F I N A L   R E P O R T

Orica Botany Environmental Survey Stage 4 - Remediation Groundwater Treatment Plant (GTP) Quarterly Groundwater and Surface Water Monitoring Report December 2008

Prepared for

Orica Australia Pty Ltd

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20 February 2009

43217910

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Contents

Contents

Tables, Figures, Plates, Drawings, Appendices

Tables

Figures

Appendices

Executive Summary

Introduction

This report presents the results of groundwater and surface water data collected in December 2008 as part of the Groundwater Treatment Plant (GTP) – Groundwater and Surface Water Monitoring Program. The scope of the December 2008 monitoring round was in accordance with the Groundwater Treatment Plant Groundwater and Surface Water Program (URS, 2008c).

Scope of Work

In accordance with the GTP monitoring program, the December 2008 sampling period represents a quarterly monitoring event. It includes an analytical program with a number of sampling locations focusing on areas in the vicinity of potential environmental and human health receptors.

A comprehensive water level monitoring program was undertaken in order to assess hydraulic containment at the three containment lines, which include the Botany Industrial Park (BIP) Containment Area, Primary Containment Area (PCA) and Secondary Containment Area (SCA). This program included assessment of continuously logged data from monitoring and extraction wells in accordance with the GTP monitoring program (URS, 2008c) (total of 323 locations). Hydraulic data included data from pressure transducers in the extraction wells and monitoring wells, and selected data from standalone loggers deployed in monitoring wells located across BIP, PCA, SCA and at other hydraulically strategic locations off site.

Hydraulic Monitoring Results

General

- Assessment of groundwater flow and hydraulic containment has been completed by analysis of observed static groundwater levels, interpreted groundwater flow lines, transient water levels and contaminant distribution in the context of the site conceptual model (URS, 2007f);
- The slow migration of groundwater and the potential for increased pumping to recapture groundwater mean that hydraulic containment can still be maintained through extended periods of no, or low, groundwater extraction. An assessment of the maximum time periods that the SCA and PCA containment lines can be off-line before groundwater at the containment line cannot be recaptured was presented in previous GTP monitoring reports (URS, 2007b);
- Implementation of hydraulic containment has altered the natural groundwater flow regime with flow now characterised by flow drawn towards the three containment lines;
- Large areas of very low hydraulic gradients have developed due to hydraulic containment. These areas represent zones of very slow groundwater flow and as a result contaminant concentrations in these areas are likely to remain relatively constant for the medium to long term;
- While the observed pattern of groundwater flow in December 2008 is clearly different to that observed during the baseline monitoring in October 2004 (URS, 2005a) it is very similar to that presented in recent monitoring reports (e.g. URS, 2007g, 2008a, 2008b and 2008d); and
- Water levels at regional monitoring wells show no discernible water level impact due to hydraulic containment thus indicating a limited potential to affect infrastructure and licensed groundwater users.

Executive Summary

BIP Containment Line

- The primary purpose of the BIP containment line is to contain contaminated groundwater migrating from source areas located on BIP. If groundwater extraction is temporarily reduced due to periodic GTP capacity limitations, this reduction occurs at sections of the BIP containment line based on a predetermined order of priorities; and
- The inferred contours and patterns of deep groundwater flow infer that hydraulic containment was achieved around the central part of the extraction line (first priority area) during the monitoring period. Containment was not achieved at the northern and southern portions of the BIP containment line during the monitoring period, although as discussed in the September 2008 monitoring report (URS 2008f) the PCA will effectively capture a large portion of this flow.

PCA Containment Line

- The primary purposes of the PCA are mass removal of the central 1,2-dichloroethane (EDC) plume in the deep aquifer, and hydraulic containment on Block 2, Southlands;
- The inferred contours and patterns of deep groundwater flow at the PCA infer that hydraulic containment was achieved during the monitoring period;
- It is important to note that consistent pumping will be required during the next monitoring period (January to March 2008) to ensure that the effects of the shutdown and slightly inconsistent pumping in December 2008 are negated;
- The interpreted contours and groundwater flow lines presented in Figure 4.1 show that although drawdown has been recorded, it cannot be conclusively determined that shallow groundwater is being contained at the PCA. However, the very low hydraulic gradient in the shallow aquifer at McPherson Street indicates that the rate of migration of shallow groundwater has been significantly reduced and the majority of the contaminant mass is located in the deep aquifer; and
- Orica has engaged URS to install additional offsite shallow groundwater monitoring bores to provide further information.

SCA Containment Line

- The primary purpose of the SCA is to minimise migration of groundwater contamination to Botany Bay (recognising that there was already contamination in areas downgradient and to the east of the containment line before groundwater extraction commenced);
- The inferred contours and patterns of shallow and deep groundwater flow at the SCA infer that hydraulic containment was achieved during the monitoring period; and
- Results of salinity monitoring downgradient of the SCA indicate similar levels to those observed during previous monitoring rounds.

Chemical Monitoring Results

Onsite Monitoring Wells

The December 2008 sampling period represents a quarterly monitoring event. As such, it is focussed on collecting data from offsite locations that are critical to environmental and human health receptors. No samples have been collected from onsite sampling locations (i.e. on BIP or Southlands).

Executive Summary

Offsite Monitoring Wells

- Concentrations reported for offsite monitoring wells were similar to those previously reported with the exception of wells located at the leading edge of the Central Plume which is continuing to slowly migrate towards the SCA and sampling locations in the dune areas in Penrhyn Estuary;
- The increase and reported maximum observed for EDC at WG154S is considered to be significant. This increase is consistent with short- and long-term historical trends. It is noted that contamination from this location will be captured at the SCA and will not discharge into Penrhyn Estuary;
- The increases observed for EDC and TCE at BP01 (2 m and 6 m ports, respectively) and PCE and CTC at MWF15I are considered to be significant. The increases are consistent with historical trends and concentrations are considered to be representative of groundwater that migrated downgradient of Foreshore Road prior to the commencement of hydraulic containment at the SCA; and
- The reported maximum concentrations at BP115 (5.25 m port) may not be representative of actual concentrations at this location and depth as it is suspected that the samples at the 5.25 m port and the 6.5 m port may have been interchanged. The March 2009 sampling round will be used to confirm the concentrations and trends at these ports.

Penrhyn Estuary

- In general, volatile CHC concentrations in pore water within Penrhyn Estuary are similar to or lower than historical concentrations; and
- Maximum concentrations for EDC, TCE and CFM in BP71A (1.0 m port) and EDC and TCE (2 m and 6 m ports, respectively) were noted. However, these concentrations were below the respective ANZECC (2000) Trigger Values.

Surface Water

- The concentrations of volatile CHCs in all surface water sampling locations were less than the respective ANZECC (2000) Trigger Values. This is consistent with the monitoring rounds performed since the GTP commenced steady operation indicating the remediation is having a significant effect on the surface water quality in the estuary; and
- Surface water samples collected from the pond within the Botany Golf Course (SW066) showed no detection of CHCs above the limits of reporting.

Implications for Human Health Risk Assessment

- There are no additional data presented in the December 2008 round of sampling with respect to the Western Margin of the Northern Plumes that affect the conclusions of the Human Health Risk Assessment (HHRA) (URS, 2005e) and Addendum (URS, 2006b). That is, the groundwater contamination within the Northern Plumes near the western margin is not considered to pose an unacceptable risk to human health, assuming that groundwater is not extracted and used;
- There are no additional data presented in the December 2008 Quarterly Monitoring Report that alter the conclusions of the HHRA (URS, 2005e) with respect to existing commercial/industrial workers in areas above the main plumes. That is, the groundwater contamination within the main plumes is not considered to pose an unacceptable risk to human health, assuming that groundwater is not extracted and used untreated; and
- Based on the data collected to December 2008 (and considering the additional review of data presented in the June 2007 (URS, 2007e) and September 2008 (URS, 2008f) monitoring reports),

the conclusions presented within the HHRA associated with exposures within the inner and outer estuary remain unchanged. That is, given the conservative nature of the range of assumptions and the safety factors applied to toxicity values, the risks to human health for all exposure scenarios are considered to be low. However, the assessment has identified worst-case exposure scenarios (particularly within the inner estuary) where the calculated risks exceed the target values. It is noted that the potential for exposure within the inner estuary is effectively eliminated by access restrictions associated with the Port Botany expansion works.

Recommendations

On the basis of the results of the December 2008 program, the following recommendations are made:

Hydraulic Monitoring

- Repair of faulty and damaged loggers and transducers identified in this monitoring period;
- Given the very similar water levels historically reported at WG75I and WG75D replacement of the faulty logger at WG75D is not required and the well should be removed from the hydraulic monitoring program;
- The logger installed at WG216S (dry) should be transferred to WG216I to assess the relative response of the shallow and deep aquifer east of the BIP to hydraulic containment. Similarly a logger should be considered for installation at WG215I;
- Monitoring well MWB10S should be replaced and additional shallow groundwater monitoring wells should be installed downgradient of the PCA as part of the continuing effort to assess shallow groundwater containment at the PCA;
- In view of the gradually increasing drawdown in the shallow aquifer at PCA as a result of increased pumping in the deep aquifer, the current pumping regime should be continued and enhanced (where possible);
- To allow more efficient allocation of resources and ensure ongoing timely delivery of reports it is proposed to modify the monitoring period for hydraulic data such that the hydrographs represent the period up to submission of the previous monitoring report; and
- As GTP capacity increases, additional pumping should be concentrated at the southern end of the BIP containment line to maximise contaminant mass removal and maximise the remedial effects on Springvale Drain.

Chemical Monitoring

- It is recommended that SW066, collected from the pond at the Botany Golf Course, be removed from the sampling program following no detections of volatile CHCs in the September 2008 and December 2008 sampling rounds;
- It is recommended that ongoing monitoring be undertaken according to the June 2008 Groundwater and Surface Water Monitoring Program (URS, 2008c); and
- It is recommended that BP44, BP66, BP108 and BP109 be deleted from the monitoring program.

Section 1 Introduction

1.1 Background

In September 2003 (subsequently amended and consolidated in February 2004) the then Department of Environment and Conservation (DEC; now the Department of Environment and Climate Change [DECC]) issued a Notice of Clean Up Action (NCUA) No 1030236 to Orica Australia Pty Ltd (Orica) requiring remediation of the chlorinated hydrocarbon (CHC) contaminant plumes emanating from the Botany Industrial Park (BIP) and present in areas to the south and west of BIP. In response to condition 3B of the NCUA, Orica prepared a Groundwater Cleanup Plan (GCP) (Orica, 2003b). Quarterly monitoring programs completed and reported under the NCUA commenced in March 2004.

The strategy selected to achieve hydraulic containment of groundwater contamination was described in the Botany Groundwater Cleanup (BGC) Project Environmental Impact Statement (EIS) (URS, 2004i) and comprised installation and operation of three hydraulic containment lines (primary, secondary and BIP) and construction of a groundwater treatment plant (GTP). The Joint Determining Authority Report (DEC, 2005) for the BGC Project EIS provided conditions of approval including requirements to monitor aquifer water levels (hydraulic monitoring) and contaminants of concern in surface water and groundwater (chemical monitoring).

To address the conditions of approval, the Draft Groundwater Treatment Plant – Groundwater and Surface Water Monitoring Program (URS, 2005g) was developed and submitted to the then DEC, and superseded the GCP Monitoring Program. The GTP monitoring program commenced in September 2005 and subsequently was amended in January 2007 (URS, 2007a) and June 2008 (URS, 2008c). Amendments to the GTP monitoring program primarily relate to the installation of data loggers, the frequency of water level measurement and water sampling at monitoring locations and the chemicals being analysed. There are three types of monitoring events reflecting the number of samples and analytes: quarterly, annual and biennial (in order of magnitude). There are some minor differences in the reporting and presentation of data between the types of monitoring events.

The June 2008 amended GTP monitoring program specifies the forward schedule for these events:

GTP Monitoring and Reporting Schedule

Sampling Schedule	Report Submission Date	Monitoring Event Type
September 2008	28 November 2008	Annual
December 2008	27 February 2009	Quarterly
March 2009	29 May 2009	Quarterly
June 2009	28 August 2009	Quarterly
September 2009	30 November 2009	Biennial
December 2009	26 February 2010	Quarterly
March 2010	31 May 2010	Quarterly
June 2010	31 August 2010	Quarterly
September 2010	30 November 2010	Annual

The scope of the December 2008 program is consistent with that of a quarterly monitoring event as outlined in the June 2008 amended GTP monitoring program.

1.2 GTP Monitoring Program Methodology

The GTP monitoring program has two distinct groundwater monitoring functions:

- Chemical monitoring of the distribution of the contaminants of concern within surface water and groundwater; and
- Monitoring of hydraulic containment performance.

1.2.1 Chemical Monitoring

The chemical monitoring program (see Table 1.1) is based on the following methodology:

- Quarterly monitoring ensures data critical to environmental and human health receptors (see URS, 2005e/2006b) is collected. Data proposed to be collected in the Quarterly GTP monitoring program includes:
  - Surface water in Penrhyn Estuary, and Springvale and Floodvale Drains;
  - Pore water at the inter-tidal groundwater discharge zone (i.e. 0.1 m ports at BP42-BP44 and BP64-BP66) located within Penrhyn Estuary; and
  - Groundwater at the top of the water table, which may be relevant to assessing risks presented by vapour migration.
- Annual chemical monitoring focuses on assessing chemical changes in areas where plume migration is expected to occur as well as detailed assessment of data with respect to the assumptions made in the Consolidated Human Health Risk Assessment (CHHRA) (URS, 2005e) and Addendum (URS, 2006b); and
- Biennial chemical monitoring focuses on identifying major changes to plume geochemistry and distribution throughout the Groundwater Extraction Exclusion Area (GEEA).

1.2.2 Hydraulic Monitoring

The BGC Project EIS approval requirements relative to hydraulic monitoring can be summarised as a number of specific objectives including the monitoring of aquifer water levels (hydraulic monitoring) to demonstrate:

- Capture of contaminated groundwater at the various hydraulic containment lines; and
- Excessive drawdown does not occur which may result in ground subsidence.

Hydraulic monitoring and regular review of pumping rates is also conducted in order to minimise the rate of saltwater intrusion at the SCA, which is undesirable for GTP operation.

The amended hydraulic monitoring program (URS 2008c) is based on the use of automated data loggers and transducers to enable continuous water level monitoring in the lower GEEA. To this end the amended program included the provision of additional data loggers across the lower GEEA (see Table 1.2). The additional data loggers were installed throughout late 2008. The methodology for the hydraulic monitoring program is as follows:

- Quarterly hydraulic monitoring to focus on assessing hydraulic containment at the SCA, PCA and BIP containment lines; and
- Annual and biennial hydraulic monitoring to assess long-term data and the groundwater flow regime within the broader area of the lower GEEA.

Section 2 Previous Investigations

2.1 General

Groundwater monitoring has been conducted throughout the Stage 3 and Stage 4 Surveys on a number of occasions. Previous quarterly monitoring programs completed and reported under the GCP and GTP programs are presented in the following table.

Previous GCP and GTP Monitoring Programs

	Year	Month	Reference
GCP Programs	2004	March June September December	URS, 2004d URS, 2004f URS, 2004h URS, 2005a
	2005	March June	URS, 2005c URS, 2005f
GTP Programs	2005	September December	URS, 2005h URS, 2006a
	2006	March June September December	URS, 2006c URS, 2006g URS, 2006i URS, 2007b
	2007	March June September December	URS, 2007d URS, 2007e URS, 2007g URS, 2008a
	2008	March June September	URS, 2008b URS, 2008d URS, 2008f

Additional groundwater investigations completed in the early stages of implementation of the GCP were:

- Penrhyn Estuary Baseline Study (URS, 2004b);
- 2003/2004 Northern Plumes Investigation (URS, 2004c); and
- Investigations of the inferred dense non-aqueous phase liquids (DNAPL) source areas which had been undertaken throughout 2004, 2005 and 2006 and are ongoing (URS, 2004e/g; URS, 2005b; URS, 2006d/e/f/h/j), including bench testing of possible DNAPL source area remediation techniques.

The previous annual GTP monitoring report was September 2008 (URS, 2008f), while the previous interim monitoring report was June 2008 (URS, 2008d).

Section 3 Scope of Work

3.1 General

The scope of work for the December 2008 quarterly monitoring program is summarised in this section. The results of the hydraulic monitoring are presented and discussed in Section 4. The results of the groundwater chemical monitoring program are presented in Section 5, while the results of Penrhyn Estuary and surface water sampling are presented in Section 6.

3.2 Hydraulic Containment Water Level Monitoring

A comprehensive water level monitoring program utilising automated data loggers and transducers was undertaken in accordance with the GTP monitoring program (URS 2008c) as shown in Figure 3.1. The monitoring well locations used for the December 2008 GTP monitoring program are presented in Table 1.2. The program involved collection and processing of data from 323 continuously logged monitoring and extraction wells.

3.3 GTP Chemical Sampling Program

In accordance with the GTP program (see Table 1.1 and URS, 2008c), the December 2008 sampling period represents a quarterly monitoring event. It includes an analytical program with a number of sampling locations focusing on areas in the vicinity of potential environmental and human health receptors. Minor variations to the amended GTP Program were made, due to inaccessible or dry ports, which are itemised in the following table. In most instances, adjacent ports were sampled.

The groundwater sampling locations are shown on Figure 3.2. Surface water and Penrhyn Estuary groundwater sampling locations are shown on Figure 3.3.

December 2008 GTP Monitoring Program Variations

Plume	Scheduled Program (see Table 1.1)		Completed December 2008 Program		Variations
	No. Locations	No. Samples	No. Locations	No. Samples	
Southern	6	10	6	10	• BP114, 4 m port dry. Substituted with 6 m port.
Central	6	10	6	10	• BP41, 2 m port dry. Substituted with 6 m port. The 4 m port was sampled as part of the program.
Northern	13	13	13	13	• BP111, 3 m port not labelled. Substituted with 6 m port. • BP58, 3 m port not labelled. Substituted with 6 m port.
Penrhyn Estuary	5	29	6	30	• BP43, 2 m port was blocked. Substituted with 1 m port. • BP71a, 1 m port was sampled.
Surface Water	12	16	12	16	• No changes
Total	***42***	***78***	***43***	***79***	

As reported in the September 2008 annual report (URS, 2008f), sampling locations BP44, BP66, BP108 and BP109 were decommissioned as part of the work being undertaken for the Port Botany expansion project. These sampling locations were decommissioned prior to the commencement of the aforementioned sampling program.

3.4 Sample Analyses

All groundwater and surface water samples were analysed for a suite of volatile CHCs. The analytical suite includes the list of compounds specified in the NCUA, and is presented in the table below.

Analytes

Volatile Chlorinated Hydrocarbons	
Carbon Tetrachloride (CTC)	Chloroform (CFM)
Methylene chloride (DCM)	Chloromethane
Pentachloroethane	1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane (1,1,2,2-TeCA)	1,1,2-Trichloroethane (1,1,2-TCA)
1,1,1-Trichloroethane	1,1-Dichloroethane
1,2-Dichloroethane (EDC)	Chloroethane
Tetrachloroethene (PCE)	Trichloroethene (TCE)
trans-1,2-Dichloroethene (trans-1,2-DCE)	*cis*-1,2-Dichloroethene (cis-1,2-DCE)
Vinyl Chloride (VC)	

A summary of the properties of volatile CHCs is presented in Appendix B.

3.5 Quality Assurance and Quality Control

3.5.1 Quality Assurance Plan

All monitoring well development, sample collection, sample handling and decontamination procedures were performed according to the Stage 2 Groundwater Survey QA Plan and are described in the Stage 2 Contract C3 report (Woodward-Clyde, 1996).

3.5.2 QA/QC Samples

The Stage 2 Survey Data Quality Objectives (DQOs) were adopted for this investigation. These DQOs are in accordance with those recommended by the United States Environment Protection Agency (USEPA) in the publication “Test Methods for Evaluation Solid Waste (SW-846)” (USEPA, 1998).

Specific mechanisms for checking the accuracy and precision of analytical data in order to ensure that data quality objectives are being met involve the analysis of laboratory and field QA/QC samples. QA/QC samples collected in the field during this sampling round including trip blanks, field duplicates and field triplicates.

In addition to field QA/QC samples, the primary and secondary analytical laboratories (ALS and LabMark, respectively) have used laboratory and batch specific QA/QC processes including laboratory duplicates, laboratory blanks, surrogate spikes, matrix spike/matrix spike duplicates and laboratory control samples.

3.5.3 Data Validation

General

Analytical data validation is the process of assessing whether the data is in compliance with method requirements and project specifications. The primary objectives of this process are to ensure that data of known quality are reported, and to identify whether data can be used to fulfil the overall project objectives.

The adopted data validation process is based upon the following data validation guidance documents published by the National Environmental Protection Council (NEPC) and the United States of Environmental Protection Agency (USEPA):

- NEPC, 1999, *National Environment Protection (Assessment of Site Contamination) Measure.* (NEPC, 1999)*;*

- USEPA, October 2002, *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review*" (US EPA, 2002); and
- USEPA, October 1999, *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*" (US EPA, 1999).

The process involves the checking of analytical procedure compliance and the assessment of the accuracy and precision of analytical data from a range of quality control measurements, generated from both field sampling and analytical programs.

It is noted that the concentrations recorded in December 2008 from the 5.25 m and 6.5 m ports at BP115 were significantly different to those recorded in previous sampling rounds. The concentrations at the 5.25 m port for EDC, PCE, TCE, VC and CFM, in particular, are more consistent with the historical concentrations for the 6.5 m port and vice versa. Considering this disparity in these concentrations, it is suspected that the samples may have been interchanged during the sample handling process, either in the field or at the laboratory (although this could not be verified). The shallowest port at this location was successfully sampled and analysed, however, the March 2009 sampling round will be used to confirm the concentrations and trends at the 5.25 m and 6.5 m ports of BP115.

Data validation summary reports are presented in Appendix C.

Variability in Vinyl Chloride Analytical Results

Vinyl chloride is a dissolved gas, similar to bromomethane, chloromethane and dichlorodifluoromethane. Relative to other volatile chlorinated CHCs, these compounds are difficult to quantify resulting in the use of a raised Limit of Reporting (LOR) of 10 µg/L (when compared with a LOR of 1 µg/L generally used for other volatile CHCs). These gaseous VOC compounds are highly sensitive to light, heat and changes in pressure. If solutions containing these compounds are stored in vials that do not have zero headspace, it is likely that volatilization may occur resulting in the loss of dissolved phase concentrations.

Standard sources of variability due to the sampling and analytical process, which are applicable to VC include:

- Sampling procedures;
- Handling (preservation) of samples in the field and in transit;
- Storage and handling techniques at the laboratory; and
- Dilution and handling techniques during analysis at the laboratory.

Whilst every effort is made to minimise the effects of these aforementioned sources, the influence of these sources on analytical variability remains, and is generally, unquantifiable.

In relation to this, two potential key sources of analytical variability in laboratory procedures have been identified. The first of these is the removal of samples from cold storage and subsequent raising of sample temperature (to room temperature) prior to analysis. This procedure is required for the accurate determination of the heavier volatile CHCs. This increase in sample temperature has the potential to drive VC from the dissolved phase into the vapour phase (should there be air inside the sample vial). However, the need to raise sample temperature is eliminated by conducting a separate SIM analysis that only targets VC for selected shallow groundwater and surface water samples in order to achieve a lower LOR of 1 µg/L.

The second source of variability is the manual dilution of samples for analysis. Dilution of the samples is often required due to the elevated concentrations of EDC, amongst other compounds. The uncapping and mixing of the sample to undertake manual dilution has the potential to release dissolved phase VC.

3.5.4 Data Management

Analytical data for the Botany project is stored in a secure SQL server and managed via the EQuIS® 5 Environmental Data Management System (EDMS). The EDMS is used to store, manage and interrogate historical (currently being migrated), as well as current and future data for the site, including:

- Spatial information;
- Geological (borehole/well installation) information;
- Chemical information for soil, water and air media;
- Field parameters; and
- Data quality parameters.

Warehoused information is linked to MapInfo, a proprietary Graphical Information System (GIS) software package used in the spatial presentation of the site's monitoring locations and the creation of contaminant distribution figures as well as geochemical and hydraulic cross sections.

Section 4 Hydraulic Monitoring

4.1 General

The December 2008 monitoring round is a quarterly event and as a result focuses on assessing hydraulic containment at the SCA, PCA and BIP containment lines. The results of the hydraulic monitoring are presented as follows:

- Historical and current hydraulic monitoring data are tabulated in Table 4.1;
- Water table elevation (shallow aquifer) and potentiometric surface (deep aquifer) maps, and associated groundwater flow lines are presented in Figures 4.1 and 4.2, respectively;
- Detailed groundwater potentiometric surface contours and flow lines are presented in Figures 4.3 and 4.4 for the PCA and SCA, respectively. The contoured data represent transducer and logger data from 28 December 2008 at 10:00 am. While the selected time period is considered representative of conditions during pumping, it is important to note that water levels during the scheduled annual shutdown were significantly higher than those presented in Figures 4.1-4.4;
- Detailed hydrographs for wells equipped with transducers/loggers are presented in Appendix A (Figures A.01 to A.36). Monitoring well hydrographs for the SCA include a representation of the adopted target water level required to achieve hydraulic containment;
- During the data download in January 2009 water levels were manually measured at each logger location (BIP, PCA, SCA and surrounding areas) and compared against the logged water level in order to ensure data quality and reliability;
- Each hydrograph includes a daily rainfall chart for Sydney Airport. Rainfall during the period was considerably below average in October (49.2 compared with an average of 70.6 mm) and November (53.4 compared with 80.5 mm), and slightly below average in December (68.0 compared with an average of 73.6 mm). The highest daily rainfall (42.8 mm) occurred on 13 December 2008; and
- Several faulty pressure transducers and data loggers (see below) were identified during the monitoring period. Given the historical data set and extent of monitoring at adjacent locations the absence of data at the locations below does not affect the quality of the assessment.

Faulty Loggers/Transducers

Location	Issue	Proposed Action
MWD02I	Faulty transducer	Repair
MWD03I	Faulty transducer	Repair
MWD07I	Faulty transducer	Repair
EWD17D	Extraction well no longer operational	Remove from program (adjacent monitoring loggers provide sufficient information to assess hydraulic containment)
EWD19I	Faulty transducer	Repair
EWD20I/D	Faulty transducer	Repair
EWD27I	Faulty transducer	Repair
WG216S	Well dry	Transfer logger to WG216I
MWB04D	Faulty logger	Replace
MWB05D	Faulty logger	Replace
MWB10S/I/D	Well destroyed, loggers lost	Replace (pending rig availability and road access)
WG171S	Incorrectly programmed logger	Re-program logger
WG70D	Logger stolen/removed from well	Replace

Location	Issue	Proposed Action
MWF07D	Faulty transducer	Repair (subject to access)
MWF08D	Faulty transducer	Repair (subject to access)
WG154D	Faulty logger	Replace
WG75D	Faulty logger	Remove from program, previously reported levels and response to pumping identical to WG75I (which is part of the ongoing hydraulic monitoring program)
EWF05D	Extraction well not operating	Repair (subject to access)
MWF15S	Faulty logger	Replace
MWF15D	Faulty logger	Replace

The quarterly assessment of hydraulic containment presented in the following sections is structured as follows:

- An assessment / summary of GTP performance is presented in Section 4.2;
- An assessment of temporal trends in groundwater elevations and the effectiveness of GTP operation with respect to hydraulic containment is presented in Section 4.3; and
- Section 4.4 presents and discusses data relevant to saline intrusion at the SCA.

4.2 GTP Performance

The GTP was shutdown for scheduled maintenance between 14 November and 4 December 2008. A summary of average daily flow rates and monthly total volume treated by the GTP during the current monitoring period is presented in the following table.

Summary of GTP Performance

Month	No. Pumping Days	Average GTP Rate (ML/d)	Total Monthly Treated Volume (ML)
October 2008	31	5.1	157
November 2008	13*	5.0	66
December 2008	27*	4.2	112

* Includes time of scheduled GTP shutdown for maintenance from 14 November to 4 December 2008

During this monitoring period, a total of 334 ML of groundwater was extracted and treated at the GTP. This is less than the 444 ML treated during the last monitoring period, but similar to the 332 ML for the July–September 2008 period, which (when the scheduled shutdown period is considered) reflects improved operation and performance of the GTP.

4.3 Assessment of Containment Area Groundwater Flow

4.3.1 General Comments

With respect to assessing the flow of groundwater at the three Containment Areas it is important to highlight the following:

- The data presented on Figures 4.1, 4.2, 4.3 and 4.4 represent a single point in time and do not account for transient effects of pumping, rainfall and tides (these effects are evident on the hydrographs in Appendix A);

- Assessment of groundwater flow and hydraulic containment is by analysis of observed static groundwater levels, interpreted groundwater flow lines, transient water levels and contaminant distribution in the context of the site conceptual model (URS, 2007f);
- While target water levels for SCA are presented on the hydrographs to aid interpretation, it is important to note that observed levels below/above these targets do not directly imply hydraulic containment is/is not achieved. As indicated above, assessment of hydraulic containment requires incorporation and analysis of a number of lines of evidence; and
- The slow migration of groundwater and the potential for increased pumping to recapture groundwater mean that hydraulic containment can still be maintained through extended periods of no, or low, groundwater extraction. An assessment of the maximum time periods that the SCA and PCA containment lines can be off-line before groundwater at the containment line cannot be recaptured was presented in previous GTP monitoring reports (URS, 2007b).

While the focus of the quarterly hydraulic monitoring program is assessment of hydraulic containment the following comments are made with respect to regional groundwater flow in the lower GEEA:

- With the implementation of hydraulic containment the groundwater flow regime has altered groundwater flow from its south westerly path to radially towards the containment lines;
- Large areas of very flat hydraulic gradients (as evidenced by the wide spacing between the 0.5, 1.0, 2.0 and 3.0 mAHD contours on Figures 4.1 and 4.2) have developed between the containment lines. These areas represent zones of very slow groundwater flow and as a result contaminant concentrations in these areas are likely to remain relatively constant for the medium to long term;
- While the observed pattern of groundwater flow in December 2008 is clearly different to that observed during the baseline monitoring in October 2004 (URS, 2005a) it is very similar to that presented in recent monitoring reports (e.g. URS, 2007g, 2008a/b/d/g/h); and
- Monitoring wells located at significant distances from the containment lines (i.e. MWC09/10/11 and WG72/215/216/217/232/235) currently show no discernible water level impact due to hydraulic containment (Table 4.1). This observation highlights the relatively localised effects of the hydraulic containment system and its limited potential to affect infrastructure and licensed groundwater users.

4.3.2 Botany Industrial Park (BIP) Containment Area

The primary purpose of the BIP containment line is to prevent ongoing contaminant migration from source areas located on the BIP. Pumping at the BIP Containment Area occurs as GTP capacity allows. The BIP is assigned the lowest priority for extraction as the PCA is located downgradient, and the significant environmental and human health benefits achieved by maintaining pumping at the SCA and PCA compared to the BIP. Nonetheless, it is Orica’s stated intention to effect steady and stable containment along the entire BIP containment line once the GTP capacity increases.

While GTP capacity is constrained the BIP containment line is operated as follows:

- First priority is given to pumps within the vicinity of Springvale Drain in order to minimise shallow groundwater discharge to the drain;
- Second priority is given to pumps on Second Street downgradient of the Central Plume source area with highest contaminant concentrations; and
- Third priority is given to pumps at the north-western end on First Street where contaminant concentrations are significantly lower.

As discussed in Section 4.3.1, the pattern of groundwater flow has been significantly altered by operation of the GTP. Based on the interpreted groundwater flow at the BIP (Figures 4.1 and 4.2) and the hydrographs presented in Appendix A, hydraulic containment during the monitoring period was limited to the central portion of the containment line. Containment was not achieved at the northern and southern portions of the BIP containment line during the monitoring period although as discussed in the September 2008 monitoring report (URS 2008f), the PCA will effectively capture a large portion of this flow.

4.3.3 Primary Containment Area (PCA)

The PCA has two purposes: mass removal from the central EDC plume; and prevention of ongoing contaminant migration from Block 2, Southlands.

Interpreted deep groundwater flow at the PCA (Figures 4.2 and 4.3) shows deep groundwater was successfully contained at the PCA. Analysis of the hydrographs presented in Appendix A indicates that pumping after the annual shutdown was less consistent than prior to the shutdown. Considering that pumping prior to the shutdown was relatively consistent it is considered that hydraulic containment was achieved in the deep aquifer through the monitoring period, even taking into account the shutdown period. However, it is important to note that more consistent pumping will be required during the next monitoring period (January to March 2008) to ensure that the effects of the shutdown and slightly inconsistent pumping in December 2008 are negated.

Groundwater at the PCA is exclusively extracted from the deep aquifer on the basis that vertical leakage from the shallow to deep aquifer would effect hydraulic containment. Previous monitoring rounds have indicated that drawdown in the shallow aquifer may be insufficient to achieve effective hydraulic containment in the shallow aquifer. Hence pumping rates were adjusted in early June 2008 to attempt to increase vertical leakage. The adjustment resulted in increased drawdown in the shallow aquifer. The hydrographs (Appendix A) show that these subdued water levels were maintained in the shallow aquifer until the shutdown period (14 November to 4 December 2008) that induced increased levels. Following re-commencement of extraction the shallow groundwater levels slowly decreased through late December 2008. However, the interpreted contours and groundwater flow lines presented in Figure 4.1 infer shallow groundwater flow is migrating from the PCA for the period of measurement.

As discussed in the September 2008 (URS 2008f) a conclusive assessment of the shallow aquifer at the PCA is not possible with the currently available data. However, it is important to note that the rate of migration of shallow containment has been significantly reduced and the majority of contaminant mass lies within the deep aquifer that is being successfully contained. As a result it is recommended that the trial of increased extraction rates at the PCA be continued and, where possible, extended to allow additional assessment during the next monitoring round. URS has been engaged to install additional offsite shallow groundwater monitoring wells along McPherson Street to allow a more conclusive assessment of shallow aquifer containment at the PCA.

4.3.4 Secondary Containment Area (SCA)

The primary purpose of the SCA is to prevent migration of groundwater contamination to Botany Bay. The western end of the containment line has a low pumping priority as contaminant concentrations in this area are generally below respective ANZECC trigger values. Target groundwater levels for SCA monitoring wells are based on subsidence constraints and an assessment of groundwater levels at the discharge point in the intertidal zone. Field studies (Turner et al 1996, Nielsen 1999, Cartwright & Nielsen 2001) have demonstrated the average groundwater elevation in the intertidal zone discharge point is above 0 mAHD. The field studies show that water levels at the discharge point (even in the quiescent conditions of Penrhyn Estuary) could exceed 0.2 mAHD. As a result, a target level of 0.1 mAHD has been adopted for long-term operation of the SCA.

Interpreted groundwater flow at the SCA (Figures 4.1, 4.2 and 4.4) shows that both shallow and deep groundwater are now intercepted across the length of the containment line where contaminant concentrations exceed respective ANZECC trigger values. The hydrographs in Appendix A show that the scheduled annual GTP shutdown was preceded and followed by consistent pumping. As a result it is concluded that containment of contaminated groundwater was successfully effected during the monitoring period.

It is important to note that groundwater discharge to Penrhyn Estuary is now largely limited to rainfall that infiltrates into the dunes and mixes with groundwater that is present between Foreshore Road and the estuary. This pattern of groundwater flow is significantly different from that observed in the October 2004 baseline monitoring (URS, 2005a) before extraction commenced, but is generally similar to the flow regimes observed from recent monitoring events.

4.4 Groundwater Salinity near the SCA

The table below summarises the results of groundwater electrical conductivity (salinity) measurements completed during this monitoring period at well MWF15 downgradient of the SCA (Figure 3.1). Monitoring wells BP108 and BP109 have been destroyed as part of the port expansion. Reported groundwater fluid electrical conductivity at BP115 and MWF15 is similar to that observed in previous monitoring rounds. As a result the detailed discussions of saline intrusion at the SCA provided in the December 2006, March 2007 and September 2007 reports (URS 2007b/d/g) are considered applicable to the current monitoring data.

Monitoring Wells Downgradient of SCA – Groundwater Electrical Conductivity (µS/cm)

Location	Depth	Sep-06	Dec-06	Mar-07	Jun-07	Sep-07	Dec-07	Mar-8	Jun-08	Sep-08	Dec-08
BP115S	2.25/ 3.00*	399	746	Dry	549	331	1168	Dry	1823	1216	686
BP115I	3.25/ 5.00*	1610	1610	1945	2007	1319	1808	3476	2339	2892	2140
BP115D	5.25/ 6.50*	2371	2320	15770	30900	21400	32000	3616	3840	27840	11670
MWF15S	4 to 7	5880	38200	42100	47900	34800	37700	43700	43600	39400	38300
MWF15I	11 to 14	6140	7230	7270	7730	7880	8990	3200	7220	7610	7710
MWF15D	22 to 25	3080	2650	2400	2810	710	2330	7730	782	1286	2680

* Depth for June 2008
Data for monitoring rounds prior to September 2006 not shown
BP108 and BP109 destroyed as part of Port Botany Expansion

Section 5 Groundwater Chemical Monitoring

5.1 General

The quarterly groundwater chemical monitoring and assessment program is focused on presenting data critical to environmental and human health receptors. The assessment of chemical changes in shallow groundwater is presented in this section and the discussion of the results with reference to the human health risk assessment is presented in Section 7.

5.2 Assessment of Groundwater Chemical Monitoring Data

The assessment of groundwater chemical monitoring data presented in this report is similar to that used in previous GTP monitoring reports. The assessment is based on the following:

- Discussion of locations where a reported contaminant concentration represents an historical maximum (Max Flag);
- Presentation of a detection limit flag (DL Flag) for locations where the reported detection limit is greater than that reported concentration or detection limit for the previous monitoring round; and
- Completion of a parametric test for selected contaminants to identify short-term (12 month) and long-term (all data) trends. Where significant increases (>20%) are observed for both the short- and long-term test the result is represented by 'double red flags' in the data table. Conversely, significant (>20%) decreases are represented by 'double green flags'. The discussions presented in the following sections are largely restricted to locations which are represented by 'double flags'.

As discussed in Section 3.5.3, it is suspected that samples from the 5.25 m and 6.5 m port at BP115 may have been interchanged during the sampling handling process, with the December 2008 results for the 5.25 m port being more similar to the historical results from the 6.5 m port and vice versa. This will be verified using the results of the March 2009 monitoring round. However, for the purposes of this report, the parametric tests have been applied using the data as reported by the laboratory.

Previous GTP monitoring reports have divided groundwater contamination according to plumes derived from DNAPL source zones. Broad descriptions of the plumes are provided below:

- Southern Plumes: Comprised of three overlapping plumes (S1, S2 and S3) inferred to be derived from the former Solvents Plant (CTC, PCE and CFM as a degradation product) and the former TCE Plant (PCE, TCE, 1,1,2,2-TeCA, 1,1,2-TCA and VC as a degradation product). CTC, PCE, TCE, CFM, VC and EDC are the dominant contaminants in terms of concentrations and distribution;
- Central Plume: The C1 Plume contains a number of volatile CHCs, with EDC being the main component and accounting for more than 90% of the estimated mass at most locations. PCE and TCE are also present at significant concentrations, albeit several orders of magnitude lower than EDC concentrations (URS, 2004d). VC is also present within the Central Plume with historical concentrations being highly variable. VC may be a product of either biological degradation of TCE or abiotic degradation of EDC and may also be present in the original source material of this plume; and
- Northern Plumes: Comprised of several separate plumes derived from a number of potential source areas in the northern portion of the plant site (BIP). A plume comprised predominantly of CTC is inferred to be derived from the former CTC/PCE storage tanks (Plume N4). Several other plumes are comprised predominantly of EDC and are inferred to be derived from storage of drummed EDC wastes. Previous works (URS, 2005b/c) have concluded that the Central Plume could extend significantly further to the north (due to historic groundwater extraction northwest of the BIP) than previously identified and commingle with contamination from the Northern Plumes' source areas.

Section 5 Groundwater Chemical Monitoring

While use of the above division of groundwater plume origin was appropriate for interpretation of monitoring data collected during the investigation and early remediation phase, it is less appropriate for the current monitoring program. As a result, the following discussion has been rearranged such that results are presented in relation to onsite (BIP and Southlands) and offsite monitoring locations, which broadly corresponds with the three containment areas: BIP, PCA (Southlands) and SCA (offsite). Where appropriate the plumes are still referenced within the onsite and offsite groundwater discussions.

To avoid repetition of information, where there is an inferred intermingling of contaminants at plume edges, the review of volatile CHC concentrations in wells located at the plume boundaries is reported only once as part of a particular plume according to the table below.

Well/Piezometer ID	Plume Label	Discussed
BP41	C1/N5	Central Plume
BP59	C1/S1	Central Plume
BP60	C1/S1	Central Plume
BP115	S2/S3/C1	Southern Plumes
MWF15	S2/S3/C1	Southern Plumes
WG154	S1/C1	Central Plume

5.3 Description of Groundwater Chemical Monitoring Data

The groundwater chemical monitoring data for the December 2008 GTP monitoring round is presented as follows:

- The locations of monitoring wells and bundle piezometers sampled in December 2008 are shown in Figure 3.2;
- Measured water quality parameters and field observations made during sampling are presented in Table 5.1;
- Analytical results of groundwater volatile CHCs and carbon disulfide are presented in Table 5.2;
- The extent of inferred DNAPL source areas is shown in Figure 5.1 (the source areas are based on the width of dissolved phase plumes before commencement of hydraulic containment in 2004);
- Dissolved contaminant concentrations in the shallow aquifer (to 12 m below ground surface) are presented in Figures 5.2 to 5.7; and
- For the key contaminants presented in Figures 5.2 to 5.7, the detection limit, historical maximum, double green and double red flags and historical concentration data are presented as a facing page to the relevant figure. All available historical data have been used in calculating the historical average for the parametric test but only data collected since March 2006 are presented in the tables.

5.4 Groundwater Chemical Monitoring – Onsite Monitoring Wells

As stated in Section 3.3, the December 2008 sampling period represents a quarterly monitoring event. As such, it is focussed on collecting data from offsite locations that are critical to environmental and human health receptors. No samples have been collected from onsite sampling locations.

5.5 Groundwater Chemical Monitoring – Offsite Monitoring Wells

The table presented on the following page summarises increased detection limits, reported maximum concentrations and significant increases and decreases at offsite monitoring locations for the December 2008 monitoring round.

Significant Decreases

- Significant decreases in contaminant concentrations were reported in six Northern Plumes offsite monitoring wells. With the exception of VC at WG234S, the decreased concentrations were mostly related to contaminant concentrations less than 1.0 mg/L. At these relatively low concentrations, minor variations due to sampling and analytical techniques have the potential to strongly influence the parametric test;
- The significant decrease in the concentration of VC at WG234S is largely a function of variable concentrations reported since the well was installed and sampled in 2007. The decrease is not considered to be representative of a decreasing trend in contaminant concentrations at the well;
- Significant decreases in contaminant concentrations were reported at five Central Plume offsite monitoring wells (eight sample depths). The decreases were mostly related to contaminant concentrations less than 1.0 mg/L. Locations reporting decreases and concentrations greater than 1.0 mg/L were VC at BP41 (4 m and 6 m ports) and EDC and VC at BP59 (8 m and 12 m ports); and
- Significant decreases in contaminant concentrations were reported at seven Southern Plumes offsite monitoring wells (ten sample depths). The decreases were mostly related to contaminant concentrations less than 1.0 mg/L. The sole location that reported a decrease and a concentration greater than 1.0 mg/L was VC at MWF15I.

Significant Increases

- Significant increases in contaminant concentrations were reported for three Northern Plumes offsite monitoring wells. In most cases, the increased concentrations were mostly related to contaminant concentrations less than 1.0 mg/L. WG234S reported a parametric increase (double red flag) for concentrations of EDC and TCE greater than 1.0 mg/L;
- Significant increases in contaminant concentrations were reported for two Central Plume offsite monitoring wells (three sample depths). Samples that reported significant increases and concentrations greater than 1.0 mg/L were CFM at BP41 (4 m port), EDC, TCE and CFM at BP41 (6 m port) and EDC at WG154S; and
- Significant increases in contaminant concentrations were reported for four Southern Plumes offsite monitoring wells (five sample depths). Samples reporting significant increases and concentrations greater than 1.0 mg/L were EDC, TCE, CFM at BP01 (2 m and 6 m ports), VC in BP01 (2 m port), EDC and VC at BP115 (5.25 m port) and CTC at MWF15I.

Historical Maximums

- Historical maximum concentrations were reported for three Northern Plumes offsite monitoring wells. The historical maximums were as follows:
  - 0.003 mg/L of CFM at BP54 (6 m port);
  - 0.017 mg/L of EDC at BP72 (3 m port); and
  - 1.29 mg/L of TCE at WG234S.

Section 5 Groundwater Chemical Monitoring

Summary Parametric Test Results, Maximum Concentration (mg/L) and Detection Limit Flags – Offsite Monitoring Wells

			DOUBLE GREEN FLAGS						DOUBLE RED FLAGS						MAXIMUM FLAGS						DETECTION LIMIT FLAGS*	
Plume Label	Well	Depth (m)	EDC	PCE	TCE	VC	CTC	CFM	EDC	PCE	TCE	VC	CTC	CFM	EDC	PCE	TCE	VC	CTC	CFM	PCE	CTC
Northern	BP54	6												0.003						0.003		
	BP56	6				<0.001																
	BP58	6	0.003			<0.001																
	BP72	3				<0.001			0.017						0.017							
	BP89	6				<0.001		<0.001														
	BP111	6			0.001	<0.001																
	WG234S	6-9		0.015		1.29		0.191	22.9		1.29		<0.02				1.29					<0.02
Central	BP41	4				2.27				0.042	0.87			1.71								<0.005
		6				3.52			11.6	0.122	1.41		<0.02	2.72		0.122						<0.02
		8																				<0.02
	BP59	4	0.008		0.004	<0.001		<0.001														
		8	1.56	0.019		4.47	<0.005	0.038														
		12	985			36.2	<0.2															
	BP60	4	<0.001	0.004	0.003	<0.001																
	BP76	4		<0.001		0.9	<0.001															
	BP77	4	0.012	0.002	0.004																	
	WG154S	4-7							92.6						92.6							<0.05
Southern	BP01	0.75				<0.001																
		1.25	<0.001		<0.001																	
		2							27		19.2	2.5		6.28	27							
		6							30		40.5			8.49			40.5					
		10				0.94	<0.02															
	BP61	4	0.015	<0.001	0.001	0.41	<0.001	<0.001														
	BP95	3		<0.005																	<0.005	
	BP114	6		0.001	<0.001	<0.001		<0.001														
	BP115	5.25							1	0.091	0.164	2.51		0.458	1	0.091	0.164	2.51		0.458		
		6.5	0.008	<0.001	0.001	<0.01	<0.001	<0.001														
	MWF15S	4-7	0.006			<0.01																
	MWF15I	11.5-14.5				1.34							12.6			31			12.6			
	WG23S	4-6				0.46	<0.001							0.047								

* EDC, TCE, VC and CFM had no detection limit flags
Where there is an inferred intermingling of contaminants, the sample locations are reported in the group identified in Section 5.2.

Section 5 Groundwater Chemical Monitoring

The reported historical maximums for the Northern Plumes sampling locations represented minor increases compared to the previously reported maximums. Based on the discussion in Section 7, the historical maximums reported for the Northern Plumes sampling locations do not alter the conclusions of the Human Health Risk Assessment (HHRA) (URS, 2005e) or Addendum (URS, 2006b).

- Historical maximum concentrations were reported for two Central Plume offsite monitoring locations. The historical maximums were as follows:
  - 0.122 mg/L of PCE at BP41 (6 m port); and
  - 92.6 mg/L of EDC at WG154S.

The reported maximum concentration of PCE at BP41 (6 m port) is similar to the previously reported maximum. The reported PCE concentration in December 2008 was 0.122 mg/L and the previously reported maximum, taken in March 2008, was 0.112 mg/L. This represents a slight increase.

The reported maximum at WG154S is considered to be significant and represents increasing trends against short- and long-term historical results. However, similar to the Northern Plumes, the maximums reported in this monitoring period for the Central Plumes sampling locations do not alter the conclusions of the Human Health Risk Assessment (URS, 2005e) or Addendum (URS, 2006b).

- Historical maximum concentrations were reported for three Southern Plumes offsite monitoring locations. The historical maximums were as follows:
  - 27.0 mg/L of EDC at BP01 (2 m port);
  - 40.5 mg/L of TCE at BP01 (6 m port);
  - EDC (1.0 mg/L), PCE (0.091 mg/L), TCE (0.164 mg/L), VC (2.5 mg/L) and CFM (0.458 mg/L) at BP115 (5.25 m port); and
  - PCE (31.0 mg/L) and CTC (12.6 mg/L) at MWF15I.

The observed increasing concentrations of EDC and TCE at BP01 (2 m and 6 m ports, respectively) are considered to be significant. The reported concentrations of these analytes at this location and depth are consistent with increasing short- and long-term trends and are considered to be representative of groundwater that migrated downgradient of Foreshore Road prior to the commencement of hydraulic containment at the SCA.

The reported maximum concentrations at BP115 (5.25 m port) may not be representative of actual concentrations at this location and depth as it is suspected that the samples at the 5.25 m port and the 6.5 m port may have been interchanged. As discussed in Sections 3.5.3 and 5.2, the March 2009 sampling round will be used to confirm the concentrations and trends at these ports.

The reported maximum concentrations of PCE and CTC at MWF15I are consistent with historical trends and, similar to EDC and TCE at BP01 (2 m and 6 m ports, respectively), are considered to be representative of groundwater that migrated downgradient of the SCA prior to commencement of hydraulic containment.

Detection Limit Flags

Six detection limit flags are presented in the offsite monitoring location summary table. The increased detection limits were generally caused by laboratory sample dilution required prior to extraction due to the presence of high concentrations of contaminants.

Section 6 Penrhyn Estuary and Surface Water Monitoring

6.1 Penrhyn Estuary Pore Water Monitoring

6.1.1 General

There are two transects of bundle piezometers installed in Penrhyn Estuary to monitor pore water quality. Transect A (BP42, BP43 and BP44) is located downgradient of the inferred axis of the Southern Plumes (Plumes S2/S3), while Transect B (BP64, BP65 and BP66) is located on the western arm of the estuary in the location where it is inferred the Central EDC Plume would discharge into the Penrhyn Estuary, if it were not contained. The locations of the piezometers are shown on Figure 3.3. Bundle piezometers in Transect A and Transect B were sampled in December 2008 at both high and low tides excluding the most seaward sampling locations (BP44 and BP66), which were decommissioned in August 2008 as part of the Port Botany expansion works. At all but one of the remaining locations, pore water samples were collected at the discharge interface (0.1 m) and at depths of 0.5 m and 2.0 m below the ground surface of the estuary within the intertidal zone. Samples from the 2 m port at BP43 were not collected due to this port being blocked. Samples at the 1 m port were collected instead.

The key finding of the baseline survey of the intertidal groundwater discharge zone in Penrhyn Estuary (URS, 2004b) was that the concentration of contaminants within the terrestrial portion of the aquifer decreased by approximately one to two orders of magnitude at the discharge interface (0.1 m). A trend of decreasing concentrations at all depths was evident in a seaward direction and concentrations were inferred to decrease towards the discharge interface due to the presence of a mixing zone with seawater. The mixing zone was clearly delineated by the electrical conductivity (EC) data, which also showed that "fresh" groundwater (<10,000 µS/cm) from the terrestrial aquifer did not directly discharge in the intertidal zone at Penrhyn Estuary. The EC of pore water samples at the seepage interface (0.1 m) has been generally greater than 40,000 µS/cm in each monitoring event.

While significant historical data have been collected through the GCP/GTP and surface water variability monitoring programs, conclusions drawn from concentration trends need to carefully consider factors that may influence the contaminant concentrations, including variations in tides and contaminant loads flowing into the estuary from surface water drains. In some instances, the concentration of volatile CHCs in surface water within the estuary exceeds the concentrations reported in the pore water at the discharge interface, suggesting that discharge from Springvale and Floodvale Drains may have a more direct influence on Penrhyn Estuary surface water quality than groundwater discharge through the intertidal zone.

All pore water and surface water samples collected in December 2008 were analysed for volatile CHCs and the results are presented in Table 5.3.

The distributions of volatile CHCs that have exceeded the ANZECC (2000) Trigger Values in one or more sampling events since the initial baseline survey in September 2003 (URS, 2004b) are presented in Figure 6.1 (PCE), Figure 6.2 (TCE), Figure 6.3 (VC), Figure 6.4 (EDC) and Figure 6.5 (CFM), and are discussed in the following sections. Historical data tables, comparing December 2008 data with long-term (all historical data) and short-term (previous year) average concentrations are presented on the facing pages.

December 2008 data illustrates that, similar to the previous monitoring rounds, the concentrations of the chemicals of concern generally decrease with decreasing depth towards the discharge interface.

6.1.2 Discharge Interface Pore Water CHC Concentrations

Concentrations of volatile CHCs at the discharge interface are considered the most relevant in terms of assessing current data against the Consolidated Human Health Risk Assessment (HHRA, URS 2005e) and Addendum (URS, 2006b) and potential impacts to surface waters within Penrhyn Estuary. The following table presents concentrations of key contaminants in samples collected from the discharge interface (0.1 m port) and shallow pore water in Penrhyn Estuary in December 2008.

Penrhyn Estuary Discharge Interface Pore Water CHC Concentrations (mg/L) –December 2008 (maximum at high and low tides)

Contaminant	ANZECC Trigger Value (mg/L)	BP01*	BP42	BP43	BP44	BP64	BP65	BP66	BP71A
		0.75 m	0.1 m	0.1 m	0.1 m	0.1 m	0.1 m	0.1 m	1.0 m
CTC	0.24	<0.001	<0.001	<0.005	NS	<0.001	<0.001	NS	<0.001
CFM	0.37	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.04**
1.1.2.2-TeCA	0.4	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.026**
1.1.2-TCA	1.9	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.035**
1.1-DCA	0.25	**0.008**	<0.001	**0.007**	NS	<0.001	<0.001	NS	**0.003**
EDC	1.9	**0.008**	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.177**
PCE	0.07	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	<0.001
TCE	0.33	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.041**
cis-1.2-DCE	-	**0.008**	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.024**
trans-1,2-DCE	-	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.003**
VC	0.1	<0.001	<0.001	<0.001	NS	<0.001	<0.001	NS	**0.02**

Note: *The 0.75 m port at BP01 is not technically at the discharge interface but data is included for illustrative purposes. Shaded cells exceed the ANZECC (2000) Trigger Value (Low Reliability). Bold values indicate results greater than the LOR. NS - No samples were obtained at BP44 and BP66 (wells decommissioned as part of Port Botany expansion works).

The above table shows that concentrations of the key contaminants are less than the ANZECC (2000) Trigger Values. The results of VC at the discharge interface (0.1 m) at BP43 were reported to be higher than the ANZECC (2000) Trigger Values during the September 2008 monitoring round (URS, 2008f). This spike in VC concentrations at this location and depth were attributed the movement of the sediment boom that was installed perpendicular to the transects as part of the Port Botany expansion project.

Prior to the December 2008 monitoring round, the sediment boom associated with the Botany Ports expansion project was removed from the estuary and construction works immediately adjacent to the estuary ceased. No detections of VC were found in any of the sampled ports including at the discharge interface (0.1 m) across both estuary pore water transects suggesting that the disturbance in the estuary only resulted in a short-term transient change in contaminant concentrations. The December 2008 concentrations are consistent with those reported prior to Port Expansion works.

Additional assessment of the reported Penrhyn Estuary contaminant concentrations are provided in Section 7 (Implications for Human Health Risk Assessment).

6.1.3 Comparison with Historical Pore Water Concentrations

Given that none of the key contaminant concentrations had reported concentrations exceeding the ANZECC (2000) Trigger Values, the very low concentrations reported at most locations, and that contaminant concentrations are assessed with respect to Human Health in Section 7, the following discussion is focused on locations reporting historical maximums. Historic maximums were reported for the following locations:

- EDC, TCE and CFM in BP71A (1.0 m);
- EDC at BP01 (2.0 m): and
- TCE at BP01 (6.0 m).

The historic maximum concentrations reported at BP01 are discussed in Section 5.5. Historical maximums at BP71A for EDC (0.177 mg/L), TCE (0.041 mg/L) and CFM (0.04 mg/L) are all significantly below respective ANZECC trigger values. As a result the results are not currently considered significant but require ongoing monitoring to assess whether the increases represent a long-term trend.

6.1.3.1 Other Volatile CHCs

In addition to the key contaminants discussed above, concentrations of the following compounds exceeded the laboratory limit of reporting in pore water.

- Methylene chloride (DCM): DCM was detected in BP43 in the 1.0 m port during low tide at a concentration of 0.014 mg/L. All other sampling locations were below LOR (0.005 mg/L);
- 1,1-Dichlorethene (1,1-DCE): The concentrations of 1,1-DCE in December 2008 ranged from <0.001 to 0.003 mg/L, with the highest detection recorded at BP64 in the 2 m port during high tide;
- Chloroform (CFM): Concentrations of 0.002 mg/L were detected in the 2 m ports of BP42 and 64 at both high and low tides. All other sampling locations were below LOR (0.001 mg/L);
- Trichloroethene (TCE): The concentrations of TCE in December 2008 ranged from <0.001 to 0.005 mg/L, with the highest concentration recorded at BP64 in the 2 m during high tide;
- cis-1,2-Dichloroethene (cis-1,2-DCE): The concentrations of cis-1,2-DCE in December 2008 ranged from <0.001 to 0.035 mg/L, with the highest detected concentration recorded at BP64 (2.0 m port at high tide);
- trans-1,2-Dichloroethene (trans-1,2-DCE): The concentrations of trans-1,2-DCE in December 2008 ranged from <0.001 to 0.012 mg/L (BP64 2 m port at high tide) and were significantly lower than the range of concentrations obtained from the September 2008 monitoring round (<0.001 to 2.46mg/L);
- Vinyl chloride (VC): The concentrations of VC in December 2008 ranged from <0.001 to 0.13 mg/L, with the highest concentration recorded at BP64 in the 2 m during low tide;
- 1,1,2-Trichloroethane (1,1,2-TCA): Concentrations of 1,1,2-TCA in December 2008 ranged from <0.001 to 0.002 mg/L (BP64 2 m port at high tide);
- 1,1-Dichloroethane (1,1-DCA): The concentrations of 1,1-DCA ranged from <0.001 to 0.016 mg/L, with the highest concentration recorded at BP42 (2.0 m port at low tide); and
- 1,2-Dichloroethane (EDC): The concentrations of EDC ranged from <0.001mg/L to 0.024 mg/L, with the maximum concentration recorded at BP64 (2 m port at high tide).

6.2 Surface Water Monitoring

Surface water samples were collected at high and low tide in Penrhyn Estuary in conjunction with pore water sampling on 8 December 2008. The major CHCs identified in surface water are EDC and VC. The highest concentration of EDC (0.028 mg/L) in December 2008 was detected at SW049 located in the realignment channel of Springvale Drain on Southlands. VC concentrations ranged from <0.001 to 0.04 mg/L, with the maximum concentration also detected in SW049. There were no detections of EDC or VC in surface waters at concentrations exceeding the respective ANZECC trigger values.

Surface water samples collected from the pond within the Botany Golf course (SW066) showed no detection of CHCs above the limits of reporting. This result is consistent with the results of the September 2008 monitoring round.

A summary of all of the volatile CHCs in samples obtained in December 2008 is presented in Table 5.4. Comparison of the surface water concentrations with the ANZECC (2000) Trigger Values is presented in Sections 6.2.1 and 6.2.2.

6.2.1 1,2-Dichloroethane (EDC)

A summary of the surface water concentrations of EDC in samples collected in December 2008 from Springvale Drain, Floodvale Drain and Penrhyn Estuary is presented with historical results in the table on the following page.

The results of surface water sampling during the December 2008 monitoring program show that:

- Concentrations of EDC in Floodvale Drain (SW052 and SW053) are either stable or decreasing with both short-term and long-term historical concentrations. It is noted that the EDC concentrations at these locations have remained relatively lower than concentrations recorded pre 2006;
- Concentrations of EDC in Springvale Drain at Southlands (SW049, SW046 and SW005) in December 2008 are substantially lower than the average of long-term historical concentrations. However, EDC concentrations at SW005 and SW046 are higher than the average of short-term historical concentrations. It is noted that, similar to the March, June and September 2008 results, the EDC concentration at the Realignment Channel is the highest concentration in the samples collected from Springvale Drain in December 2008;
- Concentrations of EDC were less than the ANZECC (2000) low reliability Trigger Value (1.9 mg/L) in Floodvale Drain, Springvale Drain and Penrhyn Estuary surface waters samples collected in December 2008; and
- Concentrations of EDC in surface water samples collected from within Penrhyn Estuary at high and low tide in December 2008 were generally below the analytical limit of reporting (<0.001 mg/L) at all sampling locations within the estuary, except at SW030 (0.002 mg/L), and at the Springvale Drain outlet (SW031) at high and low tides (0.002 mg/L). EDC concentrations of all the surface water samples collected at the Penrhyn Estuary are similar to the concentrations detected in previous rounds and are lower than the ANZECC (2000) low reliability Trigger Value (1.9 mg/L). The concentrations of EDC at SW031 (at low and high tide) and at SW030 were lower than the short-term historical concentrations and lower than the concentrations reported for the September 2008 monitoring round.

6.2.2 Other Volatile CHCs

There are a number of other volatile CHCs present in surface water. A summary of the CHCs detected at selected sampling locations in December 2008 is presented in the table on the following page.

The concentrations of volatile CHCs in all surface water sampling locations were less than the respective ANZECC (2000) Trigger Values. This is consistent with the monitoring rounds performed since the GTP commenced steady operation indicating the remediation is having a significant effect on the surface water quality in the estuary.

With the exception of the samples collected at the Springvale Drain outlet samples showing a significant decrease in VC from concentrations that exceeded ANZECC (2000) trigger values during the September 2008 monitoring round.

There were no detections of volatile CHCs above detection limits for surface water samples collected in December 2008 at the Old Boat Ramp (SW028), New Boat Ramp (SW048) and Floodvale Drain Outlet (SW029). Concentrations at other surface water sampling locations were generally low, similar or lower than the concentrations reported in September 2008, and lower than the short-term and long-term historical concentration data for all sample locations. The concentration of CTC at SW031 (0.004 mg/L) at low tide was significantly higher than the short term historical average.

Penrhyn Estuary and Surface Water Monitoring

Summary of Surface Water EDC Concentrations (mg/L) – March 2005 to December 2008

	Mar-05	Jun-05	Sep-05	Dec-05	Mar-06	Jun-06	Sep-06	Dec-06	Mar-07	Jun-07	Sep-07	Jan-08	Mar-08	Jun-08	Sep-08	Dec-08	Average (Jan 08 – Sep 08)	Average (Oct 00– Sep 08)
Springvale Drain																		
Upstream Stormwater Pipe (SW046)	3.43	1.01	1.23	6.54	0.798	0.008	11.4	4.55	0.158	<0.001	0.013	0.002	<0.005	0.005	0.003	0.012	0.001	7.6
Realignment Channel (SW049)	48.3	55.2	74.1	73.4	14.7	1.78	9.83	0.402	-	-	-	-	0.028	0.111	0.015	0.028	0.051	29.9
McPherson Street (SW005)	20.5	22.4	13.4	7.76	3.84	1.44	6.2	0.304	0.017	0.05	0.014	0.038	0.008	0.004	0.011	0.026	0.015	30.1
Floodvale Drain																		
Upstream Southlands (SW052)	1.21	2.52	0.67	1.44	0.604	0.018	0.453	0.311	0.082	0.034	0.012	0.002	0.019	0.031	0.009	0.016	0.015	2.0
Downstream Southlands (SW053)	0.6	1.13	0.61	0.746	0.326	0.019	0.363	0.217	0.062	0.02	0.012	-	0.016	0.019	0.007	0.008	0.011	1.4
Penrhyn Estuary																		
Springvale Drain Outlet (High) (SW031H)	0.078	1.36	0.066	2.48	0.387	0.427	1.99	0.033	<0.001	0.018	0.004	0.001	0.005	0.01	0.023	0.002	0.01	4.9
Springvale Drain Outlet (Low) (SW031L)	0.466	2.8	4.43	3.45	0.331	0.268	1.49	0.011	0.009	0.085	0.010	<0.001	<0.001	<0.001	0.010	0.002	0.002	7.1
Floodvale Drain Outlet (High) (SW029H)	0.022	0.255	0.098	0.307	0.06	0.049	0.054	0.003	0.006	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.131
Floodvale Drain Outlet (Low) (SW029L)	0.399	0.41	0.356	0.284	0.094	0.023	0.164	0.008	0.005	0.012	0.002	<0.001	0.003	0.007	<0.001	<0.001	0.002	0.349
Old Boat Ramp (High) (SW028H)	0.012	0.14	0.098	0.081	0.002	0.319	0.01	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.278
Old Boat Ramp (Low) (SW028L)	0.331	1.04	0.612	0.003	0.014	0.156	0.521	<0.001	<0.001	0.014	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	2.3
New Boat Ramp (High) (SW048H)	0.001	0.002	0.002	0.022	<0.001	0.069	0.003	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.086
New Boat Ramp (Low) (SW048L)	0.017	0.203	0.021	0.023	0.002	0.133	0.046	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.216

*Note: Data prior to March 2005 not shown.
- Not sampled.
Data for SW030, SW060 and SW066 are not reported in this table.

Section 6 Penrhyn Estuary and Surface Water Monitoring

Surface Water CHC Concentrations (mg/L) – December 2008

Contaminant	ANZECC Guideline		Springvale Drain			Floodvale Drain		Penrhyn Estuary	
		Location	SW046	SW049	SW005	SW052	SW053	SW031	SW031
		Tide						H	L
		Sampling Date	08 Dec 08	08 Dec 08	08 Dec 08	08 Dec 08	08 Dec 08	08 Dec 08	08 Dec 08
			Upstream Stormwater Pipe	Realign-ment Channel	McPher-son Street	Upstream South-lands	Down-stream Southlan ds	Springvale Drain Outlet	
CTC	0.24	Carbon Tetrachloride	<0.001 (0.037) *(0.086)*	<0.001 (0.012) *(0.989)*	**0.004** (0.017) *(0.202)*	<0.001 (0.001) *(0.016)*	<0.001 (0.001) *(0.004)*	**0.001** (0.001) *(0.013)*	**0.004** (0.001) *(0.026)*
CFM	0.37	Chloroform	<0.001 (0.016) *(0.058)*	**0.006** (0.018) *(1.032)*	**0.006** (0.012) *(0.240)*	<0.001 (0.001) *(0.015)*	<0.001 (0.001) *(0.01)*	**0.002** (0.006) *(0.029)*	**0.003** (0.004) *(0.058)*
1.1.2.2-TeCA	0.4	1,1,2,2-Tetra-chloroethane	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1.1.2-TCA	1.9	1,1,2-Trichloroethane	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
EDC	1.9	1,2-Dichloroethane	**0.012** (0.001) *(7.641)*	**0.028** (0.051) *(29.90)*	**0.026** (0.015) *(30.11)*	**0.016** (0.015) *(2.00)*	**0.008** (0.011) *(1.357)*	**0.002** (0.01) *(4.873)*	**0.002** (0.002) *(7.112)*
PCE	0.07	Tetrachloroethene	<0.001 (0.007) *(0.002)*	**0.001** (0.004) *(2.545)*	**0.001** (0.007) *(0.367)*	<0.001 (0.001) *(0.002)*	<0.001 (0.001) *(0.001)*	<0.001 (0.001) *(0.018)*	<0.001 (0.001) *(0.044)*
TCE	0.33	Trichloroethene	**0.001** (0.028) *(0.085)*	**0.017** (0.018) *(1.297)*	**0.005** (0.012) *(0.223)*	<0.001 (0.001) *(0.017)*	<0.001 (0.001) *(0.009)*	**0.002** (0.007) *(0.036)*	**0.003** (0.005) *(0.068)*
cis-1.2-DCE		cis-1,2-Dichloroethene	**0.001** (0.024) *(0.087)*	**0.108** (0.199) *(0.656)*	**0.016** (0.029) *(0.268)*	**0.003** (0.003) *(0.025)*	**0.001** (0.002) *(0.015)*	**0.012** (0.041) *(0.074)*	**0.011** (0.029) *(0.172)*
VC	0.1	Vinyl chloride	<0.001 (0.002) *(0.425)*	**0.04** (0.80) *(2.088)*	**0.005** (0.018) *(0.528)*	**0.01** (0.001) *(0.072)*	**0.002** (0.001) *(0.039)*	**0.01** (0.080) *(0.122)*	<0.001 (0.049) *(0.229)*
Total CHCs		Total CHCs	**0.014**	**0.201**	**0.063**	**0.038**	**0.011**	**0.039**	**0.023**
EDC	*%*	EDC %	*85.7*	*13.9*	*41.3*	*42.1*	*72.7*	*5.1*	*8.7*
Other CHCs	*%*	Other %	*14.3*	*86.1*	*58.7*	*57.9*	*27.3*	*94.9*	*91.3*

Note: Shaded data exceeds the ANZECC (2000) 95% or IIWL Trigger Value. ND – No data
(0.096) Short-Term Historical Average (12 months)
(*0.096*) Long-Term Historical Average (all historical data)

The samples showing an increase against the short-term average show a significant decrease against long-term average concentrations. The EDC concentration reported for SW005 is similar to those reported in September 2007 and January 2008. Similarly, the EDC concentration reported at SW046 and the VC concentration at SW052 are comparable to the concentrations reported in September 2007. The exceedance in the short-term average for CTC in SW031 is considered not to be significant as it represents a minor variation at a very low concentration.

The proportion of EDC has historically been greater than 70% of the total volatile CHC mass in Springvale Drain, Floodvale Drain and Penrhyn Estuary, although less so in more recent times. The December 2008 data shows that surface water samples collected from the downstream (SW049 and SW005) boundary of Southlands and the Springvale Drain outlet to Penrhyn Estuary (SW031) contain proportionally less EDC (<45 %) than historically observed. The proportion of EDC is greater than 70% in samples collected from the downstream sampling location on Floodvale Drain (SW053) and the upstream sampling location of Springvale Drain (SW046) at the northern boundary of Southlands. It is noted that temporal changes in the relative ratios of EDC and other CHCs may be related to increased variation at low CHC concentrations near the analytical limit of reporting.

Surface Water CHC Concentrations (mg/L) – December 2008

Contaminant	ANZECC Guideline		Penrhyn Estuary					
		Location	SW028	SW028	SW048	SW048	SW029	SW029
		Tide	H	L	H	L	H	L
		Sampling Date	08 Dec 08	08 Dec 08	08 Dec 08	08 Dec 08	08 Dec 08	08 Dec 08
			Old Boat Ramp		New Boat Ramp		Floodvale Drain Outlet	
CTC	0.24	Carbon Tetrachloride	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.004*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.003*)
CFM	0.37	Chloroform	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.015*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.005*)	<0.001 (0.001) (*0.008*)
1.1.2.2-TeCA	0.4	1,1,2,2-Tetra-chloroethane	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1.1.2-TCA	1.9	1,1,2-Trichloroethane	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
EDC	1.9	1,2-Dichloroethane	<0.001 (0.001) (*0.278*)	<0.001 (0.001) (*2.281*)	<0.001 (0.001) (*0.086*)	<0.001 (0.001) (*0.216*)	<0.001 (0.001) (*0.131*)	<0.001 (0.002) (*0.349*)
PCE	0.07	Tetrachloroethene	<0.001 (0.001) (*0.002*)	<0.001 (0.001) (*0.007*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.001*)
TCE	0.33	Trichloroethene	<0.001 (0.001) (*0.002*)	<0.001 (0.001) (*0.016*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.002*)	<0.001 (0.001) (*0.007*)	<0.001 (0.001) (*0.004*)
cis-1.2-DCE		cis-1,2-Dichloroethene	<0.001 (0.001) (*0.005*)	<0.001 (0.002) (*0.030*)	<0.001 (0.001) (*0.001*)	<0.001 (0.001) (*0.004*)	<0.001 (0.001) (*0.035*)	<0.001 (0.001) (*0.007*)
VC	0.1	Vinyl chloride	<0.001 (0.006) (*0.005*)	<0.001 (0.006) (*0.053*)	<0.001 (0.003) (*0.003*)	<0.001 (0.003) (*0.002*)	<0.001 (0.002) (*0.031*)	<0.001 (0.003) (*0.029*)
Total CHCs		Total CHCs	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
EDC	*%*	EDC %	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*
Other CHCs	*%*	Other %	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*

Note: Shaded data exceeds the ANZECC (2000) 95% or IIWL Trigger Value. ND – No data
(0.096) Short-Term Historical Average (12 months)
(*0.096*) Long-Term Historical Average (all historical data)

EDC (and other CHCs) in surface water has been inferred to be largely derived from the discharge of shallow groundwater from the Central Plume into Springvale Drain (primarily in the area near Nant Street Tank Farm) and shallow groundwater from the Northern Plumes discharging to Floodvale Drain up-gradient of Southlands. The reduction in volatile CHC concentrations in Floodvale and Springvale Drains, and generally decreasing proportion of EDC in Springvale Drain in the Southlands is due to the decreasing interaction between shallow groundwater and the drains (as a result of GTP operation).

6.2.3 Surface Water Variability Monitoring

Variability sampling was undertaken during periods of neap tides to assess the variability in the concentrations of volatile CHCs in surface water samples and to provide a conservative estimate of exposure scenario with concentrations of contaminants in the estuary. This monthly monitoring program was recently completed and a summary report is currently being prepared. The surface water variability monitoring locations (SW005, SW028, SW030, SW031 and SW060) are presented on Figure 3.3 and the concentrations of the key volatile CHCs (1,2-dichlorethane and vinyl chloride) collected during the current (December 2008) monitoring round are summarised in the following table with the historical data.

Concentration of EDC (mg/L) – Surface Water Variability Monitoring February 2006 to December 2008

Round	Date	SW005	SW028	SW030	SW031	SW060
EDC						
1	Feb-06	**2.07**	**0.005**	**0.075**	**0.06**	**0.009**
2	Mar-06	**3.84**	**0.014**	**0.071**	**0.331**	**0.016**
3	Apr-06	**1.38**	**0.013**	**0.036**	**0.03**	**0.002**
4	May-06	**0.094**	**0.001**	**0.047**	**0.024**	**0.006**
5	Jun-06	**1.44**	**0.156**	<0.001	**0.268**	**0.134**
6	Jul-06	**10.8**	**1.34**	**3.14**	**4.34**	**0.106**
7	Aug-06	**16.9**	**0.512**	**3.13**	**4.93**	**0.56**
8	Sep-06	**6.2**	**0.521**	**1.04**	**1.49**	**0.144**
9	Oct-06	**0.63**	**0.003**	**0.02**	**0.043**	<0.001
10	Nov-06	**0.134**	<0.001	**0.007**	**0.017**	<0.001
11	Dec-06	**0.304**	<0.001	<0.001	**0.011**	**0.007**
12	Jan-07	**0.006**	<0.001	**0.005**	**0.006**	<0.001
13	Feb-07	**0.174**	**0.004**	**0.009**	**0.048**	**0.008**
14	Mar-07	**0.017**	<0.001	**0.005**	**0.009**	**0.002**
15	Apr-07	Dry	<0.001	**0.003**	**0.001**	<0.001
16	May-07	**0.023**	<0.001	**0.005**	<0.005	**0.002**
17	Jun-07	**0.05**	**0.014**	**0.004**	**0.085**	**0.004**
18	Jul-07	**1.45**	**0.047**	**0.261**	**0.771**	**0.021**
19	Aug-07	**0.082**	<0.005	**0.006**	<0.005	<0.005
20	Sep-07	**0.014**	<0.001	**0.003**	**0.010**	<0.001
21	Oct-07	<0.005	<0.001	**0.003**	**0.001**	<0.001
22	Nov-07	<0.005	<0.001	**0.004**	**0.001**	<0.001
23	Dec-07	**0.038**	<0.001	**0.007**	**0.006**	<0.001
24	Jan-08	**0.002**	<0.001	<0.001	<0.001	<0.001
25	Feb-08	**0.008**	**0.003**	**0.019**	**0.021**	<0.001
26	Mar-08	**0.008**	<0.001	<0.001	<0.001	<0.001
27	Apr-08	<0.001	<0.001	<0.001	<0.001	<0.001
28	May-08	**0.05**	<0.001	**0.005**	**0.01**	<0.001
29	Jun-08	**0.004**	<0.001	**0.004**	<0.001	**0.004**
30	Sep-08	**0.011**	<0.001	**0.006**	**0.01**	<0.001
31	Dec-08	**0.026**	<0.001	**0.002**	**0.002**	<0.001

Note: Shaded data exceeds the relevant ANZECC (2000) Trigger Value of 1.9 mg/L
Data collected at low tide.

Concentration of VC (mg/L) – Surface Water Variability Monitoring - February 2006 to December 2008

Round	Date	SW005	SW028	SW030	SW031	SW060
VC						
1	Feb-06	**0.32**	<0.01	**0.11**	**0.04**	<0.01
2	Mar-06	**0.39**	<0.01	**0.06**	**0.04**	<0.01
3	Apr-06	**0.12**	**0.01**	**0.06**	**0.05**	<0.01
4	May-06	**0.02**	<0.01	**0.15**	**0.1**	<0.01
5	Jun-06	**0.07**	<0.01	<0.01	**0.03**	**0.02**
6	Jul-06	**0.65**	**0.08**	**0.16**	**0.23**	<0.01
7	Aug-06	**1.7**	**0.05**	**0.3**	**0.47**	**0.07**
8	Sep-06	**1.43**	**0.07**	**0.21**	**0.5**	**0.01**
9	Oct-06	**0.24**	<0.01	**0.09**	**0.21**	<0.01
10	Nov-06	**0.06**	<0.01	**0.04**	**0.04**	<0.01
11	Dec-06	**0.17**	<0.01	<0.01	**0.28**	<0.01
12	Jan-07	**0.04**	<0.001	**0.03**	**0.32**	<0.001
13	Feb-07	**0.06**	**0.06**	**0.12**	**0.18**	<0.001
14	Mar-07	<0.01	<0.001	**0.02**	**0.64**	<0.001
15	Apr-07	Dry	<0.010	**0.08**	**0.09**	<0.010
16	May-07	**0.64**	<0.010	**0.06**	<0.05	<0.010
17	Jun-07	**0.04**	<0.010	<0.010	**0.09**	<0.010
18	Jul-07	**0.32**	**0.03**	**0.17**	**0.13**	**0.02**
19	Aug-07	**0.06**	<0.05	**0.08**	<0.05	<0.05
20	Sep-07	**0.03**	<0.01	**0.05**	**0.23**	<0.01
21	Oct-07	<0.41	<0.082	**0.09**	**0.108**	<0.082
22	Nov-07	<0.05	<0.01	**0.04**	**0.02**	<0.01
23	Dec-07	**0.04**	<0.01	**0.13**	**0.14**	<0.01
24	Jan-08	<0.05	<0.01	<0.01	**0.02**	<0.01
25	Feb-08	<0.01	**0.01**	**0.1**	**0.02**	<0.01
26	Mar-08	**0.03**	<0.001	<0.001	**0.045**	<0.001
27	Apr-08	<0.01	<0.01	**0.01**	**0.02**	<0.01
28	May-08	**0.05**	**0.02**	**0.07**	**0.04**	<0.01
29	Jun-08	**0.002**	<0.001	**0.006**	**0.002**	<0.001
30	Sep-08	<0.001	<0.001	**0.08**	**0.13**	<0.001
31	Dec-08	**0.005**	<0.001	**0.03**	**0.01**	<0.001

Note: Shaded data exceeds the relevant ANZECC (2000) Trigger Value of 0.1 mg/L
Data collected at low tide.

The December 2008 results show that EDC and VC concentrations at low tide were generally similar to, or lower than, the previous sampling periods (Rounds 27, 28, 29 and 30) with the exception of EDC at SW005. The concentration reported for this sample is less than the EDC concentration reported during December 2007 and significantly less than historic maximums.

Overall, the concentrations of contaminants in the surface water samples collected from locations included in the monthly surface water variability program are consistent with long-term historical averages.

Section 7 Implications for Human Health Risk Assessment

7.1 General

The Consolidated Human Health Risk Assessment (HHRA) (URS, 2005e) considered risks to human health in the following areas surrounding the BIP:

- Western Margin of the Northern Plumes;
- Main Plume; and
- Penrhyn Estuary.

The HHRA (URS, 2005e) also included assessment of health risks associated with the Car Park Waste Encapsulation, however the associated monitoring falls outside of the scope of this report. An addendum to the 2005 HHRA report has also been completed (URS, 2006b). A Springvale Drain Air Emissions Sampling Program is also ongoing (URS, 2007c).

The HHRA (URS, 2005e) included a review of relevant groundwater, surface water and air data to enable estimates of Reasonable Maximum Exposure (RME) to key chemicals to be calculated in the areas relevant for exposures by:

- Residents;
- School children and teachers;
- Commercial and industrial workers; and
- Recreational users of areas of public open space (e.g. Botany Golf Course) and Penrhyn Estuary.

A review of the monitoring data has been completed in relation to the assumptions and conclusions made in the HHRA (URS, 2005e) and Addendum (URS, 2006b) and summarised for each area below. It should be noted that this review involves a comparison of the December 2008 groundwater monitoring and surface water data with assumptions made in the HHRA and Addendum. Other data relevant to the HHRA are not included in this monitoring report, in particular air data, residential bore sampling results and data relevant to the Car Park Waste Encapsulation. Additionally a program monitoring air emissions in areas overlying areas of the western margins of the Northern Plume and the main plumes was undertaken in early 2008 (URS, 2008e).

In addition to the air emissions monitoring program, a number of different programs are currently underway or have been conducted that affect the characterisation of risks to human health.

7.2 Comparison with Human Health Risk Assessment

7.2.1 Western Margin of the Northern Plume

The relevant exposure pathways for this area are:

- Inhalation of vapours in indoor and outdoor air by adults and children who live and/or go to work or school in areas above the western margin of the Northern Plumes;
- Ingestion of and dermal contact with groundwater extracted and used in backyards (e.g. used in a wading pool);
- Inhalation of vapours arising from groundwater extracted and used in backyards (e.g. from a sprinkler); and

- Ingestion of fruit and vegetables grown in backyards and irrigated with groundwater.

The assessment of exposures associated with the inhalation of vapours in indoor and outdoor air utilises data collected from the air sampling programs (1995-2006) which do not form part of this report. However, with respect to the assessment of vapour migration issues, the concentration in groundwater at the very top of the water table is relevant. Review of the December 2008 data relevant to the top of the groundwater table has not identified any significant increases in concentrations that would warrant more intensive assessment of vapour migration issues in the area. The assessment of exposures on the Western Margin has been evaluated on the basis of air emissions data collected to the end of 2008. The outcomes of the assessment in 2008 (URS, 2008e) did not result in a requirement to alter the conclusions presented in the HHRA (URS, 2005e). The assessment presented has not changed as a result of groundwater data collected in December 2008.

While the areas assessed by the HHRA are located within the Groundwater Extraction Exclusion Area (GEEA), the following groundwater data was used in the HHRA to provide an estimate of risks associated with groundwater extraction and use in back yards:

- Results from sampling conducted on residential bores. Residential bore data is not reported in the quarterly monitoring report; and
- Results from the following bores:
  - WG72S and WG72I located within Banksmeadow Public School (corner of Stephen Road and Herford Street). This location is sampled annually;
  - BP57 located within the residential area on the corner of Fremlyn Street and Anniversary Street. Groundwater quality to a depth of less than 15 m has been considered relevant for the assessment of exposure to groundwater that may be extracted by a residential bore. The shallowest port at this bundled piezometer is sampled quarterly with its deeper ports sampled annually; and
  - BP54 located within Banksmeadow Public School adjacent to the residential area on the corner of Wiggins Street and Trevelyan Street. Groundwater quality to a depth of less than 15 m has been considered relevant for the assessment of exposure to groundwater that may be extracted by a residential bore. All ports are sampled biannually.

Other bores in the general area are representative of groundwater quality in the industrial area (BP04, BP78), recreational area (WG88I and BP58 which are considered within the assessment presented for the main plume area) or deep plumes which are not expected to be extracted via a residential bore.

The HHRA identified the maximum concentrations within the residential bores and groundwater wells (and relevant sampling depths) at the time for the purpose of identifying contaminants of potential concern (COPC) for the assessment of exposures along the western margin of the Northern Plumes[1]. The maximum concentrations for the COPC (see table below) were then used in the risk calculations. The COPC identified within the HHRA were CTC and EDC.

Further review of residential bore data and groundwater data (from relevant wells) up to December 2005 was presented within the Addendum (URS, 2006b). This review identified TCE and VC in the Dent Street

[1] COPC were identified by comparing the maximum concentration reported against drinking water guidelines derived from the Australian Drinking Water Guidelines (NHMRC, 2004), World Health Organisation (WHO, 2004 and rolling revisions) and tap water values presented in the USEPA Region IX Preliminary Remediation Goals (PRGs), which have been harmonised with similar risk-based screening levels used in Regions 3 and 6 into “Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites” (USEPA, 2008).

area and TCE and PCE in the Collins Street area as additional COPC which were subsequently assessed within the Addendum.

For the purposes of assessing December 2008 groundwater data against the HHRA and Addendum, results for BP54, BP57 and WG72S/I have been used. However, although not used in the HHRA (as the wells were not installed at the time), December 2008 data from BP89 (in the vicinity of Botany Road, Stephen Road and Herford Street) and data from BP72 (on the Botany Golf Course near Dent Street) were also considered.

The table below presents maximum COPC concentrations in the representative bores and depths used in the HHRA (URS, 2005e) and Addendum (URS, 2006b), maximum groundwater concentrations reported during previous sampling rounds (under the GCP/GTP monitoring programs), and the maximum concentrations reported in groundwater in December 2008. The adopted screening level, namely the drinking water guideline, is also presented in the table.

Review and Identification of COPC in Groundwater - Western Margin of Northern Plume (all concentrations reported as mg/L)

Analyte	Maximum Concentration Considered in HHRA#		Maximum Concentration Considered in Addendum		Adopted Screening Level Guideline (Drinking Water Guideline and reference)		Maximum Concentration Reported in GCP/GTP Program to September 2008	Maximum Concentration Reported – December 2008
Carbon Tetrachloride	0.027	BP57 at 6m	0.027	Max from HHRA	0.003	ADWG	0.027	<0.001
Chloroform	0.063	BP57 at 12m	0.003	Collins St	0.25	ADWG	0.179	0.003
1.1.2-Trichloroethane	0.003	BP54 at 12m	0.002	Dent St	0.15##	Region IX PRG	0.008	<0.001
1.1-Dichloroethane	0.117	residential bore	0.003	Dent St	7.3##	Region IX PRG	0.117	<0.001
1.2-Dichloroethane	0.048	BP54 at 12m	0.092	Dent St	0.003	ADWG	0.087	0.017
Tetrachloroethene	0.01	residential bore	0.861	Collins St	0.05	ADWG	0.009	<0.001
Trichloroethene	0.018	residential bore	0.615	Collins St	0.02	WHO Provisional DWG	0.013	<0.001
1.1-Dichloroethene	0.002	residential bore	0.004	Dent St	0.03	ADWG	0.005	<0.001
cis-1.2-Dichloroethene	0.002	residential bore	0.02	Collins St	0.06	ADWG	0.009	<0.001
trans-1.2-Dichloroethene	0.008	residential bore	0.02	Dent St	0.06	ADWG	0.01	<0.001
Vinyl chloride	nd		0.88	Dent St	0.0003	ADWG	0.14	<0.01
Hexachlorobenzene	0.0005	WG72S	nr		0.001	WHO DWG	nr	nr
Hexachlorobutadiene	0.0004	WG72S	nr		0.0007	ADWG	<0.001	<0.001

Notes: Shaded rows are the COPC considered in the HHRA and Addendum

\# Groundwater data considered relevant for the assessment of residential exposure derived from BP54 (0 to <15 m depth), BP57 (0 to <15 m depth), WG72S and WG72I.

\## On the basis of the review undertaken by URS in consultation with DEC and NSW Health (2004) for the chemicals 1,1,2-trichloroethane and 1,1-dichloroethane, it is considered inappropriate (and conservative) to adopt PRGs which have been derived using a non-threshold approach for the assessment of oral exposures. PRGs are derived in the PRG guideline document for both non-threshold carcinogenic effects and threshold effects with the lower value suggested as the overall PRG for the chemical. Based on review of the chemicals and review of the reference dose used in the derivation of the threshold PRG, the threshold PRG value is considered appropriate for use in the screening of these chemicals.

ADWG: Australian Drinking Water Guidelines
WHO: World Health Organisation Drinking Water Guidelines
Region IX PRG: US Region IX Preliminary Remediation Goal for Tap Water
nr - not reported in analysis undertaken.

The table above shows that concentrations of the COPC (shaded) in groundwater in the representative bores and depths sampled in the December 2008 program (no residential bores were sampled) were less than those reported and used in the HHRA and/or Addendum. A review of other chemicals detected in representative bores and depths in the December 2008 program against the screening level values adopted within the HHRA does not indicate that additional COPC should be considered for further assessment. As such, there are no additional data presented in the quarterly monitoring report with respect to the Western Margin of the Northern Plume that affect the conclusions of the HHRA and Addendum.

7.2.2 Main Plumes

The relevant exposure pathways for this area are:

- Inhalation of vapours both indoors (including basements, should they exist or be constructed) and outdoors for commercial/industrial workers in areas overlying the groundwater plumes;
- Inhalation of vapours both indoors and outdoors for commercial/industrial workers in areas adjacent to Springvale Drain and Floodvale Drain; and
- Inhalation of vapours by adults and older children who may play golf at the Botany Golf Course.

Assessment of all of these pathways utilises air monitoring data that are not addressed in this monitoring report. With respect to the assessment of inhalation exposures associated with vapour migration from the groundwater plumes, air emissions data collected to March 2008 have not changed the conclusions presented in the HHRA (URS, 2005e).

In addition the quantification of risk to workers in areas adjacent to Springvale Drain has been undertaken on the basis of ambient air data collected adjacent to the drain. The sampling and assessment of air and worker exposure in a number of areas adjacent to Springvale Drain has been undertaken in 2006, 2007 and 2008 and a summary report of these works has been submitted to Orica.

While the HHRA did not directly use groundwater or surface water (from Springvale or Floodvale Drains) data, the data collected during each quarterly monitoring round have been reviewed to identify any changes that may indicate that issues associated with risks to human health warrant further sampling and assessment. With respect to the data reported December 2008, the following can be noted with respect to the main plumes:

- With respect to the assessment of exposures in areas overlying the main plumes, potential vapour migration was the key pathway assessed. For the assessment of vapour migration issues, the concentration in groundwater at the very top of the water table is relevant. Hence data collected in December 2008 relevant to the top of the aquifer have been reviewed further;
- The December 2008 monitoring data for volatile CHC concentrations within the commercial/industrial areas were generally less than or similar to those considered when the HHRA was conducted. It is noted that the maximum concentrations of EDC (985 mg/L), PCE (3.66 mg/L), TCE (10.5 mg/L) and VC (36.2 mg/L) in December 2008 were detected at BP59 (12 m port, not at the top of the water table), located on the ING property. The concentrations of these contaminants at this location and port exceed the values reported at this location and depth when the HHRA was undertaken, but are less than the maximum concentrations identified in the HHRA for all commercial/industrial areas (at WG74I for EDC and VC, BP62 for PCE and BP61 for TCE);
- As such, there is no additional data presented in the December 2008 Quarterly Monitoring Report that suggests exposure within the existing industrial and commercial areas has changed and warrants a more detailed assessment, or requires further monitoring of potential vapour issues; and
- Groundwater data for December 2008 from monitoring locations within the Botany Golf Course (relevant to the assessment of recreational areas) shows that the highest concentrations of COPCs in groundwater were detected at WG154S. However, these concentrations are less than those considered in the HHRA.

On the basis of the above, there are no additional data presented in the December 2008 Quarterly Monitoring Report that alter the conclusions of the HHRA (URS, 2005e) with respect to existing commercial/industrial workers in areas above the main plumes. It is noted that further assessment of potential exposures by workers in areas adjacent to Springvale Drain and Floodvale Drain was conducted as part of the ongoing Springvale Drain air emissions sampling program (URS 2007c) and further assessment of exposures on Southlands (should it be developed) for commercial use is being conducted.

7.2.3 Penrhyn Estuary

The relevant exposure pathways assessed in the HHRA (URS, 2005e) and Addendum (URS, 2006b) were based on conditions in Penrhyn Estuary prior to commencement of construction of the Port Botany Expansion. The Penrhyn Estuary exposure pathways presented in the HHRA (URS, 2005e) and Addendum (URS, 2006b) were:

- Exposure by adults and children to COPC identified in biota (fish and oysters) that may be recreationally caught from Penrhyn Estuary and consumed;
- Exposure by adults and children to COPC identified in sediments and surface water during wading (boating, fishing or walking/exploration), swimming and visiting/bird watching activities. The assessment presented has provided a review of exposure within the outer estuary area (near the New Boat Ramp area where most activities are likely to occur) and within the inner estuary area; and
- Exposure by young children to COPC identified in sediments and surface water during beach play activities in beach areas located near the New Boat Ramp area (considered most likely area for play) as well as within the inter-tidal groundwater discharge zone located within the inner estuary.

The HHRA utilised sediment, biota and air data that are not reported as part of the quarterly monitoring program.

Surface water data and shallow pore water data (to a depth of 0.1 m) reported as part of the quarterly monitoring program were used in the HHRA (URS, 2005e) to assess risks to human health associated with swimming, wading and beach play. The assessment of exposures within the estuary considered both the inner and outer estuary areas. COPC were identified in the HHRA by reviewing the maximum concentrations reported in surface water and pore water (to 0.1 m depth) against recreational water screening levels[2]. The HHRA utilised data collected over the period January 2002 to December 2004 and identified EDC, VC, CTC, TCE and PCE as COPC for detailed assessment. It is noted that the review of data collected in September 2008 (URS, 2008f) indicated that cis-1,2-dichloroethene and 1,1-dichloroethene should also be considered COPC within the inner estuary as the maximum concentrations reported exceeded the adopted recreational guideline values.

The following tables present the exposure concentrations of the COPC considered in the HHRA. The tables also present the revised exposure concentrations for all COPC identified calculated using data collected from January 2002 to December 2008 for the inner and outer estuary areas.

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[2] Recreational water screening levels have been based on ANZECC (2000) Recreational Water Quality Guidelines and values derived from drinking water guidelines applying a factor of 10 to adjust to recreational guidelines (refer to HHRA (URS, 2005e) for further details)

Surface Water and Pore Water Concentration Relevant to Exposure Pathways Identified in Penrhyn Estuary – Inner Estuary

COPC*	Maximum Concentrations Reported from Jan 2002 to Dec 2004 considered in HHRA (mg/L)	Exposure Concentrations Considered in HHRA (mg/L)			Maximum Concentrations Reported to September 2008 (mg/L)	Maximum Concentrations Reported in December 2008 (mg/L)	Revised Exposure Concentrations based on relevant data collected from January 2002 to December 2008		
		Adults and Children Wading[1]	Adults and Children Swimming [2]	Young Children Beach Play [3]			Adults and Children Wading[1]	Adults and Children Swimming [2]	Young Children Beach Play [3]
1,2-dichloroethane (EDC)	4.39	0.78 (O), 0.82 (D)	0.2	0.57	4.39	<0.001	0.91 (O), 0.92 (D)	0.27	0.57
vinyl chloride (VC)	4.11	0.082 (O), 0.26 (D)	0.029	0.198	5.52	<0.001	0.13 (O), 0.44 (D)	0.053	0.19
carbon tetrachloride (CTC)	0.08	0.012 (O), 0.0098 (D)	0.0027	<0.001	0.08	<0.001	0.02 (O), 0.016 (D)	0.0086	0.001
tetrachloroethene (PCE)	0.186	0.022 (O), 0.026 (D)	0.0046	<0.001	0.186	<0.001	0.031 (O), 0.032 (D)	0.018	0.002
trichloroethene (TCE)	0.714	0.036 (O), 0.062 (D)	0.012	0.018	0.714	<0.001	0.042 (O), 0.068 (D)	0.018	0.018
1,1-dichloroethene**	NA	NA	NA	NA	0.568	<0.001	0.0019 (O), 0.023 (D)	0.001	0.011
cis-1,2-dichloroethene**	NA	NA	NA	NA	2.66	<0.001	0.074 (O), 0.178 (D)	0.024	0.04

Notes: * COPC identified and considered within the HHRA as well as additional COPC identified based on comparing water concentrations reported from March 2005 to September 2008 from relevant sampling locations against adopted screening level guidelines (recreational water guidelines).
** Exposure concentrations based on data collected from March 2005 to December 2008.
O: Concentration used to evaluate oral exposure (ingestion) pathways.
D: Concentration used to evaluate dermal exposure pathways that include sinking into sand and mud while wading.
1. Wading exposures assessed using the average of maximums reported from SW028, SW029, SW048, SW054-SW059 for oral exposures. Pore water from 0.1 m depth from BP42-44 and BP64-66 considered for dermal exposure (average of maximums from pore water contributes 20%, with 80% from surface water).
2. Swimming exposures assessed using the average of maximums reported from SW028 (high tide), SW048 (high and low tide), SW054-059 (high tide).
3. Beach play exposures assessed using the maximum pore water concentration reported from BP64-BP66

Surface Water and Pore Water Concentration Relevant to Exposure Pathways Identified in Penrhyn Estuary – Outer Estuary

COPC	Concentrations Considered in HHRA from January 2002 to December 2004 (mg/L)		Concentrations Reported in Sampling to September 2008 (mg/L)		Maximum Concentration Reported in December 2008 (mg/L)	Exposure Concentration Relevant for Outer Estuary (Jan 2002 to December 2008)
	Maximum	Average*	Maximum	Average*	Maximum	Average*
1,2-dichloroethane (EDC)	0.479	0.087	0.479	0.041	<0.001	0.038
vinyl chloride (VC)	0.045	0.012	0.065	0.0075	<0.001	0.0069
carbon tetrachloride (CTC)	0.012	0.0021	0.012	0.0017	<0.001	0.0016
tetrachloroethene (PCE)	0.016	0.0025	0.016	0.0020	<0.001	0.0021
trichloroethene (TCE)	0.038	0.0055	0.038	0.0032	<0.001	0.0030

Notes: * Average of high and low tide concentrations from SW048 and low tide concentrations from SWAM9. Averages presented reflect the average of data from January 2002 to end date.

The exposure concentrations for COPC considered in the HHRA (URS, 2005e) within the inner estuary changed slightly with the inclusion of all data to September 2008 (URS, 2008f). Risks to human health within the estuary were revised in June 2007 (URS, 2007e) and September 2008 (URS, 2008f) to address changing exposure concentrations identified within the inner estuary. In addition some additional COPC were identified within the surface water in September 2008 that required consideration within the assessment. The most recent revision to the risk calculations were presented in Appendix D of the September 2008 monitoring report (URS, 2008f) and followed the methodology presented in the HHRA (URS, 2005e). Inclusion of December 2008 data does not result in significant (i.e. an increase or decrease of more than 10%) change to the exposure concentrations used in the quantification of risk presented in September 2008. Hence, risks to human health within the estuary have not been revised further following the collection of data in December 2008.

Based on the data collected to December 2008 (and considering the additional review of data presented in the June 2007 (URS, 2007e) and September 2008 (URS, 2008f) monitoring reports), the conclusions presented within the HHRA associated with exposures within the inner and outer estuary remain unchanged. That is, given the conservative nature of the range of assumptions and the safety factors applied to toxicity values, the risks to human health for all exposure scenarios are considered to be low. However, the assessment has identified worst-case exposure scenarios (particularly within the inner estuary) where the calculated risks exceed the target values. It is noted that the potential for exposure within the inner estuary is currently affected by access restrictions associated with the Port Botany expansion works.

Section 8 Conclusions and Recommendations

8.1 Conclusions

8.1.1 Hydraulic Monitoring

Subject to the Limitations in Section 11 and the extended discussion in Section 4, the following conclusions are presented for the hydraulic monitoring:

- The inferred contours and patterns of deep groundwater flow infer that hydraulic containment was achieved before and after the annual shutdown at SCA and PCA;
- The inferred contours and patterns of shallow groundwater flow at the SCA infer that hydraulic containment was achieved during the monitoring period;
- Hydrographs of shallow monitoring wells at the PCA show that shallow aquifer drawdown was induced during pumping. Although containment at PCA has not been conclusively demonstrated, the contour plot (Figure 4.1) shows that there the shallow aquifer gradient is extremely low implying that the rate of migration of shallow groundwater has been significantly reduced;
- Based on the interpreted groundwater flow hydraulic containment was achieved at the central portion of the BIP containment line in the shallow and deep aquifers;
- Containment was not achieved at the northern and southern portions of the BIP containment line during the monitoring period due to capacity restraints and the annual shutdown, although as discussed in the September 2008 monitoring report (URS 2008f) the PCA will effectively capture a large portion of this flow; and
- Water levels at regional monitoring wells show no discernible water level impact due to hydraulic containment thus indicating a limited potential to affect infrastructure and licensed groundwater users.

8.1.2 Chemical Monitoring

Subject to the Limitations in Section 11 and the extended discussion in Sections 5, 6 and 7 the following conclusions are presented for the chemical monitoring:

Onsite Monitoring Wells

The December 2008 sampling period represents a quarterly monitoring event. As such, it is focussed on collecting data from offsite locations that are critical to environmental and human health receptors. No samples have been collected from onsite sampling locations (i.e. on BIP or Southlands).

Offsite Monitoring Wells

- Concentrations reported for offsite monitoring wells were similar to those previously reported with the exception of wells located at the leading edge of the Central Plume which is continuing to slowly migrate towards the SCA and sampling locations in the dune areas in Penrhyn Estuary;
- The increase and reported maximum observed for EDC at WG154S is considered to be significant. This increase is consistent with short- and long-term historical trends. It is noted that contamination from this location will be captured at the SCA and will not discharge into Penrhyn Estuary;
- The increases observed for EDC and TCE at BP01 (2 m and 6 m ports, respectively) and PCE and CTC at MWF15I are considered to be significant. The increases are consistent with historical trends

and concentrations are considered to be representative of groundwater that migrated downgradient of Foreshore Road prior to the commencement of hydraulic containment at the SCA; and

- The reported maximum concentrations at BP115 (5.25 m port) may not be representative of actual concentrations at this location and depth as it is suspected that the samples at the 5.25 m port and the 6.5 m port may have been interchanged. The March 2009 sampling round will be used to confirm the concentrations and trends at these ports.

Penrhyn Estuary

- In general, volatile CHC concentrations in pore water within Penrhyn Estuary are similar to or lower than historical concentrations; and
- Maximum concentrations for EDC, TCE and CFM in BP71A (1.0 m port) and EDC and TCE (2 m and 6 m ports, respectively) were noted. These concentrations were below the respective ANZECC (2000) Trigger Values.

Surface Water

- The concentrations of volatile CHCs in all surface water sampling locations were less than the respective ANZECC (2000) Trigger Values. This is consistent with the monitoring rounds performed since the GTP commenced steady operation indicating the remediation is having a significant effect on the surface water quality in the estuary; and
- Surface water samples collected from the pond within the Botany Golf Course (SW066) showed no detection of CHCs above the limits of reporting.

Implications for Human Health Risk Assessment

- There are no additional data presented in the December 2008 round of sampling with respect to the Western Margin of the Northern Plumes that affect the conclusions of the HHRA (URS, 2005e) and Addendum (URS, 2006b). That is, the groundwater contamination within the Northern Plumes near the western margin is not considered to pose an unacceptable risk to human health, assuming that groundwater is not extracted and used;
- There are no additional data presented in the December 2008 Quarterly Monitoring Report that alter the conclusions of the HHRA (URS, 2005e) with respect to existing commercial/industrial workers in areas above the main plumes. That is, the groundwater contamination within the main plumes is not considered to pose an unacceptable risk to human health, assuming that groundwater is not extracted and used untreated; and
- Based on the data collected to December 2008 (and considering the additional review of data presented in the June 2007 (URS, 2007e) and September 2008 (URS, 2008f) monitoring reports), the conclusions presented within the HHRA associated with exposures within the inner and outer estuary remain unchanged. That is, given the conservative nature of the range of assumptions and the safety factors applied to toxicity values, the risks to human health for all exposure scenarios are considered to be low. However, the assessment has identified worst-case exposure scenarios (particularly within the inner estuary) where the calculated risks exceed the target values. It is noted that the potential for exposure within the inner estuary is effectively eliminated by access restrictions associated with the Port Botany expansion works.

8.2 Recommendations

Hydraulic Monitoring

- Loggers and transducers identified in Section 4.1 require repair and/or replacement;
- Given the very similar water levels historically reported at WG75I and WG75D replacement of the faulty logger at WG75D is not required and the well should be removed from the hydraulic monitoring program;
- The logger installed at WG216S (dry) should be transferred to WG216I to assess the relative response of the shallow and deep aquifer east of the BIP to hydraulic containment. Similarly a logger should be considered for installation at WG215I;
- Monitoring well MWB10S should be replaced and additional shallow groundwater monitoring wells should be installed downgradient of the PCA as part of the continuing effort to assess shallow groundwater containment at the PCA;
- In view of the gradually increasing drawdown in the shallow aquifer at PCA as a result of increased pumping in the deep aquifer, the current pumping regime should be continued and enhanced (where possible);
- To allow more efficient allocation of resources and ensure ongoing timely delivery of reports it is proposed to modify the monitoring period for hydraulic data such that the hydrographs represent the period up to submission of the previous monitoring report; and
- As GTP capacity increases, additional pumping should be concentrated at the southern end of the BIP containment line to maximise contaminant mass removal and maximise the remedial effects on Springvale Drain.

Chemical Monitoring

- It is recommended that SW066, collected from the pond at the Botany Golf Course, be removed from the sampling program following no detections of volatile CHCs in the September 2008 and December 2008 sampling rounds;
- It is recommended that ongoing monitoring be undertaken according to the June 2008 Groundwater and Surface Water Monitoring Program (URS, 2008c); and
- It is recommended that BP44, BP66, BP108 and BP109 be deleted from the monitoring program.

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Section 10 Glossary

Abiotic
Not involving biological activity. A term used to describe chemical degradation processes.

Absorption
Chemical assimilation or incorporation of liquids in solids or gases in liquids.

Accuracy
Degree of agreement between a measured value and a true or expected value.

Adsorption
The attraction and adhesion of a layer of ions from an aqueous solution to the solid surface with which it is in contact.

Advection
The process by which solutes are transported by the motion of flowing groundwater.

Aerobic
Environment where oxygen is present.

AHD
Australian Height Datum - a standard reference point for the elevation of a location.

Anaerobic
Reducing environment or without oxygen.

Aqueous Phase
Contaminants dissolved in water

Aquifer
An underground geological formation that contains water and is capable of yielding water to a well or spring; a water bearing formation.

Aquitard
A low permeability unit that can store groundwater and also transmit it slowly from one aquifer to another.

Attenuation
The removal or reduction of contaminants in groundwater with time and with distance travelled.

Biodegradation
The breaking down of compounds by biological processes including microorganism activity.

Biotic
Involving biological activity.

Bioremediation
Removal of in situ organic contamination by utilising naturally occurring or specifically engineered or introduced bacteria.

Biotransformation
Structural alteration of a chemical by an organism. In regard to organic compounds , it refers primarily to their decomposition by micro-organisms.

BIP
Botany Industrial Park

Section 10 Glossary

Block 1

The portion of the parcel of land known as Orica Southlands located to the east of Springvale Drain.

Block 2

The portion of the parcel of land known as Orica Southlands located to the west of Springvale Drain.

Bore/Borehole

An uncased well drill hole.

Bore Log

See - Geological Log

Botany Groundwater Cleanup (BGC) Project

The project to hydraulically contain and treat CHC contaminated groundwater in a Groundwater Treatment Plant (GTP) on BIP, and its associated infrastructure requirements, including groundwater extraction, effluent disposal and treated water distribution.

Botany Sands

The stratigraphic name given to unconsolidated sediments comprised predominantly of sand which underlie the Orica Plant site and adjoining areas.

BP

See Bundle Piezometer

BTEX

BTEX is an acronym for benzene, toluene, ethylbenzene, and xylene

Bundle Piezometer

A cluster of narrow diameter piezometers with very short screens at different depths in the same hole.

Central EDC Plume

Plume inferred to originate from the EDC storage tanks

CFM

Trichloromethane (Chloroform)

Chain-of-Custody

Procedure to ensure that samples are traceable from the sample collection through to laboratory analysis and reporting.

CHC

Chlorinated ***H***ydro***c***arbon

Chemical Reduction

Degradation of chemicals in an oxygen deficient environment.

CTC

Tetrachloromethane (Carbon Tetrachloride)

1,2-DCB

1,2-Dichlorobenzene

1,3-DCB

1,3-Dichlorobenzene

1,4-DCB

1,4-Dichlorobenzene

Section 10 Glossary

Dehalogenation

Selective removal of halogen (fluorine, chlorine, bromine and iodine) molecules

Density

The mass or quantity of a substance per unit volume.

Diffusion

The process by which both ionic and molecular species dissolved in water move from areas of higher concentration to areas of lower concentrations.

Desorption

Reverse of Adsorption, (ion movement from solid phase to aqueous)

Dispersion

The phenomenon by which a solute in flowing groundwater is mixed with uncontaminated water and becomes reduced in concentration. Dispersion is caused by both differences in the velocity that the water travels at the pore level and differences in the rate at which it travels through different strata in the flow path.

Dissolution

The process of dissolving DNAPL into the aqueous phase.

Dissolved Phase

See Aqueous Phase

Distribution Coefficient

The slope of a linear isotherm (Freundlich Isotherm). A numerical parameter used to quantify the ability of compounds in solution to be adsorbed onto the surface of solid particles e.g. soils, organic matter etc.

DNAPL

Dense Non-Aqueous Phase Liquid - an organic chemical or mixture of organic chemicals that does not readily mix with water and is heavier than water.

DNAPL Ribbons

Cloth impregnated with hydrophobic dye, used to determine the presence of DNAPL.

DNAPL Source Zones

Zones where residual or free phase DNAPL is present

Drawdown

A lowering of the water table of an unconfined aquifer or the potentiometric surface of a confined aquifer caused by pumping from wells.

DQOs

Data Quality Objectives

EC – Electrical Conductivity

Electrical Conductivity – A measure of the conductance of water which is general an indication of the salinity – see TDS.

EDC

1,2-Dichloroethane (Ethylene Dichloride), an intermediate compound in the production of vinyl chloride.

EDC Lights

A waste stream from distillation of EDC, more volatile than pure EDC.

Section 10 Glossary

EDC Heavies

A waste stream from distillation of EDC, less volatile than pure EDC.

EDC Tars

A waste stream from distillation of EDC Heavies, less volatile than EDC Heavies.

Equipotential

A line in a two-dimensional groundwater flow field such that the total hydraulic heads are equal for all points along the line.

Extraction Well

A well installed to enable in-situ groundwater remediation by the extraction of groundwater. Extraction wells assist in the control of a migrating plume.

Extraction Pump

Pump associated with extraction well system.

Field Duplicates

These are a set of two discrete samples collected from the one sampling point. The sample is prepared in the field by splitting a field sample, then submitting both to either the same laboratory (inter-laboratory duplicates) or a different laboratory (inter laboratory duplicate) as two independent samples, which are labelled as two discrete locations, the duplicate sample having no reference to the primary sample.

Flow Net

A set of intersecting equipotential lines and flowlines representing two-dimensional steady state flow through a porous media.

Flow Path

The direction in which groundwater is moving.

Free Phase DNAPL

DNAPL saturation exceeding the capillary pressure of the soil.

FSRIB

Full Scale Reactive Iron Barrier

GC/MS

Gas Chromatograph/Mass Spectrometer - Instruments for the measurement of concentrations of organic compounds in soil and water.

GCP

Groundwater **C**lean up **P**lan – Plan prepared in response to Notice of Clean Up Action (NCUA).

Geology

The study of the earth as a whole, its origin, structure, composition and history, and the nature of the processes which have given rise to its present state.

GTP

Groundwater Treatment Plant- A chemical treatment plant required to be constructed for the ex situ treatment of groundwater from hydraulic containment as required by the Notice of Clean Up Action (NCUA).

Geological Log

A record of the lithology or stratigraphy of the rock or soil encountered in a borehole.

Gradient

The rate of inclination of a slope. The degree of deviation from the horizontal.

Section 10 Glossary

Groundwater

Water beneath ground surface.

Groundwater Extraction Exclusion Area (formerly Groundwater Protection Zone 1)

Area of groundwater as defined by DIPNR, during August 2003, for which there is an exclusion on the extraction of groundwater except for remediation purposes.

HCB

Hexachlorobenzene

HCBD

Hexachlorobuta-1,3-diene

HCE

Hexachloroethane

Heavy Ends

Waste stream from solvent manufacturing, which includes HCB, HCBD and HCE.

Hydraulic Conductivity

A coefficient of proportionality describing the rate at which water can move through a permeable medium.

Hydraulic Containment

Measures taken to lower the potentiometric surface and/or water table and effect hydraulic capture of the contaminant plume (as defined in the NCUA).

Hydrogeology

The study of the interrelationships of geological materials and processes with water, especially groundwater.

Hydrology

The study of the occurrence, distribution and chemistry of all waters of the earth.

Hydrolysis

A chemical reaction where water molecules react with organic compounds. With chlorinated organic compounds a by-product is hydrochloric acid, which will lower the pH of water.

Flow Lines

Direction of groundwater flow.

Hydraulic Gradient

The change in total head in an aquifer with the change in distance in a given direction.

Hydrocarbon

Organic chemicals such as benzene or tetrachloroethene that contain atoms of carbon and hydrogen.

Hydrostratigraphic Unit

A formation, part of a formation, or a group of formations in which there are similar hydrologic characteristics.

Inorganic

A chemical substance that does not contain carbon.

In Situ Pore Fluids

Water occupying the volume between mineral grains in a porous medium.

Isomers

Compounds whose molecules have the same overall composition but different structures.

K_{oc}

Organic carbon partition coefficient. A parameter that can be used to estimate the mass of an organic compound that will adsorb to organic carbon in the ground.

Laboratory Control Sample

Samples prepared by the laboratory by spiking an aliquot of appropriate clean matrix reagent with known concentrations of specific analytes. The control sample is then analysed and the results are used to assess the laboratory performance on sample preparation and analysis procedure.

Laboratory Duplicate

These are prepared within the laboratory by dividing a field sample into two samples and analysing separately.

LAT

Lowest Astronomical Tide.

Lithology

The geological (physical) character of a rock or soil.

LOR

Limit of Reporting. The lowest concentration that an analytical laboratory can report for an analyte with a sufficient degree of confidence. Also commonly referred to as the detection limit.

Matrix Spike/Matrix Spike Duplicate

Samples prepared by the laboratory in duplicate by individually spiking two aliquots of a field sample with known concentrations of specific target analytes. The matrix spike and matrix spike duplicate samples were then analysed and subsequently, the results used to assess the effects of the sample matrix on the accuracy and precision of analyses.

Microgram (µg)

One thousandth part of a milligram (mg) one millionth part of a gram (g); one billionth part of a kilogram (kg).

Migration

The movement of materials (e.g.. water, gas or contaminants in soil) from one location to another.

Monitoring Well

A well installed to routinely observe groundwater levels or to systematically collect water samples and analyse these for chemical pollution.

Multilevel Piezometer

See - Bundle Piezometer

NAPL

Non-Aqueous Phase Liquid - An organic chemical or mixture of organic chemicals that does not readily mix with water.

NCUA

Notice of Clean Up Action – Notice issued by the NSW Environment Protection Authority under Section 91 of the Protection of the Environment Operations Act 1997. The notice (No. 1030236) was issued on 26 September 2003.

Northern Plumes

Plumes inferred to originate from sources located at the northern end of the Orica plant site.

Oil/water Interface Probe

Monitoring instrument used to obtain accurate measurements of product thickness in monitoring wells. Commonly used for LNAPLs and DNAPLs.

Section 10 Glossary

Organic Compound

A carbon containing compound.

PCA

Primary **C**ontainment **A**rea – Block 2 Southlands

PCE

Tetrachloroethene (Perchloroethene)

Peristaltic Pump

A pump that can be used for purging and sampling of monitoring wells and bundle piezometers.

Piezometer

A well with a short slotted screen for measuring a potentiometric surface or elevation of the water table.

Plume

A mass of contaminated water extending outward from the source of the contamination.

Plume Axis

Inferred centre line of a dissolved phase groundwater contamination.

Porosity

The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.

Potentiometric Surface

An imaginary surface representing the total head of groundwater and defined by the level to which water will rise in a well.

Precision

The degree to which a measurement is reproducible.

Primary Containment Area

The primary containment area is defined in the NCUA as Block 2 of Orica Southlands.

Pure Phase Solubility

Aqueous solubility of a single organic compound.

Recharge

Replenishment of an aquifer by a natural process such as addition of water at the ground surface, or by an artificial system such as addition through a well.

Recovery Test/ Recovery Trial

Hydraulic test performed on a monitoring well which measures the rate at which the water level rises in the well after pumping has ceased.

Residual Saturation

The term given to DNAPL that is trapped in a pore space by capillary forces. Once the residual saturation has been exceeded it is then termed free phase DNAPL.

Retardation

A term used for the adsorption of contaminants in the aquifer that results in the plume front travelling more slowly than the rate of the groundwater flow.

Rinsate Blank

Type of field blank used to check specifically for cross-contamination from reuse of the sampling equipment.

Saturated Zone

An underground geologic formation in which the pore spaces or interstitial spaces in the formation are filled with water under pressure equal to or greater than atmospheric pressure.

Screen

Perforation in a well casing and usually located near the bottom of the well or at selected depths to tap perched aquifers.

SCA

Secondary **C**ontainment **A**rea **-** The area defined in the NCUA as “the location where the EPA approved contaminant containment works upgradient of Botany Bay and Penrhyn Estuary, for the interception and containment of contaminant plumes that have migrated or may migrate beyond the primary containment area, are carried out”.

Semi-volatile Compound

An organic compound which has a low potential to form a vapour at room temperature.

Solubility Limits

Maximum concentration at which an organic contaminant will dissolve in the aqueous phase.

Sorption

See Absorption and Adsorption.

Southern Plumes

Plumes inferred to be emanating from the southern part of the plant site, in particular Southlands.

Southlands

A parcel of land that is bisected by Springvale Drain and lies to the west of the Orica Plant site. Orica purchased the land from Australian Paper Manufacturers (APM) in 1980.

Stratigraphy

The study of rock and soil strata, especially their distribution, deposition and age.

Surrogate Compound

A compound that is introduced into a sample at a known concentration and is used as a system monitoring compound to assess the performance of individual organic analyses.

Surrogate Spike

System monitoring compounds used to assess the performance of the individual analyses. Compounds are spiked into all sample aliquots then undergo normal extraction and analysis procedures. Percent recoveries are calculated for each surrogate, providing an indication of the analytical accuracy.

1,1,2,2-TeCA

1,1,2,2-Tetrachloroethane

1,1,2-TCA

1,1,2-Trichloroethane

1,2,4-TCB

1,2,4-Trrichlorbenzene

1,2,4,5-TeCB

1,2,4,5-Tetrachlorobenzene

TCE

Trichloroethene

Section 10 Glossary

TDS

Total Dissolved Solids - A basic measure of water quality (salinity), which refers to the amount of solids that remain when a water sample is evaporated to dryness.

Trip Blank

Type of field blank used to check if samples have been cross-contaminated with volatile contaminants during handling and transit between the field and laboratory. A trip spike typically comprises a sample of deionised water supplied by the laboratory in a laboratory sample bottle.

TOC

Total Organic Carbon.

Topography

The relief and contour of the land surface.

TPH

See Petroleum Hydrocarbons.

Transmissivity

The transmission rate of water (based on a unit width of an aquifer) relative to a hydraulic gradient.

Unconfined Aquifer

An aquifer whose upper level can extend to ground surface.

Unsaturated Zone

The area between ground surface and the underground water table. Interstitial spaces in this zone contain moisture (water) and air.

VC

Vinyl Chloride (Chloroethene)

VFAs

Volatile Fatty Acids

VOC Scan

Volatile Organic Compound analytical scan.

Volatile Compound

Chemical with sufficiently low vapour pressure to become a gas at room temperature.

Section 11 Limitations

The conclusions and all information in this Report is provided strictly in accordance with and subject to the following limitations and recommendations:

a) This Report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by URS for use of any part of this Report in any other context.

b) The conclusions in this report are based solely on the scope of work agreed between URS and Orica Australia Pty Ltd and described in Section 3 ("Scope of Work"), as well as the information and findings contained in this Report. Specifically, no additional soil sampling or drilling/excavation activity has been undertaken by URS as part of the investigations referred to in this Report.

c) This Report has been prepared for the sole benefit of Orica Australia Pty Ltd and neither the whole nor any part of this Report may be relied upon by any party other than Orica Australia Pty Ltd.

d) This Report is dated 20 February 2008 and is based on the conditions encountered during the site monitoring conducted, and information reviewed, from 1 October 2008 to 31 December 2008. URS accepts no responsibility for any events arising from any changes in site conditions or in the information reviewed that have occurred after the completion of the site monitoring.

e) The investigations carried out for the purposes of the Report have been undertaken, and the Report has been prepared, in accordance with normal prudent practice and by reference to applicable environmental regulatory authority and industry standards, guidelines and assessment criteria in existence at the date of this Report.

f) Where this Report indicates that information has been provided to URS by third parties, URS has made no independent verification of this information except as expressly stated in the Report.

g) URS has tested only for those chemicals specifically referred to in this Report. URS makes no statement or representation as to the existence (or otherwise) of any other chemicals.

h) Investigations have been undertaken into off-site conditions, as specified in Section 3, and URS makes no statement as to whether:

   (i) any adjoining sites may have been impacted by contamination or other conditions originating from this site or from any other source; and/or

   (ii) any contamination originating from adjoining sites has or may have an impact on the site itself.

i) Investigations undertaken in respect of this Report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and contamination may have been identified in this Report.

j) Subsurface conditions can vary across a particular site and cannot be exhaustively defined by the investigations described in this Report. It is unlikely therefore that the results and estimations expressed in this Report will represent conditions at any location removed from the specific points of sampling.

k) A site which appears to be unaffected by contamination at the time the Report was prepared may later, due to natural phenomena or human intervention, become contaminated.

l) Except as specifically stated above, URS makes no warranty, statement or representation of any kind concerning the suitability of the site for any purpose or the permissibility of any use, development or re-development of the site.

m) Use, development or re-development of the site for any purpose may require planning and other approvals and, in some cases, environmental regulatory authority and accredited site auditor approvals. URS offers no opinion as to whether the current use has any or all approvals required, is operating in accordance with any approvals, the likelihood of obtaining any approvals for development or redevelopment of the site, or the conditions and obligations which such approvals may impose, which may include the requirement for additional environmental works.

n) URS makes no determination or recommendation regarding a decision to provide or not to provide financing with respect to the site.

Section 11 Limitations

o) The ongoing use of the site and/or the use of the site for any different purpose may require the owner/user to manage and/or remediate site conditions, such as contamination and other conditions, including but not limited to conditions referred to in this Report.