groundwater impacts in the Damplands Area are primarily associated with the off-site TCE plume. The two separate plumes were interpreted to converge beneath the escarpment prior to entering the Damplands Area (Golder, 2009a). As a remediation strategy, a sequenced denitrification PRB and a zero valent iron (ZVI) PRB were installed into the Damplands Area with construction completed in May 2010.

Golder (2006a, 2008b, 2008c, and 2009c) 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 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 2010 Annual Monitoring Programme undertaken in May, June and July 2010.

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 2010 annual monitoring are as follows:

- Lot 88 and 99 – the former Waste Control site
- Lot 5 Oliver Street – Hanson Property
- Lot 1 (commonly referred to as the Damplands)
- Lot 2 (Main Roads)
- Lot 87 – Stanley Street: A&P Transport
- Lot 82 – Street Address: 3 Stanley Street

- Portion of Stanley Street Road Reserve
- Upgradient of site on Irwin Street.

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; the Guildford Formation and alluvial sediments. In the vicinity of the site, groundwater flows towards the Helena River but regionally it flows to the west. Elsewhere, this groundwater may be used for public water supply but in the vicinity of the site groundwater is more likely to be used for watering parks and for garden watering.
- The semi-confined Leederville Formation in which groundwater flows generally south-south-west 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. A description of the hydrogelogical units used in this report is included as Table A.

Table A: Summary of Hydrogeological Units

Aquifer/ Hydrogeological Unit	Definition	Description
Alluvial	Alluvial	Unconsolidated sediments varying in grain size form clay to gravel and with a relatively high value of K. Hydraulically contiguous with Guildford and Leederville Formation aquifers
Regional	Subset of the Guildford Formation aquifer – defined by wells screened over the regional water table	Uppermost part of the Guildford Formation aquifer varying from clean sand through to silts and clays. Hydraulically contiguous with the Alluvial aquifer. Generally lower K values than the other aquifers
Base of Guildford	Subset of the Guildford Formation aquifer – defined by wells screened below the continuous clay interval within the Guildford Formation	Unconsolidated sediments varying in grain size from sands to clay with iron-cemented sediments toward the base. Hydraulically contiguous with other aquifers. Moderate K values consistent with silty sand lithology
Leederville	Defined by wells screened entirely within the Leederville Formation	Unconsolidated to compacted sediments varying from sand to clay and hydraulically contiguous with the alluvial and Guildford Formation aquifers. Moderate K values consistent with the lithologies described

A 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, approximately 8 to 12 m below ground level. Perched groundwater zones have been identified above the Regional Watertable beneath the former Waste Control site but not in the off-site study area.

2.3 Monitoring Objectives

The monitoring objectives of the 2010 annual monitoring programme 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 Formation and the Helena River.
- Monitor groundwater contamination in the vicinity of the site.

The scope of work for the 2010 annual monitoring programme to meet these objectives comprised the following activities:

- Collection of a round of groundwater level measurements.
- Collection of twenty-six groundwater samples from monitoring wells at the site, Hanson, Southwest Industrial Area, Lot 2 and Damplands.
- Collection of three surface water samples from the Helena River.

The 2010 annual sampling programme was conducted between 24 May 2010 and 28 July 2010 and was based on same scope outlined in the 2009 annual groundwater programme and recommendations, guidance and data quality objectives (DQO) outlined in the Sampling and Analysis Plan (SAP) (Golder 2010b and 2010c, respectively). Samples were collected from twenty-six monitoring wells during late May and early June 2010. The monitoring well locations are summarised below based on their hydrogeological unit with the cadastral location of the locations listed in parenthesis. All sampling locations are shown on Figure 2. Surface water sampling was completed at three locations in the Helena River on 28 July 2010. The Helena River was dry during the May/June period, therefore surface water samples and surface water elevations were collected in July 2010.

The two monitoring wells proposed for installation in the SAP (2010b) were not installed and therefore were not samples.

Guildford (Regional Watertable)

- MW21i (Waste Control Site)
- MW22i (Waste Control Site)
- MW23i (Waste Control Site)
- MW42 (Lot 2)
- MWG49 (Lot 2)
- MWG54 (Lot 2)
- MWG57 (Lot 2)
- MWG59 (Lot 2)
- MWG62 (Damplands)
- MWG63 (Damplands)
- MWG64 (Hanson)
- MWG65 (A&P Transport)
- MWG70 (Stanley Street)
- MWG91A (Lot 2)

Middle of Guildford

- MWG91B (Lot 2)

Base of Guildford

- MW25 (Waste Control Site)
- MWG46 (Irwin Street)
- MWG48 (Lot 2)
- MWG91C (Lot 2)
- MWG69 (Stanley Street)

Leederville

- MWG45 (Irwin Street)
- MWG47 (Lot 2)

Alluvium

- MW36 (Damplands)
- MWG60 (Damplands)
- MWG66 (Damplands)
- MWG68 (Damplands)

Helena River

- SG05 (Downstream)
- SG07 (Upstream)
- SG06 (Midstream)

3.0 METHODOLOGY

3.1 Water Sampling

The methodology used in the 2010 annual groundwater monitoring programme is consistent with the guidelines outlined in the Golder SAP (Golder, 2010b). Twenty-two wells at the former Waste Control site, Damplands, Lot 2, Irwin Street (upgradient) 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 MW21i (40 mL/min), MW22i (65 mL/min), MW23i (110 mL/min), MWG54 (40 mL/min), MWG59 (60 mL/min) and MWG65 (100 mL/min).

Four locations in the Damplands were purged and sampled using a peristaltic pump. Constant flow rates ranging between 250 to 280 mL/min were used for all of these locations (MW36, MWG60, MWG66 and MWG68).

Three locations in the Helena River were sampled using a peristaltic pump. Constant flow rates of approximately 300 mL/min were used for all of these locations (SG05, SG06 and SG07).

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. 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.

The QED bladder pump was used for the majority of sampled wells because the depth of groundwater was generally 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 deionised water station, and again at a second deionised water wash station. The pump was finally sprayed a third time with laboratory grade deionised water using a hand sprayer prior to re-assemblage and 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. Laboratory grade deionised water was used for the final decontamination of submersible pump components prior to pump assemblage. The laboratory grade deionised water was sampled and analysed at the start of the programme (24 May 2010) and again on both 26 May 2010 and 27 May 2010 for quality assurance and quality control (QA/QC) 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 relevant 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 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, was 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.

There were three suites of analyses used for the wells. The analytes for each suite are outlined below:

3.1.1 Suite 1

Samples collected from Lot 2 and the Southwest Industrial Area monitoring locations were analysed for the following suite of analytes:

- total petroleum hydrocarbons (TPH) (C_6-C_{36}), and
- volatile organic compounds (VOCs) including chlorinated ethenes, Brominated VOCs (Br-VOCs), dichloroethane and benzene, toluene, ethylbenzene and xylene (BTEX).

The following monitoring wells were analysed for suite 1: MW42; MWG47; MWG48; MWG49; MWG54; MWG57; MWG59; MWG65; MWG69; MWG70; MWG91A; MWG91B and MWG91C.

3.1.2 Suite 2

Samples collected from on-site, Hanson and upgradient monitoring locations were analysed for the following suite of analytes:

- TPH (C_6-C_{36})
- VOCs including chlorinated ethenes, Br-VOCs, dichloroethane and BTEX, and
- total metals (including aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc).

The following monitoring wells were analysed for suite 2: MW21i, MW22i, MW23i, MW25, MWG45, MWG46; and MWG64.

3.1.3 Suite 3

Samples collected from the Damplands and the Helena River monitoring locations were analysed for the following suite of analytes:

- TPH (C_6-C_{36})
- VOCs including chlorinated ethenes, Br-VOCs, dichloroethane and BTEX
- total metals (including aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc)
- metals (ultra-trace arsenic and mercury)
- major ions, and
- nitrate.

The following locations were analysed for suite 3: MWG36; MWG60; MWG62; MWG63; MWG66; MWG68; SG05; SG06 and SG07.

Analytes such as metals and nitrates in the Helena River and Damplands are monitored to provide context for the interpretation of the hydrogeochemical changes occurring both at site and downgradient and are not considered to be emanating from on-site sources.

All monitoring wells were tested for the following field parameters by Golder field technicians:

- electrical conductivity (EC)
- dissolved oxygen (DO)
- temperature
- pH
- redox potential (Eh), and
- water levels.

3.1.4 QA/QC

The field QA/QC programme adopted for the investigation complied with recommendations in the SAP (Golder, 2010b). In particular, the field QA/QC included the following:

- The use of dedicated equipment at each location coupled with stringent field decontamination procedures to minimise the potential risk of cross-contamination.
- The collection of samples into laboratory provided sample containers with appropriate preservatives where required.
- The collection and review of trip blanks as a check on sample integrity and laboratory data quality.
- Field duplicates submitted to the primary NATA approved laboratory, with duplicate split being sent an alternative NATA approved laboratory.
- Consideration of internal laboratory QA/QC results, including a review of laboratory duplicate and blank sample results, as well as the results of surrogate and spike analyses.

- Discussion of any other QA/QC issues that arise.

The laboratory QA/QC programme adopted for the investigation also complied with the SAP (Golder, 2010b) and included the following:

- The primary laboratory for the annual samples was conducted by Leeder Consulting with ALS as the duplicate laboratory. All laboratories are NATA registered for all the required analyses.
- A minimum of one laboratory duplicate performed on each batch of samples provided to the lab. The relative percent difference (RPD) is considered satisfactory if below 50%. Laboratory blanks will be run at the beginning and end of each batch of samples. Spike recovery analyses for each analytical suite, for each batch of samples received (i.e. one spike recovery analyses for every 10 samples) will be undertaken. Spike recovery analysis results within a range of 75% to 125% is considered satisfactory for quality.

3.2 Sampling Locations

There were fewer locations sampled in the 2010 annual monitoring programme compared to the 2009 annual monitoring programme. This was predominantly due to the removal and decommissioning of wells formerly located in the vicinity of the PRB. There were eight wells (MWG73, MWG74, MWG75, MWG76, MWG78, MWG79, MWG92 and MWG93) and three multi-level wells (MWG87, MWG88 and MWG89) removed from the vicinity of the PRB. New wells and multi-level wells were installed in the vicinity of the PRB following its completion and form part of the long-term PRB monitoring network which are to be sampled on a quarterly basis starting from July 2010 (Golder, 2010a). Multi-level wells have been given an alphabetic notation (A, B, C or D) to represent the monitoring location depth with A being the shallowest and D the deepest.

4.0 EVALUATION CRITERIA

Results from the 2010 annual monitoring programme are provided in Tables 1 to 7. Groundwater results from monitoring wells on site, Lot 2, the Southwest Industrial Area and upgradient were compared against updated site-specific RBC for the site and Lot 2 (Golder 2008b and 2009b). 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 2010 groundwater results along with the relevant RBCs 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 2010 groundwater results along with the relevant RBCs for the Hanson Property are presented in Table 5.

Results from the Damplands samples were compared against health RBC (Golder, 2008b) for the Damplands and 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 does not include the potential exposure of outdoor workers performing irrigation. The Damplands RBC also does not include a swimmer or recreational bather in the Damplands Pond as this is not considered a credible exposure pathway. 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 associated 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 Helena 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 2010 groundwater sampling along with the relevant RBCs 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. Analytical results along with the relevant RBCs for the Helena River are presented in Table 7.

5.0 2010 ANNUAL MONITORING RESULTS

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

5.1 Water Levels

Water levels collected during the 2010 sampling programme have been included in Table 8 along with historical measurements, and presence of non-aqueous phase liquid (NAPL) for each monitoring location.

5.1.1 Groundwater Movement

Groundwater surface elevations were measured during May 2010 and June 2010 in the four groundwater bearing zones (Regional Watertable, Alluvium, Base of Guildford and Leederville). Groundwater surface elevations maps for the Regional Watertable and Base of Guildford Formations are presented in Figures 3 and 4, respectively. Groundwater surface elevations at the Regional Watertable in the Guildford Formation and in the Damplands Alluvial Formations 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 elevation contours across the escarpment (the transition zone between the Guildford and Alluvial units) also incorporate a large component of vertical hydraulic gradients associated with topographic relief across this feature.

Table B below presents interpreted groundwater flow directions and gradients for the Regional Watertable and Base of Guildford Formation. Vertical hydraulic gradients were determined by comparing the groundwater levels at two wells screened in the same groundwater bearing zone. The difference between the upgradient and downgradient wells was then divided by the distance between the wells. There were only two groundwater levels measured in wells that were located in the Leederville Formation (MWG45 and MWG47), therefore flow directions and gradients were not calculated for the Leederville Formation. For the Alluvial formation, comparison of water levels at MWG66 and SG06 could not be obtained since surface water levels were not collected during the original dipping event on 17 June 2010 as the Helena River was dry. Water levels in the Helena River were later collected on 28 July 2010.

Table B: Groundwater Flow Direction and Gradient

Groundwater Bearing Zone	Flow Direction	Gradient (m/m)	Comment
Regional Watertable (Guildford Formation)	SSW	3.6×10^{-3}	Average flow direction from site (MW22i) to top of the Escarpment (MWG91A).
Base of Guildford Formation	SSW	3.5×10^{-3}	Average flow direction from site to top of Escarpment (MWG91C).

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

Calculated lateral gradients for the Regional Watertable and Base of Guildford were slightly lower than previously calculated for these units in the 2009 annual monitoring programme (Golder, 2010a).

Table C outlines trends in groundwater flow direction by formation between 2005 and 2010. The 2010 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 south-west, whereas in 2005 it was interpreted as south-south-west.

The installation of a Permeable Reactive Barrier (PRB) in April 2010 in the Damplands may have altered the groundwater flow direction in some formations at a local scale.

Table C: Groundwater Flow Directions by Formation between 2005 and 2010

Formation	Reporting Year and Groundwater Flow Direction				
	2005	2007	2008	2009	2010
Guildford	SSW				
Regional		SW	SW	SW	SSW
Base of Guildford		SW	SW	SW	SSW
Leederville	SSW	SSW	SSW	SSW	
Alluvial		S	SSW	SSW	SSW

5.1.2 Groundwater Velocities

Approximate groundwater velocities can be obtained from the Darcy equation:

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

where:

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 B.

Representative hydraulic conductivity values were selected using the geometric mean for each groundwater bearing zone from 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 of 0.3 was used. An effective porosity of 0.25 was assumed for the Alluvial Formation.

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 May 2010 Hydraulic Gradients

Formation	Hydraulic Conductivity	Gradient	Effective Porosity	Velocity	
	(m/d)	(m/m)	(-)	(m/day)	(m/year)
Regional Guildford	0.2	3.6×10^{-3}	0.3	2.6×10^{-3}	1
Base of Guildford	2.3	3.5×10^{-3}	0.3	2.7×10^{-2}	10
Leederville	0.4	7.2×10^{-3} [B]	0.3	1.1×10^{-2}	4

[A] Does not include results from the A series wells.

[B] Based on the calculated gradient in March 2009.

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

5.1.3 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), and
- Standing water in Helena River and the Alluvial Formation at the base of the escarpment (Table 9c).

There was no 2010 groundwater level data collected for the Alluvial Formation to Guildford Formation. The monitoring wells investigated in 2010 did not allow for a vertical gradient to be measured between the Alluvial Formation and Guildford Formation. Historical information on this vertical gradient relationship has been previously reported (Table 9c, Golder 2010a). Monitoring well locations are shown in Figure 2.
A summary of vertical hydraulic gradient information for the above relationships between May 2005 and July 2010 is presented in Table E below.

Table E: Current and Historical 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	MWG91A/MWG91C		
	MWG70/MWG69				
Base of Guildford to Leederville	MWG46/MWG45	MWG48/MWG47	MWG75/MWG76	-0.128 to 0.009	Moderate Downward
	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*		-0.009 to 0.928	Moderate Downward
Helena River to Alluvium	SG06/MW36	SG07/WCB04*	SG06/WCB05	-0.091 to 0.058	Moderate Upward

*These results are historical as these monitoring locations are no longer in existence.

Within the Guildford Formation, between the Regional Watertable and the base of this formation the vertical hydraulic gradients were generally considered weakly downward. The results from the most recent water level monitoring programme were consistent with a weakly downward gradient. The following vertical pairs were measured in 2010:

- A weakly downward gradient of -0.001 was observed between MW22i (8.090 m AHD) and MW25 (8.083 m AHD). The water level in both wells had decreased by approximately 0.5 m compared to March 2009 data.
- A weakly downward gradient of -0.004 was observed between MWG49 (7.457 m AHD) and MWG48 (7.419 m AHD).
- A weakly downward gradient of -0.003 was observed between MWG91A (7.405 m AHD) and MWG91C (7.391 m AHD). 2010 was the first time that MWG91A and MWG91C were compared as vertical pairs.

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 it is unlikely that there is large 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 were observed at monitoring wells in the Leederville, suggesting that the upper part of the formation may be acting as a semi-confining unit.

The following vertical pairs were measured in 2010:

- A weakly downward gradient of -0.001 was observed between MWG46 (8.841 m AHD) and MWG45 (8.834 m AHD). The water level in MWG46 had decreased by approximately 0.5 m compared to March 2009 levels.
- A weakly downward gradient of -0.002 was observed between MWG48 (7.419 m AHD) and MWG47 (7.403 m AHD).

There were no paired wells measured in 2010 to compare vertical hydraulic gradient data between the:

- Alluvium and Base of Guildford formations. Historically, a weak downward gradient has existed between the Alluvial Formation and the Base of the Guildford Formation.
- Regional Watertable and Base of Guildford in the vicinity of the PRB. Historically, a weak to moderate downward gradient has existed between the Regional Watertable and the Base of the Guildford in the vicinity of the PRB.
- Base of Guildford and Leederville in the vicinity of the PRB. Historically, there was a strong downward gradient between the Base of the Guildford and Leederville Formations, indicating the potential for downward movement of groundwater in the vicinity of the PRB.
- Damplands Pond and Alluvium. 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 Formation.

During the initial monitoring period in May 2010, there was no flow in the Helena River. There was heavy precipitation during June 2010 and the Helena River was sampled and measured in late July 2010. Historically, the vertical hydraulic gradient between the Helena River and Alluvial Formation has been a moderately upward trend. The paired locations MW36 and SG06 were an anomaly to this trend according to the 2010 data. A strongly downward trend of 0.058 was observed between SG06 (6.789 m AHD) and MW36 (6.135 m AHD). This was most likely due to the heavy precipitation experienced during the winter months (June and July) which increased the water level in the river.

Seasonal changes in the groundwater regime appear to have an effect on vertical gradients within the Damplands and Helena River areas. In 2005, 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, monitoring during the wetter winter period showed a downward gradient indicating flow from the river to the Alluvial Formation consistent with higher urban runoff experienced during this time.

5.2 Water Quality Results

The following discussion summarises locations where 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 2010 monitoring results exceeded the site-specific RBC are shown on Figure 5. Monitoring well locations where groundwater concentrations from the 2010 monitoring results exceeded the aquatic ecosystem screening criteria are shown in Figure 6.

5.2.1 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 over all locations ranged between 4.75 (MWG62, Damplands, Regional Watertable) and 6.90 (SG07, Upstream, Helena River). The pH at 18 of the 29 monitoring locations was found to be below 6.00 and therefore can be considered slightly acidic. These slightly acidic waters were identified in three of the four geologic formations (not identified in the Leederville Formation). The greatest variations in pH in comparison to the 2009 annual monitoring results were decreases in pH of 0.47 and 0.43 between MWG59 and MWG63, respectively. MWG59 is located in the Regional Watertable at Lot 2 and MWG63 is located in the Regional Watertable in the Damplands.

Eleven wells had dissolved oxygen (DO) levels above 1 mg/L (MW42, MWG47, MWG49, MWG54, MWG57, MWG59, MWG62, MWG63, MWG70, MWG91A and MWG91B) with the highest reading at MWG54 (4.91 mg/L, Regional Watertable, Lot 2). In comparison to 2009 results, the DO level increased in all locations, with the exception of (MWG60, MWG65, MWG66, MWG68 and MWG70) with location MWG65 having the maximum decrease (0.59 mg/L). The dissolved oxygen levels in all three surface samples were above 5 mg/L which was greater than 2009 values. This likely resulted from the fact that the Helena River was flowing and had high water levels.

The conductivity measured ranged from 407 µS/cm (MWG46, Base of Guildford, Irwin Street) to 3530 µS/cm (MWG45, Leederville Formation, Irwin Street). MWG46 was the only well to record conductivity less than 500 µS/cm. Generally, low conductivities indicate areas of high recharge, however, MWG46 is an exception as it is located in the Base of Guildford and therefore would be anticipated to not be influenced by recharge. In comparison, conductivities greater than 2000 µS/cm were identified at:

- MW22i (site, Regional Watertable), and
- MWG45 (Upgradient, Leederville).

The on-site regional watertable well (MW22i) is located below areas which were sealed in order to prevent recharge. MWG45 is located upgradient and on an unsealed area indicating that recent recharge would be expected to influence the groundwater quality.

Conductivity in the three samples from the Helena River ranged between 633 µS/cm (SG06, midstream) and 647 µS/cm (SG07, upstream). These values have decreased since monitoring in April 2009.

The redox potential ranged from -113 mV (MWG23i, On-site, Regional Watertable) to 264 mV (MWG62, Damplands, Regional Watertable). It should be noted that only 6 of 26 sampling locations were noted as being less than 0 mV with all of them being only slightly reducing. Four of these locations MW21i, MW22i, MW23i 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 two locations with negative redox potential (MW36 and MWG45) were located in the Damplands and upgradient of the site. In comparison, 15 of the 26 sampling locations had redox potentials greater than 100 mV which indicate oxidising conditions (EPA, 1998). One of these locations was MW25 (151 mV), located in the Base of the Guildford formation 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. The three surface sample locations had redox potential ranging from 27 mV (SG07, downstream) to 54 mV (SG05, upstream).

5.2.2 Upgradient

Two upgradient monitoring wells MWG45 (Leederville) and MWG46 (Base of Guildford) both located on Irwin Street were sampled for background purposes. Both upgradient samples were analysed for suite 2 analytes. The complete results of the 2010 groundwater sampling for all locations upgradient are presented in Table 4, along with historical groundwater sampling results dating back to 2005.

5.2.2.1 RBC Exceedences

The results indicated all analytes were below RBC criteria.

5.2.2.2 Dissolved Metals

A number of metals were detected above the laboratory limit of reporting (LOR) but below relevant RBC (where applicable). Concentrations of aluminium, iron, manganese, nickel and zinc were found above LOR in both wells. Generally, the metal concentrations were consistent with historical results except for the following:

- concentrations of iron increased from 4.6 mg/L in March 2009 to 16 mg/L in May 2010 for MWG45 and from <0.001 mg/L in March 2009 to 0.01 mg/L in May 2010 for MWG46
- the concentration of manganese increased from 0.14 mg/L in March 2009 to 0.39 mg/L in May 2010 for MWG45, and
- concentrations of zinc decreased from 0.45 mg/L in March 2009 to 0.01 mg/L in May 2010 for MWG45 and from 0.085 mg/L in March 2009 to 0.008 mg/L in May 2010 for MWG46.

5.2.3 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 suite 2. The complete results of the 2010 groundwater sampling for all locations on the site are presented in Table 1 along with historical groundwater sampling results dating back to 2005.

5.2.3.1 RBC Exceedences

Groundwater results on site were compared against site-specific RBC for the site and Lot 2. Table F below presents an overall summary of the analytes detected at concentrations above relevant RBC as well as the sample location and relevant monitoring zone. In most cases, the concentration of the analytes identified above the relevant RBC were consistent with previous results or indicate a general decrease in VOC concentrations on site.

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

Location	Monitoring Zone	Analytes	2009 Concentration (mg/L)	2010 Concentration (mg/L)	Relevant RBC (mg/L)
MW21i	Regional Watertable	Arsenic	0.0014	0.0062	0.00241
		Benzene	0.008	0.007	0.00274
		Vinyl Bromide	0.0041	0.079	0.00113
MW22i	Regional Watertable	Arsenic	0.0022	0.0047	0.00241
		Benzene	0.011	0.012	0.00274
		1,2-Dichloroethane	0.003	0.003	0.00126
MW23i	Regional Watertable	Arsenic	0.04	0.04	0.00241
		Benzene	0.005	0.005	0.00274
		Vinyl Bromide	0.0036	0.0027	0.00113
		1,2-Dichloroethane	<0.001	0.002	0.00126

The concentration of benzene in MW25 (Base of Guildford) was 0.001 mg/L in 2010. Historical results for benzene in MW25 have been above RBC. These results suggest that downward migration of benzene may have ceased, or natural attenuation may be greater than in the past.

The following contaminants have historically been above the relevant RBC but were identified in 2010 at concentrations below relevant RBC:

- benzene at location MW25 (Base of Guildford), and
- 1,2-dichloroethane in MW21i (Regional Watertable).

5.2.3.2 *Other Results*

In addition to the contaminants listed in Table F, a number of additional analytes were detected above the laboratory limit of reporting (LOR) but below relevant RBC (where applicable). Generally, the metals results were consistent with historical results with no increases in aluminium, cadmium, chromium, iron and zinc concentrations. The following increases in metal concentrations were noted since 2009:

- Concentrations of arsenic increased at MW21i (Regional Watertable) and MW22i (Regional Watertable) from 0.0014 mg/L to 0.0062 mg/L and 0.0021 mg/L to 0.0047 mg/L, respectively.
- Concentrations of copper increased at MW25 (Base of Guildford) from <0.0005 mg/L to 0.084 mg/L.
- Concentrations of manganese increased at MW23i (Regional Watertable) from 0.027 mg/L to 0.031 mg/L.
- Concentrations of nickel increased at MW21i (Regional Watertable) from <0.001 mg/L to 0.014 mg/L.

A number of other organics were also detected in samples collected from site. Generally, the results for these organics were consistent with historical results or decreased in concentration.

Exceptions include the results from the sample collected from MW21i (Regional Watertable) which indicated an increase in the concentration of the TPHs C_{10}-C_{14} fraction (1.3 mg/L to 12 mg/L). In contrast, results from the sample collected at MW25 (Base of Guildford) indicated decreased concentration of TPHs C_6-C_9 fraction, TPH C_{10}-C_{14} fraction and TPH C_{15}-C_{28} fraction (all to below LOR). These results may suggest a reduced downward migration of TPH on site.

These trends are also consistent with the noted first occurrence of benzene above RBC in MW25 beginning in 2008 and which remained relatively constant in 2009 before decreasing to 0.001 mg/L in 2010. Because of its higher solubility and lower adsorption, benzene is often the most mobile petroleum hydrocarbon.

Consistent with historical results, no VOCs were detected in MW25 (Base of Guildford). In addition, the following decreases in concentrations were also noted;

- TCE, PCE, trichlorofluoromethane, benzene, total xyelene concentrations at MW21i
- Total xylene concentrations at MW22i and MW25, and
- Total xylenes, TCE, PCE, 1,1-dichloroethene, cis- and trans- 1,2-dibromoethane and chloroethane in MW21i.

There were no other noteworthy increases in VOCs or sVOCs from samples collected on site. These results show an overall reduction in the concentration of VOCs in groundwater on site.

5.2.4 Lot 2

Ten monitoring wells on Lot 2 were included as part of the 2010 annual monitoring programme:

- MW42 (Regional Watertable)
- MWG47 (Leederville)
- MWG48 (Base of Guildford)
- MWG49 (Regional Watertable)
- MWG54 (Regional Watertable)
- MWG57 (Regional Watertable)
- MWG59 (Regional Watertable)
- MWG91A (Regional Watertable
- MWG91B (Middle of Guildford)
- MWG91C (Base of Guildford).

All samples collected from Lot 2 were analysed for suite 1. The complete results of the 2010 groundwater sampling for all locations on Lot 2 are presented in Table 2, along with historical groundwater sampling results dating back to 2005.

5.2.4.1 RBC Exceedences

Results for Lot 2 were compared against the site and Lot 2 RBC.

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

Table G: Summary of Lot 2 Results above Relevant RBC

Location	Monitoring Zone	Analyte	2009 Concentration (mg/L)	2010 Concentration (mg/L)	Relevant RBC (mg/L)
MWG48	Base of Guildford	Benzene	NA	0.015	0.00274
MWG49	Regional Watertable	Vinyl Bromide	<0.0001	0.0022	0.00113
MWG57	Regional Watertable	TCE	0.77	0.46	0.0351

Location	Monitoring Zone	Analyte	2009 Concentration (mg/L)	2010 Concentration (mg/L)	Relevant RBC (mg/L)
MWG59	Regional Watertable	1,2-Dichloroethane	0.003	0.005	0.00126
		Vinyl Bromide	0.0059	0.054	0.00113
MWG91A	Regional Watertable	TCE	0.029*	0.59	0.0351
MWG91B	Middle of Guildford	TCE	0.001*	0.23	0.0351

*indicates sample was from the interim monitoring program in September 2009.

The concentration of TCE at MW42 (Regional Watertable) decreased from 0.067 mg/L in 2009 to 0.024 mg/L in 2010. The concentration of TCE at MWG49 (Regional Watertable) was slightly lower in 2010 as compared to 2009, continuing much lower than post-installation in 2005 (0.44 mg/L). Increases in TCE concentration were noted in MWG91A, B and C. These well have only recently been installed and, based on the limited data set, it is not possible to establish if the increase in concentrations is a trend or due to seasonal differences. It should also be noted that these locations are upgradient of the PRB system.

Vinyl bromide concentrations at MWG59 and MWG49 increased in comparison to 2009 results. Vinyl bromide is a contaminant that is remediated by the PRB system and therefore increases in its concentrations are unlikely to pose a risk.

MWG48 was last sampled in 2006. It was the only well within Lot 2 to record an exceedence in benzene concentration in 2010, increasing from <0.001 mg/L in 2006 to 0.015 mg/L in 2010. This is the first time that benzene was above the relevant RBC in MWG48.

5.2.4.2 Other Results

The 2010 results were generally consistent with historical results. There was a general decrease in TCE concentration in the Regional Watertable at Lot 2 as indicated by the following wells:

- MW42 decreased from 0.085 mg/L in 2009 to 0.024 mg/L in 2010
- MWG49 decreased from 0.049 mg/L in 2009 to 0.025 mg/L in 2010
- MWG57 decreased from 0.77 mg/L in 2009 to 0.46 mg/L in 2010, and
- MWG59 decreased from 0.056 mg/L in 2009 to 0.025 mg/L in 2010.

Concentrations of TPH C_6-C_9, C_{15}-C_{28} and C_{29}-C_{36} decreased to below LOR in MW42 (Regional Watertable) in 2010. In comparison, the concentration of cis-1,2-dibromoethene (DBE) increased in MW42 (Regional Watertable) from 0.00016 mg/L in 2009 to 0.0008 mg/L in 2010. Concentrations of both cis- and trans-1,2-dichoroethene (DCE) have shown a decreasing trend in MW42 since 2005 whereas there has been an increase in cis-1,2-DCE concentrations in MWG48 (Base of Guildford) and MWG59 (Regional Watertable) since 2009.

Concentrations of 1,1-dichloroethane (DCA) have decreased in MWG49 (Regional Watertable) and MWG91B (Middle of Guildford) since March 2009 and September 2009, respectively. Concentrations of tetrachloroethene (PCE) have decreased in MWG49, MWG54 and MWG59 since March 2009.

5.2.5 Southwest Industrial Area

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

- MWG65 (Regional Watertable)
- MWG69 (Base of Guildford), and
- MWG70 (Regional Watertable).

All samples collected from the Southwest Industrial Area were analysed using suite 1. The complete results of the 2010 groundwater sampling programme for all locations on the Southwest Industrial Area are presented in Table 3, along with historical groundwater sampling results dating back to 2005.

5.2.5.1 RBC Exceedences

Results for the Southwest Industrial Area were compared against the site and Lot 2 RBC. Table H presents an overall summary of the analytes detected at concentrations above relevant RBC as well as the sample location and relevant monitoring zone.

Table H: Summary of Southwest Industrial Area Results above Relevant RBC

Location	Monitoring Zone	Analyte	2009 Concentration (mg/L)	2010 Concentration (mg/L)	Relevant RBC (mg/L)
MWG70	Regional Watertable	TCE	0.24	0.13	0.0351

The results are consistent with previous concentrations of TCE from the same location.

5.2.5.2 Other Results

In addition to the contaminant listed in Table H, a number of additional analytes were detected above the laboratory LOR but below relevant RBC (if any).

The results from the 2010 annual monitoring programme are generally consistent with historical results with the following exceptions:

- The concentration of cis 1,2-DCE increased from 0.006 mg/L in March 2009 to 0.026 mg/L in May 2010 at MWG65 (Regional Watertable), and
- The concentration of TCE at MWG70 (Regional Watertable) decreased from 0.24 mg/L in 2009 to 0.13 mg/L in 2010.

Generally, there was little variation in concentrations across the three wells sampled in the Southwest Industrial Area as compared to 2009.

5.2.6 Hanson

Only one sample was collected from the Hanson Property in the 2010 annual monitoring programme (MWG64, Regional Watertable). The sample was analysed for suite 2. The complete results of the 2010 groundwater sampling on the Hanson Property are presented in Table 5, along with historical groundwater sampling results dating back to 2005.

5.2.6.1 RBC Exceedences

Results for the Hanson Property sample were compared against the Hanson RBC and site and Lot 2 RBC. A summary of the contaminants identified at concentrations above RBC is presented in Table I.

Table I: Summary of Hanson Property Results above Relevant RBC

Location	Monitoring Zone	Analyte	2009 Concentration (mg/L)	2010 Concentration (mg/L)	Relevant RBC (mg/L)
MWG64	Regional Watertable	Arsenic	0.011*	0.07	0.00241

* indicates sample was from the interim monitoring program in September 2009.

Concentrations of TPH C_{10}-C_{14}, benzene and vinyl bromide have historically been above relevant RBC at MWG64. The 2009 annual monitoring round recorded these contaminants below the relevant RBC and vinyl bromide below the LOR. The 2010 results also recorded reduced levels for these contaminants indicating low levels have been maintained at MWG64.

5.2.6.2 Other Results

In addition to the contaminants listed in Table I, a number of additional analytes were detected above the laboratory LOR but below relevant RBC (if any).

The concentrations of these other analytes are consistent with historical results with the lighter TPH fractions, benzene and ethylbenzene found to be similar to 2009 values.

5.2.7 Damplands

Samples were collected from 6 locations in the Damplands during the 2010 annual monitoring programme:

- MW36 (Alluvium)
- MWG60 (Alluvium)
- MWG62 (Regional Watertable)
- MWG63 (Regional Watertable)
- MWG66 (Alluvium), and
- MWG68 (Alluvium).

All wells were analysed for suite 3. The complete results of the 2010 groundwater sampling for all locations in the Damplands are presented in Table 6, along with historical groundwater sampling results dating back to 2005.

5.2.7.1 RBC Exceedences

Results for the Damplands were compared against both health RBC for the Damplands and Aquatic Ecosystem Screening Criteria as discussed in Section 4.0.

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

Table J: Summary of Damplands Results Above Relevant RBC

Location	Monitoring Zone	Analyte	2009 Concentration (mg/L)	2010 Concentration (mg/L)	Relevant RBC or Screening Criteria (mg/L)
MW36	Alluvium	Iron	17	16	0.3 – Aquatic Screening Criteria
MWG60	Alluvium	Iron	2	1.3	0.3 – Aquatic Screening Criteria
MWG62	Regional Watertable	Nitrate (as N)	10	9.6	7 – Aquatic Screening Criteria
		Aluminium	0.055*	0.16	0.055 – Aquatic Screening Criteria
		Zinc	0.33*	0.009	0.008 – Aquatic Screening Criteria
MWG63	Regional Watertable	Nitrate (as N)	17	18	7 – Aquatic Screening Criteria
		TCE	0.056	0.42	0.33 – Aquatic Screening Criteria
		Zinc	0.27*	0.01	0.008 – Aquatic Screening Criteria
MWG66	Alluvium	Iron	1.4	1.1	0.3 – Aquatic Screening Criteria
MWG68	Alluvium	Iron	1.2	0.71	0.3 – Aquatic Screening Criteria

* indicates sample was from the interim monitoring program in September 2009.

Concentrations of iron decreased across all monitoring wells sampled in the Damplands (MW36, MWG60, MWG66 and MWG68), however, remained above the Aquatic Ecosystem Screening Criteria.

The concentration of aluminium in MWG62 decreased from 0.51 mg/L in 2009 to 0.16 mg/L, which still exceeds the screening criteria. The concentration of aluminium in MWG63 decreased from 0.43 mg/L in 2009 to 0.02 mg/L in 2010 which is below screening criteria.

The concentration of zinc decreased in both MWG62 and MWG63 since March 2009. Both results from the 2010 sampling programme remained above relevant RBC.

The concentration of TCE increased in MWG63 from 0.056 mg/L in March 2009 to 0.42 mg/L in May 2010. MWG63 is located upgradient of the PRB system and therefore it is not considered by Golder to pose a risk to receptors.

It should be noted that the Damplands receives groundwater from the entire Southwest Industrial Area and concentrations of metals and nitrates detected in the Damplands are not believed to be related to contamination at the former Waste Control site.

5.2.7.2 *Other Results*

The following metal results were noted:

- The concentration of aluminium decreased in monitoring wells MWG60 (Alluvium), MWG63 (Regional Watertable), MWG66 (Alluvium) and MWG68 (Alluvium) but increased slightly in MW36 (Alluvium).
- Arsenic was detected in MWG62 and MWG66 for the first time.
- The concentration of copper decreased in MW36, MWG62 and MWG63. Copper concentrations decreased below both the aquatic ecosystem screening criteria and below LOR for MW36 and MWG63.
- The concentration of iron decreased in monitoring wells MWG62 and MWG63.
- The concentration of manganese decreased in MWG60, MWG63, MWG66 and MWG68.
- The concentration of zinc decreased in MWG62 (Regional Watertable) and MWG63 (Regional Watertable from 0.29 to 0.009 mg/L and 0.27 mg/L to 0.01 mg/L in 2010, respectively.

There was a slight decrease in the concentrations of TPH C_6-C_9 fraction in MWG63 (Regional Watertable) from 0.13 mg/L in 2009 to 0.09 mg/L in 2010. Leeder noted that a concentration of 0.09 mg/L for TPH C_6-C_9 and therefore a concentration of 0.09 mg/L for total TPH C_6-C_{36} is ‘not typical’ of TPH. This lab indicated that this result is probably due to the relatively high TCE result for MWG63 (0.42 mg/L) and this note was added to Table 6.

The concentration of TCE increased slightly from 0.002 mg/L in 2009 to 0.007 mg/L in 2010 in MWG62 (Regional Watertable) and from 0.002 mg/L in 2009 to 0.003 mg/L in 2010 in MWG66 (Alluvium). There was a slight decrease in TCE concentration from 0.006 mg/L in 2009 to 0.003 mg/L in 2010 in MWG68 (Alluvium).

5.2.8 Helena River

Samples were collected from three locations in the Helena River in July 2010:

- SG05 (Downstream)
- SG06 (Midstream)
- SG07 (Upstream).

They were not sampled at the same time as the annual monitoring programme as surface water was not present in the River.

All wells were analysed for suite 3. The complete results of the 2010 groundwater sampling for all locations in the Helena River are presented in Table 7, along with historical groundwater sampling results dating back to 2008.

5.2.8.1 RBC Exceedences

Results for the Helena River were compared to the Helena River RBC and the Aquatic Ecosystem Screening Criteria as discussed in Section 4.0.

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

Table K: Summary of RBC Exceedences for the Helena River

Location	Analyte	2009 Concentration (mg/L)	2010 Concentration (mg/L)	Relevant RBC or Screening Criteria (mg/L)
SG05 (Downstream)	Aluminium	0.025	0.11	0.055 – Aquatic Screening Criteria
	Iron	21	1.1	0.3 – Aquatic Screening Criteria
SG06 (Midstream)	Aluminium	0.02	0.11	0.055 – Aquatic Screening Criteria
	Iron	38	1.1	0.3 – Aquatic Screening Criteria
SG07 (Upstream)	Aluminium	0.065	0.11	0.055 – Aquatic Screening Criteria
	Iron	1.9	1.1	0.3 – Aquatic Screening Criteria

The concentration of aluminium increased above aquatic screening criteria across all locations in 2010.

Iron concentration decreased across all locations compared to April 2009 levels, however, remained above the aquatic screening criteria.

The concentrations of aluminium and iron detected in the Helena River are not believed to be related to contamination at the former Waste Control site. This is supported by the aluminium concentration at the upgradient location SG07 being greater than that at downgradient monitoring locations.

5.2.8.2 Other Results

The concentration of copper increased across all locations compared to 2009 data whereas manganese and zinc decreased at all locations compared to 2009 data. The largest decrease of manganese was at SG05 which recorded 0.034 mg/L in July 2010 compared to 1.2 mg/L in April 2010. SG05 and SG07 which previously recorded zinc concentrations exceeding aquatic screening criteria were found to below the criteria.

The concentration of Nitrate (as N) was recorded at 0.45 mg/L in SG05 and SG07 and 0.46 mg/L in SG06. This is the first time Nitrate (as N) has been detected in the Helena River.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

As per the requirements of the SAP (Golder, 2010b), the field QA/QC programme adopted for the investigation included the following:

- Equipment wash blanks were collected each day on the submersible pump that was used. The equipment wash blanks were 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.
- Field blanks (also known as container blanks) were collected on 24 May 2010, 26 May 2010 and 27 May 2010. The field blank contained laboratory grade deionised water provided by Leeder. On 24 May 2010 and 27 May 2010, the field blanks were analysed for suite 1 analytes. On 26 May 2010, the field blank was analysed for total and ultra-trace metals only.

- Three field duplicates and one field triplicate were collected during the 2010 annual groundwater monitoring program.
- Waste groundwater generated from the sampling programme was collected in 205 L drums provided by Cleanaway and will be temporarily stored on the site. These drums were labelled with the source of waste and likely contaminants and once the waste has been characterised it will be disposed of by Cleanaway.

6.1 Field Testing

Water quality meters used for field parameter measurement during the 2010 sampling round were calibrated by the supplier (Airmet Scientific) prior to shipment and at least weekly during the sampling programme. The calibration certificates are included at the end of Appendix C. 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 6.7-7.3 for pH 7 as indicating acceptable meter calibration. The greatest pH deviation from the pH 4 solution occurred on 27 May 2010 (reading of 4.24). The greatest pH deviation from the pH 7 solution occurred on 31 May 2010 (reading of 7.29). Both of these deviations fell within the acceptable range. The pH solutions were changed on 27 May 2010 as slightly elevated pH readings indicated the pH solution may have been contaminated. However, 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. 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/cm 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 within two days upon arrival at the laboratory. Therefore, samples were extracted and/or analysed within 48 hours of sampling, complying with acceptable holding times for the various analytes.

6.2.2 Secondary Laboratory (ALS)

Analytical reports were reviewed to assess whether holding times were met for analytes reported. All samples were extracted and analysed 2 days following the sampling date, indicating all samples complied with the acceptable holding times for the various analytes.

6.3 Field Duplicates

Four field duplicates were taken during groundwater sampling and one field duplicate was taken during river sampling. Four of these duplicates were sent to the primary laboratory (Leeder), with the final 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 metals duplicate was taken at a Damplands well located in the alluvium layer (MWG66) and a duplicate was taken at SG05 (Helena River, Downstream). 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:

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

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.

No RPDs greater than 50% were noted during the comparison of the primary and duplicate samples from MW42 (a well on Lot 2). 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 four analytes (nickel, n-propylbenzene, sec-butylbenzene and 1,1-DCA). Of these exceedences, two, n-propylbenzene (RPD=56%) and 1,1-DCA(RPD=69%), had a difference between results above ten times the laboratory LOR. The results for n-propylbenzene were well below the site-specific RBC. There is no RBC for the site for 1,1-DCA so the aquatic ecosystem screening criteria value of 0.09 mg/L was used for determining the potential importance of this RPD exceedence. Historical results for 1,1-DCA in MW22i have had concentrations well above the aquatic ecosystem criteria, with a maximum of 0.162 mg/L in March 2003. Given the large exceedence of the criteria, the actual variation in the reported concentrations is not likely to impact on the outcomes of this investigation; however, the data point should be treated with a greater degree of uncertainty. Concentrations of other analytes, nickel and sec-butylbenzene 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 metal analytes in the primary and duplicate samples from MWG66 (Damplands well). Thus Golder considers these results acceptable for the purposes of this investigation. No RPDs greater than 50% were noted during comparison of the primary and supplicate samples from SG05 (Helena River, Downstream).

In general, the RPD exceedence for 1,1-DCA in MW22i may be of some concern and so this result should be treated with caution. All other intra-laboratory testing did not highlight any significant issues with the quality of the data.

6.3.2 Secondary Laboratory (ALS)

One field triplicate sample (MW42 (Lot 2, Regional Watertable) was 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.

At MW42 (Lot 2, Regional Watertable), sixty-two analytes in total were found to have RPDs greater than 50%. Fifty-seven of these RPD exceedences were due to differences in LOR between the laboratories. As the LORs were generally below the relevant criteria, these results were not considered to affect the outcomes of this investigation.

Three of the remaining RPD exceedences had the difference between analytes as less than ten times the LOR. Therefore, the data quality was not considered to adversely affect the outcomes of this investigation.

Two analytes had an RPD exceedence where the difference between both analytes was greater than ten times the LOR. TPH C_6-C_9 and TPH C_{15}-C_{28} had an exceedence value of RPD=192% and RPD=186% respectively. Generally, these elevated RPDs arose from one result being below the laboratory LOR and the other above. The secondary laboratory (ALS) recorded the larger of the two values at 0.25 mg/L and 0.67 mg/L for TPH C_6-C_9 and TPH C_{15}-C_{28}. The RBC for Lot 2 identifies 1920 mg/L as the level for TPH C_6-C_9 and 9.82 mg/L as the level for TPH C_{15}-C_{28}. All TPH C_6-C_9 and TPH C_{15}-C_{28} concentrations for wells at Lot 2 were below these criteria levels and therefore, the data quality was not considered to adversely affect the outcomes of the investigation.

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

6.4 Laboratory Duplicates

6.4.1 Primary Laboratory (Leeder)

A total of ten laboratory duplicates were analysed by Leeder over the duration of the investigation. The laboratory duplicates were analysed for a range of analytes. One of the laboratory duplicates was only analysed for metals and one was only analysed for TPH. 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 formations. One of the laboratory duplicates was located at an upgradient monitoring well, MWG45 (Regional Watertable). Four duplicates were located at Lot 2 (MWG47 (Leederville), a wash blank between MWG47 (Base of Guildford) and MWG48 (Leederville), MW42 (Regional Watertable) and at a wash blank between MW42 (Lot 2, Regional Watertable) and MWG64 (Hanson, Regional Watertable). Two of the duplicates were located in the Damplands (MWG62 (Regional Watertable) and MWG68 (Alluvium)). One of the duplicates was located on site (MW25 (Base of Guildford)), one was located at Lot 2 (MWG91A (Regional Watertable)) and one was located at SG07 (Helena River, upstream).

Nine of the ten laboratory duplicate samples did not have RPDs greater than 50%, indicating satisfactory agreement between results and acceptable internal laboratory reproducibility of results. The sample which reported laboratory duplicates RPDs greater than 50% was collected from MWG91A (Lot 2, Regional Watertable)).

The laboratory duplicate for MWG91A (Lot 2, Regional Watertable) reported two RPDs which exceeded the acceptable range of between 0% and 50%. PCE had an RPD of 55% based on a primary result of 0.004 mg/L and a duplicate result of 0.007 mg/L. This RPD was greater than 50%, however, the difference between results was less than ten times the LOR and so this result is not considered to have adversely affected the outcomes of the investigation. Cis-1,2-DCE had an RPD of 67% based on a primary result of 0.001 mg/L and a duplicate result of 0.002 mg/L. This RPD was greater than 50%, however, the difference between results was less than ten times the LOR and so Golder does not consider this result 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 ten times the LOR, no acceptable RPD range is applied, for samples with concentrations between ten and twenty times the LOR an acceptable range of 0 to 50% is applied and for samples with concentrations greater than twenty 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 field and laboratory wash blanks and trip blank samples are presented in Table 13.
A laboratory (method) blank analysis was also conducted by each laboratory for each batch of samples that were received. Laboratory certificates of analysis are presented in Appendix A.

6.5.1 Laboratory (Method) 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 analysis 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

Nine 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 most samples were below the respective LOR for VOCs and Br-VOCs. A trip blank sent on 28 July 2010 to Leeder recorded concentrations of Dibromochloromethane (0.002 mg/L) and Tribromomethane (0.003 mg/L). All samples for this batch recorded less than LOR concentrations for Dibromochloromethane and Tribromomethane. Hence the trip blanks results were considered acceptable for this investigation.

6.6 Wash Blanks

Wash blanks are samples consisting of laboratory grade distilled water which was collected following rinsing decontaminated parts of the sampling equipment which had had contact with groundwater. The wash blank tests for cross-contamination between wells according to which, if any, analytes are still present on the pump after decontamination. Three representative samples of un-used rinse water were also submitted to the laboratory to facilitate a comparison with wash blank analytical results. The un-used rinse water samples were collected on 24 July, 26 July and 27 July 2010. Detections of aluminium and iron were noted in the un-used rinse water samples. The lab was contacted and confirmed that these results were correct. Both aluminium and iron concentrations recorded in the un-used rinsate water were below the relevant RBC. Table L provides a summary of rinse water detections.

Table L: Detections in Un-Used Rinse Water

Analyte	Concentration range (mg/L)
Aluminium	0.001-0.002
Iron	0.002-0.005

Six wash blank samples were collected during the 2010 annual groundwater monitoring programme. 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 indicated that metals were detected in some wash blank samples. 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 M provides a summary of the detected analytes in the wash blanks. Further discussion of the wash blank results is provided below.

Table M: 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	3	0.003	309
Iron	0.001	5	0.03	217
Lead	0.001	1	0.002	0.0034*
Zinc	0.001	4	0.005	0.008*

*When a Site and Lot 2 RBC was not available, the Aquatic Ecosystem Screening Criteria was used for comparison.

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. Aluminium was detected in three wash blank samples and iron was detected in five of the six wash blank samples. These results appear to be associated with the laboratory grade rinse water which also had concentrations of aluminium and iron. The concentration of iron in one of the wash blanks was greater than the other readings, however, the result was still less than site and Lot 2 RBC. Lead was detected in one sample (wash blank collected from the washed submersible pump at MWG47 (Lot 2, Leederville)), though results were only marginally above the LOR and fell below the Aquatic Ecosystem Screening Criteria. Zinc was detected in four of the wash blank samples. The results were not greater than the RBC and zinc has been observed in wash blank samples historically (Golder, 2009b). It appears that the decontamination procedures adopted were sufficient to minimise cross contamination between wells and to allow for meaningful interpretation of the results.

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. Both 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 2010 groundwater monitoring programme.

All samples surrogate recoveries from Leeder were within the acceptable range of 60% to 130%. For one sample (wash blank between MW42 and MWG64), the surrogate recovery for one VOC surrogate (dibromofluoromethane) was at the upper limit (130%). As all sample surrogate recoveries were within the acceptable range, 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 implications with regards to the outcomes of the investigation.

6.7.2 Secondary Laboratory (ALS)

Surrogate recovery analysis was performed on VOCs, TPH (V)/BTEX and Br- VOCs. 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%. All surrogate recoveries fell within both Golder’s acceptable range and 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, 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 iron at MWG45 (Upgradient, Regional Watertable), copper at MW25 (Site, Base of Guildford) and both iron and manganese at MWG68 (Damplands, Alluvium). Primary sample results indicated elevated levels of these analytes, therefore the lack of a spike recovery result is considered 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)

All spike recoveries were within the acceptable recovery limits. There was no matrix spike determined for cis-1,2-DBE and trans-1,2-DBE individually. ALS were contacted and explained that a spike recovery is completed for the total 1,2-DBE, which was within the acceptable recovery limits. Golder does not expect these results to affect the outcome of the investigation.

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

6.9 Quality Assurance/Quality Control Summary

As per the SAP (Golder, 2010b), the field QA/QC programme adopted for the investigation included the following:

- The use of dedicated equipment at each location coupled with stringent field decontamination procedures to minimise the potential risk of cross-contamination.
- The collection of samples into laboratory provided sample containers with appropriate preservatives where required.
- The collection and review of trip blanks as a check on sample integrity and laboratory data quality.
- Field duplicates submitted to the primary NATA approved laboratory, with duplicate split being sent an alternative NATA approved laboratory.
- Consideration of internal laboratory QA/QC results, including a review of laboratory duplicate and blank sample results, as well as the results of surrogate and spike analyses.
- Discussion of any other QA/QC issues that arise.

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

- The primary laboratory for the annual samples was conducted by Leeder Consulting with ALS as the duplicate laboratory. All laboratories are NATA registered for all the required analyses.
- A minimum of one laboratory duplicate performed on each batch of samples provided to the lab. The relative percent difference (RPD) is considered satisfactory if below 50%. Laboratory blanks will be run at the beginning and end of each batch of samples. Spike recovery analyses for each analytical suite, for each batch of samples received (i.e. one spike recovery analyses for every 10 samples) will be undertaken. Spike recovery analysis results within a range of 75% to 125% is considered satisfactory for quality.

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 metals 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.

- 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 all results were considered acceptable for this investigation.

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 2010 groundwater monitoring programme. Furthermore, the QA/QC program implemented for the 2010 annual groundwater monitoring programme was consistent with the guidelines outlined in the Golder SAP (Golder, 2010b).

7.0 DISCUSSION

In general, the results indicate that concentrations of chlorinated solvents both on and off site have decreased since 2009 (Golder, 2010a). A review of the groundwater flow direction and velocities in 2010 indicate little change from previous years. Groundwater flow direction in the Regional and Base of Guildford have changed slightly from a south-westerly to a south-south-westerly direction. These changes correspond with groundwater flow in the Leederville and Alluvial formations. Groundwater velocities can provide information regarding the speed that contaminants will move within the formations. These groundwater velocities agree with expected groundwater flows and will be compared with future readings to assess changes in velocity.

The TCE distribution over the study area is presented in Figure 7. In 2010, decreases in the concentration of TCE were observed at MW21i (Site, Regional Watertable), MW23i (Site, Regional Watertable), MW42 (Lot 2, Regional Watertable), MWG49 (Lot 2, Regional Watertable), MWG57 (Lot 2, Regional Watertable), MWG59 (Lot 2, Regional Watertable), MWG68 (Damplands, Alluvial) and MWG70 (Southwest Industrial Area, Regional Watertable). TCE concentrations on site remained below the relevant RBC.

There were TCE concentration increases at locations MWG91A (Lot 2, Regional Watertable), MWG91B (Lot 2, Middle of Guildford), MWG91C (Lot 2, Base of Guildford), MWG62 (Damplands, Regional Watertable), MWG63 (Damplands, Regional Watertable) and MWG66 (Damplands, Alluvial).

The largest increases in TCE were observed in the set of wells MWG91A (Lot 2, Regional Watertable), MWG91B (Lot 2, Middle of Guildford), and MWG91C (Lot 2, Base of Guildford) along with MWG63 (Damplands, Regional Watertable). These wells are located upgradient of the PRB system. Downgradient concentrations of TCE at MW36, MWG60, SG05, SG06 and SG07 were below LOR and below RBC at MWG68 and MWG66 indicating the TCE plume is likely not impacting on sensitive receptors in the Helena River. Other than this round of monitoring the MWG91 series has only previously been sampled during the 2009 interim monitoring (September 2010) and therefore the increase in concentrations may be due to seasonality and not indicative of a trend. The increase in TCE concentration at MWG63 has seen the concentration return to levels above RBC and is consistent with results prior to the 2009 monitoring. Concentrations of TCE at MWG66 increased in 2010 compared to 2009 results from 0.056 mg/L to 0.42 mg/L. Nevertheless, a general decrease in TCE concentrations has been noted at MWG63 since 2006.

Figure 8 presents the distribution of chlorinated ethenes (PCE, TCE, cis-1,2-DCE and 1,2-DCA) in the Regional Watertable across the study area. As previously identified in the 2008 and 2009 annual monitoring results, two plume centrelines can be identified 1) a plume consisting of a mixture of chlorinated solvents with concentrations generally below RBC 2) a plume of predominantly TCE emanating from the Stanley Street Cul-de-Sac. Both plumes converge at the base of the escarpment where the permeable reactive barrier system has been installed. The plume centrelines have remained consistent with results from 2009 and concentrations of chlorinated ethenes along these plume centrelines have generally decreased since 2009.

Results from the 2009 annual programme showed concentrations of chlorinated solvents above the detection limit in the Helena River. Subsequent pore water sampling also detected concentrations of chlorinated solvents. Results from this annual sampling round did not detect any concentrations of chlorinated solvents above detection limits in the Helena River. Analytes exceeding the aquatic screening criteria in the Helena River were iron and aluminium. There are no indications that these exceedences are directly related to on-site contamination.

The concentration of benzene in MW25 (Site, Base of Guildford) has decreased to below the relevant RBC over the last year indicating that downward migration of benzenes has potentially reached a steady state. Concentrations of benzene were above the relevant RBC in 2008 and 2009 but has previously been identified as being below the laboratory LOR. There was also a decrease in total TPH fractions C_6-C_{36} (0.46 mg/L to <0.05 mg/L) which indicates that there may be a reduced downward migration of other hydrocarbons. Concentrations of TPH fractions C_6-C_{36} has fluctuated over the years although this is the first time since 2004 where concentrations fell below the laboratory LOR. Decreased concentrations of both benzene and total TPH fractions at the Base of Guildford indicate that the downward migration of hydrocarbons may be slowing down. This could be due to natural degradation of the plume.

In Lot 2, the concentration of benzene at MWG48 (Lot 2, Base of Guildford) was above relevant RBC for the first time since sampling began in 2005. Surrounding monitoring wells (MWG47, MWG49) have not detected benzene. It should also be noted that the concentration of TPH C_6-C_9 at MWG48 was below the detection limit. The laboratory was contacted and Golder was advised that the discrepancy is due to the analysis of benzene and TPH being undertaken on different equipment. The benzene detection was close to the limit of reporting and the chromatograph indicated a spike in the TPH C_6-C_9, however, it was below the detection limit.

There has been an increase in vinyl bromide concentration at MWG49 (Regional Watertable) and MWG59 (Regional Watertable) at Lot 2 with both exceeding RBC. However, as both locations are upgradient of the PRB, which has the capability of remediating vinyl bromide, it is not considered by Golder to currently pose a risk to human or ecological receptors.

There were increases in arsenic, copper, manganese and nickel in on-site wells. Increases in arsenic concentrations at MWG62 (Damplands, Alluvial) and MWG66 (Damplands, Alluvial) were detected which exceeded the aquatic ecosystem screening criteria. Arsenic has previously been detected at MWG62 but not MWG66. Concentrations of aluminium, iron, copper, manganese, lead and zinc all decreased at MWG63 (Damplands, Regional Watertable). There were decreases in metal concentrations across the remaining wells in the Damplands. It is likely that metals concentrations in the Damplands and Helena River are not attributable to contamination originating from the former Waste Control site.

8.0 CONCLUSIONS AND RECOMMENDATIONS

This report has presented the results of the 2010 annual groundwater monitoring round undertaken at the former Waste Control site and its surrounds. The programme included the collection of groundwater measurements and the collection of samples from 29 locations. The results from this annual monitoring programme are in general agreement with the results of previous programmes.

The following is a summary of the results of the 2010 annual monitoring programme:

- No chlorinated solvents were detected in the Helena River.

- Generally, chlorinated solvent results have decreased in comparison to 2009 results.
- Benzene and TPH fractions in MW25 were below the relevant RBC and therefore downward migration of hydrocarbons has potentially reached steady state.
- Increases in metals were detected in on-site wells (MW21i, MW22i, MW23i and MW25) and some Dampland wells (MWG62, MWG63 and MWG66).

Golder recommends that an annual monitoring programme be undertaken in 2011. All monitoring locations undertaken in 2010 should be included in the 2011 monitoring programme.

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