



Report

Darwin Waterfront Precinct

Stage 2A Qualitative Risk Assessment

6/3/14

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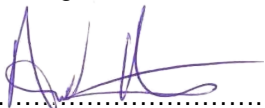
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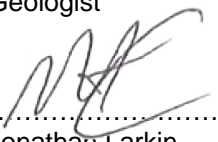

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Definition of Terms and Abbreviations

Absorption	The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.
ADI	Acceptable Daily Intake - The amount of a chemical a person can be exposed to on a daily basis over an extended period of time (usually a lifetime) without suffering deleterious effects.
Acute exposure	Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].
Additive effect	A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].
Adverse health effect	A change in body function or cell structure that might lead to disease or health problems
AHD	Australian Height Datum
Antagonistic effect	A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].
ASTM	American Society for Testing and Materials
ANZECC	Australia and New Zealand Environment and Conservation Council
Background level	An average or expected amount of a substance or material in a specific environment, or typical amounts of substances that occur naturally in an environment.
BGL	Below ground level
Biodegradation	Decomposition or breakdown of a substance through the action of micro-organisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).
Carcinogen	A substance that causes cancer.
Chronic exposure	Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]
COPC	Chemical of Potential Concern – chemicals identified within relevant media (groundwater, air, biota, sediment, and surface water) that are considered to be of potential significance and warrant further quantification as part of the health risk assessment.
CSMS	Contaminated Sites Monograph Series
Dermal contact	Contact with (touching) the skin [see route of exposure].
Detection limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.
Dose	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose is, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].
Exposure assessment	The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance with which they are in contact.

Definition of Terms and Abbreviations

Exposure pathway	The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of impacts (such as chemical leakage into the subsurface); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching); and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.
Groundwater	Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].
Guideline Value (GV)	A GV is a concentration in soil, sediment, water, biota, or air (established by relevant regulatory authorities such as the NSW Department of Environment and Conservation (DEC) or institutions such as the NHMRC, ANZECC, and WHO), that is used to identify conditions below which no adverse effects or nuisance or indirect health effects are expected. The derivation of a GV utilises relevant studies on animals or humans and relevant factors to account for inter- and intra-species variations and uncertainty factors. Separate GVs may be identified for protection of human health and the environment. Dependent on the source, GVs will have different names, such as adopted screening level, trigger value, ambient guideline, etc.
Hazard Quotient and Hazard Index (HI)	Hazard quotient is the ratio of daily chemical calculated for a specific receptor and exposure pathway, to the acceptable or safe dose (ADI, TDI, RfD, etc.) for that chemical. A value less than 1 indicates that the intake is less than the safe intake. A hazard index is the sum of the hazard quotients for all chemicals exposure pathways for a receptor.
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Inhalation	The act of breathing. A hazardous substance can enter the body this way [see route of exposure].
Intermediate duration exposure	Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].
IPCS	International Program on Chemical Safety
LNAPL	Light non-aqueous phase liquid
mBGL	Metres below ground level
NAPL	Non-aqueous phase liquid
NEPC	National Environmental Protection Council
NEPM	National Environmental Protection Measure
NHMRC	National Health and Medical Research Council.
Non-sensitive use	Uses other than those defined as sensitive.
Plume	A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can describe a column of smoke from a chimney or a substance moving with groundwater.
Point of exposure	The place where someone can come into contact with a substance present in the environment [see exposure pathway].
Population	A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).
Receptor population	People who could come into contact with hazardous substances [see exposure pathway].
Reference dose (RfD)	Specifically refers to a toxicity value identified by the USEPA. The RfD is similar to an ADI or TDI and incorporates uncertainty, or safety factors, to identify a safe dose assuming daily lifetime exposure to a substance that is unlikely to cause harm in humans.
Reasonable Maximum Exposure (RME)	The RME represents exposure scenario based on a set of exposure parameters that is representative of expected maximum exposure for that receptor and activity. The RME would not be expected to be exceeded except by for highly specific and exceptional circumstances.

Definition of Terms and Abbreviations

Reference concentration (RfC)	The concentration of a specific chemical in air to which a human population may be exposed to without appreciable risk to their health. RfC's are identified by the US EPA.
Report	This document and all appendices, tables, figures and other attachments
Risk	The probability that something will cause injury or harm.
Route of exposure	The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation] , eating or drinking [ingestion] , or contact with the skin [dermal contact] .
Sensitive Use	A residential use, a child care centre, a pre-school centre or a primary school, as defined in Minister's Direction No.1 (Potentially Contaminated Land) as amended from time to time under section 12(2)(a) of the Planning and Environment Act 1987.
Surface water	Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater] .
Synergistic effect	A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect] .
Tolerable Concentration (TC)	A TC (established by WHO) is an airborne concentration to which it is believed that a person can be exposed continuously over a lifetime without deleterious effects. The TC is based on non-carcinogenic effects and is usually calculated by applying uncertainty factors to a NOAEL or LOAEL. As such, the tolerable concentration is similar to the RfC for inhalation exposures and ADI, TDI, or RfD for oral exposures.
Tolerable Daily Intake (TDI)	The term TDI is used by the IPCS to describe exposure limits of toxic chemicals and ADI is used by the WHO and other national and international health authorities and institutes.
Toxicity	The degree of danger posed by a substance to human, animal, or plant life.
Toxicity Data	Characterisation or quantitative value estimated (by recognised authorities) for each individual chemical for relevant exposure pathway (inhalation, oral, or dermal), with special emphasis on dose-response characteristics. The data are based on based on available toxicity studies relevant to humans and/or animals and relevant safety factors.
Toxicological Profile	An assessment that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.
Toxicology	The study of the harmful effects of substances on humans or animals.
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
Uncertainty factor	Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the LOAEL or the NOAEL to derive an MRL . Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor] .
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation

Executive Summary

URS Australia Pty Ltd (URS) was commissioned by The Darwin Waterfront Office to undertake a quantitative risk assessment (QRA) for the Stage 2A portion of the Darwin Waterfront Precinct Redevelopment.

The purpose of the QRA is to assess whether site contamination may pose an unacceptable risk to human health or to the environment in the event of redevelopment of the site for the proposed more sensitive land use, and thereby to assist in determining what, if any, remedial action is required.

The risk assessment was undertaken in general accordance with guidelines recommended by enHealth (enHealth-Environmental Health Risk Assessment, "Guidelines for Assessing Human Health Risks from Environmental Hazards", June 2002).

It is understood and assumed for the purpose of this risk assessment that the development proposed for the Stage 2A redevelopment includes both residential and commercial facilities. It is assumed that residential building(s) will be multi-storey and may include apartments with both contiguous basements, and those constructed as slab on ground residences. Buildings will occupy the whole of the site except for some small paved areas. It is understood that there is some potential for commercial use of the building, however it is noted that the assumption of residential use will overestimate the risks to future occupational workers, should commercial premises be included in the design.

A quantitative assessment of the contamination in soil and groundwater at the site has been undertaken. Potentially significant exposure pathways for future residents and occupational workers were considered limited to the potential for soil vapour migration with subsequent intrusion into proposed residential type buildings.

Based on these exposure pathways and contaminant concentrations identified in the course of the environmental investigations at the site, no unacceptable risks were identified. A significant factor in this assessment is the fact that only a very small portion of the hydrocarbon contamination identified at the site is volatile and none of the relatively toxic mono-aromatic BTEX compounds were identified as COPC for the site.

Introduction

As part of the Darwin Waterfront redevelopment (**Figure 1**), URS has prepared this qualitative risk assessment (QRA) to assess hydrocarbon contamination identified in soil and groundwater at the site (**Figure 2**).

The purpose of the QRA is to assess whether site contamination may pose an unacceptable risk to human health or to the environment in the event of redevelopment of the site for the proposed more sensitive land use, which is the development of three multistorey towers for a mixture of commercial, university and residential facilities (as detailed in Section 2), and thereby to assist in determining what, if any, remedial action is required.

The degree of risk that may be associated with contamination is dependent upon both the nature of the contamination (i.e. its toxicity) and the likely level of exposure. As such, the proposed site usage and surrounds, the location and accessibility of the contamination, and the magnitude and toxicity of the contamination can all significantly influence the assessment of potential risks.

1.1 Scope and Objectives

The objective of the risk assessment is to assess whether or not soil and groundwater contamination identified at the site represent a significant human health or environmental risk, based on the proposed high density residential, commercial and open space site usage.

The scope of works involved the following tasks.

- Development of a Conceptual Site Contamination Model:
 - reviewing and summarising existing data on the nature, extent and magnitude of contamination;
 - identifying contaminants of potential concern;
 - identifying potential receptors of contamination; and
 - providing a qualitative description of potential exposure pathways.
- Exposure Assessment:
 - presenting qualitative assessment of intake of site contaminants by each potentially exposed population.
 - Presenting qualitative assessment of potential environmental exposure
- Risk Characterisation:
 - comparing the data evaluation with the exposure assessment to enable a qualitative assessment of potential risks.

1.2 Approach

The risk assessment was undertaken in general accordance with the following protocols and guidance:

- Guidelines recommended by enHealth (enHealth-Environmental Health Risk Assessment, “Guidelines for Assessing Human Health Risks from Environmental Hazards”, June 2002). These guidelines draw on and are supplemented by those provided by ANZECC and NHMRC and detailed in the documents:
 - “The Health Risk Assessment and Management of Contaminated Sites” (CSMS 1991, 1993, 1996 and 1998 and enHealth 2002);

1 Introduction

- “The Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites”(ANZECC/NHMRC, 1992) , and
- “National Environmental Protection (Assessment of Site Contamination) Measure [NEPM], Schedule B(4), Guideline on Health Risk Assessment Methodology” (National Environment Protection Council [NEPC], December 1999).
- National Environment Protection Council, 16 May 2013 ‘Amended National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC 2013)’.

Proposed Development

It is understood that the development proposed for the Stage 2A portion of the Waterfront site will consist of three multistorey towers called Buildings 4, 5 & 6. These buildings will include a mixture of commercial, university and residential facilities. Proposed layouts for the basement and ground levels are attached as **Appendix C**.

Stage 2A – Building 4

This building is located at the Kitchener Drive end of the development with some of the building located on the basement car park for Stage 1, the remaining portion of the building having the ground slab at approximately RL 6.5 mAHD (i.e. no basement under part of this building).

The building includes a mixture of residential dwellings at the ground floor (some on the stage 1 basement and some off the basement with a slab on ground construction), above ground car-parking and a commercial/university/residential tower.

The building elements of interest (for the risk assessment and other environmental works) are described as follows:

- A suspended reinforced slab and beams on piles. Given the soils within this area comprise uncontrolled fill, the structure has been designed to be entirely self-supporting and is not reliant on any support being provided by the fill.
- The 40 MPa slab will have a minimum thickness of 220 mm and will be reinforced in both directions top and bottom. There will be 50mm of concrete cover to the bottom reinforcement and 20mm to the top.
- The groundwater level following auditor approvals to cease operation of the subsoil drain may vary from 3.0 mAHD at the lagoon up to approximately 5.5 to 6 mAHD along Kitchener Drive.
- The services conduits under the slab level will be encased in concrete, which will be attached to the underside of the concrete slab. Thus in the event of localised soil settlement within the fill materials, these services will not be damaged. In addition close attention has been given to preventing damage to services at the edges of the building, by providing a sophisticated pipe jointing system that is designed to accommodate the high amount of both vertical and longitudinal differential movement expected.
- Small conduits and small bore pipes will be located only within the middle third of the slab depth, and spaced not less than three diameters apart. These provisions are designed to prevent slab cracking in the vicinity of the conduits and pipes.
- A portion of the Building 4 university tower will be constructed on top of the Stage 1 basement car park.
- All construction joints in the floor structure will include a waterproofing system (i.e. Hydrotite strip). The structure will have a damp proof membrane throughout, as required by the Building Code of Australia.

Stage 2A – Buildings 5 & 6

These building are at the lagoon end of the development and will be residential towers with a contiguous basement constructed under both the towers with the base of the basement having a RL of approximately 3.0 mAHD

The building elements of interest (for the risk assessment and other environmental works) are described as follows:

2 Proposed Development

- Buildings will incorporate a suspended reinforced slab and beams supported on piles driven through the fill to the underlying siltstone bearing stratum. Given the soils within this area comprise uncontrolled fill, the structure has been designed to be entirely self-supporting, such that should any settlement of the fill occur over time the building structure will not suffer adverse effects.
- Reinforced concrete floor slabs are anticipated to be of a nominal thickness of 220 mm and constructed using 40 MPa concrete. The structure will have a damp proof membrane throughout as required by the Building Code of Australia.
- The toe drain at the base of the basement will be connected to the subsoil drain at regular intervals (spaced at 30m or less)
- The groundwater level following auditor approvals to cease operation of the subsoil drain will vary from 3.0 mAHD at the lagoon to approximately 5.5 to 6 mAHD along Kitchener Drive.
- The underside of basement slabs and the outside of basement walls will be finished with a waterproof moisture/vapour barrier (i.e. Volclay) designed to prevent ingress of groundwater.
- All construction joints in the floor structure will include a waterproofed strip (i.e. Hydrotite strip).
- There are to be no service penetrations through the basement slab and limited penetrations through the walls, these penetrations are to include a waterproofing system and a pipe jointing system that is designed to accommodate the high amount of both vertical and longitudinal differential movement expected.
- The basement ventilation system will be designed to provide 1.5 air exchanges per hour. This is based on information provided by the developer for the purposes of the risk assessment.

Data Evaluation

3.1 Site Description

The information presented in this section has been sourced from the URS Phase 1 ESA 2003 and URS's 2009 soil bore and test pit investigations. Other than as specifically detailed, no attempt to verify the information sourced from previous reports has been made.

3.1.1 Prior Development

It is understood that the Stage 2A site (Figure 2) and its surrounds were reclaimed in the early 1940s. Prior to land reclamation the site was partially situated over tidal mud flats and coastline of Kitchener Bay. Kitchener Bay was used as anchorage for commercial and military ships around Stokes Hill wharf. Warehouses and a cement plant were constructed over parts of the site between 1950s and 1960s, the bitumen plant was constructed adjacent to the Stage 2A area in the early 1960s.

3.1.2 Site Surroundings

The site lies within a former industrial area, and is bounded to the south-east by former cement manufacturing yards, to the south-west by a former bitumen plant, tipping shed area and iron ore and zinc concentrate storage area, to the north-east by Kitchener Drive and a former warehouse area, and to the north-west by Hughes Avenue, escarpment monsoon thicket, operational and decommissioned (and removed) fuel and oil lines, and former WWII oil storage tunnels (never commissioned) across Kitchener Drive. Further information on adjacent land uses is provided in the URS Phase 1 report 2003.

3.2 Geology and Hydrogeology

3.2.1 Local Geology

The 1:100,000 scale 'Darwin' (1983) Geological Survey of Northern Territory, Sheet No. 5073, indicates that the geology underlying the site environs includes:

- Coastal sedimentation along the foreshore consisting of mud, clays, silts and intertidal marine alluvium. Quaternary and Recent aged sediments are developed in the intertidal zone as poorly sorted fragments of quartz sand, coral and shell debris. Limonitic and lithic material occurs in the swash zone.
- Bathurst Island Formation sediments of the Lower Cretaceous age, comprising radiolarian claystone, sandy claystone, clayey sandstone, quartz-sandstone, ferruginous sandstone and glauconitic sandstone.
- Burrell Creek Formation of the Proterozoic age Finiss River Group, comprising siltstone, shale, sandstone (quartz arenite, sublitharenite), quartz pebble and conglomerate. The Burrell Creek Formation is metamorphosed to lower greenschist facies and referred to as phyllite.

The area is also characterised by land reclamation, filling and raising of the coastal embayment between Fort Hill and Stokes Hill and enlarging the peninsulas formed by these hills.

3.2.2 Local Hydrogeology

Within the Waterfront area, the most significant aquifer zones are formed by the fill materials in a narrow band between the escarpment and the coast. The underlying bedrock of the Burrell Creek

3 Data Evaluation

Formation is of low transmissivity, forming a poor, low-yielding, and low-storage aquifer system. Both the fill materials and bedrock profile form an unconfined aquifer that is recharged from the escarpment along the northern boundary of the project area, from direct infiltration of rainfall; and in near-shore areas from tidal events.

Discharge occurs in coastal zones and due to evaporation from shallow water table areas. The unconfined aquifer spans the entire project area. The fill materials and Burrell Creek Formation are closely hydraulically connected, even where separated by Quaternary and Recent coastal sediments.

The fill materials are recognised as being heterogeneous, forming a widely variable and anisotropic groundwater flow medium. Groundwater flow along preferred, comparatively high transmissivity pathways is likely to occur. Significant variation in groundwater level and flow is evident between wet and dry seasons, with typical seasonal water table fluctuations of 1 to 3 m, being greatest in upper catchment areas and of lower magnitude in near-coastal zones. In the central portion of the site (Stage 1 and Stage 2A areas) the influence of tidal fluctuation is negated by the constant hydrostatic head of the recreational lagoon and the sub-soil drain.

3.2.3 Site Geology and Hydrogeology

The soil and groundwater conditions encountered beneath the Stage 2A site appear to be consistent with those encountered across the broader Waterfront precinct, in particular the Stage 1 and Bitumen plant areas where extensive investigation and characterisation has been undertaken. Investigations by URS in the Stage 2A area of the site identified three main subsurface units:

- **FILL:** Fill comprising clay, silt and pieces of weathered siltstone and phyllite was encountered to depths ranging between 5.0 m and 6.0 below ground level (mBGL).
- **MUDS:** Where natural soils were encountered, they typically comprised dark grey to blue grey sandy silts/muds with mangrove matter and shells
- **BEDROCK:** The mangrove muds and Fill are underlain by phyllite bedrock.

Groundwater in the vicinity of the Stage 2A site is generally encountered between approximately 4 and 5 mBGL.

3.3 Site Contamination

Due to the staged development of the Waterfront precinct, the nature and extent of contamination at the site is reviewed for each sub-division of the precinct. As a result of these reviews it can be seen that the nature of contamination is generally consistent across each portion of the precinct (where historical contaminating activities were similar) and that the extent of contamination is reducing significantly with time as a result of remediation activities and biodegradation of petroleum hydrocarbons.

3.3.1 Nature of Potential Site Contaminants

Based on known former site activities, and extensive previous works across the waterfront redevelopment site, identified chemicals of potential concern include:

- Total petroleum hydrocarbons (TPH);
- Polyaromatic hydrocarbons (PAHs) and phenolic compounds;
- Heavy metals (As, Cd, Cr, Cu, Pb, Mn, Ni, Ag, Zn, Hg)

3 Data Evaluation

It is noted that benzene has not been encountered within the Stage 2A area during 2003-2013 investigations and toluene, ethylbenzene and xylenes (TEX) have been encountered in one sample from the excavated spoil during removal of the Building 5 basement hydrocarbon hot spot. No BTEX was reported in validation samples following the hotspot removal.

For the purpose of this risk assessment works undertaken within the Stage 2A boundary prior to 2009 have been used as reference data showing characterisation of the site at the commencement of the Waterfront redevelopment project. Given that significant remediation and development works occurred across the Waterfront precinct between 2003 and 2008, characterisation of contamination at the site over the period 2003-2013 has changed significantly – in particular the nature and extent of petroleum hydrocarbon contamination. Data from 2009 to 2013 has been used to characterise the site for this risk assessment.

3.3.2 Investigation Scope – 2009 to 2013

2009 Soil Bores and Test Pits

The URS bore hole and test pit investigation conducted between August and November 2009 included boring of 88 soil bores and excavation of 7 test pits to a nominal depth of 6 m. Temporary casing was installed in each well and standing water level was observed. Test pits were observed for ingress of groundwater. Soil samples were collected at regular intervals and were selectively analysed for site specific COPCs as tabulated below.

Table 3-1 URS (2009 soil bores and test pits) Analytical Scope Summary

Analytes	No of Primary Soil Samples
TPH, BTEX and lead	149
PAHs and Phenolic compounds	149
Heavy metals (As, Cd, Cr, Cu, Pb, Mn, Ni, Ag, Zn, Hg)	149
Speciated TPH	2

2010 Asbestos Abandonment beneath Stage 2A Road

Suspected asbestos containing material (ACM) was encountered during excavation below the Stage 2A roadway. This potential ACM was buried in-situ, covered with a capping layer of not less than 1 m of Class 1 fill beneath the Stage 2A road alignment. Assessment and management of ACM was undertaken by third party contractors (McMahon Contractors and Elfenbein & Associates). URS undertook assessment of the frequency of ACM in stockpiled material (soil with bonded ACM fragments) and assessed soil samples for the presence of asbestos fibres prior to reinstatement.

2013 Basement Excavation Observation and Hot Spot Validation

URS attended site during basement excavation between December 2012 and February 2013 to observe material being removed and to assess the finished excavation for visual or olfactory indications of contamination. One small area (approximately 15x15 m) of hydrocarbon contamination was observed within the Building 5 basement excavation, this material was observed to be excavated and replaced with site won Class 1 fill.

No additional sampling of the finished basement excavation was undertaken as it was considered that the Stage 2A building footprints were well characterised by the 2009 test bore and test pit works. Soil

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samples that were collected from the hot spot area were selectively analysed for site specific COPCs as tabulated below.

Table 3-2 URS (2013 Hot Spot Validation) Analytical Scope Summary

Analytes	No of Primary Soil Samples
TPH and BTEXN	11
PAHs, Phenols and PCB	11
Heavy metals (As, Cd, Cr, Cu, Pb, Mn, Ni, Ag, Zn, Hg)	11
Organochlorine pesticides	11

2013 Shallow Soil Validation – Open Space Areas

As per the RAP V6 the upper 1 m of open space areas is required to meet site specific Class 1 acceptance criteria (based on NEPM 1999 EILs and site specific values derived by risk assessment). Test pitting was undertaken to 1.2 m depth on an approximately 10 m grid across open space areas of the site. No indication of hydrocarbon odour or staining, general refuse, ore material or aesthetically incompatible material was encountered during works. Soil samples that were collected at regular depth intervals in the open space area were selectively analysed for site specific COPCs as tabulated below.

Table 3-3 URS (2013 Open Space Area) Analytical Scope Summary

Analytes	No of Primary Soil Samples
TPH and BTEXN	78
Heavy metals (As, Cd, Cr, Cu, Pb, Ni, Zn, Hg)	78
pH	78

3.3.3 Soil Investigation Results

Soil Bores and Test Pits August and November 2009

The Stage 2A grid based environmental site assessment was undertaken by URS in 2009 on largely vacant land, with the exception of areas occupied by the Stage 1 construction site office infrastructure. Soil investigation locations were generally distributed on a 10 m grid across the site.

Identified soil impacts were limited to total petroleum hydrocarbon impact in the less volatile C10-C36 chain lengths (with approximately 81% in the non-volatile C15+ range and 19% in the semi-volatile C10-C14 range), and isolated heavy metal impacts that are generally considered to be indicative of background variation. The following table summarises the frequency of impact in soil samples. A summary of analytical results for the 2009 investigations are provided in **Appendix A**. Detailed discussion of exceedances of screening level guidelines are included in the Stage 2A Validation Report (URS 2014a)..

Table 3-4 Summary of 2009 Soil Investigations

Analytes	Number of Primary Samples	Adopted Guideline Value mg/kg	Number of Samples Exceeding Guideline
TPH C6-C9	149	65	0
TPH C10-C36	149	1000	3
BTEX	149	Variable	0
PAH/Phenols	149	Variable	0

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Analytes	Number of Primary Samples	Adopted Guideline Value mg/kg	Number of Samples Exceeding Guideline
Arsenic	149	20	6
Cadmium	149	3	4
Copper	149	100	4
Lead	149	600	1
Manganese	149	500	6
Mercury	149	1	0
Nickel	149	60	1
Zinc	149	200	14
Speciated TPH	2		0

As can be seen from **Table 3-4**, only three samples (TB01_3.0, TB43_3.0 and TB78_4.0) from the 95 investigation locations were found to have TPH exceeding the screening level guideline of 1000 mg/kg. The highest TPH concentration reported was 6,600 mg/kg in TB01_3.0, while the other two identified exceedances were marginally above the adopted guideline.

Each of these three samples was taken from depths of three or more metres below the ground surface. Further review of the soil data (**Appendix A**) shows that only one of these three impacted samples contained any measureable volatile or semi-volatile hydrocarbons (TP78_4.0 contained 330 mg/kg TPH C10-C14 and 0.1 mg/kg naphthalene), with all reported TPH from TB01_3.0, TB43_3.0 and the majority from TB78_4.0 being in the essentially non-volatile C15+ TPH range.

Concentrations of C10-C14 TPH in excess of the laboratory limit of reporting (LOR) were only reported for nine of 149 primary samples analysed, compared to 42 for the heavier C15+ fractions, C6-C9 TPH was encountered at one of 149 primary samples (test pit TP91 at 5 mBGL) while no BTEX was found.

2010 Asbestos Abandonment beneath Stage 2A Road

URS observed the abandonment of ACM and soil beneath the Stage 2A road alignment, the material was capped with 1 m of Class 1 fill. URS did not undertake sampling to identify ACM, this was undertaken by a third party contractor (Elfenbein & Associates). A sieve analysis undertaken by URS suggested the frequency of ACM fragments in the reinstated material was low (no fragments were encountered at the 5 locations sampled from the approximately 70 m³ stockpile) and no asbestos fibres were reported in the soil samples submitted for laboratory analysis.

2013 Basement Excavation Observation and Hot Spot Validation

A small pocket of hydrocarbon contamination (approximately 15x15 m) was identified in the vicinity of the 2009 test pit TP91 and test bores TB77, TP79, TB80 and TB87. Material was removed from this hot spot to a depth of 1 m below basement slab level and extending laterally until no further visual or olfactory evidence of hydrocarbon contamination was observed in the field. Validation samples were taken from the base and walls of the excavation and guideline exceedances are summarised below. Hydrocarbon results reported at two validation locations in the base of the hot spot excavation were restricted to the semi-volatile C10-C14 fraction.

Table 3-5 Summary of 2013 Soil Hot Spot Investigation

Analytes	Number of Primary Samples	Adopted Guideline Value mg/kg	Number of Samples Exceeding Guideline
TPH C6-C9	11	65	0
TPH C10-C36	11	1000	0

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Analytes	Number of Primary Samples	Adopted Guideline Value mg/kg	Number of Samples Exceeding Guideline
BTEX	11	Variable	0
PAH/Phenols	11	Variable	0
PCB total	11	10	0
Metals (As, Ba, Be, Cd, Cr, Cu, Pb, Mn, Hg, Ni, Zn)	11	Variable	0
Vanadium	11	50	6
Organochlorine pesticides	11	Variable	0

As can be seen in **Table 3-5** exceedances were only noted for vanadium, these results are considered to be within the normal range of background concentrations as detailed in the “National Environment Protection (Assessment of Site Contamination) Measure [NEPM], Schedule B(1), “Investigation Levels for Soil and Groundwater” document Table 5-A (background range 20 to 500 mg/kg). It is noted that vanadium is not included in the amended ASC NEPM 2013 ‘EIL Calculation Spreadsheet’ for calculation of background concentrations.

2013 Shallow Soil Validation – Open Space Areas

The Stage 2A open space areas environmental site assessment was undertaken across proposed public open space located between the Wharf 1 residential towers and Stage 2A structures. Works were undertaken in December 2013 and consisted test pits to approximately 1.2 mBGL generally distributed on a 10 m grid across the site.

There were no identified petroleum hydrocarbon impacts within test pits across the open space area. Six out of a total of 84 samples (including inter and intra-laboratory duplicates) exceeded the Class 1 guideline value for zinc. Zinc exceedances were isolated and are generally considered to be indicative of background variation based output from the amended ASC NEPM 2013 ‘EIL Calculation Spreadsheet’ (aged zinc concentration of 430 mg/kg based on cation exchange capacity of 6 cmolc/kg dwt, pH of 8 and Queensland as the nearest state). The following table summarises the frequency of impact in soil samples. A summary of analytical results for the 2013 open space investigations are provided in **Appendix A**. Detailed discussion of exceedances of screening level guidelines are included in the Stage 2A Validation Report (URS 2014a).

Table 3-6 Summary of 2013 Open Space Area Soil Investigations

Analytes	Number of Primary Samples	Adopted Guideline Value mg/kg	Number of Samples Exceeding Guideline
TPH C6-C9	78	65	0
TPH C10-C36	78	1000	0
BTEX	78	Variable	0
pH	78	6-8	75
Arsenic	78	20	0
Cadmium	78	3	0
Chromium	78	400	0
Copper	78	100	0
Lead	78	600	0
Mercury	78	1	0
Nickel	78	60	0
Zinc	78	200	6

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3.3.4 Groundwater Investigations

There are currently no operational wells within the Stage 2A area of the Waterfront Precinct monitoring well network. However groundwater conditions beneath the Stage 2A area have been inferred based on the nature of groundwater impacts across nearby areas of the Waterfront precinct, the most recent concentrations from wells within the Stage 2A area prior to destruction, concentration trends in monitoring wells across the Waterfront Precinct and the significance of biodegradation of petroleum hydrocarbons across the Waterfront precinct. Due to similar contamination and groundwater conditions encountered at the adjacent Stage 1 (east to north-east) and Bitumen Plant (west) areas, groundwater conditions and contamination trends encountered across these areas have been used to infer conditions across the Stage 2A area following loss of groundwater monitoring infrastructure.

Groundwater analytical results are presented in more detail in the annual summary reports prepared for the Darwin Waterfront Corporation. A qualitative summary of groundwater conditions beneath the site based on these reports is included in **Table 3-7**. Graphical representation of contaminant trends at selected Stage 1 wells from 2007 to 2013 are included in **Chart 3-1** and for Stage 2A wells prior to destruction in **Chart 3-2**.

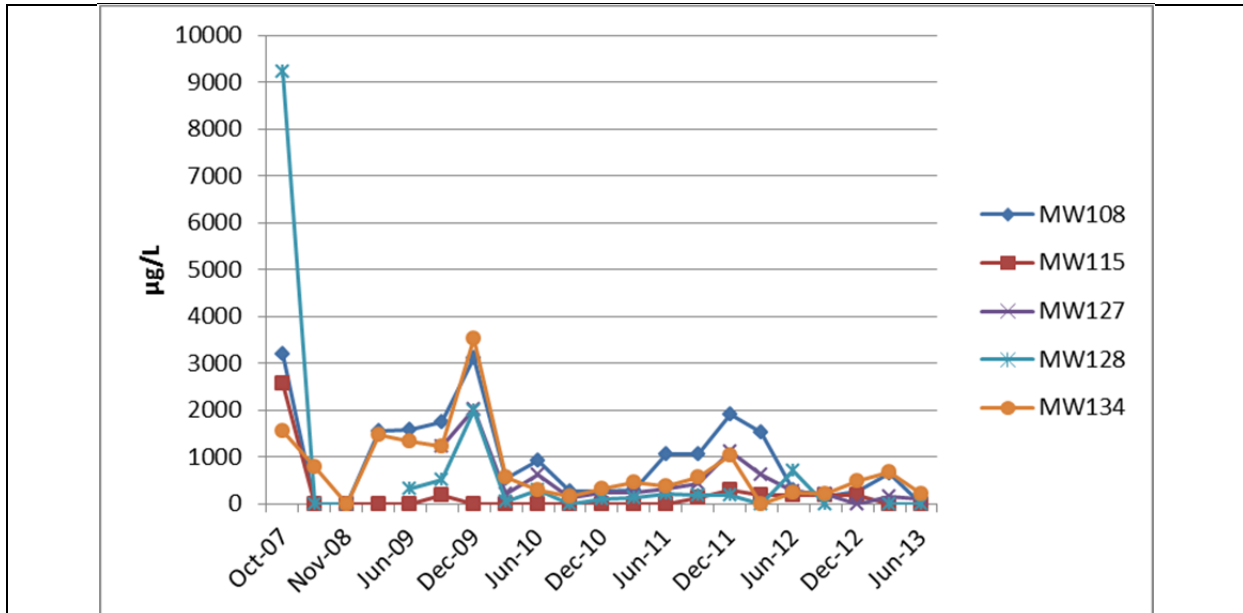
Table 3-7 General Summary of Previous Groundwater Investigation Results

TPH C6-C9	No samples since July 2008 contained light fraction TPH concentrations exceeding laboratory limits of reporting.
TPH C10-C36	TPH C10-C36 has been identified marginally exceeding laboratory limit of reporting at wells distributed across the site. Phase separated hydrocarbon (PSH) has been identified at two locations (adjacent to the Stage 1 car park entrance and the Kitchener Drive roundabout in the vicinity of the former valve pit), the extent of the PSH has remained stable since 2007
BTEX	No samples have been identified during groundwater monitoring exceeding the laboratory limits of reporting.
PAH/Phenols	No PAHs or phenolic compounds have been identified during groundwater monitoring
Metals	Concentrations of heavy metals including Arsenic, Cadmium, Copper, Iron, Lead, Manganese, Mercury, Nickel, Vanadium and Zinc in groundwater have exceeded the adopted screening criteria; broad distribution of many of these analytes are considered to be indicative of background concentrations.
PCBs, OC/OPs, VHCs	No samples have been identified during groundwater monitoring exceeding the laboratory limits of reporting.

Monitoring wells within the Stage 2A were last sampled in September and December 2012 prior to destruction during construction works. TPH concentrations have largely been restricted to heavy end fractions, with monitoring wells in the vicinity of the Stage 2A area generally reporting no TPH concentrations greater than LOR or marginally over LOR in the non-volatile C15+ range. This trend is consistent across the Waterfront precinct, where concentrations across the current monitoring well network were generally greatest in 2007, decreasing rapidly to less than LOR or marginally above LOR over subsequent monitoring events. **Chart 3-1** presents this trend over time at wells located within the Stage 1 area, it is noted that whilst there are significant decreases from concentrations observed in 2007 there are also observed seasonal fluctuations over the monitoring period as a result of the magnitude and intensity of wet season rainfall events.

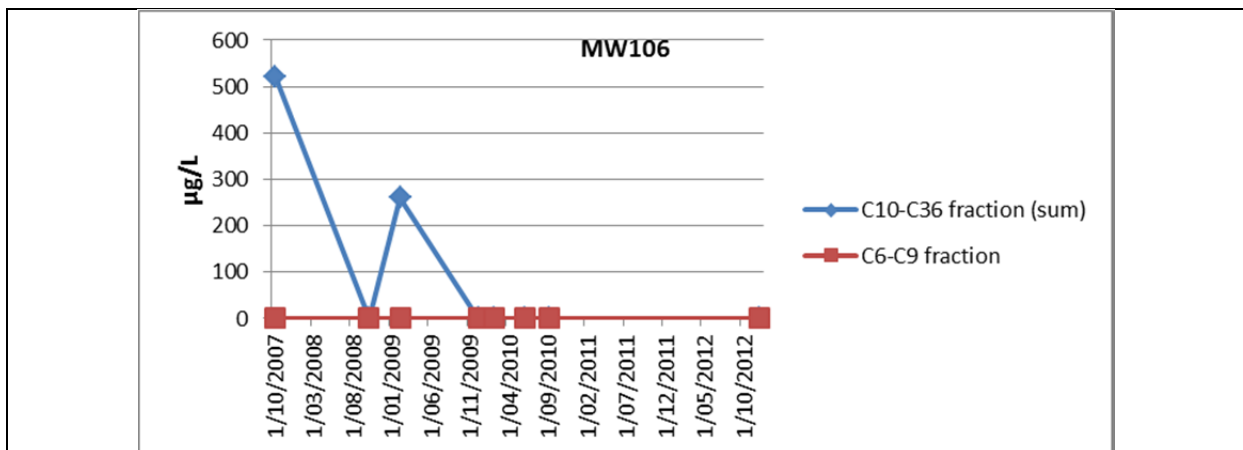
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Chart 3-1 TPH C10-C36 vs Time – Selected Stage 1 Wells 2007-2013

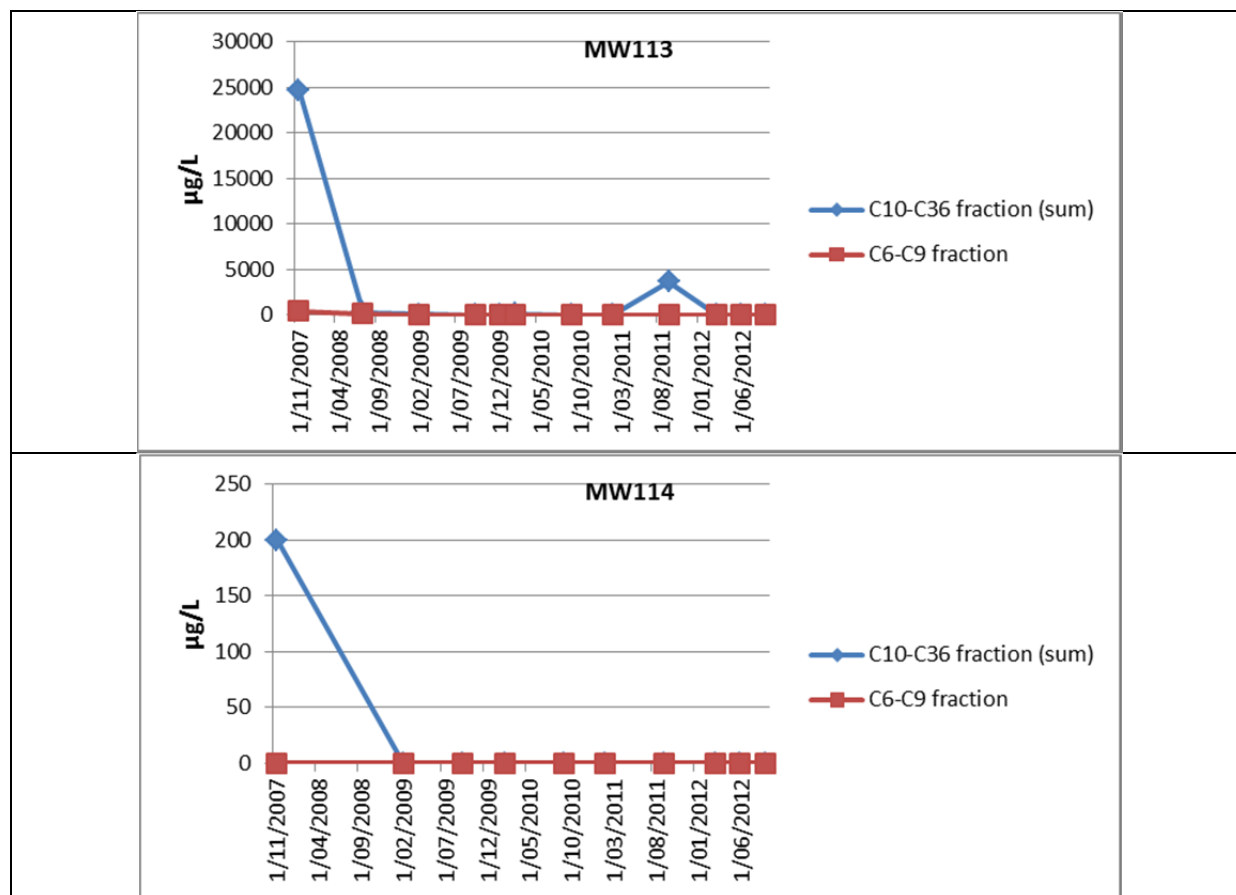


A similar trend is evident for monitoring wells formerly located within the Stage 2A area in **Chart 3-2**, of particular note is the significant decrease observed at MW113. This well was located at the down gradient edge of the Bitumen Site plume.

Chart 3-2 TPH C10-C36 vs Time – Stage 2A Wells 2007-2012 – Destroyed 2012



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3.3.5 Characterisation of Stage 2A Contaminants of Potential Concern

Soil

Little evidence of significant petroleum hydrocarbon impacted soil has been identified in the area of the Stage 2A building footprint during 2009 soil bore and test pit characterisation works or during 2012/2013 excavation observation and hotspot validation works.

During the 2009 characterisation works only three of the 95 sample locations were found to be impacted above the adopted screening guideline of 1000 mg/kg, this is in contrast to the 2003/2004 preliminary assessment works that identified pockets of hydrocarbon staining, odour and free product within smear zone soils (approximately 3-5 mBGL) of the Warehouse area (northern portion of the Stage 2A area), pockets of odour and staining within smear zone soils in the vicinity of the former drainage channel (drainage point for the former Bitumen Plant interceptor/stormwater) through the Northern Cement area (central and southern portion of the Stage 2A area) and pockets of odour and staining within smear zone soils in the Recently Reclaimed area (south eastern corner of the Stage 2A area).

Small areas of these 2003/2004 impacts were identified during 2009 soil bore and test pit works in the vicinity of Kitchener Drive (Warehouse area) and the central portion of the Stage 2A site (Northern Cement area drainage channel). Additionally during excavation of the Building 5 basement a small area of hydrocarbon impact was identified and removed (measuring approximately 15x15 m) in the same location as the drainage channel and 2009 impacted test pits and soil bores. The nature of the

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impact identified in 2009 and 2013 was consistent with the 2003/2004 results (predominantly non-volatile C15+ TPH with limited volatile C6-C9 and semi-volatile C10-C14 TPH, and no BTEX). Significantly, the magnitude of observed soil impacts decreased by at least an order of magnitude, with most areas of previous impact reporting analytical results less than LOR, and the extent of impact was significantly reduced over the 2003 to 2009 and 2013 period with only three limited areas of impact identified within the Stage 2A area during 2009 works and one of those being also encountered during Building 5 basement excavation.

This observed rapid reduction in extent and magnitude of hydrocarbon impact across the Stage 2A area is consistent with detailed observations and analytical results across Stage 1 audit of the Waterfront precinct.

Groundwater

The current network of monitoring wells was established in 2007 and while all monitoring wells located within the Stage 2A boundary have been destroyed as of June and December 2012, the concentrations of hydrocarbon impact beneath the site can be seen to have reduced by 2-3 orders of magnitude over that period, most notably at MW113, with significant reductions observed over the first 2 years of monitoring (**Chart 3-2**). Monitoring wells within the Stage 1 area show a similar reducing trend over the 2007-2013 monitoring period (**Chart 3-1**) with limited hydrocarbon impact present during the most recent monitoring events.

A dissolved phase hydrocarbon plume has been previously identified to the west of Stage 2A at the former Shell Bitumen site. Historical works done at the Bitumen site by IT Environmental had identified free product in one well during monitoring events prior to 2003, a dissolved phase hydrocarbon plume extending to the south-east of Bitumen site (towards the Stage 2A area), and a second plume in the north of the Bitumen site largely contained on-site. Monitoring wells located on the Bitumen site were destroyed during decommissioning works in 2004. Waterfront monitoring wells installed down gradient of the site in 2007 reported greatest concentrations in 2007 with concentrations decreasing rapidly over time.

Consistent with soil results, the distribution of TPH fractions in groundwater was skewed towards heavy end fractions.

Natural attenuation

Natural attenuation of petroleum hydrocarbons has been identified as a significant contributor to the reduction in magnitude and extent of impact across the Waterfront Precinct. Groundwater conditions at the site are seasonably variable from the wet season (December to March/April) to dry season (May to October/November), groundwater temperature is consistently warm (~30°C during monitoring events) and natural recharge is typically restricted to the wet season. Accordingly, availability of dissolved oxygen (and to a lesser extent nutrients) is relatively high during and immediately following the wet season and decreases with time through the dry season.

Biodegradation of dissolved phase hydrocarbon impact has been observed at the site, preferentially in the presence of dissolved oxygen, nitrate, and ferric/ferrous iron. Attenuation of hydrocarbon breakdown products by methanogenesis has been observed at the site at impacted locations in the absence of more readily available electron acceptors. It is considered that methanogenesis is likely to

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be progressively more prevalent at the site through the dry season as groundwater conditions become more reducing.

Natural attenuation of hydrocarbons is discussed in greater detail in Section 5-10 of the 2012 and 2013 Annual Groundwater Monitoring Summary Reports (URS, July 2013 and January 2014 respectively).

Distribution of Hydrocarbon Fractions

It is noted that where hydrocarbon impact has been identified at the Stage 2A site, the hydrocarbon chain length distribution of this contamination and concentration trends bear strong similarities to that observed across the Waterfront precinct, specifically at the Stage 1 and Bitumen plant areas. Site contamination was considered within the Stage 1 QRA undertaken by URS February 2008 and the Bitumen site QRA undertaken by URS for the Shell Company of Australia, February 2013.

The observed TPH distribution in groundwater across the Waterfront precinct is skewed towards heavy-end hydrocarbons, with, on average, approximately 94% of the TPH found in groundwater being C15+, approximately 6% being C10-C14 and 0% C6-C9 (**Table A-2**).

This preference to heavy-end constituents is equally pronounced in the soil data. The TPH distribution in soil across the Stage 2A area was found to be skewed towards heavy-end hydrocarbons, with, on average, approximately 81% of the TPH found in soil being C15+, approximately 19% being C10-C14 and 0.1% C6-C9.

A similar distribution of TPH fractions in soil was observed in Table 1 of the Stage 1 QRA, on average approximately 90% C15+, 10% C10-C14 and 0.3% C6-C9.

The apparently higher proportion of heavy-end compounds in the groundwater is consistent with the biodegradation of petroleum hydrocarbons in groundwater at the site and the depletion of the generally higher solubility light-end compounds in soils.

Table 3-8 presents a summary of hydrocarbon results showing the highest reported TPH concentrations in soils across the Stage 2A site. Given that the site was assessed on an approximately 10 m grid the largest hotspot represented by these maximum concentrations has a maximum radius of approximately 10 m (and more likely, much less). It is noted that this is consistent with the approximate dimensions of hotspots identified during Building 5 basement excavation works.

Table 3-8 Maximum Soil Concentrations Stage 2A – 2009-2013

Analyte	Maximum Sample ID	Maximum Observed Concentration
C6-C9	TP91_5.0	30 mg/kg
C10-C14	TB80_4.0	820 mg/kg
C15-C28	TB01_3.0	2300 mg/kg
C29-C36	TB01_3.0	4300 mg/kg
Benzene	-	<0.5 mg/kg
Toluene	-	<0.5 mg/kg
Ethylbenzene	-	<0.5 mg/kg
Xylenes	-	<1.5 mg/kg
Naphthalene	TB78_4.0	0.1 mg/kg
Benzo(a)pyrene	QC102 (duplicate of TB05)	0.25 mg/kg (0.05 mg/kg)
Total PAHs	TB78_4.0	3.98 mg/kg

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Table 3-9 presents a summary of hydrocarbon results showing the highest reported TPH concentrations in selected groundwater monitoring wells across the Waterfront Precinct from 2012 to 2013. Representative monitoring wells were selected from across the Waterfront precinct the basis of similarity to hydrocarbon contamination at Stage 2A wells prior to destruction, qualitative assessment of groundwater during 2009 soil bore and test pit works for the presence of PSH, and observations of soils during basement excavation. On the basis of no indication of significant soil or groundwater impact and strong evidence of active biodegradation of petroleum hydrocarbons in the Stage 2 A area, monitoring wells with observed PSH, occasional observed PSH or hydrocarbon concentrations indicative of saturation concentrations were not included in the groundwater assessment. Groundwater data adopted for the purpose of this risk assessment is included in Table A-2 and has been restricted to the 2012-2013 monitoring period due to the demonstrated active biodegradation of hydrocarbons across the Waterfront Precinct.

Table 3-9 Maximum Groundwater Concentrations (Selected Wells) – 2012-2013

C6-C9	-	<20 µg/L
C10-C14	MW108	110 µg/L
C15-C28	MW108	1310 µg/L
C29-C36	MW128	220 µg/L
Benzene	-	<1 µg/L
Toluene	-	<2 µg/L
Ethylbenzene	-	<2 µg/L
Xylenes	-	<2 µg/L
Naphthalene (VOC)	-	<5 µg/L

3.3.6 Suitability of Data for Risk Assessment

The suitability of data collected in any site investigation for use in the assessment of risks to human health and the environment is determined by the following factors.

Data Accuracy and Precision

The accuracy and precision of data from the URS investigation is assessed in the Stage 2A validation report (URS, 2014a) and found to be adequate for interpretation of this data.

Sampling Density

A large number of soil bores, test pits and groundwater investigation wells have been drilled and excavated at the site prior to 2009 as part of earlier phases of work across the Waterfront precinct. The URS (2009) work provided an additional grid-based assessment of soil across the entire site area, unsealed finished surfaces were assessed in a 10 m grid pattern in late 2013. Further field observation was undertaken across the entire basement during excavation for Buildings 5 and 6 during December 2012 and January 2013.

Conclusions

In conclusion, the groundwater and soil data is assessed as being generally suitable for use in the assessment of risks to human health and the environment.

Exposure Assessment

To provide a quantitative estimate of risks to human health, two things must be present: there must be an exposure to a COPC; and the COPC must be toxic. This section identifies the human populations (receptors) that may be exposed to the COPC, outlines the mechanisms (pathways) by which these populations may be exposed and in the case of the Stage 2A area demonstrates that there are no complete exposure pathways based on a lack of COPC and incomplete mechanisms for exposure.

The exposure assessment is undertaken to be representative of a particular population and does not calculate the exposure for a given individual. Populations are grouped so as to reflect common activities undertaken by that group (such as workers or residents) or by the location of the population in relation to the contaminant distribution (i.e. on-site or off-site). For this reason it is important that the exposure assessment be undertaken in such a way that the most sensitive individuals within the potentially exposed population are adequately protected. The qualitative exposure assessment has been structured in the following way:

- Identification of the population that may be exposed to the COPC;
- Identification of the activities by which exposure may take place for each population;

Additional consideration of the following structure has been made in the quantitative comparison in **Appendix D**

- Identification of parameters which define activity (such as time spent indoors) and physiological exposure parameters (such as body weight and inhalation rate); and
- Identification of the chemical concentration at the point of exposure. This includes the use of models to estimate chemical concentrations for receptors and exposure pathways that cannot be measured directly since the exposure pathway (relevant buildings etc.) are not yet present.

4.1 Contaminants of Potential Concern

Based on the potentially insignificant exposure pathways identified in **Section 4.2** (no potentially significant exposure pathways were identified) it is considered that only those contaminants which are volatile represent a potentially significant exposure risk. Since essentially no BTEX has been found in either soil or groundwater at the site, the COPC are considered to be limited to the C6-C9 and C10-C14 TPH fractions and volatile PAHs such as naphthalene.

Actual maximum concentrations of TPH C6-C9 and C10-C14 observed in groundwater samples over the 2012-2013 period were <20 µg/L C6-C9, 110 µg/L C10-C14 and <5 µg/L naphthalene as detailed in **Table 3-7 and Table A-2**,

Actual maximum concentrations of TPH C6-C9 and C10-C14 observed in soil samples were 30 mg/kg C6-C9, 820 mg/kg TPH C10-C14 and 0.1 mg/kg naphthalene as detailed in **Table 3-6 and Table A-1**.

4.1.1 Screening Soil Results against RAP V6 Criteria and Amended ASC NEPM

Analytical soil results across the Stage 2A area from 2009 and 2013 were screened against acceptance criteria for the RAP V6 (URS 2005). Material with concentrations below Class 1 criteria is suitable for unrestricted use at the site including public open space and beneath dwellings (without the requirement for a moisture/vapour barrier). Of the 224 primary, 15 field duplicate and 14 field duplicate samples analysed, three exceeded the Class 1 and Class 2A criteria for non-volatile and semi-volatile TPH fractions (both 1000 mg/kg). Results are summarised in **Table 4-1**.

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Results for two of the three samples marginally exceed the Class 1 and 2A acceptance criteria for TPH C10-C36 of 1000 mg/kg (TB78_4.0 1155 mg/kg within the Building 5 footprint and the field triplicate (inter-laboratory) of TB43_3.0 1280 mg/kg). At both these locations the analytical results were heavily skewed to the non-volatile C15+ fraction, the primary and field duplicate samples at TB43 reported results of 480 mg/kg and 610 mg/kg TPH C10-C36 respectively (all C15+), and at TB78 the sample at 3.0 mBGL reported concentrations <LOR for all TPH fractions.

The third exceedance TB01_3.0 was located within the footprint of the Building 4 university tower at 3 mBGL. There is no basement structure planned below this building. The analytical results were heavily skewed towards the non-volatile C15+ fraction and additional test pit investigation in this area (TP95_3.5) three months after the soil bore works reported concentrations <LOR for all TPH fractions. Additionally there were no odours or staining noted at the sample depth interval in the logs and the drilling method changed from hollow stem auger to air hammer immediately before this sample interval. It is considered likely based on comparison to test pit results at this location as well as the change in drilling method at the first location, that vegetable based lubricating oils for the air hammer may have contributed to the TPH result. No samples at shallower depths were analysed.

Table 4-1 Stage 2A Soil Analytical Results Summary

Analyte	Number Samples			Samples >LOR	*Samples >RAP V6 Class 1	RAP V6 Criteria		Maximum (mg/kg)	Mean (mg/kg)
	1°	2°	3°			Class 1	Class 2A		
TPH C6-C9	224	15	14	1	0	65	530	30	0.1
TPH C10-C14	224	15	14	11	-		855	820	15.5
TPH C15-C28	224	15	14	36	-			2300	37.0
TPH C29-C36	224	15	14	18	-			4300	27.8
TPH C10-C36	224	15	14	40	3	1000	1000	6600	80.4
Benzene	224	15	14	0	0	1	1	<0.2	<0.2
Toluene	224	15	14	0	0	1.4	1.4	<0.5	<0.5
Ethylbenzene	224	15	14	0	0	3.1	3.1	<0.5	<0.5
Xylene (total)	224	15	14	0	0	14	14	<0.5	<0.5
Naphthalene	224	15	14	1	-			0.1	<<0.1
Total PAH	148	11	10	17	-	20	40	3.98	0.08
Total Phenol	148	11	10	16	-	10	17000	0.2	<<0.1
1° - Primary Sample									
2° - Field Duplicate Sample									
3° - Field Triplicate Sample									

For the purpose of further screening URS has referred to the amended National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC, 2013) [the “amended ASC NEPM”]. This document includes soil criteria for use in evaluating potential risk to human health and ecosystems from soil chemical impacts, which are presented as generic investigation levels and screening levels appropriate to a Tier 1 risk-based assessment applicable to the first stage of site assessment.

It is noted that application of these screening levels is subject to a range of limitations, and as a result of a number of considerations (such as groundwater potentially contacting basements and foundations, groundwater being less than 2 m below ground level and structures at certain times of year and contaminant thickness potentially greater than 2 m within smear zone soils) the amended ASC NEPM guidelines are not immediately applicable at the Waterfront precinct. However as the guidelines are inherently conservative qualitative comparison is made to the Health Screening Levels (HSLs) (Amended ASC NEPM Table 1 A[3]), the Ecological Screening Levels (ESLs) (Amended ASC NEPM Table 1 B[6]) and the Physical and Aesthetic Management guidelines (Amended ASC NEPM Table 1 B[7]) in order to provide an additional line of evidence to the risk assessment.

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It is noted that the TRH fraction banding for the amended ASC NEPM is slightly different to the TPH banding of the 2009 Stage 2A results. Given that the results are predominantly well below the amended ASC NEPM criteria TPH fraction banding is considered to be effectively equivalent to the TRH fraction banding for the purpose of this assessment.

Table 4-2 Comparison to Amended ASC NEPM HSLs

Analyte*	Number of Samples			**NEPM Criteria mg/kg	Samples >NEPM Criteria			Maximum mg/kg	Mean mg/kg
	1°	2°	3°		1°	2°	3°		
TPH C6-C9/ F1 comparison	224	15	14	70	0	0	0	30	0.1
TPH C10-C14/ F2 comparison	224	15	14	240	5	1	1	820	15.5
TPH C15-C28	224	15	14	-				2300	37.0
TPH C29-C36	224	15	14	-				4300	27.8
TPH C10-C36	224	15	14	-				6600	80.4
*BTEX results have been excluded as all results were reported <LOR – see Table 4-1									
**Based on SAND medium and impact 1<2 m below ground and/or slab/basement level									
1° - Primary Sample									
2° - Field Duplicate Sample									
3° - Field Triplicate Sample									

As summarised in **Table 4-2** of the 253 samples results (including QA/QC samples) seven samples from five locations exceeded the amended ASC NEPM F2 criteria. All of these five locations are located within the footprint of Building 5 at depths ranging from 1 to 2 m below slab level. As detailed in **Section 2**, Building 5 consists of commercial and residential premises constructed on top of a ventilated basement car park, additionally the basement is protected from ingress of potentially contaminated groundwater by the presence of an engineered moisture/vapour barrier and the operation of the sub-soil hydrostatic relief drain.

Table 4-3 Comparison to Amended ASC NEPM ESLs

Analyte*	Number of Samples			**NEPM Criteria mg/kg	Samples >NEPM Criteria			Maximum mg/kg	Mean mg/kg
	1°	2°	3°		1°	2°	3°		
TPH C6-C9/ F1 comparison	224	15	14	180	0	0	0	30	0.1
TPH C10-C14/ F2 comparison	224	15	14	120	5	1	1	820	15.5
TPH C15-C36/ F3 comparison	224	15	14	300	11	1	1	6600	64.9
*BTEX results have been excluded as all results were reported <LOR – see Table 4-1									
**Based on coarse medium and urban residential/public open space									
1° - Primary Sample									
2° - Field Duplicate Sample									
3° - Field Triplicate Sample									

It is noted that the entire data set has been compared to the ESL criteria, however of the exceedances all except one was located beneath Stage 2A structures. Of the single exceedance outside of building footprints (TP94_1.0 TPH C15-C36/amended ASC NEPM F3 comparison 510 mg/kg) subsequent 2013 test pitting works in open space areas of Stage 2A reported no results greater than LOR. Additionally, public open space areas of the waterfront precinct are landscaped with a mixture of grassed and paved surfaces such that erosion of surface soils is negligible. As discussed in **Section 4.2.5** groundwater flow is engineered to flow into the marine environment via a controlled discharge point.

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Table 4-4 Comparison to Amended ASC NEPM Aesthetics Management Limits

Analyte*	Number of Samples			**NEPM Criteria mg/kg	Samples >NEPM Criteria			Maximum mg/kg	Mean mg/kg
	1°	2°	3°		1°	2°	3°		
TPH C6-C9/ F1 comparison	224	15	14	700	0	0	0	30	0.1
TPH C10-C14/ F2 comparison	224	15	14	1000	0	0	0	820	15.5
TPH C15-C36/ F3 comparison	224	15	14	2500	1	0	1	6600	64.9
*BTEX results have been excluded as all results were reported <LOR – see Table 4-1									
**Based on coarse medium and residential/parkland/public open space									
1° - Primary Sample									
2° - Field Duplicate Sample									
3° - Field Triplicate Sample									

As noted for the ESL comparison the entire data set has been used, however it is noted that of the two samples exceeding TPH C15-C36/ amended ASC NEPM F3 comparison criteria, one is located beneath the Building 4 footprint at a depth of approximately 3 m and the other is located beneath the Building 6 footprint and was an inter-laboratory duplicate sample (the primary and intra-laboratory duplicate samples were less than the criteria). The data set mean and all samples located within open space areas of the site reported results less than the amended ASC NEPM management limits.

4.1.2 Screening Groundwater Results against Marine Ecological and Amended ASC NEPM Criteria

Groundwater monitoring infrastructure located within and adjacent the Stage 2A area has been destroyed during general Waterfront site works. In the absence of operational groundwater monitoring infrastructure on the site URS has assessed the nature and extent of groundwater impacts across the broader Waterfront precinct. In making this assessment URS has considered the nature and extent of impact at locations within and adjacent to the Stage 2A boundary prior to destruction, the nature of biodegradation of petroleum hydrocarbons across the Waterfront precinct, trends in hydrocarbon concentrations from 2007 to 2013, nature and extent of PSH across the Waterfront precinct and the nature and extent of hydrocarbon impacts in soil across Stage 2A and the Waterfront precinct.

On the basis of active biodegradation of hydrocarbons across the precinct, no observed PSH or indication of TPH saturation concentrations in the vicinity of Stage 2A and no recent (2007 to present) indication of extensive hydrocarbon impact to soils within the Stage 2A or adjacent Stage 1 and Bitumen plant areas, representative groundwater data has been used from the 2012-2013 monitoring period with exclusion of monitoring wells containing PSH and/or TPH approaching saturation concentrations. Data are summarised in **Table A-2**.

Groundwater data has been screened against amended ASC NEPM Table 1A (4) Groundwater HSLs for Vapour Intrusion – **Table 4-5**. It is noted that the assumptions inherent in these HSLs are true for portions of the Stage 2A area (i.e. beneath Building 4 and public open space) however for portions beneath Buildings 5 and 6 the depth to groundwater assumption is not true. The qualitative comparison is made to demonstrate that the maxima and mean over the 2012-2013 monitoring period are well below the amended ASC NEPM criteria for potential vapour risk. As discussed in **Section 4.2.2** the results show no evidence of significant volatile or semi-volatile hydrocarbon contamination beneath or in the vicinity of the Stage 2A site. Additionally where the depth to groundwater beneath basement structures is less than the amended ASC NEPM assumptions,

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basement structures will be protected with an engineered moisture/vapour barrier designed to prevent ingress of groundwater or soil vapour, rendering the vapour intrusion pathway incomplete.

Table 4-5 Comparison of Waterfront Precinct Groundwater Summary Results 2012-2013 to amended ASC NEPM Groundwater HSLs for Vapour Intrusion

Analyte	Number Samples			Samples >LOR	*NEPM Criteria (µg/L)	Samples >NEPM Criteria			Maximum (µg/L)	Mean (µg/L)
	1°	2°	3°							
TPH C6-C9/ F1 comparison	101	12	9	0	1000	0	0	0	<20	<20
TPH C10-C14/ F2 comparison	101	12	9	9	1000	0	0	0	110	6.0
TPH C15-C28	101	12	9	30	-	-	-	-	1310	88.5
TPH C29-C36	101	12	9	5	-	-	-	-	220	6.3
TPH C10-C36	101	12	9	30	-	-	-	-	1540	100.8
Benzene	101	12	9	0	800	0	0	0	<1	<1
Toluene	101	12	9	0	NL	0	0	0	<2	<2
Ethylbenzene	101	12	9	0	NL	0	0	0	<2	<2
Xylene (total)	101	12	9	0	NL	0	0	0	<2	<2
Naphthalene	101	12	9	0	NL	0	0	0	<5	<5
*Based on sand medium, low-high density residential and groundwater 2<4m below ground level										
1° - Primary Sample										
2° - Field Duplicate Sample										
3° - Field Triplicate Sample										

Comparison has also been made to relevant marine acceptance criteria of the Water Quality Objectives for the Darwin Harbour Region (DWQO 2010). Guidelines for toxicants in the DWQO are referenced to the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000). Comparison of site specific COPC is detailed in **Table 4-6**.

As with comparison to the groundwater HSLs for vapour intrusion, concentrations of COPC are well below ANZECC 2000 acceptance criteria. Additionally as discussed in Section 4.1.6 dilution at the point of discharge to the marine environment is significant as a result of tidal fluctuation and volume exchange in the recreational lagoon.

Table 4-6 Comparison of Waterfront Precinct Groundwater Summary Results 2012-2013 to ANZECC 2000 Marine Water Quality Guidelines

Analyte	Number Samples			Samples >LOR	*ANZECC Criteria (µg/L)	Samples >NEPM Criteria			Maximum (µg/L)	Mean (µg/L)
	1°	2°	3°							
TPH C6-C9	101	12	9	0	-	-	-	-	<20	<20
TPH C10-C14	101	12	9	9	-	-	-	-	110	6.0
TPH C15-C28	101	12	9	30	-	-	-	-	1310	88.5
TPH C29-C36	101	12	9	5	-	-	-	-	220	6.3
TPH C10-C36	101	12	9	30	-	-	-	-	1540	100.8
Benzene	101	12	9	0	500	0	0	0	<1	<1
Toluene	101	12	9	0	-	-	-	-	<2	<2
Ethylbenzene	101	12	9	0	-	-	-	-	<2	<2
Xylene (total)	101	12	9	0	-	-	-	-	<2	<2
Naphthalene	101	12	9	0	50	0	0	0	<5	<5
*Based on discharge to the marine environment and protection of 99% species										
1° - Primary Sample										
2° - Field Duplicate Sample										
3° - Field Triplicate Sample										

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4.2 Potential Receptors and Exposure Pathways

An exposure pathway is a means by which individuals of a population (“receptor”) may be exposed to site-derived contaminants. Potential exposure pathways are evaluated for completeness based on the existence of:

- a source of chemical contamination;
- a mechanism for release of contaminants from identified sources;
- a contaminant retention or transport medium (e.g. soil, air, groundwater etc.);
- receptors who may be exposed to the contamination; and
- a mechanism for chemical intake by receptors at the point of exposure (i.e. ingestion, dermal contact or inhalation).

Whenever one or more of the exposure pathway elements is missing, the exposure pathway is incomplete, i.e. there is no exposure and therefore no risk to human health.

In the cases where the exposure pathways are complete, or have the potential to be complete, then the pathways can be considered significant, less significant or insignificant. The significance of the exposure pathway depends on the nature of the contamination present and the evaluation of the likely exposure concentrations that may be associated with the pathway. An exposure pathway can be considered to be insignificant if the potential for a receptor or population to be exposed to the COPC is considered to be low. This may be due to a number of factors, which may include dilution during the transport from the source to the point of exposure or limited time for exposure.

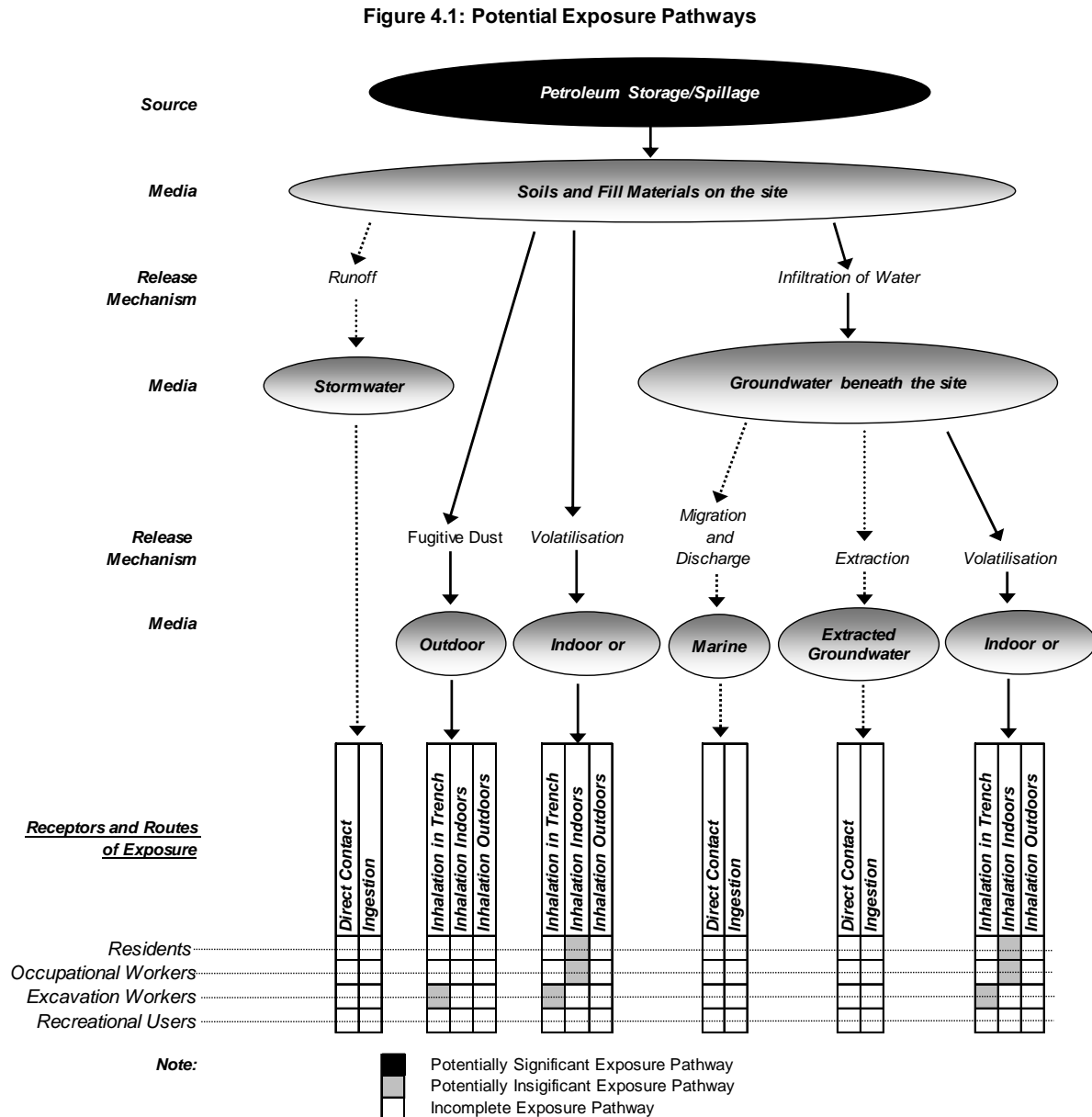
For the purpose of this risk assessment, potentially exposed human populations are considered to be:

- Utility or construction workers involved in the remediation and redevelopment of the site;
- Future residents living at the site – assuming a residential development;
- Future occupational (commercial) workers at the site – assuming some commercial use; and
- Recreational users of the site.

The potential human exposure pathways identified for the site are shown schematically in **Figure 4.1**.

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Figure 4-1 Potential Exposure Pathways Quantification of Chemical Intake



4.2.1 Utility or Construction Workers

Some potential may exist for utility or construction workers undertaking excavation work on the site to be exposed to site contaminants during such activities as remediation works, construction and trenching for services, however such works are not considered a potentially significant exposure pathway.

It is assumed that such intrusive activities would be undertaken in conjunction with a site management plan, following appropriate health and safety protocols (such as the wearing of personal protective equipment, airspace monitoring) aimed at minimising potential exposure. Consequently, such work activities, in relation to long term or chronic human health risks are considered unlikely to be

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significant, as any worker exposure would be expected to be relatively infrequent and of short term duration only.

Additionally validation works undertaken in 2009 and 2013, observation of basement excavation works in 2012/2013 and assessment of groundwater concentrations and trends have indicated that there is negligible residual hydrocarbon impact present beneath and in the vicinity of the Stage 2A area.

4.2.2 Residents

Direct Contact with Soils

Direct contact with contaminated soils (i.e. via dermal exposures and/or incidental ingestion) by on-site residents is not considered to be a potentially significant exposure pathway.

It is assumed for the purpose of this risk assessment that the top 1.0 m of soil in areas of Public Open Space will meet NEPM EIL guidelines (as per RAP V6). As such, there will be negligible likelihood for significant exposure to any underlying contamination (buildings and/or paving likely to overly any residual contamination outside of these open space areas). As these EILs are lower than the recreational and restricted residential HIL criteria, no unacceptable risks to residents through direct contact are considered likely.

Inhalation of Dusts

The inhalation of contaminated dusts by residents is not considered to be a potentially significant exposure pathway.

As noted above, the absence of surface contamination in accessible areas means there will be minimal potential for generation of contaminated dusts originating from the site.

Inhalation of Vapours in Residential Building

The inhalation of hydrocarbon vapours by future residents in a residential building is considered to be a potentially insignificant exposure pathway

Limited hydrocarbon contamination of soil and groundwater has been identified at the site, with a negligible portion of that (0.1% in soil and less than 0.1% in groundwater) in the volatile C6-C9 TPH range, no BTEX detected and a limited portion of the hydrocarbon contamination present in the semi-volatile C10-C14 TPH range (approximately 19.3% in soil and 5.9% in groundwater). While the pathway for migration of contamination beneath buildings with subsequent migration and infiltration into the surface structures is potentially present, there is no evidence of significant volatile or semi-volatile hydrocarbon contamination beneath or in the vicinity of the Stage 2A site. Additionally the basement structures across Buildings 5 and 6 will be protected with an engineered moisture/vapour barrier designed to prevent ingress of groundwater or soil vapour. The pathway for exposure to volatile contamination outdoors is also potentially present however the likelihood of exposure to volatile hydrocarbon contamination by this pathway is negligible, due to the limited and largely non-volatile hydrocarbon contamination beneath the site. Additionally there is negligible potential for vapour build-up in outdoor areas.

Use of any basement of a residential building is assumed to be limited to car parking. Consequently the potential daily exposure time to volatile contamination emanating from the sub-surface into the

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basement will be relatively short. It has been assumed that cycled air in the basement will be separate to the apartment building and that any storage areas in the basement will be ventilated at a rate consistent with that of the greater car park.

Flooding of the Basement

Section 2.1 includes a discussion of the potential for a 1-in-100 year storm surge event (likely related to a cyclone) resulting in over-topping of the breakwater and flooding of the basement in the residential buildings. This would likely also result in a temporary increase in the groundwater level which may result in hydrocarbon contaminated groundwater entering the basement.

While this could potentially result in an increase in hydrocarbon vapours in the car-park for a period of time, given the design-frequency for such an event, the limited exposure time per day in the car-park, the presence of an engineered moisture/vapour barrier beneath the basement that prevents ingress of groundwater or soil vapour and the limited hydrocarbon impact to groundwater observed across the Waterfront precinct, this potential scenario is not considered to represent a significant hydrocarbon vapour chronic exposure risk. Furthermore, if groundwater were to enter the basement, it is assumed that site management would take action to remove it (i.e. pump it out) in order to prevent it from being a nuisance.

Similarly minor fluctuations in the separation between the water table and the basement are not considered to significantly influence the assessment of risk.

4.2.3 Occupational Workers

Direct Contact with Soils

Consistent with the assessment made for on-site residents, direct contact with contaminated soils (i.e. via dermal exposures and/or incidental ingestion) by on-site workers is not considered to be a potentially significant exposure pathway.

Inhalation of Dusts

Consistent with the assessment made for on-site residents, the inhalation of contaminated dusts by on-site workers is not considered to be a potentially significant exposure pathway.

Inhalation of Vapours

Consistent with the assessment made for on-site residents, the inhalation of hydrocarbon vapours by on-site workers is considered to be a potentially insignificant human pathway

The potential risks associated with inhalation of hydrocarbon vapours by commercial workers will likely be less than that of co-located residents, as the exposure time, frequency and duration of residential exposure will be longer than that of occupational workers at the site. Consequently, it would only be necessary to quantify exposure risks to future on-site workers, should the risk to residents be assessed to be unacceptable.

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4.2.4 Recreational Users

Inhalation of Vapours

The inhalation of hydrocarbon vapours by recreational users is not considered to be a potentially significant exposure pathway.

Recreational users would be expected to spend their time outdoors where concentrations of hydrocarbon vapour are lower (due to greater mixing and dilution with ambient air). This combined with the negligible presence of volatile soil and groundwater contamination identified at the Stage 2A site results in low likelihood of exposure to volatile contamination outdoors.

Direct Contact with Soils

Consistent with the assessment made for on-site residents and occupational workers, direct contact with contaminated soils (i.e. via dermal exposures and/or incidental ingestion) by recreational users is not considered to be a potentially significant exposure pathway.

Direct Contact with Recreational Waters

The direct contact with contaminated recreational waters by recreational users is not considered to be a potentially significant exposure pathway.

The recreational lagoon at the Waterfront precinct is protected from ingress of potentially contaminated groundwater by two engineered mechanisms. Groundwater flow is induced away from the recreational lagoon by the static head in the lagoon (RL2.95) and the artificial sump of the sub soil drain and spur lines (RL2.5-2.0). Additionally the water in the lagoon is pumped directly from the harbour at a rate that allows complete volume exchange over approximately 6 days.

4.2.5 Groundwater Extraction

The extraction and subsequent use of groundwater at the site is not considered a potentially significant human exposure pathway.

While local groundwater investigations have reported TDS concentrations at potable levels (<500 mg/L) in the recharge zones, they ranged up to sea water salinities (approximately 35,000 mg/L) in the discharge zones. Salt-water ingress and seasonal groundwater level fluctuations would likely limit any practical beneficial use of the water table aquifer. Given the nature of the proposed development (high density residential) there is considered to be negligible potential for on-site extraction of groundwater for irrigation and/or potable use purposes. Correspondence between the NT EPA and the Auditor regarding a nearby petroleum site has indicated that the NT EPA does not consider extraction of groundwater for beneficial uses to be likely in the Darwin CBD. A site management plan will also be prepared to prevent access to groundwater.

4.2.6 Environmental Receptors – Marine Environment

The discharge of potentially contaminated groundwater to the surrounding marine environment at the site is not considered a potentially significant ecological exposure pathway.

Groundwater flow across the site is controlled by the operation of the recreational lagoon and the subsoil drain, consistent with the description in **Section 4.1.4**. Discharge to the marine environment is

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via the sub soil drain and associated triple interceptor at a controlled discharge point, via seepage into the recreational lagoon or via seepage at the adjacent coast. The NT EPA has recently informed URS that a determination was made no longer requiring monitoring of the subsoil drain discharge. In all three scenarios significant mixing and dilution of groundwater occurs at the point of discharge as a result of tidal mixing (with tidal variations up to 8 m) or circulation and replenishment of the recreational lagoon. Additionally groundwater and subsoil drain monitoring discharge results do not suggest significant discharge of contaminated groundwater to the marine environment. This is further discussed in **Section 4.3.2**

4.3 Summary of Potentially Significant Exposure Pathways

No potentially significant human exposure pathways have been identified via which site-derived hydrocarbon contamination could impact upon identified receptors.

It is important to note that for the Stage 2A area potential exposure pathways are considered to be insignificant. This is based on the apparent negligible presence of petroleum hydrocarbon contamination in soil and groundwater, and the fact that where hydrocarbon contamination has been detected it is skewed heavily to non-volatile TPH fractions. Furthermore, the air exchange rate of the partially enclosed basement and the presence of an engineered moisture/vapour membrane are likely to effectively eliminate the potential ingress of contaminated groundwater or soil vapour into habitable indoor spaces.

Potentially insignificant human exposure pathways via which site-derived hydrocarbon contamination could impact upon identified receptors are assessed to be limited to inhalation of hydrocarbon vapours by future residents in residential buildings, and future occupational workers should commercial premises be co-located in the building. Estimation of the potential vapour inhalation risks to residents will tend to overestimate potential risks to commercial workers due to their increased levels of exposure. As such, quantification of risks to commercial workers would only be necessary should the estimated risks to residents be assessed to be unacceptable.

As it is not considered that there are potentially significant exposure pathways present at the Stage 2A quantitative modelling of the volatile exposure pathways has not been undertaken. Discussion of quantitative assessment undertaken previously at the Bitumen site within the Waterfront precinct (based on theoretical saturation concentrations and mole fraction calculations) is included in **Appendix D**.

Risk Characterisation

5.1 Risks to Human Health

Risk characterisation is the final step in the risk assessment process. Quantitative risk assessment involves the incorporation of the exposure assessment and toxicity assessment to provide a quantitative assessment of non-threshold carcinogenic risk and threshold risk. In the assessment presented, evaluation of exposures to the COPC has been qualitative based on no completed exposure pathways and the fact that only a very small portion of the limited hydrocarbon contamination identified at the site is volatile with none of the relatively toxic mono-aromatic BTEX compounds identified.

Previous risk assessment work undertaken at the Waterfront Precinct (Stage 1 Residential and Bitumen Plant) has involved calculation of risks using an in-house spreadsheet model, RiskE. The equations utilised within RiskE follows risk assessment methodology adopting protocols established by NEPM and USEPA. The output from previous modelling has been based on assumption of petroleum hydrocarbons occurring at saturation concentrations and mole fraction calculations in soil and groundwater. Discussion of modelled data (consistent with previous modelling methodology) has been presented in **Appendix D** in order to present secondary quantitative line of evidence to support the qualitative conclusions of this assessment.

5.2 Risks to the Environment

Consistent with the risks to human health, evaluation of exposures to the COPC has been qualitative based on engineered control of groundwater flow direction and discharge via the subsoil drain, dilution at the point of discharge, and the fact that only a very small portion of the limited hydrocarbon contamination identified at the site is volatile with none of the relatively toxic mono-aromatic BTEX compounds identified.

5.3 Conclusions

A qualitative assessment of the contamination in soil and groundwater at the site has been undertaken. No potentially significant completed exposure pathways for future residents, commercial workers, intrusive workers, visitors or the environment were identified at the site.

Based on these incomplete exposure pathways and contaminant concentrations identified in the course of the URS site investigation programs, no unacceptable risks were identified. A significant factor in this assessment is the fact that only a very small portion of the limited hydrocarbon contamination identified at the site is volatile and none of the relatively toxic mono-aromatic BTEX compounds were identified as COPC for the site. Additionally, biodegradation of hydrocarbons across the Waterfront precinct has been demonstrated to be active, no ongoing primary source of contamination is present at the site, an engineered moisture/vapour barrier has been installed beneath basement structures and the sub-soil drain and perimeter hydrostatic relief drains currently operate to maintain groundwater levels beneath basement slab level and induce groundwater flow away from the recreational lagoon.

5.4 Uncertainties

In general, the uncertainties and limitations of human health risk assessment can be classified into the following categories:

- Data gaps

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- Sampling and analysis, including groundwater fate and transport modelling
- Receptor exposure assessment

The risk assessment process following both ANZECC/NHMRC and USEPA guidance documents provides a systematic means for organising, analysing and presenting information on the nature and magnitude of risks to public health posed by chemical exposures. Despite the advanced state of the current risk assessment methodology, uncertainties and limitations are inherent in the risk assessment process. This section discusses the uncertainties and limitations associated with this risk assessment.

5.4.1 Data Gaps

Several data gaps were identified in the course of the risk assessment:

- No current groundwater data was available from within the Stage 2A site area. Former monitoring wells were destroyed during Stage 1 and Stage 2A preparation works. Groundwater data has been inferred based on the nature of groundwater impacts across nearby areas of the Waterfront precinct, the most recent concentrations from wells within the Stage 2A area prior to destruction, concentration trends in monitoring wells across the Waterfront Precinct and the significance of biodegradation of petroleum hydrocarbons across the Waterfront precinct.
- While a significant number of both soil and groundwater samples were analysed for TPH, only two of the 253 soil samples and none of the groundwater samples were analysed to assess the ratio of aromatic to aliphatic compounds within each fraction. This is of lesser significance for this qualitative assessment than the previous quantitative work completed across the Waterfront Precinct and further discussed in **Appendix D**.
- During previous quantitative risk assessment works at the Waterfront Precinct it has been assumed that within the C10-C14 range, the aliphatic:aromatic ratio is 50:50. The significance of this assumption is not relevant to the qualitative assessment in the body of this report however it is explored further in the context of quantitative assessment in **Appendix D**.
- No data on the amount of total organic carbon present in the soil was available. The presence of organic carbon affects the estimation of saturation concentrations. Previous risk assessments were based on an estimated value as discussed in **Appendix D**, this does not affect the qualitative assessment.

5.4.2 Sampling and Analysis

The assessment of soil and groundwater conditions has been based on the results of soil and groundwater investigations undertaken at and adjacent to the Stage 2A portion of the Waterfront site by URS. A substantial amount of data has been collected from both soil and groundwater beneath the site, and it is noted that the characterisation of hydrocarbon impacts beneath the site is consistent with knowledge of the site operational history and product storages; nevertheless, inferences about the nature and continuity of soil and groundwater contamination away from the sampling points are made but cannot be guaranteed.

5.4.3 Exposure Assessment

Risk assessments require the adoption of several assumptions in order to assess potential human exposure. This risk assessment includes assumptions about general characteristics and patterns of human exposure relevant to the on-site groups. These assumptions are conservative and developed

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to provide an estimate of maximum possible exposures rather than the actual exposures. Where these exposures are quantified this approach is expected to overestimate the risks.

The assessment of exposure pathways concluded that there are no complete exposure pathways based on a lack of COPC and incomplete mechanisms for exposure.

The assessment of potential exposure on the site has focused on exposures associated with the presence of hydrocarbons in soils and groundwater beneath the site. No assessment has been provided for the potential exposure to fugitive emissions associated with the operation of the site.

5.5 Sensitivity Analysis

The qualitative assessment of risk is sensitive to the conceptual understanding of the site based on geology, hydrogeology, characterisation of COPC, nature and magnitude of contamination, and contaminant behaviour with time. The broader Waterfront Precinct has been well characterised by several stages of assessment, risk assessment, groundwater monitoring, remediation and development between 2003 and 2013.

Stage 2A specific soil assessment has been undertaken within the site boundary on an approximate 10 m grid in 2009 and subsequently across open space areas in 2013. Prior to 2009 soil investigation works have been carried out in 2003 and 2004 as part of the Waterfront Precinct pre-remediation and development works. The geology and soil contamination beneath Stage 2A is considered to be consistent and well characterised.

Stage 2A specific groundwater assessment for the 2012-2013 monitoring period has not been possible due to the destruction of monitoring infrastructure prior to 2012. This is not considered to affect assessment based on the site specific contaminant characterisation and trends prior to destruction being consistent with the broader Waterfront Precinct monitoring network. Assessment of Stage 2A groundwater has been based on comparison to surrounding representative Waterfront Precinct wells.

Previous assessment of risk at the Waterfront Precinct has involved the use of models to estimate exposure and in some cases exposure point concentrations. These models require a number of input variables, some of which may be site-specific and others may be derived from other sources of information. In the case of Stage 2A the lack of COPC and incomplete mechanisms for exposure has meant the assessment has been qualitative, however comparison to previous assessment methodology and modelling is made in **Appendix D** including sensitivity analysis of the models.

Comparison of the outcomes of the qualitative risk assessment to the quantitative modelling in **Appendix D** suggests that the outcome of the qualitative risk assessment is consistent with and consequently not affected by the outcomes of the quantitative assessment.

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6 References

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Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of the Darwin Waterfront Corporation (DWC). A complete or partial copy of the report may only be provided by DWC to the EPA (Victoria) accredited Environmental Auditor (Contaminated Land) appointed by DWC to the project and to developers and contractors (Interested Parties) working on the Darwin Waterfront Redevelopment Project if the entire limitations statement of this report is included in the complete or partial copy of this report. Whilst URS does not admit that any action may exist or be available to any Interested Party, this report may only be relied on by an Interested Party on the basis that subject to any law the terms of which cannot be excluded or modified by agreement:

- I. the maximum amount payable (if any) by URS to Interested Parties or any party claiming through an Interested Party in aggregate, whether in contract, tort or otherwise, in relation to claims, damages, liabilities, losses or expenses, under or in any way related to this report and/or its appendices or the services performed by URS to prepare the Report, shall be **A\$2,000,000**; and
- II. if there is more than one Interested Party, the maximum amount payable to any and all Interested Parties in total shall be **A\$2,000,000**.

Except as specifically stated in this limitations statement, this report may not be used by any third party.

This report is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the proposal dated 30 November 2005 as clarified on 13 December 2005.

The methodology adopted and sources of information used by URS are outlined in this report. 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 this report. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between August 2009 and January 2013 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

Appendix A Tables

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4
Location						TB01	TB01	TB02	TB02	TB03	TB03	TB04	TB05	TB05	TB05	TB05
Sample ID						TB01_3.0 5/8/09	TB01_6.0 5/8/09	TB02_3.4 5/8/09	TB02_5.5 5/8/09	TB03_2.0 5/8/09	TB03_3.0 5/8/09	TB04_3.0 5/8/09	TB05_3.0 6/8/09	QC102 6/8/09	QC202	TB05_6.0 6/8/09
Date Sampled						5/08/2009	5/08/2009	5/08/2009	5/08/2009	5/08/2009	5/08/2009	5/08/2009	6/08/2009	6/08/2009	6/08/2009	6/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				15	13	14	20	12	13	10	14	15	13.8	16
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<20	<20	<20	<10	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<20	<20	<20	<20	<50	<20
C15-C28 fraction	50	mg/kg				2300	350	200	75	53	69	<50	<50	100	<100	89
C29-C36 fraction	50	mg/kg				4300	280	330	53	<50	59	<50	<50	50	<100	66
Sum of C10-C36		mg/kg	1000	1000		6600	630	530	128	53	128	ND	ND	150	ND	155
Sum of C6-C36		mg/kg				6600	630	530	128	53	128	ND	ND	150	ND	155
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				180	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				<30	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	4400	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	530	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	<90	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				<50	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	<0.5	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	<0.5	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<0.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	0.11	0.16	2.95	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	-	-	-	<0.5	-
Total Phenolics	0.1	mg/kg				0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4
Location						TB06	TB06	TB07	TB08	TB08	TB09	TB09	TB10	TB10 3.0	TB10	TB11
Sample ID						TB06 3.0 6/8/09	TB06 5.0 6/8/09	TB07 4.0 6/8/09	TB08 3.0 6/8/09	TB08 5.0 6/8/09	TB09 3.0 6/8/09	TB09 5.0 6/8/09	TB10 3.0 7/8/09	QC104 7/8/09	QC204	TB11 4.0 7/8/09
Date Sampled						6/08/2009	6/08/2009	6/08/2009	6/08/2009	6/08/2009	6/08/2009	6/08/2009	7/08/2009	7/08/2009	7/08/2009	7/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				12	21	13	15	20	10	18	11	12	13.6	17
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<20	<20	<20	<10	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<20	<20	<20	<20	<50	<20
C15-C28 fraction	50	mg/kg				<50	53	60	<50	<50	<50	<50	<50	<50	<100	<50
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<50	<50	<50	<50	<50	<100	<50
Sum of C10-C36		mg/kg	1000	1000		ND	53	60	ND	ND	ND	ND	ND	ND	ND	ND
Sum of C6-C36		mg/kg				ND	53	60	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	<0.5	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	<0.5	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<0.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.1
Total PAHs	1.75	mg/kg				ND	0.11	0.86	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	-	-	-	<0.5	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4
Location						TB12	TB13	TB13 4.0	TB13	TB14	TB15	TB16	TB17	TB18	TB19	TB20
Sample ID						TB12 5.0 7/8/09	TB13 4.0 7/8/09	QC105 7/8/09	QC205	TB14 3.0 7/8/09	TB15 3.0 8/8/09	TB16 4.0 8/8/09	TB17 5.0 8/8/09	TB18 4.0 8/8/09	TB19 3.0 8/8/09	TB20 4.0 10/8/09
Date Sampled						7/08/2009	7/08/2009	7/08/2009	7/08/2009	7/08/2009	8/08/2009	8/08/2009	8/08/2009	8/08/2009	8/08/2009	10/08/2009
Sample Type						Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				16	12	13	12.5	9	24	24	10	16	12	8
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<10	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<50	<20	<20	42	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				<50	<50	<50	<100	<50	270	74	200	<50	<50	<50
C29-C36 fraction	50	mg/kg				<50	<50	<50	<100	<50	220	<50	310	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	ND	490	116	510	ND	ND	ND
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	490	116	510	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	<0.5	-	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	<0.5	-	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<0.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	0.89	ND	0.38	0.35	0.11	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	<0.5	-	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 4	Building 6	Building 6	Building 6	Building 6	Building 6	Building 6	Open Space	Building 6	Open Space	Open Space
Location						TB21	TB23	TB24	TB25	TB26	TB26 4.0	TB26	TB27	TB28	TB29	TB30
Sample ID						TB21_3.0 10/8/09	TB23_2.0 11/8/09	TB24_3.0 11/8/09	TB25_4.0 11/8/09	TB26_4.0 12/08/09	QC108 07/08/09	QC208	TB27_2.0 12/08/09	TB28_1.0 07/08/09	TB29_1.0 07/08/09	TB30_3.0 12/08/09
Date Sampled						10/08/2009	11/08/2009	11/08/2009	11/08/2009	12/08/2009	7/08/2009	7/08/2009	12/08/2009	17/08/2009	7/08/2009	12/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				11	11	15	16	14	13	12.4	13	15	13	13
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<10	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<20	<50	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				<50	<50	<50	<50	110	130	160	<50	<50	<50	<50
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<50	<50	100	<50	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	110	130	260	ND	ND	ND	ND
Sum of C6-C36		mg/kg				ND	ND	ND	ND	110	130	260	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	<0.5	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	<0.5	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<0.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	0.53	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	<0.5	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	0.1	0.1	ND	0.2	ND	0.1	ND

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Building 6	Building 6	Building 6	Building 6	Open Space	Open Space	Building 6	Building 6	Building 6	Building 6
Location						TB31	TB32	TB33	TB33	TB33	TB34	TB35	TB37	TB38	TB39	TB40
Sample ID						TB31_3.0 12/08/09	TB32_3.0 12/08/09	TB33_2.0 13/08/09	QC109 13/08/09	QC209	TB34_4.0 13/08/09	TB35_3.0 13/08/09	TB37_3.0 13/08/09	TB38_3.0 13/08/09	TB39_5.0 13/08/09	TB40_3.0 13/08/09
Date Sampled						12/08/2009	12/08/2009	13/08/2009	13/08/2009	13/08/2009	13/08/2009	13/08/2009	13/08/2009	13/08/2009	13/08/2009	13/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				12	12	11	10	10.9	13	10	12	12	16	15
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<10	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<50	<20	<20	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				<50	<50	<50	<50	<100	<50	<50	<50	150	<50	<50
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<100	<50	<50	<50	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	ND	ND	ND	ND	150	ND	ND
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	150	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	<0.5	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	-	<0.5	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<0.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	<0.5	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	0.1	0.1	ND	ND	ND	0.1	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 6	Building 6	Building 6	Building 6	Outside Stage 2A	Building 5	Building 5	Building 5	Building 5	Outside Stage 2A	Building 5
Location						TB42	TB43	TB43	TB43	TB44	TB45	TB46	TB47	TB48	TB49	TB50
Sample ID						TB42 3.0 14/08/09	TB43 3.0 14/08/09	QC110 14/08/09	QC210	TB44 2.0 14/08/09	TB45 3.0 14/08/09	TB46 3.0 14/08/09	TB47 3.0 14/08/09	TB48 3.0 14/08/09	TB49 3.0 14/08/09	TB50 3.0 15/08/09
Date Sampled						14/08/2009	14/08/2009	14/08/2009	14/08/2009	14/08/2009	14/08/2009	14/08/2009	14/08/2009	14/08/2009	14/08/2009	15/08/2009
Sample Type						Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				11	9	10	11.2	11	9.9	12	13	14	14	14
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<10	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<50	<20	<20	<20	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				<50	480	520	940	110	<50	<50	<50	<50	<50	<50
C29-C36 fraction	50	mg/kg				<50	<50	90	340	<50	<50	<50	<50	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		ND	480	610	1280	110	ND	ND	ND	ND	ND	ND
Sum of C6-C36		mg/kg				ND	480	610	1280	110	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	<0.5	-	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	<0.5	-	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<0.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	<0.5	-	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	0.2	ND	ND	ND	0.2	ND	ND	ND	0.2	0.2

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Outside Stage 2A	Building 5
Location						TB51	TB52	TB53	TB54	TB55	TB55	TB55	TB55	TB55	TB56	TB56
Sample ID						TB51_3.0 15/08/09	TB52_3.0 15/08/09	TB53_3.0 15/08/09	TB54_3.0 15/08/09	TB55_3.0	TB55_5.0	QC112	QC212	TB55_6.0	TB56_3.0	TB56_5.0
Date Sampled						15/08/2009	15/08/2009	15/08/2009	15/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				16	15	16	14	-	-	-	17.5	-	-	-
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<20	<10	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	23	23	<50	28	<20	<20
C15-C28 fraction	50	mg/kg				<50	<50	<50	<50	170	150	140	190	160	<45	<45
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	140	100	90	<100	150	<45	<45
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	310	273	253	190	338	ND	ND
Sum of C6-C36		mg/kg				ND	ND	ND	ND	310	273	253	190	338	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	<0.5	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	<0.5	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	0.5	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	-	<0.5	-	-	-
Total Phenolics	0.1	mg/kg				0.2	0.2	0.2	ND	ND	ND	ND	ND	ND	ND	ND

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5
Location						TB57	TB57	TB58	TB58	TB59	TB59	TB60	TB60	TB61	TB62	TB63
Sample ID						TB57_3.0	TB57_6.0	TB58_3.0	TB58_6.0	TB59_3.0	TB59_5.0	TB60_3.0	TB60_6.0	TB61_5.0 18/08/09	TB62_3.0 18/08/09	TB63_3.0 18/08/09
Date Sampled						17/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009	17/08/2009	18/08/2009	18/08/2009	18/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				-	-	-	-	-	-	-	-	17	18	16
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				<45	<45	<45	<45	<45	<45	<45	<45	<50	<50	<50
C29-C36 fraction	50	mg/kg				<45	<45	<45	<45	<45	<45	<45	<45	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 5	Building 5	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space
Location						TB63	TB64	TB66	TB66	TB66	TB67	TB67	TB68	TB68	TB69	TB69
Sample ID						TB63 6.0 18/08/09	TB64 6.0 18/08/09	TB66 1.0 19/08/09	TB66 5.0 19/08/09	TB66 6.0 19/08/09	TB67 3.0 19/08/09	TB67 6.0 19/08/09	TB68 1.0 19/08/09	TB68 5.0 19/08/09	TB69 3.0 20/8/09	TB69 5.0 20/8/09
Date Sampled						18/08/2009	18/08/2009	19/08/2009	19/08/2009	19/08/2009	19/08/2009	19/08/2009	19/08/2009	19/08/2009	20/08/2009	20/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				20	20	13	25	16	12	16	9	15	5	11
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				<50	<50	<50	<50	55	52	<50	<50	<50	<50	<50
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	55	52	ND	ND	ND	ND	ND
Sum of C6-C36		mg/kg				ND	ND	ND	ND	55	52	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Building 5	Building 5	Building 5
Location						TB69	TB69	TB70	TB70	TB71	TB71	TB72	TB72	TB73	TB74	TB74
Sample ID						QC115	QC215	TB70_ 2.0 20/8/09	TB70_ 6.0 20/8/09	TB71_ 2.0 20/8/09	TB71_ 4.0 20/8/09	TB72_ 2.0 20/8/09	TB72_ 5.0 20/8/09	TB73_ 5.0 21/8/09	TB74_ 5.0 20/8/09	TB74_ 4.0 21/8/09
Date Sampled						20/08/2009	20/08/2009	20/08/2009	20/08/2009	20/08/2009	20/08/2009	20/08/2009	20/08/2009	21/08/2009	20/08/2009	21/08/2009
Sample Type						Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				11	9.5	6	10	9	16	8	14	19	15	10
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<10	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<50	<20	<20	<20	<20	<20	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				<50	<100	<50	<50	<50	<50	<50	<50	<50	<50	<50
C29-C36 fraction	50	mg/kg				<50	<100	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	<0.5	-	-	-	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	<0.5	-	-	-	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<0.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	0.5	0.33	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	<0.5	-	-	-	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 5	Building 5	Building 5	Building 4	Building 4	Building 4	Building 4	Building 4	Building 4	Building 5	Building 5
Location						TB74	TB75	TB75	TB76	TB76	TB76	TB77	TB77	TB77	TB78	TB78
Sample ID						TB74. 6.0 21/8/09	TB75. 3.0 21/8/09	TB75. 6.0 21/8/09	TB76. 3.0 20/8/09	TB76. 6.0 20/8/09	TB76. 4.0 21/8/09	TB77. 3.0 24/8/09	TB77. 5.0 24/8/09	TB77. 6.0 24/8/09	TB78. 3.0 24/8/09	TB78. 4.0 24/8/09
Date Sampled						21/08/2009	21/08/2009	21/08/2009	20/08/2009	20/08/2009	21/08/2009	24/08/2009	24/08/2009	24/08/2009	24/08/2009	24/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content						18	12	1	12	17	12	20	22	22	5	15
Moisture Content	1	%														
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	330
C15-C28 fraction	50	mg/kg				96	<50	<50	<50	<50	<50	<50	<50	<50	<50	770
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	55
Sum of C10-C36		mg/kg	1000	1000		96	ND	ND	ND	ND	ND	ND	ND	ND	ND	1155
Sum of C6-C36		mg/kg				96	ND	ND	ND	ND	ND	ND	ND	ND	ND	1155
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	270
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	89
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	370
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	<50
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	96
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	<50
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.98
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 4	Building 4	Building 4	Building 4	Building 4
Location	Sample ID	Date Sampled	Sample Type													
						TB79	TB80	TB80	TB80	TB80	TB80	TB81	TB81	TB81	TB81	TB81
						TB79 4.0 24/8/09	TB80 3.0 24/8/09	TB80 4.0 24/8/09	QC118 24/8/09	QC218	TB80 6.0 24/8/09	TB81 2.0 25/8/09	TB81 3.0 25/8/09	QC119 25/8/09	QC219	TB81 5.0 25/8/09
						24/08/2009	24/08/2009	24/08/2009	24/08/2009	24/08/2009	24/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009
						Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				16	13	15	14	14.8	13	10	13	12	13.4	17
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<10	<20	<20	<20	<20	<10	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	820	770	590	<20	<20	<20	<20	<50	<20
C15-C28 fraction	50	mg/kg				<50	<50	65	59	<100	<50	<50	<50	<50	<100	<50
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<100	<50	<50	<50	<50	<100	<50
Sum of C10-C36		mg/kg	1000	1000		ND	ND	885	829	590	ND	ND	ND	ND	ND	ND
Sum of C6-C36		mg/kg				ND	ND	885	829	590	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5	<0.5	<0.5	<0.5	<0.2	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	<0.5	-	-	-	-	<0.5	-
o-Xylene	0.5	mg/kg				-	-	-	-	<0.5	-	-	-	-	<0.5	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<0.5	<1.5	<1.5	<1.5	<1.5	<0.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<0.1	<0.5	<0.1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	<0.5	-	-	-	-	<0.5	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 4	Building 4	Building 4	Building 4	Building 4	Outside Stage 2A	Outside Stage 2A	Outside Stage 2A	Outside Stage 2A	Outside Stage 2A	Outside Stage 2A
Location						TB81	TB82	TB82	TB83	TB83	TB84	TB84	TB85	TB85	TB85	TB86
Sample ID						TB81 6.0 25/8/09	TB82 2.0 25/8/09	TB82 5.0 25/8/09	TB83 1.0 25/8/09	TB83 5.0 25/8/09	TB84 2.0 25/8/09	TB84 5.0 25/8/09	TB85 1.0 25/8/09	TB85 4.0 25/8/09	TB85 6.0 25/8/09	TB86 2.0 25/8/09
Date Sampled						25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				17	11	17	9	15	12	15	7	13	4	11
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C15-C28 fraction	50	mg/kg				570	100	100	<50	<50	<50	<50	<50	<50	<50	<50
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C10-C36		mg/kg	1000	1000		570	100	100	ND	ND	ND	ND	ND	ND	ND	ND
Sum of C6-C36		mg/kg				570	100	100	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-	-	-	-	-	-	-
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-	-	-	-	-	-	-
Aromatic > C35	50	mg/kg				-	-	-	-	-	-	-	-	-	-	-
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
o-Xylene	0.5	mg/kg				-	-	-	-	-	-	-	-	-	-	-
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total PAHs	1.75	mg/kg				ND	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	-	-	-	-	-	-
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Outside Stage 2A	Building 4	Building 4	Building 4	Building 6	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5
Location						TB86	TB87	TB87	TB87	TB88	TP89	TP89	TP91	TP91	TP92	TP92
Sample ID						TB86 5.0 25/8/09	TB87 1.0 25/8/09	TB87 4.0 25/8/09	TB87 6.0 25/8/09	TB88 3.0 25/8/09	TP89 3.0	TP89 5.0	TP91 3.0	TP91 5.0	TP92 3.0	TP92 5.0
Date Sampled						25/08/2009	25/08/2009	25/08/2009	25/08/2009	25/08/2009	26/11/2009	26/11/2009	26/11/2009	26/11/2009	26/11/2009	26/11/2009
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				15	8	13	14	12	16.2	21.9	16.1	20.7	14.8	20.8
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<20	<20	<20	<20	<20	<10	<10	<10	30	<10	<10
C10-C14 fraction	20	mg/kg		855		<20	<20	<20	<20	<20	<50	<50	<50	580	<50	<50
C15-C28 fraction	50	mg/kg				<50	<50	<50	<50	<50	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<50	<50	<50	<50	<50	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		ND	ND	ND	ND	ND	<50	<50	<50	580	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	610	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg				-	-	-	-	-						
Aromatic > C10-C16	30	mg/kg				-	-	-	-	-						
Aliphatic > C16-C35	90	mg/kg		11200	28000	-	-	-	-	-						
Aliphatic > C35	50	mg/kg		112000	280000	-	-	-	-	-						
Aromatic > C16-C35	90	mg/kg		180	450	-	-	-	-	-						
Aromatic > C35	50	mg/kg				-	-	-	-	-						
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				-	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				-	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<1.5	<1.5	<1.5	<1.5	<1.5	ND	ND	ND	ND	ND	ND
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total PAHs	1.75	mg/kg				ND	0.78	ND	ND	0.63	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	-	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Phenolics	0.1	mg/kg				0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 6	Open Space	Building 4	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5	Building 5
Location						TP93	TP94	TP95	EXB0T01	EXB0T02	EXB0T03	EXED01	EXED02	EXED03	EXED04	EXED05
Sample ID						TP93_5.0	TP94_1.0	TP95_3.5	EXB0T01_11/1/13	EXB0T02_11/1/13	EXB0T03_11/1/13	EXED01_11/1/13	EXED02_11/1/13	EXED03_11/1/13	EXED04_11/1/13	EXED05_11/1/13
Date Sampled						27/11/2009	27/11/2009	27/11/2009	11/01/2013	11/01/2013	11/01/2013	11/01/2013	11/01/2013	11/01/2013	11/01/2013	11/01/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				17.6	12.3	11.2	22.2	18	13.9	18.8	16.7	19.7	20.2	19.7
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	410	310	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	200	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	310	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	520	<50	410	310	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	520	ND	410	310	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	ND	ND	ND	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total PAHs	1.75	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Building 5	Building 5	Building 5	Building 5	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Open Space	Open Space	Open Space
Location						EXED06	EXED07	EXED08	EXED08	TP001	TP001	TP001	TP001	TP002	TP002	TP002
Sample ID						EXED06_11/1/13	EXED07_11/1/13	EXED08_11/1/13	QC01	TP001_0.1	TP001_0.5	TP001_1.0	TP001_2.0	TP002_0.1	TP002_0.5	TP002_1.0
Date Sampled						11/01/2013	11/01/2013	11/01/2013	11/01/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				18.9	24.3	16.2	17	14.1	9.9	9.1	10.8	14.4	15.2	16.1
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<0.5	<0.5	<0.5	<0.5	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg				ND	ND	ND	ND							
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500	<0.5	<0.5	<0.5	<0.5							
Total Phenolics	0.1	mg/kg				ND	ND	ND	ND							

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Building 4 Courtyard	Open Space	Open Space
Location	Sample ID	Date Sampled	Sample Type													
						TP002	TP003	TP003	TP003	TP003	TP004	TP004	TP004	TP004	TP005	TP005
						TP002_2.0	TP003_0.1	TP003_0.5	TP003_1.0	TP003_2.0	TP004_0.1	TP004_0.5	TP004_1.0	TP004_2.0	TP005_0.1	TP005_0.5
						4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				13.1	10	9.9	10.9	11.9	9.9	10.1	11.1	10.9	8.6	9.6
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg														
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500											
Total Phenolics	0.1	mg/kg														

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space
Location						TP005	TP006	TP006	TP006	TP007	TP007	TP007	TP007	TP007	TP008	TP008
Sample ID						TP005_1.0	TP006_0.1	TP006_0.5	TP006_1.0	TP007_0.1	QAQC01_041213	QAQC02_041213	TP007_0.5	TP007_1.0	TP008_0.1	TP008_0.5
Date Sampled						4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				10.1	12.1	14.4	14.5	10.8	9.4	18	11	11.5	11.1	9.9
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg														
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500											
Total Phenolics	0.1	mg/kg														

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space
Location						TP008	TP009	TP009	TP009	TP010	TP010	TP010	TP011	TP011	TP011	TP012
Sample ID						TP008_1.0	TP009_0.1	TP009_0.5	TP009_1.0	TP010_0.1	TP010_0.5	TP010_1.0	TP011_0.1	TP011_0.5	TP011_1.0	TP012_0.1
Date Sampled						4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				11.2	10.7	13.3	11.8	9.6	10.5	11.2	13.1	10.9	11	11.9
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg														
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500											
Total Phenolics	0.1	mg/kg														

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space
Location						TP012	TP012	TP013	TP013	TP013	TP013	TP013	TP014	TP014	TP014	TP015
Sample ID						TP012_0.5	TP012_1.0	TP013_0.1	TP013_0.5	QAQC03_041213	QAQC04_041213	TP013_1.0	TP014_0.1	TP014_0.5	TP014_1.0	TP015_0.1
Date Sampled						4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				11.9	12	11.1	8.5	7.2	20	9.2	10.2	12.3	12.3	10.4
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg		1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg														
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500											
Total Phenolics	0.1	mg/kg														

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space
Location						TP015	TP015	TP016	TP016	TP016	TP017	TP017	TP017	TP018	TP018	TP018
Sample ID						TP015_0.5	TP015_1.0	TP016_0.1	TP016_0.5	TP016_1.0	TP017_0.1	TP017_0.5	TP017_1.0	TP018_0.1	TP018_0.5	TP018_1.1
Date Sampled						4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				10.9	11.9	10.4	10.9	10.6	12.6	13.5	10.7	9.3	8.1	10.1
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg														
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500											
Total Phenolics	0.1	mg/kg														

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space
Location						TP019	TP019	TP019	TP020	TP020	TP020	TP020	TP020	TP021	TP021	TP021
Sample ID						TP019_0.1	TP019_0.5	TP019_1.1	TP020_0.1	TP020_0.5	TP020_1.1	QAQC05_041213	QAQC06_041213	TP021_0.1	QAQC07_041213	QAQC08_041213
Date Sampled						4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Duplicate Sample	Triplicate Sample	Primary Sample	Duplicate Sample	Triplicate Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'											
Moisture Content																
Moisture Content	1	%				9.9	13.1	11.4	10.3	9.9	12.8	11.5	19.2	9.5	8	21.5
Total Petroleum Hydrocarbons																
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation																
Aliphatic > C10-C16	30	mg/kg														
Aromatic > C10-C16	30	mg/kg														
Aliphatic > C16-C35	90	mg/kg		11200	28000											
Aliphatic > C35	50	mg/kg		112000	280000											
Aromatic > C16-C35	90	mg/kg		180	450											
Aromatic > C35	50	mg/kg														
BTEX Compounds																
Benzene	0.5	mg/kg	1	1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons																
Naphthalene	0.1	mg/kg				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg														
Phenolic Compounds																
Phenol	0.5	mg/kg		17000	42500											
Total Phenolics	0.1	mg/kg														

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

						Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space
Location						TP021	TP021	TP022	TP022	TP022	TP023	TP023	TP023	TP024	TP024
Sample ID						TP021_0.5	TP021_1.1	TP022_0.1	TP022_0.5	TP022_1.1	TP023_0.1	TP023_0.5	TP023_1.1	TP024_0.1	TP024_0.5
Date Sampled						4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013	4/12/2013
Sample Type						Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample	Primary Sample
Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'										
Moisture Content															
Moisture Content	1	%				9.5	10.2	9	9.2	15.9	8.3	8.8	11.4	9.7	14.4
Total Petroleum Hydrocarbons															
C6-C9 fraction	20	mg/kg	65	530		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C10-C14 fraction	20	mg/kg		855		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	50	mg/kg				<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Sum of C10-C36		mg/kg	1000	1000		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sum of C6-C36		mg/kg				ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Petroleum Hydrocarbons-Speciation															
Aliphatic > C10-C16	30	mg/kg													
Aromatic > C10-C16	30	mg/kg													
Aliphatic > C16-C35	90	mg/kg		11200	28000										
Aliphatic > C35	50	mg/kg		112000	280000										
Aromatic > C16-C35	90	mg/kg		180	450										
Aromatic > C35	50	mg/kg													
BTEX Compounds															
Benzene	0.5	mg/kg		1	1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	0.5	mg/kg	1.4	1.4	1.4	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m&p-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
o-Xylene	0.5	mg/kg				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes		mg/kg	14	14	14	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polynuclear Aromatic Hydrocarbons															
Naphthalene	0.1	mg/kg				<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total PAHs	1.75	mg/kg													
Phenolic Compounds															
Phenol	0.5	mg/kg		17000	42500										
Total Phenolics	0.1	mg/kg													

Legend:

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Table A-1
Soil Investigation Results - August and November 2009, and January 2013

Location
Sample ID
Date Sampled
Sample Type

Analyte	LOR	Units	Class 1 NEPM - EILs	Class 2A NEPM - HILs 'E'	Class 2B NEPM - HILs 'F'
Moisture Content					
Moisture Content	1	%			
Total Petroleum Hydrocarbons					
C6-C9 fraction	20	mg/kg	65	530	
C10-C14 fraction	20	mg/kg		855	
C15-C28 fraction	50	mg/kg			
C29-C36 fraction	50	mg/kg			
Sum of C10-C36		mg/kg	1000	1000	
Sum of C6-C36		mg/kg			
Total Petroleum Hydrocarbons-Speciation					
Aliphatic > C10-C16	30	mg/kg			
Aromatic > C10-C16	30	mg/kg			
Aliphatic > C16-C35	90	mg/kg		11200	28000
Aliphatic > C35	50	mg/kg		112000	280000
Aromatic > C16-C35	90	mg/kg		180	450
Aromatic > C35	50	mg/kg			
BTEX Compounds					
Benzene	0.5	mg/kg	1	1	1
Toluene	0.5	mg/kg	1.4	1.4	1.4
Ethylbenzene	0.5	mg/kg	3.1	3.1	3.1
m&p-Xylene	0.5	mg/kg			
o-Xylene	0.5	mg/kg			
Total Xylenes		mg/kg	14	14	14
Polynuclear Aromatic Hydrocarbons					
Naphthalene	0.1	mg/kg			
Total PAHs	1.75	mg/kg			
Phenolic Compounds					
Phenol	0.5	mg/kg		17000	42500
Total Phenolics	0.1	mg/kg			

Legend:
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Interim Urban
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial
Exceeds the National Environment Protection Council, 1999, Health-based Investigation Levels - Commercial/Industrial

- Not Analysed
* LOR Exceeds Guideline Trigger Value

Number of Samples	Samples >LOR	Max	Average	Average >LOR
253	155	25	8.6	14.1
253	1	30	0.1	30.0
253	11	820	15.5	356.9
253	36	2300	37.0	260.3
253	18	4300	27.8	391.3
253	40	6600	80.4	508.7
253	40	6600	80.5	509.5
2	2	270	1.8	225.0
2	1	89	0.4	89.0
2	2	4400	18.9	2385.0
2	1	530	2.1	530.0
2	1	96	0.4	96.0
2	0	0	0.0	0.0
253	0	0	0.0	0.0
253	0	0	0.0	0.0
253	0	0	0.0	0.0
253	0	0	0.0	0.0
253	0	0	0.0	0.0
253	1	0.1	0.0	0.1
169	17	3.98	0.1	0.8
11	0	0	0.0	0.0
169	16	0.2	0.0	0.2

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL - 2012 - 2013

Location ID	SH_MW09				SH_MW10				FH_MW101			
Well Depth (m)	10				10				7.8			
Screened Interval	4-10m				4-10m				1-7.8m			
Sampled Date	6/03/2012	7/06/2012	6/09/2012	6/03/2013	6/03/2012	7/06/2012	6/09/2012	6/03/2013	9/03/2012	12/06/2012	4/09/2012	6/03/2013
Lab Batch	ES1205485	ES1214335	ES1221566	ES1305223	ES1205485	ES1214335	ES1221566	ES1305223	EP1201888	ES1214577	ES1221483	ES1305223
Sample Type	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary

ChemName	Unit	LOR	Adopted ILs										
BTEXN Compounds													
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<5	<2	<2	<2	<5	<2	<2	<2	<2	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	<5	<5	<5	<5	NA	NA	<5	<5	<5	<5
Total Petroleum Hydrocarbons													
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	µg/L	0		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Recoverable Hydrocarbons													
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16-C34 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID	FH_MW102							FH_MW103				
Well Depth (m)	6							6.8				
Screened Interval	1-6m							1-6.8				
Sampled Date	6/03/2013	6/03/2013	12/03/2012	13/06/2012	4/09/2012	4/09/2012	4/09/2012	6/03/2013	12/03/2012	12/03/2012	12/03/2012	13/06/2012
Lab Batch	ES1305223	ES1305223	ES1205892	ES1214657	ES1221483	ES1221483	78502	ES1305223	ES1205892	ES1205892	SE106317	ES1214657
Sample Type	Duplicate	Duplicate	Primary	Primary	Primary	Duplicate	Triplicate	Primary	Primary	Duplicate	Triplicate	Primary

ChemName	Unit	LOR	Adopted ILs												
BTEXN Compounds															
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1
Toluene	µg/L	0.5		<2	<2	<5	<2	<2	<2	<1	<2	<5	<5	<0.5	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<2	<1	<2	<2	<2	<0.5	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<1	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<2	<1	<2	<2	<2	<0.5	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	<5	<5	<5	<5	<5	<5	NA	<5	NA	NA	NA	<5
Total Petroleum Hydrocarbons															
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<20	<10	<20	<20	<20	<40	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<100	<50
C15-C28 fraction	µg/L	0		<100	<100	<100	<100	100	100	<100	<100	<100	<100	<200	<100
C29-C36 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<100	<50	<50	<50	<200	<50
C10-C36 fraction (sum)	µg/L	50		<50	<50	<50	<50	100	100	<250	<50	<50	<50	<500	<50
Total Recoverable Hydrocarbons															
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<20	NA	<20	<20	<20	NA	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<20	NA	<20	<20	<20	NA	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	NA	<100	<100	<100	NA	<100
>C16-C34 fraction	µg/L	100		<100	<100	<100	<100	100	110	NA	<100	<100	<100	NA	<100
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	NA	<100	<100	<100	NA	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	ND	ND	100	110	NA	ND	ND	ND	NA	ND

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID					WA_MW106				WA_MW108				SMW_MW113											
Well Depth (m)					8.2				6.3				7											
Screened Interval					1-8.2m				1-6.3m				1-7m											
Sampled Date	4/09/2012		4/03/2013		12/12/2012		9/03/2012		14/06/2012		5/09/2012		11/12/2012		5/03/2013		26/06/2013		26/06/2013		12/03/2012		12/06/2012	
Lab Batch	ES1221483		ES1304969		ES1229380		EP1201888		ES1214894		ES1221566		ES1229380		ES1305174		ES1314611		ES1314611		ES1205892		ES1214577	
Sample Type	Primary		Primary		Primary		Primary		Primary		Primary		Primary		Primary		Primary		Duplicate		Primary		Primary	

ChemName	Unit	LOR	Adopted ILs												
BTEXN Compounds															
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<5	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Total Petroleum Hydrocarbons															
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	µg/L	0		<50	NA	<50	90	<50	<50	80	110	<50	<50	<50	<50
C15-C28 fraction	µg/L	0		<100	NA	<100	1310	300	170	200	540	120	120	<100	<100
C29-C36 fraction	µg/L	0		<50	NA	<50	140	<50	<50	<50	<50	<50	<50	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	NA	<50	1540	300	170	280	650	120	120	<50	<50
Total Recoverable Hydrocarbons															
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	µg/L	100		<100	NA	<100	210	<100	<100	130	220	<100	<100	<100	<100
>C16-C34 fraction	µg/L	100		<100	NA	<100	1440	250	140	130	400	<100	<100	<100	<100
>C34-C40 fraction	µg/L	100		<100	NA	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	NA	ND	1650	250	140	260	620	ND	ND	ND	ND

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID	SMW_MW114				RR_MW115							
Well Depth (m)	7				7							
Screened Interval	1-7m				1-7m							
Sampled Date	4/09/2012	9/03/2012	12/06/2012	4/09/2012	9/03/2012	13/06/2012	4/09/2012	11/12/2012	5/03/2013	27/06/2013	9/03/2012	13/06/2012
Lab Batch	ES1221483	EP1201888	ES1214577	ES1221483	EP1201888	ES1214657	ES1221357	ES1229380	ES1305174	ES1314611	EP1201888	ES1214657
Sample Type	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary

ChemName	Unit	LOR	Adopted ILs												
BTEXN Compounds															
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	<5	<5	<5	<5	NA	<5	NA	<5	<5	<5	NA	<5
Total Petroleum Hydrocarbons															
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	µg/L	0		<100	<100	<100	<100	200	<100	<100	<100	<100	<100	150	<100
C29-C36 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	<50	<50	<50	200	<50	<50	<50	<50	<50	150	<50
Total Recoverable Hydrocarbons															
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C16-C34 fraction	µg/L	100		<100	<100	<100	<100	240	<100	<100	<100	<100	<100	190	<100
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	ND	ND	240	ND	ND	ND	ND	ND	190	ND

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID	WA_MW116						SH_MW117			SH_MW118		
Well Depth (m)	7						9.3			9.5		
Screened Interval	1-7m						1-9.3m			1-9.5m		
Sampled Date	4/09/2012	11/12/2012	5/03/2013	25/06/2013	25/06/2013	25/06/2013	7/03/2012	7/06/2012	6/09/2012	6/03/2012	7/06/2012	6/09/2012
Lab Batch	ES1221357	ES1229380	ES1305174	ES1314375	ES1314375	384097	ES1205485	ES1214335	ES1221566	ES1205485	ES1214335	ES1221566
Sample Type	Primary	Primary	Primary	Primary	Duplicate	Triplicate	Primary	Primary	Primary	Primary	Primary	Primary

ChemName	Unit	LOR	Adopted ILs												
BTEXN Compounds															
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<2	<2	<2	<2	<2	<1	<5	<2	<2	<5	<2	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<1	<2	<2	<2	<2	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<1	<2	<2	<2	<2	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	NA	<5	<5	<5	<5	<20	<5	<5	<5	NA	NA	<5
Total Petroleum Hydrocarbons															
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	60	100	70
C15-C28 fraction	µg/L	0		<100	<100	<100	<100	<100	<100	<100	<100	<100	760	700	850
C29-C36 fraction	µg/L	0		<50	<50	<50	<50	<50	<100	<50	<50	<50	<50	170	170
C10-C36 fraction (sum)	µg/L	50		<50	<50	<50	<50	<50	<100	<50	<50	<50	820	970	1090
Total Recoverable Hydrocarbons															
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	<100	<100	<50	<100	<100	<100	120	190	180
>C16-C34 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	570	860	830
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	ND	ND	ND	ND	ND	ND	ND	690	1050	1010

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID	SH_MW119							SH_MW120	WA_MW121			
Well Depth (m)	9.5							6.5	7			
Screened Interval	1-9.5m							1-6.5m	1-7m			
Sampled Date	7/03/2012	7/06/2012	7/06/2012	7/06/2012	6/09/2012	6/03/2013	6/03/2013	7/06/2012	9/03/2012	14/06/2012	4/09/2012	5/03/2013
Lab Batch	ES1205485	ES1214335	ES1214335	74692	ES1221566		ES1305223	ES1214335	EP1201888	ES1214894	ES1221357	ES1305174
Sample Type	Primary	Primary	Duplicate	Triplicate	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary

ChemName	Unit	LOR	Adopted ILs													
BTEXN Compounds																
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	NA	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<5	<2	<2	<1	<2	NA	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<1	<2	NA	<2	<2	<2	<2	<2	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	NA	<2	<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<1	<2	NA	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	<5	<5	<5	NA	<5	NA	<5	<5	NA	<5	<5	<5	<5
Total Petroleum Hydrocarbons																
C6-C9 fraction	µg/L	0		<20	<20	<20	<10	<20	NA	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	NA	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	µg/L	0		<100	<100	<100	<100	<100	NA	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	µg/L	0		<50	<50	<50	<100	<50	NA	<50	<50	<50	<50	<50	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	<50	<50	<250	<50	NA	<50	<50	<50	<50	<50	<50	<50
Total Recoverable Hydrocarbons																
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	NA	<20	NA	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	NA	<20	NA	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	NA	<100	NA	<100	<100	<100	<100	<100	<100	<100
>C16-C34 fraction	µg/L	100		<100	<100	<100	NA	<100	NA	<100	<100	<100	<100	<100	<100	<100
>C34-C40 fraction	µg/L	100		<100	<100	<100	NA	<100	NA	<100	<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID				SP_MW122						KD_MW125					
Well Depth (m)				7						6.8					
Screened Interval				1-7m						1-6.8m					
Sampled Date				7/03/2012	7/06/2012	4/09/2012	4/03/2013	4/03/2013	4/03/2013	9/03/2012	13/06/2012	4/09/2012	12/12/2012	4/03/2013	27/06/2013
Lab Batch				ES1205485	ES1214335	ES1221483	ES1304969	ES1304969	86813	EP1201888	ES1214657	ES1221357	ES1229380	ES1304969	ES1314611
Sample Type				Primary	Primary	Primary	Primary	Duplicate	Triplicate	Primary	Primary	Primary	Primary	Primary	Primary

ChemName	Unit	LOR	Adopted ILs												
BTEXN Compounds															
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1	<1	NA	<1	<1
Toluene	µg/L	0.5		<5	<2	<2	<2	<2	<1	<2	<2	<2	NA	<2	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<1	<2	<2	<2	NA	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	NA	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<1	<2	<2	<2	NA	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND
Naphthalene (VOC)	µg/L	5	16	<5	<5	<5	<5	<5	NA	<5	<5	<5	NA	<5	<5
Total Petroleum Hydrocarbons															
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<10	<20	<20	<20	NA	<20	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	NA	<50	<50
C15-C28 fraction	µg/L	0		<100	<100	<100	<100	<100	<100	<100	<100	<100	NA	<100	<100
C29-C36 fraction	µg/L	0		<50	<50	<50	<50	<50	<100	<50	<50	<50	NA	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	<50	<50	<50	<50	<250	<50	<50	<50	NA	<50	<50
Total Recoverable Hydrocarbons															
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<10	<20	<20	<20	NA	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<10	<20	<20	<20	NA	<20	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	<100	<100	<50	<100	<100	<100	NA	<100	<100
>C16-C34 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	NA	<100	<100
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100	<100	NA	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID	KD_MW127								KD_M			
Well Depth (m)	6.8								7			
Screened Interval	1-6.8m								0.8			
Sampled Date	9/03/2012	12/06/2012	4/09/2012	4/09/2012	4/09/2012	11/12/2012	4/03/2013	27/06/2013	7/03/2012	7/03/2012	7/03/2012	12/06/2012
Lab Batch	EP1201888	ES1214577	ES1221357	ES1221357	78400	ES1229380	ES1304969	ES1314611	ES1205485	ES1205485	SE106212	ES1214577
Sample Type	Primary	Primary	Primary	Duplicate	Triplicate	Primary	Primary	Primary	Primary	Duplicate	Triplicate	Primary

ChemName	Unit	LOR	Adopted ILs												
BTEXN Compounds															
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.5	<1
Toluene	µg/L	0.5		<2	<2	<2	<2	<1	<2	<2	<2	<2	<5	<5	<0.5
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<1	<2	<2	<2	<2	<2	<0.5	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<1	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<1	<2	<2	<2	<2	<2	<0.5	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	NA	NA	NA	NA	NA	<5	<5	<5	<5	<5	NA	<5
Total Petroleum Hydrocarbons															
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<10	<20	<20	<20	<20	<20	<40	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<100	<50
C15-C28 fraction	µg/L	0		570	270	220	220	<100	<100	150	100	<100	<100	<200	500
C29-C36 fraction	µg/L	0		70	<50	<50	<50	<100	<50	<50	<50	<50	<50	<200	220
C10-C36 fraction (sum)	µg/L	50		640	270	220	220	<250	<50	150	100	<50	<50	<500	720
Total Recoverable Hydrocarbons															
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	NA	<20	<20	<20	<20	<20	NA	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	NA	<20	<20	<20	<20	<20	NA	<20
>C10-C16 fraction	µg/L	100		100	120	<100	<100	NA	<100	<100	<100	<100	<100	NA	110
>C16-C34 fraction	µg/L	100		620	230	160	180	NA	<100	<100	<100	<100	<100	NA	680
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	NA	<100	<100	<100	<100	<100	NA	170
>C10-C40 fraction (sum)	µg/L	100		720	350	160	180	NA	ND	ND	ND	ND	ND	NA	960

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID	Well Depth (m)	Screened Interval	Sampled Date	Lab Batch	Sample Type
W128	.3	-7.3	4/09/2012	ES1221357	Primary
KD_MW134	6.6	1-6.6m	12/12/2012	ES1229380	Primary
			4/03/2013	ES1304969	Primary
			26/06/2013	ES1314611	Primary
			12/03/2012	ES1205892	Primary
			12/06/2012	ES1214577	Primary
			12/06/2012	ES1214577	Duplicate
			12/06/2012	ES1214577	Triplicate
			5/09/2012	ES1221566	Primary
			12/12/2012	ES1229380	Primary
			5/03/2013	ES1305174	Primary
			27/06/2013	ES1314611	Primary

ChemName	Unit	LOR	Adopted ILs												
BTEXN Compounds															
Benzene	µg/L	0.5	700	<1	NA	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<2	NA	<2	<2	<5	<2	<2	<2	<2	<2	<2	<2
Ethylbenzene	µg/L	0.5		<2	NA	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
m&p-Xylene	µg/L	2		<2	NA	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	NA	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Total Xylenes	µg/L	1.5		ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	<5	NA	<5	<5	NA	NA	NA	NA	<5	<5	<5	<5
Total Petroleum Hydrocarbons															
C6-C9 fraction	µg/L	0		<20	NA	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C10-C14 fraction	µg/L	0		<50	NA	<50	<50	70	<50	<50	<50	<50	80	70	<50
C15-C28 fraction	µg/L	0		<100	NA	<100	<100	710	240	320	260	210	410	620	210
C29-C36 fraction	µg/L	0		<50	NA	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	NA	<50	<50	780	240	320	260	210	490	690	210
Total Recoverable Hydrocarbons															
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	NA	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
C6-C10 fraction	µg/L	20		<20	NA	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
>C10-C16 fraction	µg/L	100		<100	NA	<100	<100	180	<100	110	110	<100	140	180	<100
>C16-C34 fraction	µg/L	100		<100	NA	<100	<100	400	220	220	230	150	310	480	140
>C34-C40 fraction	µg/L	100		<100	NA	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	NA	ND	ND	580	220	330	340	150	450	660	140

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID	KD_MW135							
Well Depth (m)	8							
Screened Interval	2-8m							
Sampled Date	9/03/2012	13/06/2012	4/09/2012	11/12/2012	11/12/2012	11/12/2012	5/03/2013	27/06/2013
Lab Batch	EP1201888	ES1214657	ES1221357	ES1229380	ES1229380	83189	ES1305174	ES1314611
Sample Type	Primary	Primary	Primary	Primary	Duplicate	Triplicate	Primary	Primary

ChemName	Unit	LOR	Adopted ILs								
BTEXN Compounds											
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<2	<2	<2	<2	<2	<1	<2	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<1	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<1	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	NA	NA	NA	<5	<5	<1	<5	<5
Total Petroleum Hydrocarbons											
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<10	<20	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50	<50	<50
C15-C28 fraction	µg/L	0		<100	<100	<100	<100	<100	<100	<100	<100
C29-C36 fraction	µg/L	0		<50	<50	<50	<50	<50	<100	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	<50	<50	<50	<50	<250	<50	<50
Total Recoverable Hydrocarbons											
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<10	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<10	<20	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	<100	<100	<50	<100	<100
>C16-C34 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	ND	ND	ND	ND	ND	ND

LEGEND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Marine Water 95% species protection

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems -
Freshwater 95% species protection

ND - Non detect - <LOR

NA - not analysed

Table A-2
Groundwater Analytical Results - Operational Wells Excluding Wells Containing LNAPL -

Location ID
Well Depth (m)
Screened Interval
Sampled Date
Lab Batch
Sample Type

KD_MW136					
8					
2-8m					
9/03/2012	13/06/2012	4/09/2012	11/12/2012	5/03/2013	27/06/2013
EP1201888	ES1214657	ES1221357	ES1229380	ES1305174	ES1314611
Primary	Primary	Primary	Primary	Primary	Primary

ChemName	Unit	LOR	Adopted ILs						
BTEXN Compounds									
Benzene	µg/L	0.5	700	<1	<1	<1	<1	<1	<1
Toluene	µg/L	0.5		<2	<2	<2	<2	<2	<2
Ethylbenzene	µg/L	0.5		<2	<2	<2	<2	<2	<2
m&p-Xylene	µg/L	2		<2	<2	<2	<2	<2	<2
o-Xylene	µg/L	2	350	<2	<2	<2	<2	<2	<2
Total Xylenes	µg/L	1.5		ND	ND	ND	ND	ND	ND
total BTEX	µg/L	-		ND	ND	ND	ND	ND	ND
Naphthalene (VOC)	µg/L	5	16	NA	NA	NA	<5	<5	<5
Total Petroleum Hydrocarbons									
C6-C9 fraction	µg/L	0		<20	<20	<20	<20	<20	<20
C10-C14 fraction	µg/L	0		<50	<50	<50	<50	<50	<50
C15-C28 fraction	µg/L	0		<100	<100	170	<100	<100	<100
C29-C36 fraction	µg/L	0		<50	<50	<50	<50	<50	<50
C10-C36 fraction (sum)	µg/L	50		<50	<50	170	<50	<50	<50
Total Recoverable Hydrocarbons									
C6-C10 fraction (F1 minus BTEX)	µg/L	20		<20	<20	<20	<20	<20	<20
C6-C10 fraction	µg/L	20		<20	<20	<20	<20	<20	<20
>C10-C16 fraction	µg/L	100		<100	<100	<100	<100	<100	<100
>C16-C34 fraction	µg/L	100		<100	<100	140	<100	<100	<100
>C34-C40 fraction	µg/L	100		<100	<100	<100	<100	<100	<100
>C10-C40 fraction (sum)	µg/L	100		ND	ND	140	ND	ND	ND

Exceedance of Adopted ILs based on the more stringent value from:

ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems - Marine Water 95% species protection
ANZECC/ARMCANZ 2000 trigger values for the protection of aquatic ecosystems - Freshwater 95% species protection

NA - not analysed

23 sampling locations, 6 sampling events, March 2012 to June 2013				
Number of Samples	Samples >LOR	Max	Average	Average >LOR
122	0	0	0	0
122	0	0	0	0
122	0	0	0	0
122	0	0	0	0
122	0	0	0	0
122	0	0	0	0
122	0	0	0	0
122	0	0	0	0
122	0	0	0	0
122	9	110	6.0	81.1
122	30	1310	88.5	360.0
122	5	220	6.3	154.0
122	30	1540	100.8	410.0
122	0	0	0.0	0.0
122	0	0	0.0	0.0
122	14	220	17.2	150.0
122	26	1440	77.2	362.3
122	1	170	1.4	170.0
122	26	1650	95.8	449.6

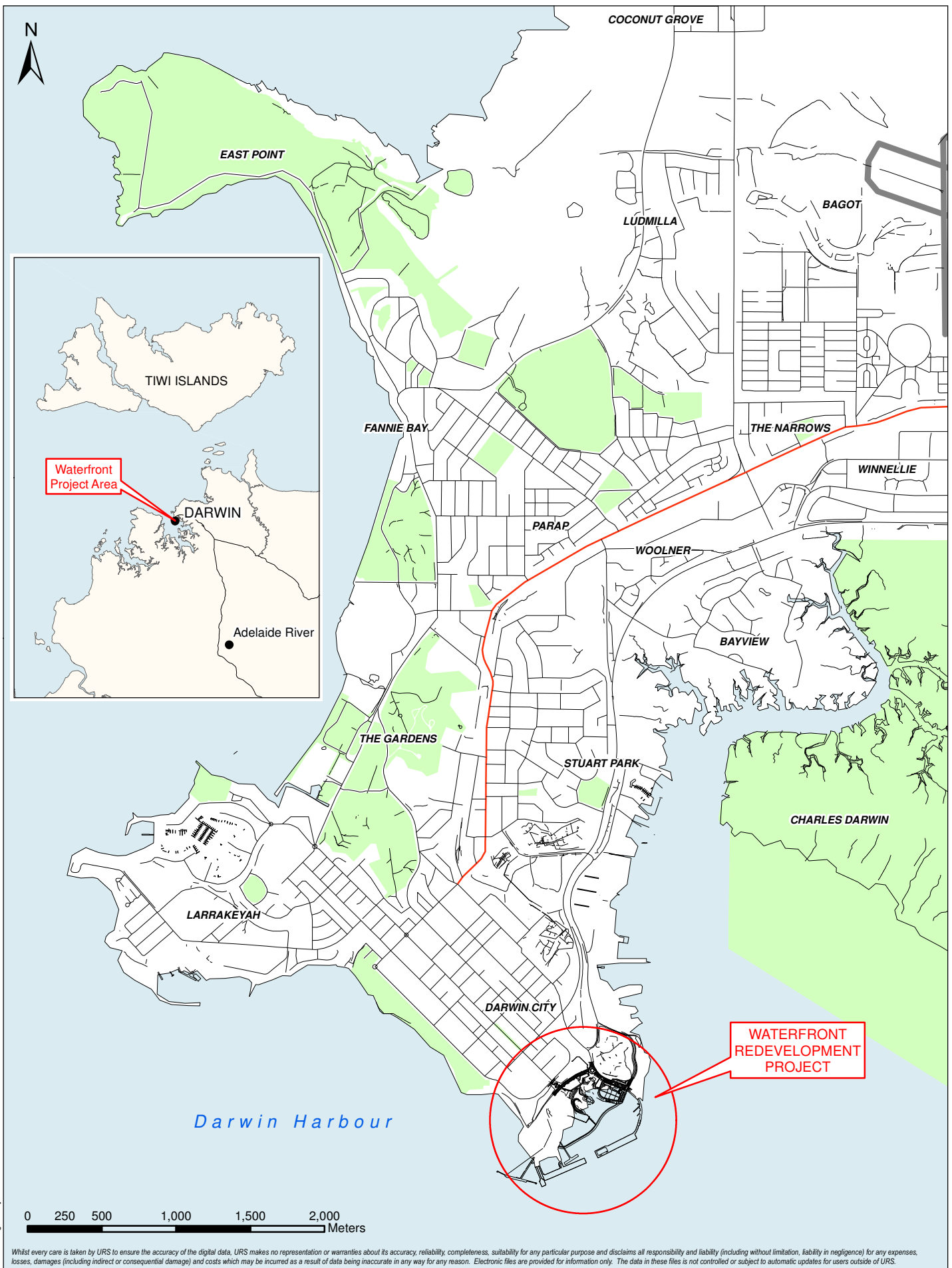
Table A-3
Mole Fraction Calculations

	Average Observed Concentration (mg/kg)	Average Observed Mass Fraction	Assumed Average Molecular Weight* (g/mole)	Moles	Mole Fraction**
Naphthalene	0.1	7.8E-04	128	7.8E-04	1.5E-04
C6-C9	30	2.9E-02	110	2.7E-01	5.2E-02
C10-C14	357	3.4E-01	160	2.2E+00	4.2E-01
C15-C28	260	2.5E-01	200	1.3E+00	2.5E-01
C29-C36	391	3.8E-01	265	1.5E+00	2.8E-01
Totals	1038	1		5.3E+00	1.0E+00
* Average concentration based on average of results >LOR					
** Molecular weights adopted from TPHCWG (Vol 3, July 1997)					

	Average Observed Concentration (µg/L)	Average Observed Mass Fraction	*Assumed Average Molecular Weight (g/mol)	Moles	Mole Fraction**
C6-C9	0	0.0E+00	110	0.0E+00	0.0E+00
C10-C14	81.1	1.4E-01	160	5.1E-01	1.9E-01
C15-C28	360	6.0E-01	200	1.8E+00	6.7E-01
C29-C36	154	2.6E-01	400	3.9E-01	1.4E-01
Totals	595.1	1.0E+00		2.7E+00	1.0E+00
* Average concentration based on average of results >LOR					
** Molecular weights adopted from TPHCWG (Vol 3, July 1997)					

Appendix B Figures

Figure-B-1 Site Location Plan
Figure-B-2 Stage 2A Site Location
Figure-B-3 Stage 2A Sampling Locations 2003 to 2013



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DARWIN WATERFRONT PROJECT -
STAGE 2A

SITE LOCATION PLAN

URS

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File: 42213719-QRA-001.mxd

Drawn: JD

Approved: BA

Date: 21/01/2014

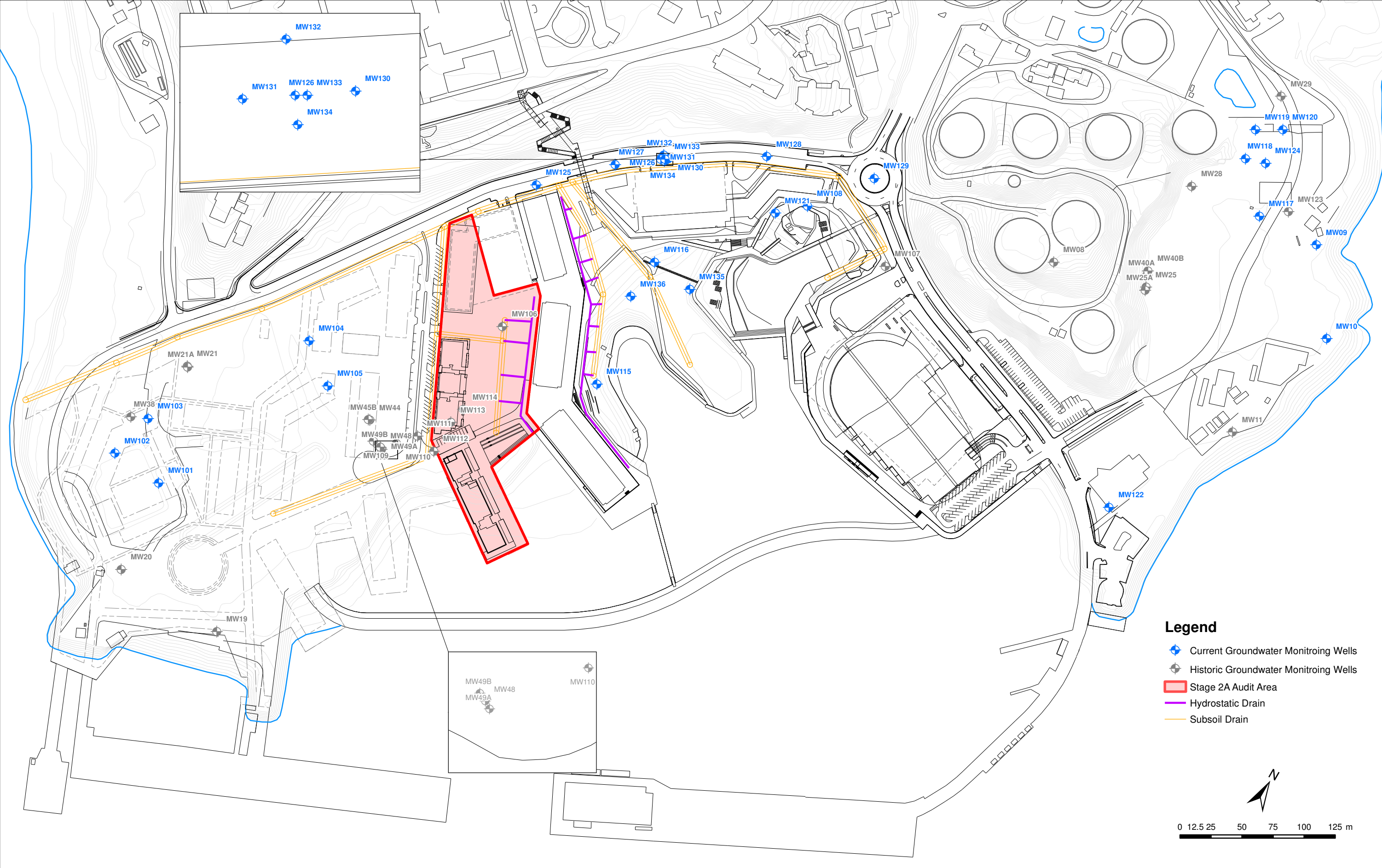
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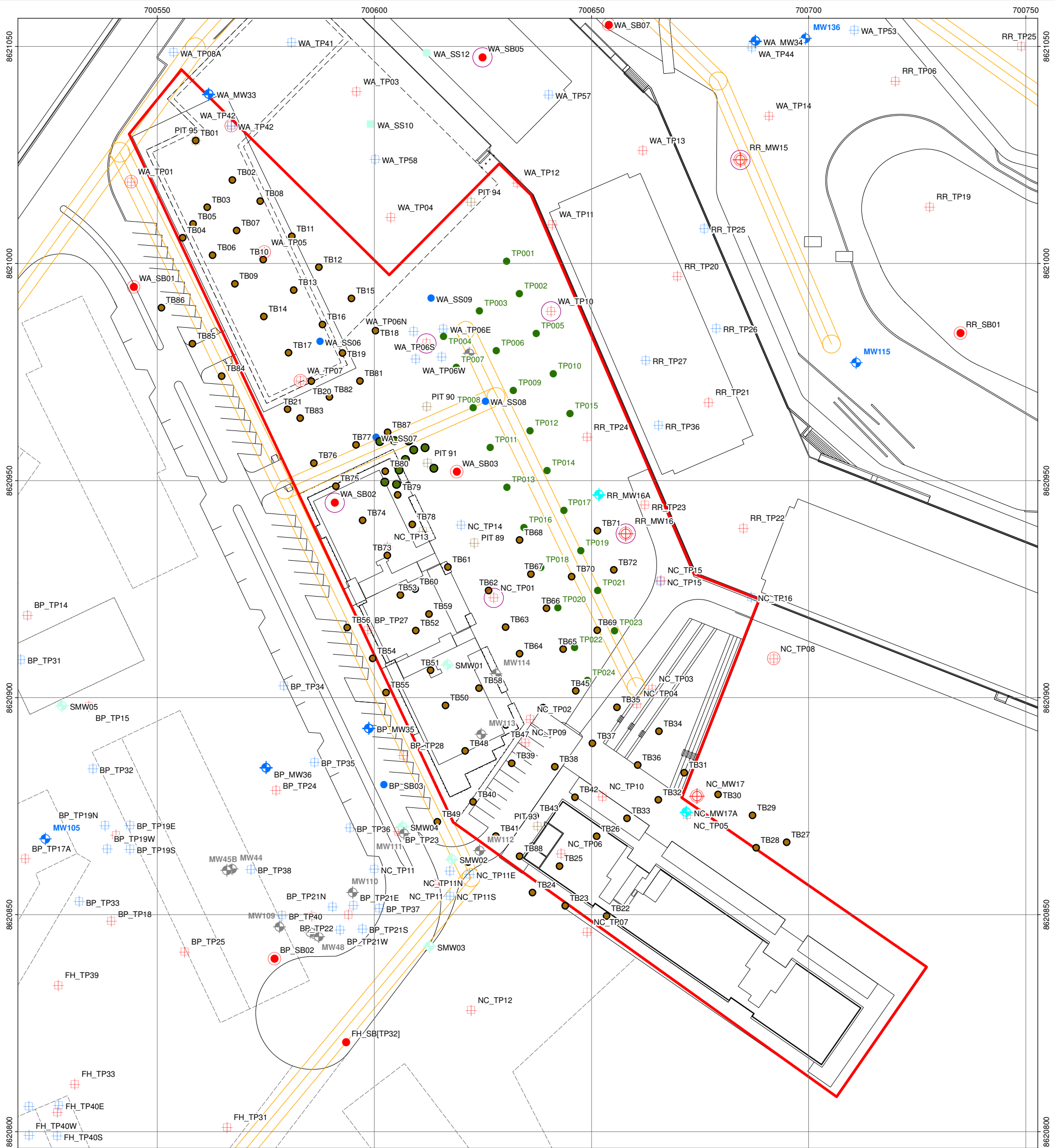
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Rev. A

A4







Legend

- | | |
|---------------------------------------|--|
| Current Groundwater Monitoring Wells | Groundwater Monitoring Wells |
| Historic Groundwater Monitoring Wells | Soil Bore |
| Stage 2A Audit Area | Surface and Shallow Samples |
| Subsoil Drain | Test Pit |
| | Acid Sulphate Soil Locations |
| | Potential asbestos containing fragments collected and analysed |
| | Soil Samples analysed for asbestos fibres |

- Phase 2 Sampling Locations**
- Groundwater Monitoring Well
 - Shell Monitoring Well
 - Nested Well for PSH Delineation
 - Phase 2 Groundwater Monitoring Well
 - Soil Bore
 - Test Pit
 - Surface and Shallow Samples

- Phase 3 Sampling Locations**
- Bore Hole (August 2009)
 - Test Pit (August 2009)
 - 2013 Validation Samples
 - 2013 Excavation Sample Locations



0 5 10 20 30 40 m

Datum: GDA 94 Zone 52

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DARWIN WATERFRONT PROJECT -
STAGE 2A

**STAGE 2A
SAMPLING LOCATIONS
2003 TO 2013**

URS

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File No: 42213719-QRA-003.mxd

Drawn: JD

Approved: TS

Date: 21/01/2014

Figure:

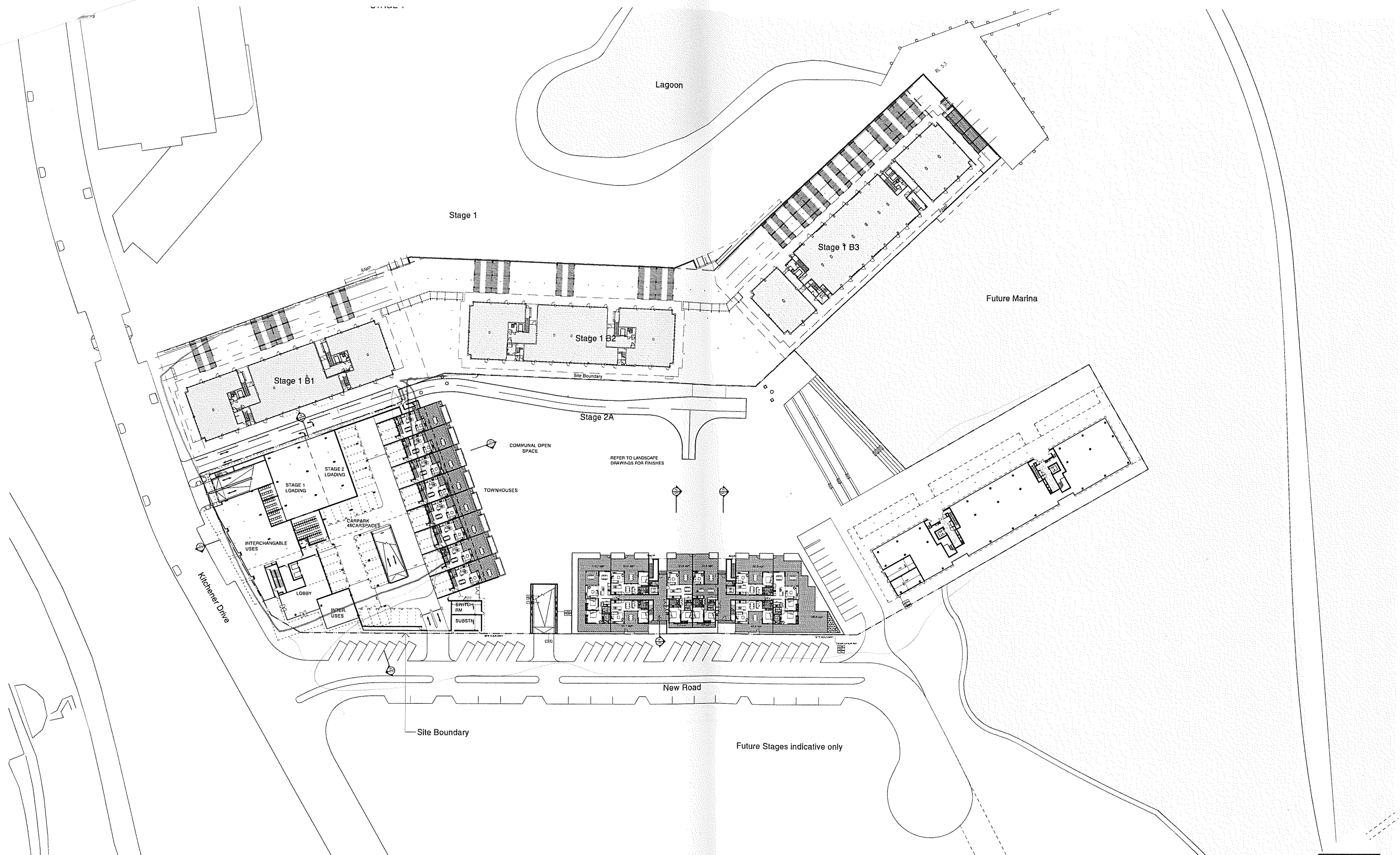
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Rev. A

A3



Appendix C Proposed Building Layouts



B2	02/09/09	Preliminary Pricing	AW	ECPAY
B1	03/08/09	DA Submission	SV	ECPAY
Rev.	Date	Description	Initial	Checked

TOGA GROUP

Darwin City Waterfront
Stage 2a

Level 00
Ground Floor

4 5 6

Check all dimensions and site conditions prior to commencement of any work. The purchaser or user of any materials, fittings, plant, services or equipment and the provision of other drawings and/or the location of any construction.
Do not scale drawings - refer to figure dimensions only. Any discrepancies shall immediately be referred to the architect.
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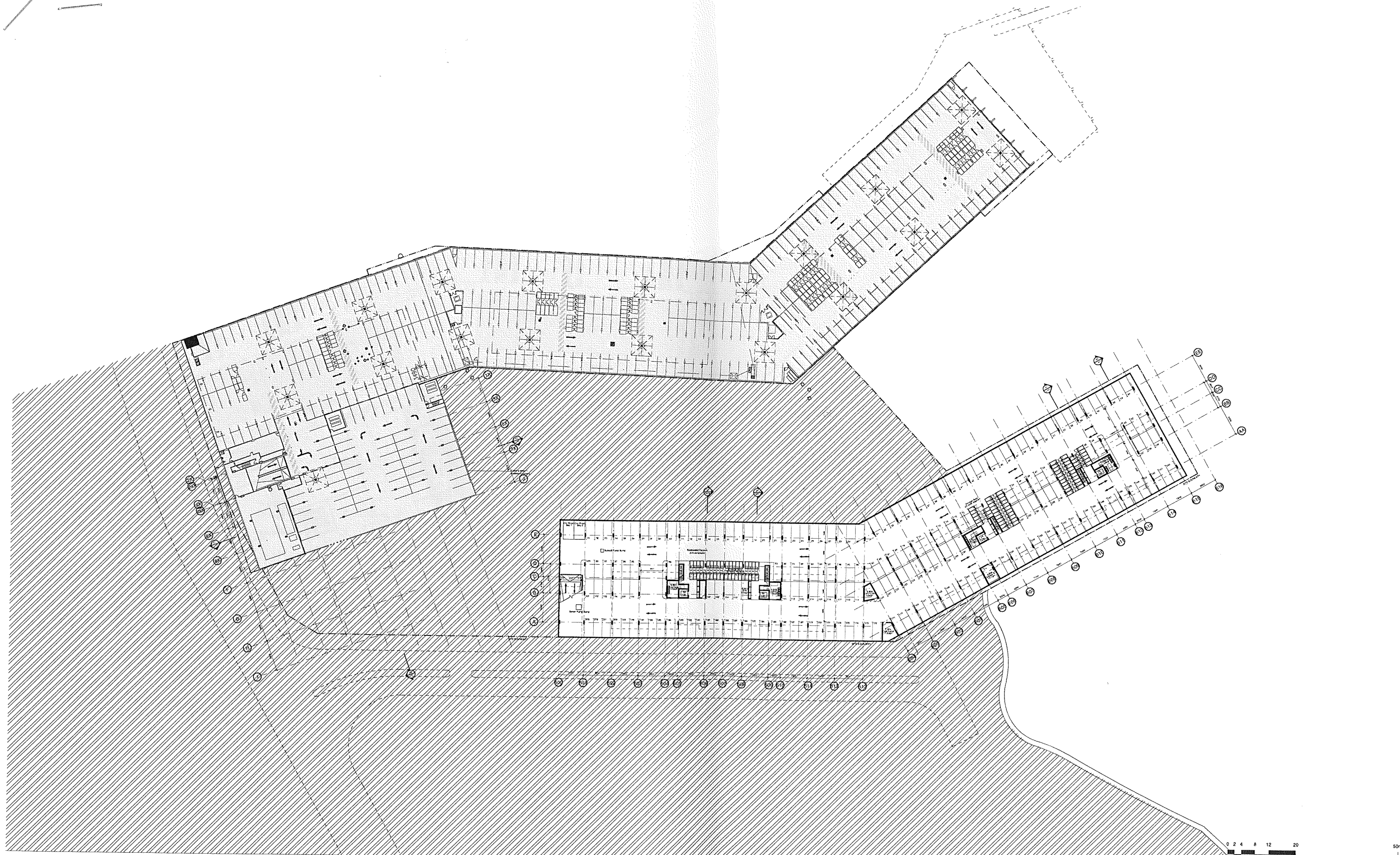
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Status	DA
Plot Date	Wednesday, 2 September 2009 10:39:49
Plot File	S:\10986-10999\S10986_TOGA_DARWIN\00_MAIN\CAD\PLOTS\DA_BLDG4 A02-002 B1.DWG
Drawing No.	[Revision] A02-002[B2]

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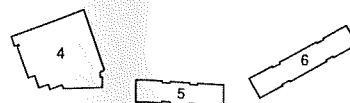
Rev. Date	Description	Initial	Checked
B2 02/29/09	Preliminary Pricing	AW	EC/PAY
B1 03/08/09	DA Submission	SV	EC/PAY



Darwin City Waterfront
Stage 2a

Basement
Level 001

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Plot Date	Wednesday, 2 September 2009 11:22:38
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Drawing No.	[Revision] A02-001[B2]

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Appendix D Quantification Assumptions

A principally qualitative approach to risk assessment has been undertaken at the Stage 2A site based on identified receptor pathways, the limited magnitude and extent of hydrocarbon contamination identified at the site, and the fact that the majority of the residual impact is non-volatile with none of the relatively toxic mono-aromatic BTEX compounds identified.

Previous quantitative risk assessment work completed across the Waterfront Precinct with Stage 1 and Bitumen Plant risk assessments has concluded that no unacceptable risks to human health were present based on the proposed high density residential and public open space development.

Development of the Stage 2A site is largely consistent with the completed Stage 1 residential building site and with the development proposed for the Bitumen Plant site. Quantitative modelling consistent with Stage 1 and the Bitumen Plant site has been included in this appendix as a secondary line of evidence to support the conclusions of the qualitative assessment.

D.1 Data Evaluation

Data for the Stage 2A site is evaluated in Section 3. The nature of TPH at the site and the application of the data in a quantitative assessment is completed in this appendix.

D.1.1 Nature of TPH Present at the Site

Both the soil and groundwater vapour transport models used in the risk assessment include terms which estimate the vapour concentration at the source (the maximum vapour concentration) and then calculate the attenuation of this concentration away from the source zone.

In the case of the soil model, the saturation soil concentration (above which free phase will form) is a function of the soil organic carbon content, the soil bulk density, the moisture content of the soil, the solubility and Henry's Law constant for the COPC. These same parameters are used to estimate the source vapour concentration.

In groundwater, whether saturation has occurred and a free phase is present is determined by the solubility of the given COPC and also by the nature and concentrations of other constituents present. The solubility of an individual compound in a mixture (e.g. benzene in petrol) is significantly less than the pure phase compound solubility; determined by the proportion of the component in the mixture (e.g. 1%). The source zone vapour concentration is calculated from the dissolved phase concentration and the Henry's Law constant.

Above the limit of saturation the source zone vapour concentration is determined (via Raoult's Law) for each component from the pure phase vapour pressure and the mole fraction (proportion) of the given component. This is the same for both soil and groundwater sources. The free phase calculation effectively provides an upper limit of the concentration of volatile COPC in the vapour phase in the source zone.

Estimation of Soil Saturation

The soil concentration (C_{soil}) at which immiscible hydrocarbon phase forms in soil matrix is given by (ASTM 1739-95):

$$C_{\text{soil}} = S_i / \rho_s \cdot (\theta_w + k_s \cdot \rho_s + H \theta_v)$$

where:

- S_i = the pure phase component solubility

Appendix D - Quantification Assumptions

- ρ_s = soil bulk density
- θ_w = volumetric content of soil pore water
- k_s = sorption coefficient = $K_{oc} * f_{oc}$
- K_{oc} = organic carbon partitioning coefficient
- f_{oc} = fraction of organic carbon in the soil matrix
- H = Henry's Law coefficient
- θ_v = volumetric content of soil vapour

In essence, the three terms represent the quantity of hydrocarbon which will be present in the soil-water, adsorbed and soil vapour phases. The soil saturation concentration is therefore dependent upon soil properties such as the soil bulk density, fraction of organic carbon and the volumetric content of soil and water, but also contaminant-specific properties such as the Henry's Law coefficient and the organic carbon partitioning coefficient.

This three-phase model has been used to calculate the soil vapour concentration at the depth of the soil source. However, consistent with guidance outlined by the UK Environment Agency and adopted by CRC CARE¹, the ASTM equilibrium partitioning equations have been modified to reduce the predicted vapour-phase concentrations by a factor of 10, based on a review of empirical evidence.

In order to maintain the integrity of the Henry's Law relationship, the CRC CARE have approached this issue by revising up the soil saturation algorithm by the same factor of 10. This results in estimation of higher soil concentrations prior to the formation of a separate phase. This approach has also been adopted in this assessment.

For the volatile compounds under consideration in this appendix and adopted soil conditions, **Table D-1** summarises the saturated soil concentrations.

D.2 Exposure Assessment

D.2.1 Potentially Significant Exposure Pathways

When quantifying exposure, the risk assessment process focuses on exposure occurring over a prolonged period; that is, chronic exposure that occurs over years and possibly a lifetime. Whilst an activity may occur infrequently (i.e., several days a year), it may occur regularly over a long period and, therefore, have the potential to increase long term or chronic intake of the chemical. The approach and equations used to quantify exposure are derived from guidance provided by the USEPA (1989, 1991, 1996, 2002, 2004 and 2009). In applying these equations to the quantification of exposure the following are required:

- Identification of relevant exposure parameters for each of the identified exposure pathways and receptors. The magnitude of the chemical intake (where relevant) or exposure is a function of a number of variables (termed exposure parameters), which describe the physical, and behavioural parameters relevant to the potentially exposed population; and
- Estimation of the chemical concentration in each medium relevant to the receptor groups and exposure pathways. This involves the use of relevant soil and groundwater data collected from the area as well as a number of models to estimate exposure concentrations in air.

¹ CRC CARE (2011) – Technical Report No 10- Health Screening Levels for Petroleum hydrocarbons in soil and groundwater, Part 1: Technical Development Document.

Appendix D - Quantification Assumptions

The quantitative assessment presented in this appendix has addressed potential exposure to COPCs identified by providing an estimate of a Reasonable Maximum Exposure (RME) scenario. This has been undertaken by using exposure parameters/variables and chemical concentrations that define the highest exposure that is theoretically possible to occur in the area assessed. The RME is likely to provide a conservative or overestimate of total exposure and, therefore, health risk. This approach follows ANZECC/NHMRC guidance (1992) supplemented by USEPA guidance (USEPA, 1989).

D.2.2 Exposure Parameters

The potential receptors and significance of relevant exposure pathways have been identified in **Figure 4-1** and discussed in **Section 4.2**. In order to quantify the risks to these receptors associated with site contamination intake factors have been calculated for the significant receptors and exposure pathways as detailed in **Appendix E** with the RiskE modelling results.

Where available, exposure parameters have been obtained from Australian sources (CRC CARE 2011, enHealth 2012). As required, this has been supplemented with data from the USEPA (1989, 1992, 1996, 2002 and 2009).

The quantification of potential inhalation exposures has followed guidance provided by the USEPA (2009). This approach recognises the approach and uncertainties associated with the derivation of inhalation toxicity values and requires the consideration of an exposure concentration rather than an intake. Therefore the approach adopted does not require receptor and age specific inputs on body weight and inhalation rates; rather it requires consideration of exposure time, frequency and duration.

All relevant references, assumptions, comments and equations used in the calculation of intake factors are included in **Appendix E**.

Residents

- Consideration is given to adults, older children and young children who may be exposed for 14 years, 10 years and 6 years respectively such that a total 30 year lifetime exposure may occur while living in the area above contaminated groundwater.
- During this time it is assumed that adults and children may be home for 337 days (every day of the year minus 4 weeks holiday) and the contamination remains beneath the area for the entire 70 years.
- Assuming the basement of a residential building will only be used as a car park, the daily exposure time has been estimated as 0.5 hr/day for young children and 1 hr/day for older children and adults. The remainder of the day is assumed to be spent indoors. This is considered conservative and should overestimate likely exposure times.

D.2.3 COPC

Based on the potentially significant exposure pathways identified in **Section 4.2**, it is assessed that only those contaminants which are volatile represent a potentially significant exposure risk. Since essentially no BTEX has been found in either soil or groundwater at the site, the COPC are considered to be limited to the C6-C14 TPH fractions and volatile PAHs such as naphthalene. It is noted that the majority of the data for the site predates the recent change in TPH/TRH banding ranges, however C10-14 and C10-C16 have been considered equivalent from a toxicological and physico-chemical perspective in this assessment.

Appendix D - Quantification Assumptions

D.2.4 Estimation of Representative Soil and Groundwater Concentrations of COPC

Soil

As discussed in **Section 3.3**, little hydrocarbon impact was identified in the Stage 2A area. This is consistent with the data from the broader Waterfront precinct and with observations undertaken during basement excavation and Stage 2A site works.

In the case of the Stage 1 Residential and Bitumen Plant risk assessments it was assumed that PSH was present in soils. The presence of PSH represents an upper limit to the source vapour concentration for a given mole fraction. Comparison of Stage 2A soil concentrations to the saturated soil concentrations below indicates that a limited number of TPH C10-C14 results (assuming 50:50 aliphatic:aromatic split) exceed the practical solubility limits of aliphatic TPH in soil, although PSH is not considered widely present.

Table-D-1 Theoretical TPH Soil Saturation Concentrations

Analyte	Saturated Soil Concentration (mg/kg)
Naphthalene	178
TPH C6-C9 Aromatic	457
TPH C6-C9 Aliphatic	77
TPH C10-C14 Aromatic	191
TPH C10-C14 Aliphatic	33

As such, the average concentrations for the results greater than LOR have been used to derive mole fractions for the various TPH chain lengths (based on total TPH present), as shown in **Table D-2**, below.

Table-D-2 TPH Mole Fractions – Soil – Average of Results >LOR

	Number of Results >LOR	Total Samples	*Average Observed Concentration (mg/kg)	Average Observed Mass Fraction	Assumed Average Molecular Weight* (g/mole)	Mole Fraction**
Naphthalene	1	253	0.1	0.000096	128	0.00015
C6-C9	1	253	30	0.029	110	0.052
C10-C14	11	253	357	0.34	160	0.42
C15-C28	36	253	260	0.25	200	0.25
C29-C36	18	253	391	0.38	265	0.28
Totals			1038	1		1
* Average concentration based on average of results >LOR						
** Molecular weights adopted from TPHCWG (Vol 3, July 1997)						

In order to utilise the TPH fraction toxicity information outlined in **Section D-5**, the aliphatic and aromatic components of the TPH concentrations need to be identified. Two soil samples from the site were analysed for aromatic/aliphatic speciation with an average aliphatic/aromatic ratio of 90:10, however as only two samples were speciated a more conservative 50:50 aliphatic/aromatic split has been adopted.

Appendix D - Quantification Assumptions

The approach adopted for the fractionation of TPH in soils and groundwater into aromatic and aliphatic components is summarised below:

- TPH C6-C9 – it is assumed that the total BTEX concentration reported is representative of the aromatic portion of TPH (and is assessed on the basis of individual BTEX compounds) and the remaining TPH (i.e. total TPH C6-C9 minus total BTEX) is representative of the aliphatic portion of the TPH fraction. As no significant concentrations of BTEX were detected in soil it has been assumed that 100% of the TPH C6-C9 is aliphatic.
- The higher TPH fractions have been split 50:50 using a conservative assumption that the TPH fractions in soil and groundwater are representative of petrol which is approximately 50% aromatic compounds and 50% aliphatic compounds (conservative value for gasoline as per Park, 1999).

Historical analysis of soil samples at the Waterfront precinct comprised over 300 samples for the “standard” TPH analysis and 22 samples for the speciated aromatic/aliphatic TPH analysis. While the split of aromatic and aliphatic TPH for these 22 samples varied from approximately 35% to 65%, on average the aromatic/aliphatic split was approximately 50:50.

It is considered a reasonable approach to adopt this 50:50 split from the Waterfront precinct for the Stage 2A site in order to utilise the available toxicity data for the aromatic and aliphatic components. The sensitivity analysis (**Section E.4.7**) reviews the implication of this assumption.

Groundwater

As discussed in **Section 3.3**, little hydrocarbon impact was evident across broader Waterfront precinct monitoring network including Stage 2A wells prior to destruction since October 2007 (excluding monitoring wells with PSH on Kitchener Drive – noting that the distribution of wells with observed PSH has been stable since 2007 and distant to the Stage 2A site). **Table D-3**, below, summarises the average of TPH results >LOR from groundwater monitoring across the broader Waterfront precinct over the 2012-2013 monitoring period. The maximum concentrations identified at representative wells for the site do not exceed the maximum solubilities for the TPH fractions. This is consistent with field observations during groundwater monitoring and groundwater observed during test pitting and test bores. Maximum groundwater concentrations (**Table 4-5**) have been considered for vapour modelling.

No aromatic/aliphatic speciation was undertaken for groundwater samples; accordingly (as for soil), it has been assumed that the proportions of aromatic and aliphatic C10-C14 TPH in PSH are a 50:50 split.

D.2.5 Chemical Concentrations in Air

For the Stage 2A investigation there is limited impact to act as a source of exposure based on the fact that only a very small portion of the limited hydrocarbon contamination identified at the site is volatile with none of the relatively toxic mono-aromatic BTEX compounds identified. Some minor impacts and data gaps do exist however, therefore quantification of risks has been based on the inhalation of volatile COPC identified in soils and groundwater that may migrate through overlying soils and into the indoor air environments.

No ambient air data are available for the indoor and outdoor air environments above the identified impacts. In addition it is noted that ambient air data may not be relevant for the assessment of emissions derived from subsurface soils and groundwater only as the COPC identified are common air

Appendix D - Quantification Assumptions

contaminants (derived from motor vehicles and other industrial emissions) and ambient air data will only provide a measure of all sources, atmospheric as well as the contribution from subsurface sources. The assessment presented in **Appendix D** provides an evaluation of risk to human health associated with the contribution of COPCs identified in soil and groundwater only. Hence exposure concentrations used in this appendix must be derived from the soil and groundwater source only.

Indoor air concentrations in areas above the impacted soil and groundwater can be estimated using two methods:

1. Modelling based on measured soil and/or groundwater concentrations and information on overlying soil and relevant buildings. This typically provides an overestimate of actual air concentrations as it relies on many assumptions and a number of conservative simplifications of a complex process; or
2. A combination of direct measurement (soil gas concentrations or surface flux emission rates) and modelling.

No surface emissions data or soil gas concentrations are available for the site and hence the estimation of potential indoor air concentrations has been undertaken using a vapour migration model and relevant concentrations at the source (soil and/or groundwater). The source concentrations considered relevant are the calculated mole fractions presented in **Tables D-2 and D-3**.

Phase Partitioning

Groundwater Sources

Consistent with standard industry practice, vapour-phase concentrations at the groundwater are estimated from equilibrium partitioning based on Henry's Law for dissolved phase impacts.;

Soil Sources

As discussed in **Section D.1.1**, the modified three-phase (vapour phase, dissolved in soil moisture and adsorbed) model outlined in ASTM (1995)² and adapted by CRC CARE (2011), has been used to calculate the soil vapour concentration at the depth of the soil source.

Residential with Basement

A number of vapour migration models are available to estimate concentrations of volatile COPC within different types of buildings. As discussed in **Section 2**, a portion of the development will have a residential structure which includes a contiguous basement. URS has used the Johnson & Ettinger model (US EPA Vapour Migration Guidance 2003) to estimate potential indoor air concentrations in the basement.

This model assumes there is advective (pressure-driven) flow close to the building in addition to the diffusion-driven flow (based on a concentration gradient) that dominates deeper in the soil profile. The approach used to estimate the Q_{soil} factor (volumetric flow rate into the building from the soil) used in the vapour migration modelling is based on the ratio of Q_{soil} to Q_{building} (the building volumetric air exchange rate) as advocated by CRC CARE (2011).

² ASTM (1995) -

Appendix D - Quantification Assumptions

A 200-fold attenuation factor ($0.005 Q_s/Q_b$) is advocated by CRC CARE for *residential* buildings (and used as default for all buildings), while they note that a higher attenuation factor (i.e. more dilution) of 0.001 (1000-fold attention) is considered likely to be appropriate for commercial buildings. As the proposed development for the site is a large, multi-story residential apartment (rather than smaller, individual dwellings), the assumption of the less conservative (0.001) attenuation factor is considered justifiable, however modelling has been undertaken with the more conservative value, to address the potential for smaller buildings to be constructed..

Where individual terrace style apartments are proposed (rather than large apartment buildings), then the recommended residential ratio of $0.005 Q_s/Q_b$ would likely be more appropriate at a screening level. It is noted, however, that in such a circumstance, the smaller building footprints would no longer serve to potentially preclude oxygen transport from the building perimeter and biodegradation of hydrocarbon vapours would therefore likely act to substantially reduce the concentration of vapours. No quantitative estimates of biodegradation have been incorporated into the assessment, however the local Darwin Waterfront environment is considered to be conducive to sub-surface biodegradation (as briefly discussed in **Section 3.3.4** for groundwater).

Key Input Parameters

Based on the proposed nature of the development, the key transport modelling assumptions include:

- The basement occupies the entire building envelope for Buildings 5 and 6 and a portion of Building 4, with contaminated soil and/or groundwater underlying the entire building. This is considered to be highly conservative, based on the available site data. This has been conservatively assumed to address potential localised impact issues.
- Advective flow is assumed to be active for both slab-on-grade and basement scenarios, with the ratio of Q_{soil} to $Q_{building}$ equal to 0.005 (i.e. 200-fold dilution).
- The building constructions are assumed to have a 200 mm clean gravel sub-base immediately underlying the slab.
 - For the *basement* construction modelling, impacted soil was assumed to lie 0.3 m below this sub-base depth.
 - For the slab-on-grade modelling, a minimum of 200 mm of clean gravel sub-base was assumed to be present, based on validation data (**Table A-1**). This showed no volatile impacts occurring at the site and negligible semi-volatile impact within 1.0 m of basement, with the majority of the identified soil impacts deeper than approximately 3 m below slab on ground structures.

Ground Floor (Living Area) Concentrations above Basement

The concentration of volatile COPCs (derived from a subsurface source) in floors above the basement (such as residential units on the ground-floor) is difficult to model due to the large number of variables which affect migration from the basement air to indoor air and between floors. The problem of vapour migration in the buildings is complex due to the partition wall between units as well as the size of the building air envelope. Other key influences include adjacent units, stairwell doors, garbage chutes, elevator shafts, electrical and plumbing ducts, ventilation shafts (air conditioning) and windows. All of these factors vary between buildings and constructions (including the age of the construction) and modelling vapour migration in a multi-storey building is very complex and difficult. It is even more difficult when the proposed building is not fully defined.

Appendix D - Quantification Assumptions

However based on review of the available information a simple approach has been adopted to estimate concentrations within indoor air on floors located above a basement of a building constructed as slab on grade using an attenuation factor. The attenuation factor relates the air concentration on the ground floor to that estimated (as discussed above) in the basement.

The attenuation factor adopted for the building considered on the site is based on the following:

- Adoption of an attenuation factor of 10 to estimate the concentration in air within the basement and ground floor or other upper floors of the proposed building. This factor has been adopted on the basis that the basement and ground floor (and subsequent floors) are not well connected with large openings. The attenuation factor relates the concentration in the ground floor (1/10) to the estimated air concentration in the basement level directly below the ground floor. The 10 fold attenuation factor used in this assessment is derived from a number of sources as follows:
 - Data collected by Olson and Corsi (2001) based on tracer experiments within a multi-storey home (with internal stairway access) indicates that the concentration within the first-floor is approximately 10 times lower than the concentration within the basement.
 - Review of the transfer of tobacco smoke between apartments within multi-storey buildings (between levels and across floors) indicated (CEE, 2004) that the transfer of air between floors of a multi-floor building was 2% for the lower floors, 7% for the middle floors and 19% for the upper floors. The trend was associated with the thermal stack effect during the heating season. During this period, warmer air inside the building is less dense than the outside air resulting in cold air from outside entering the lower portion of the building, rising and exiting through the upper floors. Hence the lower floors tend to get most of the air exchange from outside and upper floors get a more significant air exchange from floors beneath. When evaluating vapour migration from a subsurface source, the migration into the ground floor is considered more significant than outside air. Hence concentrations within the first-floor above the ground floor are expected to be diluted with outdoor air resulting in lower concentrations between 2% and 7% of the lower floor concentration.
 - Review of radon simulation results for a range of multistorey buildings (Fang J.B and Persily A.K., 1995) indicates that under a range of temperature and wind conditions the concentration difference between the basement and first floors was between a factor of 0 and 100. A 10-fold factor between concentrations within the basement and the first-floor would provide a conservative estimation of first floor concentrations (derived from ground floor or basement concentrations) under most conditions.

This is consistent with recent guidance from CRC Care (2013)³ which advises:

For buildings where there is a good separation between the basement and upper floors the concentration of (petroleum hydrocarbons) PHCs on the floors above the basement(s) are 1/10th of the basement concentrations. For small buildings where there is more connection between a basement and upper floors (such as a single family residence) the concentration of PHCs on the floors above the basement is one-third of the basement concentration.

It should be noted that, in general, models used for the estimation of air concentrations from a subsurface source are simplistic and typically conservative which result in an overestimate of actual

³ CRC Care (2013) – *Petroleum hydrocarbon vapour intrusion assessment: Australian Guidance*, Technical Report 23, CRC for contamination assessment and remediation of the environment, July 2013.

Appendix D - Quantification Assumptions

concentrations (derived from the subsurface source) within a building. In particular these models do not incorporate any source or vadose zone degradation. Biodegradation in the vadose zone can result in orders of magnitude reductions in vapour concentrations (API, 2005; CRC CARE). Given the large size of the building footprint compared to the relatively shallow depth to groundwater, biodegradation in the vadose zone has *not* been incorporated into the modelling. This is considered likely to be a conservative assumption.

Modelled Results – Residential with Basement

Table D-4 summarises the modelled air concentrations within the basement and on the ground floor for the residential structure. The significance of these results is considered in **Section D-4**.

Table-D-3 Estimated Indoor Air Concentrations (mg/m3)

Volatile COPC	Residential Building Concentrations – Derived from Soil Source		Residential Building Concentrations – Derived from Groundwater Source	
	Basement	Ground Floor	Basement	Ground Floor
Naphthalene	0.0000084	0.0000084	-	-
TPH C ₆ -C ₉ aromatic	-	-	-	-
TPH C ₆ -C ₉ aliphatic	3.5	0.35	-	-
TPH C ₁₀ -C ₁₄ aromatic	0.38	0.038	0.000017	0.0000017
TPH C ₁₀ -C ₁₄ aliphatic	1.0	0.1	0.0006	0.00006

Residential Slab on Ground

As discussed in **Section 2**, a portion of the development will have a residential slab on ground structure (i.e. no basement).

The Johnson & Ettinger (J & E) vapour transport model (USEPA, 2003) has also been used to estimate the potential concentration of volatile COPC within buildings constructed on the site above impacts identified in soil and groundwater. Parameters in the model were adjusted to characterise emissions into a building constructed on a concrete slab.

The assessment of slab-on-grade buildings has assumed that advective (or pressure-driven) flows into the building are active for slab-on-ground buildings. This is consistent with the approach advocated by CRC CARE and is considered likely to be a conservative assumption (i.e. to overestimate risks).

Modelled Results – Residential Slab on Ground

Table D-5 summarises the modelled air concentrations within the ground floor for the residential structure. The significance of these results is considered in **Section D-4**.

Table-D-4 Estimated Indoor Air Concentrations (mg/m3)

Volatile COPC	Residential Building from Soil Source	Residential Building from Groundwater Source Ground Floor
Naphthalene	0.0000019	-
TPH C ₆ -C ₉ aromatic	-	-
TPH C ₆ -C ₉ aliphatic	0.79	-
TPH C ₁₀ -C ₁₄ aromatic	0.084	0.000035
TPH C ₁₀ -C ₁₄ aliphatic	0.23	0.0013

Appendix D - Quantification Assumptions

Aesthetic Considerations

The only relevant aesthetic consideration is the potential for odours associated with volatile COPC that may migrate into the indoor or outdoor air on the site and off-site areas. The odour thresholds associated with the detection of odours for the volatile COPC (which are lower than the thresholds associated with recognition of specific chemical odours) have been derived from relevant ATSDR toxicity profiles as follows:

- Naphthalene – 0.44 mg/m³;
- TPH (C6-C9, utilising n-hexane as surrogate) – 453 mg/m³; and
- TPH (C10-C14, utilising JP-8 as a surrogate) – 6.9 mg/m³.

No odour thresholds are available for mixtures of petroleum hydrocarbons, where odours may be noticed at lower concentrations than presented above for individual compounds, particularly within excavations. However, no odours were noted during basement excavation (outside of the hotspot beneath Building 5) or during near surface validation of open space areas and terrace apartment backyards and the odour thresholds are significantly higher than the modelled indoor air concentrations presented in **Table D-5**, vapours derived from site related impacts are not expected to be associated with detectable odours.

It should be noted that this assessment is focused on the potential emissions to air derived from contamination sources in groundwater and soil only and does not consider other fugitive sources that may be in the area, including emissions from the cars within the car park, or adjacent roads.

D.3 Toxicity Assessment

The objective of the toxicity assessment is to identify toxicity values for the COPC that can be used to quantify risks to human health associated with the calculated intake. The quantification of risk (**Section D.4**) requires a quantification of potential toxicity for the COPC identified (this section) as well as the potential for exposure (**Section D.2**).

Toxicity can be defined as “the quality or degree of being poisonous or harmful to plant, animal or human life” (NEPC, 1999).

The steps involved in this process include the following:

- Obtain relevant qualitative and quantitative toxicity information on the COPC relevant to the significant exposure pathways being assessed.
- Identify the appropriate toxicity values for assessing both threshold effects and non-threshold carcinogenic effects.

Appendix D - Quantification Assumptions

D.3.1 Selection of Toxicity Values

The toxicity values used in this risk assessment are those used by CRC CARE (2011) and adopted in the amended 1999 ASC NEPM (NEPC 2013) and presented in **Table D-6**.

Table-D-5 TPH Surrogate Fractions and Toxicity Data for Inhalation Exposures

Hydrocarbon Group	Fraction	RfC (mg/m ³)
Aliphatic	C ₆ -C ₉	0.7
	C ₁₀ -C ₁₄	1.0
Aromatic (non-carcinogenic)	C ₆ -C ₉	0.4
	C ₁₀ -C ₁₄	0.2

Background intakes of TPH in an urban environment consistent with the location of the site are considered to be 10% of the RfCs presented in **Table D-6**.

D.3.2 Toxicity of Other COPC

Naphthalene

Polycyclic aromatic hydrocarbons (PAHs) are a group of more than 100 chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances. PAH can be man-made, but may also occur naturally.

Naphthalene is the only PAH identified in this assessment as a COPC. It is the lightest and most volatile of the PAHs and is one of the PAHs which are not considered to be a genotoxic carcinogen. Hence, naphthalene has been evaluated on an individual basis based on potential for threshold effects.

The USEPA provide an RfC of 0.003 mg/m³ for naphthalene and this has been adopted by CRC CARE (2011). Background intakes of naphthalene in an urban environment consistent with the location of the site are considered to be 5% of the RfC.

D.4 Risk Characterisation

D.4.1 Risks to Human Health

Risk characterisation is the final step in a quantitative risk assessment. It involves the incorporation of the exposure assessment and toxicity assessment to provide a quantitative assessment of non-threshold carcinogenic risk and threshold risk. In the assessment presented, evaluation of exposures to the COPC involves an assessment of threshold and non-threshold risks.

The calculation of risks has been undertaken using an in-house spreadsheet model, RiskE (Version 2014A). The equations utilised within RiskE follows risk assessment methodology as outlined in **Section D-2**, adopting protocols established by NEPM and USEPA. The output from this model has been incorporated into the included tables, and calculation sheets are presented in **Appendix E**.

It is noted that no carcinogenic (non-threshold) compounds were identified as COPC for the QRA hence calculations have only been presented for threshold effects.

Appendix D - Quantification Assumptions

D.4.2 Hazard Index for Threshold Effects

The potential for adverse threshold effects, resulting from exposure to an individual COPC, is evaluated by comparing an exposure level, expressed as a daily chemical intake, with the TC or RfC. The resulting ratio is referred to by the USEPA as the hazard quotient (USEPA, 1989) and is derived in the following manner for inhalation exposures:

$$\text{Hazard Quotient (inhalation)} = \frac{\text{Exposure Concentration in Air}}{(\text{TC, RfC} - \text{Background})}$$

If the exposure concentration in air for the individual COPC exceeds the TC or RfC (with consideration of background intakes) (i.e., if the hazard quotient exceeds one), then this would indicate potentially unacceptable exposures. The hazard quotient does not represent a statistical probability of an effect occurring.

To assess the overall potential for adverse health effects posed by simultaneous exposure to multiple chemicals, the hazard quotients for each chemical and exposure pathway have been summed. The resulting sum is referred to by the USEPA as the hazard index (HI) (USEPA, 1989). The HI approach assumes that multiple sub-threshold exposures to several chemicals could result in a cumulative adverse health effect, and exposures are summed over all intake routes.

D.4.3 Acceptable Risk

An “acceptable” risk in this assessment has been defined as a Hazard Index of below 1.0 (as per risk assessment industry practice, supported by protocols outlined in NEPM (1999) and USEPA guidance).

If the Hazard Index is less than one, cumulative exposure to the site chemicals is judged unlikely to result in an adverse effect. If the index is greater than one, a more detailed and critical evaluation of the risks (including consideration of specific target organs affected and mechanisms of toxic action of the chemicals of concern) would be required to ascertain if the cumulative exposure would in fact be likely to harm exposed individuals.

All hazard quotient and hazard index calculations are presented in **Appendix E**.

D.4.4 Summary of Risk

Table D-6 presents a summary of the calculated lifetime risks for residents associated with the potential inhalation of volatile COPC that have been identified in soil and groundwater beneath the site based on the construction of a building with one level of car park basement and residents living on the ground floor.

Table-D-6 Risks Associated with Potential Inhalation Exposures to Hydrocarbon Impacts

Receptor and Pathway	Threshold Hazard Index
Residential with Basement Car Park	
Inhalation of volatile COPC in basement and indoors – Soil Source	0.25
Inhalation of volatile COPC in basement and indoors – Groundwater Source	0.00003
TOTAL	0.25
Residential Slab on Ground	
Inhalation of volatile COPC in ground floor residential – Soil Source	0.39
Inhalation of volatile COPC in ground floor residential – Groundwater Source	0.001
TOTAL	0.39

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On the basis of the evaluation undertaken (based on available data), the estimated Hazard Indices for the residential type buildings (both with basement and without) are below the adopted guideline of $HI=1$. The hydrocarbon contamination identified in soil and groundwater at the site is therefore not considered to represent a significant vapour inhalation risk with regard to the proposed development. This is related to the fact that only a small portion of the hydrocarbon contamination identified at the site is volatile and none of the relatively toxic mono-aromatic BTEX compounds were identified as COPC for the site.

It is noted that the calculated risk for inhalation from a soil source within a slab on ground building is well below an unacceptable risk level, but relatively high compared to the basement scenario. This is due to the assumptions regarding exposure duration in a basement compared to a slab-on-ground building and attenuation between floors in a basement scenario.

D.4.5 Conclusions

Little hydrocarbon impact has been identified remaining on the Stage 2A site, however there are some identified data gaps with regard to recent groundwater data and spatial data for soils. As such a quantitative estimation of risk was undertaken using conservative site data, as a secondary line of evidence in assessing environmental risk.

Potentially significant exposure pathways for future residents were considered limited to the potential for soil vapour migration with subsequent intrusion into proposed residential type buildings with a basement car park or slab on ground construction.

Based on these exposure pathways and contaminant concentrations identified in the course of the URS site investigations, no unacceptable risks were identified. A significant factor in this assessment is the fact that only a very small portion of the hydrocarbon contamination identified at the site is volatile and none of the relatively toxic mono-aromatic BTEX compounds were identified as COPC for the site.

D.4.6 Uncertainties

In general, the uncertainties and limitations of human health risk assessment can be classified into the following categories:

- Data gaps
- Sampling and analysis, including groundwater fate and transport modelling
- Receptor exposure assessment
- Toxicological assessment

The risk assessment process following both ANZECC/NHMRC and USEPA guidance documents provides a systematic means for organising, analysing and presenting information on the nature and magnitude of risks to public health posed by chemical exposures. Despite the advanced state of the current risk assessment methodology, uncertainties and limitations are inherent in the risk assessment process. This section discusses the uncertainties and limitations associated with this risk assessment.

Data Gaps

Several data gaps were identified in the course of the risk assessment:

Appendix D - Quantification Assumptions

- No groundwater data was available from within the Stage 2A site area. Former monitoring wells were destroyed during Stage 1 and Stage 2A preparation works. Groundwater data has been inferred based on the nature of groundwater impacts across nearby areas of the Waterfront precinct, the most recent concentrations from wells within the Stage 2A area prior to destruction, concentration trends in monitoring wells across the Waterfront Precinct and the significance of biodegradation of petroleum hydrocarbons across the Waterfront precinct.
- The assessment conservatively assumes that groundwater concentrations equal to the average of results greater than LOR during 2012-2013 monitoring events are present beneath the Stage 2A site.
- While a significant number of both soil and groundwater samples were analysed for TPH, two of the 253 soil samples and no groundwater samples were analysed to assess the ratio of aromatic to aliphatic compounds within each fraction. As discussed in **Section D.2.4**, it has been assumed that within the C10-C14 range, the aliphatic:aromatic ratio is 50:50. The significance of this assumption is explored further in the sensitivity analysis discussed in **Section D.4.7**.
- No data on the amount of total organic carbon present in the soil was available. The presence of organic carbon affects the estimation of saturation concentrations. The risk assessment is based on an estimated value.

Sampling and Analysis

The assessment of soil and groundwater conditions has been based on the results of soil and groundwater investigations undertaken at and adjacent to the Stage 2A portion of the Waterfront site by URS. A substantial amount of data has been collected from both soil and groundwater beneath the site, and it is noted that the characterisation of hydrocarbon impacts beneath the site is consistent with knowledge of the site operational history and product storages; nevertheless, inferences about the nature and continuity of soil and groundwater contamination away from the sampling points are made but cannot be guaranteed.

As noted in the Data Gaps section the assessment conservatively assumes concentrations of TPH greater than LOR may be present beneath Stage 2A. To an extent this assumption negates theoretical uncertainty around the occurrence of contamination between sampling locations with the exception of potential for other contaminants not observed in samples beneath the site (e.g. BTEX).

Exposure Assessment

Risk assessments require the adoption of several assumptions in order to assess potential human exposure. This risk assessment includes assumptions about general characteristics and patterns of human exposure relevant to the on-site groups. These assumptions are conservative and developed to provide an estimate of maximum possible exposures rather than the actual exposures. This approach is expected to overestimate the risks.

Vapour migration models have been used to estimate the concentration of volatile chemicals in outdoor and indoor air on the basis of measured soils and groundwater concentrations. The vapour migration models used to estimate air concentrations are conservative and utilise simplistic assumptions.

These models consider diffusion from the soil or groundwater source but do not consider further degradation of the chemicals or the adsorption to soil or water molecules. The assessment of potential exposure on the site has focused on exposures associated with the presence of

Appendix D - Quantification Assumptions

hydrocarbons in soils and groundwater beneath the site. No assessment has been provided for the potential exposure to fugitive emissions associated with the operation of the site.

Toxicological Assessment

In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals.

This may introduce two types of uncertainties into the risk assessment, as follows:

- Those related to extrapolating from one species to another; and
- Those related to extrapolating from the high exposure doses, usually used in experimental animal studies, to lower doses usually estimated for human exposure situations.

The majority of the toxicological knowledge of chemicals comes from experiments with laboratory animals, although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response. There may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the frequent necessity to extrapolate results of short term or subchronic animal studies to humans exposed over a lifetime has inherent uncertainty.

In order to adjust for these uncertainties, ADI's and RfD's incorporate safety factors that may vary from 10 to 1000.

The approach for evaluating risks to mixtures of chemicals assumes dose additivity and does not account for potential synergism, antagonism or differences in target organ specificity and mechanism of action. In general, the additivity approach has the effect of overestimating the risks. This is because chemicals that have no additive effects are included together as well as chemicals that may have additive effect.

D.4.7 Sensitivity Analysis

The assessment of risk involves the use of models to estimate exposure and in some cases exposure point concentrations. These models require a number of input variables, some of which may be site-specific and others may be derived from other sources of information.

While a number of parameters used within the risk assessment have a moderate degree of uncertainty associated with them and the modelling is sensitive to changes in these parameters, values used to define these parameters have been selected to be reasonably conservative. This has resulted in the calculation of risk which is expected to be conservative and an overestimation of actual risk.

It is considered that adopted base-case model inputs provide an adequate level of conservatism in estimating the potential indoor air vapour inhalation risks. The sensitivity analysis undertaken suggests that slight modification of reasonable alternative input parameters would not alter the finding that the TPH contamination present does not represent a significant vapour inhalation risk

Appendix E RiskE Calculation Modelling

Residential Slab on Ground – Soil Source

Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Maximum Hazard Quotient
Adult Residents (Chronic Exposures)		
Inhalation of COPC Indoors - Slab on Ground		0.39
Inhalation of COPC Outdoors		0.0000
Total Risk		0.39
Older Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors - Slab on Ground		0.39
Inhalation of COPC Outdoors		0.0000
Total Risk		0.39
Young Child Residents (Chronic Exposures)		
Inhalation of COPC Indoors - Slab on Ground		0.39
Inhalation of COPC Outdoors		0.0000
Total Risk		0.39
Lifetime Risk (Chronic)		
		0.39

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED SOILS
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Thickness of Soil Above Contaminated Layer	[m]	d	3.5	Calculated from layers
Thickness of Contaminated Layer	[m]	surfd	2	Estimated for soil types
Soil Temperature	[C]	T	25	site-specific assumption
<u>Vadose Zone Layer 1 Characteristics</u>				<i>CRC Care - Sand, Sandy Clay</i>
Depth of Layer 1	[m]	vd1	0.2	
Moisture Content	[cm ³ /g]	mocon	0.08	Estimated for soil type
Organic Carbon Fraction	-	foc	0.003	Average of measured values
Soil Bulk Density	[g/cm ³]	rhob	1.625	Estimated for soil type
Density of Solids	[g/cm ³]	sd	2.65	site-specific assumption
Total Soil Porosity	[cm ³ /cm ³]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[cm ³ /cm ³]	wacon	0.130	mocon*rhob
Volumetric Air Content	[cm ³ /cm ³]	acon	0.257	theta-wacon
<u>Vadose Zone Layer 2 Characteristics</u>				<i>CRC Care - Silt, Silty Clay</i>
Depth of Clean Soil overlying impact in Layer 2	[m]	vd2	3.3	
Moisture Content	[cm ³ /g]	mocon2	0.22	Estimated for soil type
Organic Carbon Fraction	-	foc2	0.003	Average of measured values
Soil Bulk Density	[g/cm ³]	rhob2	1.367	Estimated for soil type
Density of Solids	[g/cm ³]	sd2	2.65	site-specific assumption
Total Soil Porosity	[cm ³ /cm ³]	theta2	0.48	1 - (rhob2/sd2)
Volumetric Water Content	[cm ³ /cm ³]	wacon2	0.301	mocon2*rhob2
Volumetric Air Content	[cm ³ /cm ³]	acon2	0.183	theta2-wacon2

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				<i>Residential - Slab On Ground</i> <i>(Building Type)</i>
Depth of Basement	[m]	basement	3	Depth of basement below ground level
Width of Building	[m]	bwidth	40	Site specific assumption
Length of Building	[m]	blength	160	Site specific assumption
Area of Building Below Ground Level	[m ²]	area	6400	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.25	Site specific assumption
Building Mixing Height	[m]	boxh	2.7	Assumption for room
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	0.6	CRC CARE for residential
Fraction of Cracks in Walls and foundation	-	cracks	0.005	Max from CRC CARE 2011
Qbuilding	[cm ³ /s]	Qb	2880000.00	Calculated from building volume and exchange rate
Qsoil	[cm ³ /s]	Qs	14400.00	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Acrack	[cm ²]	Ac	320000	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[cm ³ /cm ³]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[cm ³ /cm ³]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	10	site-specific assumption
Width of Contaminated Area	[m]	width	10	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	4	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm ³ /g)	Air Diffusion Coefficient (cm ² /s)	Water Diffusion Coefficient (cm ² /s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
Naphthalene	31.00	128.17	1820	0.059	7.5E-06	0.09	1.80E-02
C6-C10 Aromatic	82.22	120.00	1259	0.070	8.0E-06	4.56	4.20E-01
C6-C10 Aliphatic	8.41	110.00	3162	0.070	1.0E-05	53.20	7.70E+01
C10-C16 Aromatic	31.26	140.00	3162	0.060	8.0E-06	0.71	3.40E-01
C10-C16 Aliphatic	0.05	160.00	316228	0.050	6.0E-06	0.55	1.60E+02

Vapour Transport Calculations	Deff Layer 1 (cm ² /s)	Deff Layer 2 (cm ² /s)	Deff Foundations and Cracks (cm ² /s)	Total Effective Diffusion (source to indoor (cm ² /s))	Total Effective Diffusion (source to outdoor (cm ² /s))
Naphthalene	4.25E-3	9.15E-4	4.43E-3	9.58E-4	9.37E-4
C6-C10 Aromatic	5.04E-3	1.05E-3	5.25E-3	1.10E-3	1.07E-3
C6-C10 Aliphatic	5.04E-3	1.05E-3	5.25E-3	1.10E-3	1.07E-3
C10-C16 Aromatic	4.32E-3	8.99E-4	4.50E-3	9.42E-4	9.22E-4
C10-C16 Aliphatic	3.60E-3	7.48E-4	3.75E-3	7.83E-4	7.66E-4

Subsurface Soils Phase Partitioning Results	Soil Concentration (mg/kg)	Vapour Phase Concentration (g/cm ³)	Pure Component Saturated Soil Concentration (mg/kg)	Pure Component Saturated Vapour Concentration (g/cm ³)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm ³)	Mixture Saturated Soil Concentration (mg/kg)
Naphthalene	0.1	3.2E-11	1850	5.9E-07			
C6-C10 Aromatic	0.0		2841	2.9E-05			
C6-C10 Aliphatic	30	1.2E-05	819	3.1E-04			
C10-C16 Aromatic	410	1.4E-06	1544	5.4E-06			
C10-C16 Aliphatic	410	6.8E-06	286	4.7E-06			

Calculated Air Concentrations (with advection)	Vapour Phase Concentration at Source (ug/m ³)	Vapour Phase Concentration at Source (mg/m ³)	JE Attenuation Coefficient (unitless)	Emission Rate to Indoor Air (g/s)	Depletion Time (years)	Indoor Concentration (mg/m ³)
Naphthalene	3.2E+01	3.2E-02	6.0E-05	5.5E-09	10121.7	1.9E-06
C6-C10 Aromatic					INF	
C6-C10 Aliphatic	1.2E+07	1.2E+04	6.9E-05	2.3E-03	7.3	7.9E-01
C10-C16 Aromatic	1.4E+06	1.4E+03	5.9E-05	2.4E-04	935.2	8.4E-02
C10-C16 Aliphatic	4.7E+06	4.7E+03	4.9E-05	6.7E-04	340.5	2.3E-01
Calculated Air Concentrations ASTM Guidance (without advection)	Vapour Phase Concentration at Source (g/cm ³)	Vapour Phase Concentration at Source (mg/m ³)	Emission Rate into building (g/s)	Depletion Time (years)	Indoor Concentration (mg/m ³)	Outdoor Air Concentration (mg/m ³)
Naphthalene	3.2E-11	3.2E-02	1.4E-09	40910.4	4.7E-07	1.4E-09
C6-C10 Aromatic						
C6-C10 Aliphatic	1.2E-05	1.2E+04	5.8E-04	28.7	2.0E-01	5.9E-04
C10-C16 Aromatic	1.4E-06	1.4E+03	6.2E-05	3687.7	2.1E-02	6.3E-05
C10-C16 Aliphatic	4.7E-06	4.7E+03	1.7E-04	1343.4	5.9E-02	1.7E-04

Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

Chemical	<u>Oral/Dermal Exposures</u>							
	Non- Threshold Slope Factor (mg/kg/day) ⁻¹	Ref	Threshold Chronic TDI (mg/kg/day)	Ref	Threshold Subchronic TDI (mg/kg/day)	Ref	Dermal Permeability (cm/hr)	Dermal Adsorption (Unitless)
Naphthalene	0.00E+00	-	2.00E-02	USEPA	0.00E+00	-	4.66E-02	1.30E-01
C6-C10 Aromatic	0.00E+00	-	2.00E-01	WHO	8.00E-02	S-Toluene	4.53E-02	1.00E-02
C6-C10 Aliphatic	0.00E+00	-	5.00E+00	CSMS	0.00E+00	n-hexane	3.34E-01	1.00E-02
C10-C16 Aromatic	0.00E+00	-	3.00E-02	WHO	1.00E+00	S-naphthalene	6.94E-02	1.30E-01
C10-C16 Aliphatic	0.00E+00	-	1.00E-01	CSMS	2.00E-02	C	0.00E+00	1.00E-02
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Toxicity and Derma

C = calculated from chronic va

Chemical	<u>Inhalation Exposures</u>						Background Intake (% TDI)	
	Inhalation Unit Risk (ug/m ³) ⁻¹	Ref	Threshold Chronic TC (mg/m ³)	Ref	Threshold Subchronic TC (mg/m ³)	Ref	Chronic Assessment (%)	Subchronic Assessment
Naphthalene	0.00E+00	-	3.00E-03	USEPA	0.00E+00	-	5.00%	0.00%
C6-C10 Aromatic	0.00E+00	-	4.00E-01	CSMS	4.00E+00	Ch	10.00%	10.00%
C6-C10 Aliphatic	0.00E+00	-	1.84E+01	TPHCWG	2.10E+00	hexane	10.00%	10.00%
C10-C16 Aromatic	0.00E+00	-	2.00E-01	CSMS	2.00E+00	Ch	10.00%	10.00%
C10-C16 Aliphatic	0.00E+00	-	1.00E+00	CSMS	1.00E+01	C	10.00%	0.00%
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Chronic Exposures

[illegible]

Chronic Exposures

[illegible]

Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations		Residential Exposure Parameters (RME) Inhalation Indoors by Older Children	
Exposure Parameters	Units		
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Include Source Depletion	Y		
Inhalation Rate (InhR)	m ³ /hr	0.7	Based on male (17-18yrs) daily inhalation rate (long-term) (UESPA 1997)
Exposure Time (ET)	hr/day	20	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i> <i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i> <i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)								(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
												TOTAL			3.9E-1
Naphthalene		3.0E-03	5%	2.9E-03	10121.7	10.0	6.1E+05	8.8E+04		8.3E-01	1.9E-06		1.6E-06	--	5.6E-04
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	10.0	6.1E+05	8.8E+04		8.3E-01				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	7.3	7.3	6.1E+05	6.4E+04		8.3E-01	7.9E-01		6.6E-01	--	4.0E-02
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	935.2	10.0	6.1E+05	8.8E+04		8.3E-01	8.4E-02		7.0E-02	--	3.9E-01
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	340.5	10.0	6.1E+05	8.8E+04		8.3E-01	2.3E-01		1.9E-01	--	2.1E-01
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Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation Outdoors by Older Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i>			
<i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i>			
<i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Outdoor Air (mg/m³)	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m³) ⁻¹	(mg/m³)		(mg/m³)	(years)	(years)	(hours)	(hours)				(mg/m³)	(mg/m³)	(unitless)	(unitless)
TOTAL															2.9E-5
Naphthalene		3.0E-03	5%	2.9E-03	10121.7	10.0	6.1E+05	8.8E+04		8.3E-02	1.4E-09		1.2E-10	--	4.1E-08
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	10.0	6.1E+05	8.8E+04		8.3E-02				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	7.3	7.3	6.1E+05	6.4E+04		8.3E-02	5.9E-04		4.9E-05	--	3.0E-06
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	935.2	10.0	6.1E+05	8.8E+04		8.3E-02	6.3E-05		5.2E-06	--	2.9E-05
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	340.5	10.0	6.1E+05	8.8E+04		8.3E-02	1.7E-04		1.4E-05	--	1.6E-05
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Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation Indoors by Younger Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	6	Total exposure during ages 0 to 5 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Include Source Depletion	Y		
Inhalation Rate (InhR)	m ³ /hr	0.7	Based on male (17-18yrs) daily inhalation rate (long-term) (UESPA 1997)
Exposure Time (ET)	hr/day	20	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
AT			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i>			
<i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i>			
<i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)	(years)	(years)	(hours)	(hours)			(mg/m ³)	(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
TOTAL															3.9E-1
Naphthalene		3.0E-03	5%	2.9E-03	10121.7	6.0	6.1E+05	5.3E+04		8.3E-01	1.9E-06		1.6E-06	--	5.6E-04
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	6.0	6.1E+05	5.3E+04		8.3E-01				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	7.3	6.0	6.1E+05	5.3E+04		8.3E-01	7.9E-01		6.6E-01	--	4.0E-02
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	935.2	6.0	6.1E+05	5.3E+04		8.3E-01	8.4E-02		7.0E-02	--	3.9E-01
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	340.5	6.0	6.1E+05	5.3E+04		8.3E-01	2.3E-01		1.9E-01	--	2.1E-01
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Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation Outdoors by Younger Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	6	Total exposure during ages 0 to 5 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i> <i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i> <i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Outdoor Air	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)								(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
													TOTAL		2.9E-5
Naphthalene		3.0E-03	5%	2.9E-03	10121.7	6.0	6.1E+05	5.3E+04		8.3E-02	1.4E-09		1.2E-10	--	4.1E-08
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	6.0	6.1E+05	5.3E+04		8.3E-02				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	7.3	6.0	6.1E+05	5.3E+04		8.3E-02	5.9E-04		4.9E-05	--	3.0E-06
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	935.2	6.0	6.1E+05	5.3E+04		8.3E-02	6.3E-05		5.2E-06	--	2.9E-05
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	340.5	6.0	6.1E+05	5.3E+04		8.3E-02	1.7E-04		1.4E-05	--	1.6E-05
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Appendix E - RiskE Calculation Modelling

Residential Slab on Ground – Groundwater Source

Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Threshold Risks Hazard Index
Residents (Chronic Exposures)		
Inhalation of COPC Indoors - Slab on Ground		0.001
Inhalation of COPC Outdoors		0.0000001
Total Risk		0.001
Lifetime Risk (Chronic)		
		0.001

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Depth of Top of Contaminated Aquifer (BGS)	[m]	d	5	Calculated from layers
Thickness of Capillary Fringe	[m]	cd	1.5	Estimated for soil type
Thickness of Vadose Zone	[m]	vd	3.5	Calculated from layers
Average Soil Temperature	[C]	T	25	site-specific assumption
<u>Vadose Zone Layer 1 Characteristics</u>				<i>CRC Care - Sand, Sandy Clay</i>
Depth of Layer 1 from Foundations	[m]	vd1	0.2	
Moisture Content	[ml/g]	mocon	0.0800	Estimated for soil type
Organic Carbon Fraction	-	foc	0.003	Estimated for soil type
Soil Bulk Density	[g/ml]	rhob	1.625	Estimated for soil type
Density of Solids	[g/ml]	sd	2.65	default
Total Soil Porosity	[ml/ml]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[ml/ml]	wacon	0.130	mocon*rhob
Volumetric Air Content	[ml/ml]	acon	0.257	theta-wacon
<u>Vadose Zone Layer 2 Characteristics</u>				<i>CRC Care - Silt, Silty Clay</i>
Depth of Layer 2 to Water Table	[m]	vd2	3.3	
Moisture Content	[ml/g]	mocon2	0.22	Estimated for soil type
Organic Carbon Fraction	-	foc2	0.003	Estimated for soil type
Soil Bulk Density	[g/ml]	rhob2	1.367	Estimated for soil type
Density of Solids	[g/ml]	sd2	2.65	default
Total Soil Porosity	[ml/ml]	theta2	0.48	1 - (rhob2/sd2)
Volumetric Water Content	[ml/ml]	wacon2	0.301	mocon2*rhob2
Volumetric Air Content	[ml/ml]	acon2	0.183	theta2-wacon2
<u>Capillary Fringe</u>				
Volumetric Water Content	[ml/ml]	cfwacon	0.45	Value representative of capillary fringe, ASTM (2002)
Volumetric Air Content	[ml/ml]	cfacon	0.03	theta2-cfwacon

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				Residential - Slab On Ground
Depth of Basement	[m]	basement	3	Depth of basement below ground level
Width of Building	[m]	bwidth	40	Site specific assumption
Length of Building	[m]	blength	160	Site specific assumption
Area of Emission - Building Area	[m ²]	emarea	6400	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.25	Site specific assumption
Height of Room	[m]	boxh	2.7	Assumption for basement
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	0.6	
Fraction of Cracks in Walls and foundation	-	cracks	0.005	Max from CRC CARE 2011
Qbuilding	[cm ³ /s]	Qb	2880000	Calculated from building volume and exchange rate
Qsoil	[cm ³ /s]	Qs	14400	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Area of Cracks (ACrack)	[cm ²]	Ac	320000	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[ml/ml]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[ml/ml]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	10	site-specific assumption
Width of Contaminated Area	[m]	width	10	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	4	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm ³ /g)	Air Diffusion Coefficient (cm ² /s)	Water Diffusion Coefficient (cm ² /s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
C10-C16 Aromatic	31.26	140.00	3.16E+03	6.00E-02	8.00E-06	0.714	3.40E-01
C10-C16 Aliphatic	0.1	160.00	3.16E+05	5.00E-02	6.00E-06	0.55	1.60E+02

Vapour Transport Calculations	Deff Layer 1 (cm ² /s)	Deff Layer 2 (cm ² /s)	Deff Foundations and Cracks (cm ² /s)	Deff Capillary Fringe (cm ² /s)	Total Effective Diffusion (cm ² /s) to indoor air
C10-C16 Aromatic	4.32E-3	8.99E-4	4.50E-3	9.38E-6	3.05E-5
C10-C16 Aliphatic	3.60E-3	7.48E-4	3.75E-3	1.80E-6	5.97E-6

Phase Partitioning Results	Dissolved Phase Concentration (mg/L)	Vapour Phase Concentration (g/cm ³)	Saturated Vapour Concentration (g/cm ³)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm ³)	Calculation Vapour Phase Concentration Adopted (g/cm ³)
C10-C16 Aromatic	0.055	1.9E-08	5.4E-06			1.9E-08
C10-C16 Aliphatic	0.055	8.8E-06	4.7E-06			4.7E-06

Calculated Air Concentrations (with advection)	Vapour Phase Concentration at Source (ug/m ³)	Vapour Phase Concentration at Source (mg/m ³)	JE Attenuation Coefficient (unitless)	Indoor Air Concentration (mg/m ³)
C10-C16 Aromatic	1.9E+04	1.9E+01	1.4E-06	2.5E-05
C10-C16 Aliphatic	4.7E+06	4.7E+03	2.7E-07	1.3E-03

[illegible]

C = calculated from chronic value, Ch = chronic value adopted

C = calculated from chronic value, Ch = chronic value adopted

[illegible]

Toxicity and Derma

C = calculated from chronic va

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Chronic Exposures

<p><i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i></p> <p><i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i></p> <p><i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i></p>	
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Add comments regarding concentrations here

Chronic Exposures

↑
Add comments regarding concentrations here

Appendix E - RiskE Calculation Modelling

Residential Basement – Soil Source

Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Maximum Hazard Quotient
<u>Adult Residents (Chronic Exposures)</u>		
Inhalation of COPC Indoors in Basement		0.09
Inhalation of COPC Indoors		0.17
Inhalation of COPC Outdoors		0.0002
Total Risk		0.25
<u>Older Child Residents (Chronic Exposures)</u>		
Inhalation of COPC Indoors in Basement		0.09
Inhalation of COPC Indoors		0.17
Inhalation of COPC Outdoors		0.0002
Total Risk		0.25
<u>Young Child Residents (Chronic Exposures)</u>		
Inhalation of COPC Indoors in Basement		0.09
Inhalation of COPC Indoors		0.17
Inhalation of COPC Outdoors		0.0002
Total Risk		0.25
Lifetime Risk (Chronic)		0.25

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED SOILS

Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Thickness of Soil Above Contaminated Layer	[m]	d	0.5	Calculated from layers
Thickness of Contaminated Layer	[m]	surfd	2	Estimated for soil types
Soil Temperature	[C]	T	25	site-specific assumption
<u>Vadose Zone Layer 1 Characteristics</u>				<u>CRC Care - Sand, Sandy Clay</u>
Depth of Layer 1	[m]	vd1	0.2	
Moisture Content	[cm ³ /g]	mocon	0.08	Estimated for soil type
Organic Carbon Fraction	-	foc	0.003	Average of measured values
Soil Bulk Density	[g/cm ³]	rhob	1.625	Estimated for soil type
Density of Solids	[g/cm ³]	sd	2.65	site-specific assumption
Total Soil Porosity	[cm ³ /cm ³]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[cm ³ /cm ³]	wacon	0.130	mocon*rhob
Volumetric Air Content	[cm ³ /cm ³]	acon	0.257	theta-wacon
<u>Vadose Zone Layer 2 Characteristics</u>				<u>CRC Care - Silt, Silty Clay</u>
Depth of Clean Soil overlying impact in Layer 2	[m]	vd2	0.3	
Moisture Content	[cm ³ /g]	mocon2	0.22	Estimated for soil type
Organic Carbon Fraction	-	foc2	0.003	Average of measured values
Soil Bulk Density	[g/cm ³]	rhob2	1.367	Estimated for soil type
Density of Solids	[g/cm ³]	sd2	2.65	site-specific assumption
Total Soil Porosity	[cm ³ /cm ³]	theta2	0.48	1 - (rhob2/sd2)
Volumetric Water Content	[cm ³ /cm ³]	wacon2	0.301	mocon2*rhob2
Volumetric Air Content	[cm ³ /cm ³]	acon2	0.183	theta2-wacon2

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				Residential - Basement <u>(Building Type)</u>
Depth of Basement	[m]	basement	3	Depth of basement below ground level
Width of Building	[m]	bwidth	40	Site specific assumption
Length of Building	[m]	blength	160	Site specific assumption
Area of Building Below Ground Level	[m ²]	area	7600	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.25	Site specific assumption
Building Mixing Height	[m]	boxh	2.7	Assumption for room
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	1.5	CRC CARE for residential
Fraction of Cracks in Walls and foundation	-	cracks	0.005	Max from CRC CARE 2011
Qbuilding	[cm ³ /s]	Qb	7200000.00	Calculated from building volume and exchange rate
Qsoil	[cm ³ /s]	Qs	36000.00	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Acrack	[cm ²]	Ac	380000	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[cm ³ /cm ³]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[cm ³ /cm ³]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	10	site-specific assumption
Width of Contaminated Area	[m]	width	10	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	4	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm ³ /g)	Air Diffusion Coefficient (cm ² /s)	Water Diffusion Coefficient (cm ² /s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
Naphthalene	31.00	128.17	1820	0.059	7.5E-06	0.09	1.80E-02
C6-C10 Aromatic	82.22	120.00	1259	0.070	8.0E-06	4.56	4.20E-01
C6-C10 Aliphatic	8.41	110.00	3162	0.070	1.0E-05	53.20	7.70E+01
C10-C16 Aromatic	31.26	140.00	3162	0.060	8.0E-06	0.71	3.40E-01
C10-C16 Aliphatic	0.05	160.00	316228	0.050	6.0E-06	0.55	1.60E+02

Vapour Transport Calculations	Deff Layer 1 (cm ² /s)	Deff Layer 2 (cm ² /s)	Deff Foundations and Cracks (cm ² /s)	Total Effective Diffusion (source to indoor (cm ² /s)	Total Effective Diffusion (source to outdoor (cm ² /s)
Naphthalene	4.25E-3	9.15E-4	4.43E-3	1.33E-3	9.58E-4
C6-C10 Aromatic	5.04E-3	1.05E-3	5.25E-3	1.53E-3	1.10E-3
C6-C10 Aliphatic	5.04E-3	1.05E-3	5.25E-3	1.53E-3	1.10E-3
C10-C16 Aromatic	4.32E-3	8.99E-4	4.50E-3	1.32E-3	9.42E-4
C10-C16 Aliphatic	3.60E-3	7.48E-4	3.75E-3	1.09E-3	7.83E-4

Subsurface Soils Phase Partitioning Results	Soil Concentration (mg/kg)	Vapour Phase Concentration (g/cm ³)	Pure Component Saturated Soil Concentration (mg/kg)	Pure Component Saturated Vapour Concentration (g/cm ³)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm ³)	Mixture Saturated Soil Concentration (mg/kg)
Naphthalene	0.1	3.2E-11	1850	5.9E-07			
C6-C10 Aromatic	0.0		2841	2.9E-05			
C6-C10 Aliphatic	30	1.2E-05	819	3.1E-04			
C10-C16 Aromatic	410	1.4E-06	1544	5.4E-06			
C10-C16 Aliphatic	410	6.8E-06	286	4.7E-06			

Calculated Air Concentrations (with advection)	Vapour Phase Concentration at Source (ug/m ³)	Vapour Phase Concentration at Source (mg/m ³)	JE Attenuation Coefficient (unitless)	Emission Rate to Indoor Air (g/s)	Depletion Time (years)	Indoor Concentration (mg/m ³)
Naphthalene	3.2E+01	3.2E-02	2.7E-04	6.1E-08	1084.0	8.4E-06
C6-C10 Aromatic					INF	
C6-C10 Aliphatic	1.2E+07	1.2E+04	3.0E-04	2.5E-02	0.8	3.5E+00
C10-C16 Aromatic	1.4E+06	1.4E+03	2.6E-04	2.7E-03	99.7	3.8E-01
C10-C16 Aliphatic	4.7E+06	4.7E+03	2.2E-04	7.5E-03	36.1	1.0E+00
Calculated Air Concentrations ASTM Guidance (without advection)	Vapour Phase Concentration at Source (g/cm ³)	Vapour Phase Concentration at Source (mg/m ³)	Emission Rate into building (g/s)	Depletion Time (years)	Indoor Concentration (mg/m ³)	Outdoor Air Concentration (mg/m ³)
Naphthalene	3.2E-11	3.2E-02	1.7E-09	37924.1	2.4E-07	1.0E-08
C6-C10 Aromatic						
C6-C10 Aliphatic	1.2E-05	1.2E+04	7.5E-04	26.4	1.0E-01	4.2E-03
C10-C16 Aromatic	1.4E-06	1.4E+03	8.0E-05	3393.9	1.1E-02	4.5E-04
C10-C16 Aliphatic	4.7E-06	4.7E+03	2.2E-04	1235.8	3.0E-02	1.2E-03

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Depth of Top of Contaminated Aquifer (BGS)	[m]	d	3.75	Calculated from layers
Thickness of Capillary Fringe	[m]	cd	0.3	Estimated for soil type
Thickness of Vadose Zone	[m]	vd	3.45	Calculated from layers
Average Soil Temperature	[C]	T	25	site-specific assumption
<u>Vadose Zone Layer 1 Characteristics</u>				<u>Sand</u>
Depth of Layer 1 from Foundations	[m]	vd1	0.2	
Moisture Content	[ml/g]	mocon	0.1200	Estimated for soil type
Organic Carbon Fraction	-	foc	0.003	Estimated for soil type
Soil Bulk Density	[g/ml]	rhob	1.6	Estimated for soil type
Density of Solids	[g/ml]	sd	2.65	default
Total Soil Porosity	[ml/ml]	theta	0.40	1 - (rhob/sd)
Volumetric Water Content	[ml/ml]	wacon	0.192	mocon*rhob
Volumetric Air Content	[ml/ml]	acon	0.204	theta-wacon
<u>Vadose Zone Layer 2 Characteristics</u>				<u>Silty Sand</u>
Depth of Layer 2 to Water Table	[m]	vd2	3.25	
Moisture Content	[ml/g]	mocon2	0.05	Estimated for soil type
Organic Carbon Fraction	-	foc2	0.003	Estimated for soil type
Soil Bulk Density	[g/ml]	rhob2	1.6	Estimated for soil type
Density of Solids	[g/ml]	sd2	2.65	default
Total Soil Porosity	[ml/ml]	theta2	0.40	1 - (rhob2/sd2)
Volumetric Water Content	[ml/ml]	wacon2	0.080	mocon2*rhob2
Volumetric Air Content	[ml/ml]	acon2	0.316	theta2-wacon2
<u>Capillary Fringe</u>				
Volumetric Water Content	[ml/ml]	cfwacon	0.37	Value representative of capillary fringe, ASTM (2002)
Volumetric Air Content	[ml/ml]	cfacon	0.03	theta2-cfwacon

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				Residential - Slab On Ground
Depth of Basement	[m]	basement	3	Depth of basement below ground level
Width of Building	[m]	bwidth	40	Site specific assumption
Length of Building	[m]	blength	160	Site specific assumption
Area of Emission - Building Area	[m ²]	emarea	6400	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.25	Site specific assumption
Height of Room	[m]	boxh	2.7	Assumption for basement
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	0.6	
Fraction of Cracks in Walls and foundation	-	cracks	0.005	Max from CRC CARE 2011
Qbuilding	[cm ³ /s]	Qb	2880000	Calculated from building volume and exchange rate
Qsoil	[cm ³ /s]	Qs	14400	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Area of Cracks (ACrack)	[cm ²]	Ac	320000	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[ml/ml]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[ml/ml]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	10	site-specific assumption
Width of Contaminated Area	[m]	width	10	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	4	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm ³ /g)	Air Diffusion Coefficient (cm ² /s)	Water Diffusion Coefficient (cm ² /s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
C10-C16 Aromatic	31.26	140.00	3.16E+03	6.00E-02	8.00E-06	0.714	3.40E-01
C10-C16 Aliphatic	0.1	160.00	3.16E+05	5.00E-02	6.00E-06	0.55	1.60E+02

Vapour Transport Calculations	Deff Layer 1 (cm ² /s)	Deff Layer 2 (cm ² /s)	Deff Foundations and Cracks (cm ² /s)	Deff Capillary Fringe (cm ² /s)	Total Effective Diffusion (cm ² /s) to indoor air
C10-C16 Aromatic	1.92E-3	8.23E-3	4.29E-3	8.47E-6	1.04E-4
C10-C16 Aliphatic	1.60E-3	6.86E-3	3.57E-3	2.68E-6	3.33E-5

Phase Partitioning Results	Dissolved Phase Concentration (mg/L)	Vapour Phase Concentration (g/cm ³)	Saturated Vapour Concentration (g/cm ³)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm ³)	Calculation Vapour Phase Concentration Adopted (g/cm ³)
C10-C16 Aromatic	0.075	2.6E-08	5.4E-06			2.6E-08
C10-C16 Aliphatic	0.075	1.2E-05	4.7E-06			4.7E-06

Calculated Air Concentrations (with advection)	Vapour Phase Concentration at Source (ug/m ³)	Vapour Phase Concentration at Source (mg/m ³)	JE Attenuation Coefficient (unitless)	Indoor Air Concentration (mg/m ³)
C10-C16 Aromatic	2.6E+04	2.6E+01	6.2E-06	1.6E-04
C10-C16 Aliphatic	4.7E+06	4.7E+03	2.0E-06	9.3E-03

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Toxicity and Dermal Absorption Parameters

C = calculated from chronic value, Ch = chronic value adopted

Chemical	<u>Oral/Dermal Exposures</u>							
	Non- Threshold Slope Factor (mg/kg/day) ⁻¹	Ref	Threshold Chronic TDI (mg/kg/day)	Ref	Threshold Subchronic TDI (mg/kg/day)	Ref	Dermal Permeability (cm/hr)	Dermal Adsorption (Unitless)
Naphthalene	0.00E+00	-	2.00E-02	USEPA	0.00E+00	-	4.66E-02	1.30E-01
C6-C10 Aromatic	0.00E+00	-	2.00E-01	WHO	8.00E-02	S-Toluene	4.53E-02	1.00E-02
C6-C10 Aliphatic	0.00E+00	-	5.00E+00	CSMS	0.00E+00	n-hexane	3.34E-01	1.00E-02
C10-C16 Aromatic	0.00E+00	-	3.00E-02	WHO	1.00E+00	S-naphthalene	6.94E-02	1.30E-01
C10-C16 Aliphatic	0.00E+00	-	1.00E-01	CSMS	2.00E-02	C	0.00E+00	1.00E-02
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Toxicity and Derma

C = calculated from chronic va

Chemical	<u>Inhalation Exposures</u>						Background Intake (% TDI)	
	Inhalation Unit Risk (ug/m ³) ⁻¹	Ref	Threshold Chronic TC (mg/m ³)	Ref	Threshold Subchronic TC (mg/m ³)	Ref	Chronic Assessment (%)	Subchronic Assessment
Naphthalene	0.00E+00	-	3.00E-03	USEPA	0.00E+00	-	5.00%	0.00%
C6-C10 Aromatic	0.00E+00	-	4.00E-01	CSMS	4.00E+00	Ch	10.00%	10.00%
C6-C10 Aliphatic	0.00E+00	-	1.84E+01	TPHCWG	2.10E+00	hexane	10.00%	10.00%
C10-C16 Aromatic	0.00E+00	-	2.00E-01	CSMS	2.00E+00	Ch	10.00%	10.00%
C10-C16 Aliphatic	0.00E+00	-	1.00E+00	CSMS	1.00E+01	C	10.00%	0.00%
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Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation In Basement by Adult	
Units			
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	14	30 year lifetime exposure less childhood years
Body Weight (BW)	kg	70	CRC CARE
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	1	Assumed time in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
AT			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i>			
<i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i>			
<i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)							(mg/m ³)	(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
													TOTAL		8.7E-2
Naphthalene		3.0E-03	5%	2.9E-03	1084.0	14.0	6.1E+05	1.2E+05		4.2E-02	8.4E-06		3.5E-07	--	1.2E-04
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	14.0	6.1E+05	1.2E+05		4.2E-02			1.2E+05	--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	0.8	0.8	6.1E+05	6.1E+04		4.7E-03	3.5E+00		1.6E-02	--	9.9E-04
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	99.7	14.0	6.1E+05	1.2E+05		4.2E-02	3.8E-01		1.6E-02	--	8.7E-02
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	36.1	14.0	6.1E+05	1.2E+05		4.2E-02	1.0E+00		4.3E-02	--	4.8E-02
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Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation Indoors by Adult	
Units			
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	14	30 year lifetime exposure less childhood years
Body Weight (BW)	kg	70	CRC CARE
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	122640	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	19	CRC CARE less time in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
AT			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i>			
<i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i>			
<i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)								(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
												TOTAL			1.7E-1
Naphthalene		3.0E-03	5%	2.9E-03	1084.0	14.0	6.1E+05	1.2E+05		7.9E-01	8.4E-07		6.7E-07	--	2.3E-04
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	14.0	6.1E+05	1.2E+05		7.9E-01			1.2E+05	--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	0.8	0.8	6.1E+05	6.1E+04		8.9E-02	3.5E-01		3.1E-02	--	1.9E-03
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	99.7	14.0	6.1E+05	1.2E+05		7.9E-01	3.8E-02		3.0E-02	--	1.7E-01
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	36.1	14.0	6.1E+05	1.2E+05		7.9E-01	1.0E-01		8.2E-02	--	9.2E-02
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Chronic Exposures

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Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation in Basement by Older Children	
Units			
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	1	Assumed time in basement
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
AT			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i>			
<i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i>			
<i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air (mg/m ³)	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)								(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
												TOTAL			8.7E-2
Naphthalene		3.0E-03	5%	2.9E-03	1084.0	10.0	6.1E+05	8.8E+04		4.2E-02	8.4E-06		3.5E-07	--	1.2E-04
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	10.0	6.1E+05	8.8E+04		4.2E-02				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	0.8	0.8	6.1E+05	6.1E+04		4.7E-03	3.5E+00		1.6E-02	--	9.9E-04
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	99.7	10.0	6.1E+05	8.8E+04		4.2E-02	3.8E-01		1.6E-02	--	8.7E-02
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	36.1	10.0	6.1E+05	8.8E+04		4.2E-02	1.0E+00		4.3E-02	--	4.8E-02
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Inhalation of Volatile Chemicals

Chronic Exposures

General Data/ Equations		Residential Exposure Parameters (RME) Inhalation Indoors by Older Children	
Exposure Parameters	Units		
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	19	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i> <i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i> <i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Indoor Air (mg/m ³)	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)								(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
												TOTAL			1.7E-1
Naphthalene		3.0E-03	5%	2.9E-03	1084.0	10.0	6.1E+05	8.8E+04		7.9E-01	8.4E-07		6.7E-07	--	2.3E-04
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	10.0	6.1E+05	8.8E+04		7.9E-01				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	0.8	0.8	6.1E+05	6.1E+04		8.9E-02	3.5E-01		3.1E-02	--	1.9E-03
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	99.7	10.0	6.1E+05	8.8E+04		7.9E-01	3.8E-02		3.0E-02	--	1.7E-01
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	36.1	10.0	6.1E+05	8.8E+04		7.9E-01	1.0E-01		8.2E-02	--	9.2E-02
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Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation Outdoors by Older Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	10	Total exposure during ages 6 to 15 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	87600	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i>			
<i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i>			
<i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data								Concentration in Outdoor Air	Daily Exposure		Calculated Risk			
	Inhalation	Chronic	Background	Chronic TC	Depletion	Exposure	Averaging	Averaging		Intake Factor	Intake Factor	Inhalation	Inhalation	Non	Max Chronic
	Unit Risk	TC air	Intake (%)	Allowable for	Time	Duration	Time (AT)	Time (AT)		(Non-	(Threshold)	Exposure	Exposure	Threshold Risk	Hazard Quotient
			Chronic TC)	Assessment (TC- Background)		(ED)	Non- Threshold	Threshold		Threshold)		Concentration - NonThreshold	Concentration - Threshold		
	(mg/m³)⁻¹	(mg/m³)		(mg/m³)	(years)	(years)	(hours)	(hours)			(mg/m³)	(mg/m³)	(mg/m³)	(unitless)	(unitless)
													TOTAL		2.1E-4
Naphthalene		3.0E-03	5%	2.9E-03	1084.0	10.0	6.1E+05	8.8E+04		8.3E-02	1.0E-08		8.4E-10	--	3.0E-07
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	10.0	6.1E+05	8.8E+04		8.3E-02				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	0.8	0.8	6.1E+05	6.1E+04		9.3E-03	4.2E-03		3.9E-05	--	2.4E-06
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	99.7	10.0	6.1E+05	8.8E+04		8.3E-02	4.5E-04		3.7E-05	--	2.1E-04
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	36.1	10.0	6.1E+05	8.8E+04		8.3E-02	1.2E-03		1.0E-04	--	1.1E-04
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Chronic Exposures

General Data/ Equations		Units		Inhalation in Basement by Younger Children	
Exposure Parameters					
Exposure Frequency (EF)	days/year	365	Every day of the year		
Exposure Duration (ED)	years	6	Total exposure during ages 0 to 5 years		
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996		
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009		
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009		
Include Source Depletion	Y				
Exposure Time (ET)	hr/day	1	Assumed time in basement		
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils		
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$	-				

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)

$$\text{NonThreshold Risk} = \text{Inhalation Exposure Concentration} \times \text{Unit Risk}$$
$$\text{Hazard Quotients} = (\text{Inhalation Exposure Concentration} / \text{Allowable TC air})$$
[illegible]

Chronic Exposures

General Data/ Equations		Units		Inhalation Indoors by Younger Children	
Exposure Parameters					
Exposure Frequency (EF)	days/year	365	Every day of the year		
Exposure Duration (ED)	years	6	Total exposure during ages 0 to 5 years		
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996		
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009		
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009		
Include Source Depletion	Y				
Exposure Time (ET)	hr/day	19	CRC CARE - time in basement		
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils		
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$	-				

Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)

$$\text{NonThreshold Risk} = \text{Inhalation Exposure Concentration} \times \text{Unit Risk}$$
$$\text{Hazard Quotients} = (\text{Inhalation Exposure Concentration} / \text{Allowable TC air})$$
[illegible]

Inhalation of Volatile Chemicals

Chronic Exposures

Chronic Exposures		Residential Exposure Parameters (RME)	
General Data/ Equations		Inhalation Outdoors by Younger Children	
Exposure Parameters			
Exposure Frequency (EF)	days/year	365	Every day of the year
Exposure Duration (ED)	years	6	Total exposure during ages 0 to 5 years
Body Weight (BW)	kg	70	USEPA 1989 and CSMS 1996
Averaging Time - NonThreshold (ATc)	hours	613200	USEPA 2009
Averaging Time - Threshold (ATn)	hours	52560	USEPA 2009
Include Source Depletion	Y		
Exposure Time (ET)	hr/day	2	CRC CARE
Fraction Inhaled from Contaminated Source (FI)	-	1	Assume all of residence above groundwater/soils
Intake Factor = $\frac{ET \cdot FI \cdot EF \cdot ED}{AT}$			
<i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i>			
<i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i>			
<i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i>			

Chemical	Toxicity Data				Depletion Time	Exposure Duration (ED)	Averaging Time (AT) Non-Threshold	Averaging Time (AT) Threshold	Intake Factor (Non-Threshold)	Intake Factor (Threshold)	Concentration in Outdoor Air	Daily Exposure		Calculated Risk	
	Inhalation Unit Risk	Chronic TC air	Background Intake (% Chronic TC)	Chronic TC Allowable for Assessment (TC-Background)								Inhalation Exposure Concentration - NonThreshold	Inhalation Exposure Concentration - Threshold	Non Threshold Risk	Max Chronic Hazard Quotient
	(mg/m ³) ⁻¹	(mg/m ³)		(mg/m ³)								(mg/m ³)	(mg/m ³)	(unitless)	(unitless)
													TOTAL		2.1E-4
Naphthalene		3.0E-03	5%	2.9E-03	1084.0	6.0	6.1E+05	5.3E+04		8.3E-02	1.0E-08		8.4E-10	--	3.0E-07
C6-C10 Aromatic		4.0E-01	10%	3.6E-01	INF	6.0	6.1E+05	5.3E+04		8.3E-02				--	--
C6-C10 Aliphatic		1.8E+01	10%	1.7E+01	0.8	0.8	6.1E+05	5.3E+04		1.1E-02	4.2E-03		4.6E-05	--	2.8E-06
C10-C16 Aromatic		2.0E-01	10%	1.8E-01	99.7	6.0	6.1E+05	5.3E+04		8.3E-02	4.5E-04		3.7E-05	--	2.1E-04
C10-C16 Aliphatic		1.0E+00	10%	9.0E-01	36.1	6.0	6.1E+05	5.3E+04		8.3E-02	1.2E-03		1.0E-04	--	1.1E-04
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Appendix E - RiskE Calculation Modelling

Residential Basement – Groundwater Source

Summary of Risk for RME Exposure

Pathway	NonThreshold Risks	Threshold Risks Hazard Index
Residents (Chronic Exposures)		
Inhalation of COPC Indoors in Basement		0.00003
Inhalation of COPC Indoors		0.00001
Inhalation of COPC Outdoors		0.0000000
Total Risk		0.00003
Lifetime Risk (Chronic)		
		0.00003

VAPOUR PARTITIONING, EMISSION AND AIR DISPERSION MODEL FOR CONTAMINATED GROUNDWATER
Using USEPA Vapor Migration Guidance (2003), Johnson Ettinger Model

Site Specific Physical Input Parameters	Units	Abbrev.	Value	Comments
Depth of Top of Contaminated Aquifer (BGS)	[m]	d	2	Calculated from layers
Thickness of Capillary Fringe	[m]	cd	1.5	Estimated for soil type
Thickness of Vadose Zone	[m]	vd	0.5	Calculated from layers
Average Soil Temperature	[C]	T	25	site-specific assumption
<u>Vadose Zone Layer 1 Characteristics</u>				<i>CRC Care - Sand, Sandy Clay</i>
Depth of Layer 1 from Foundations	[m]	vd1	0.2	
Moisture Content	[ml/g]	mocon	0.0800	Estimated for soil type
Organic Carbon Fraction	-	foc	0.003	Estimated for soil type
Soil Bulk Density	[g/ml]	rhob	1.625	Estimated for soil type
Density of Solids	[g/ml]	sd	2.65	default
Total Soil Porosity	[ml/ml]	theta	0.39	1 - (rhob/sd)
Volumetric Water Content	[ml/ml]	wacon	0.130	mocon*rhob
Volumetric Air Content	[ml/ml]	acon	0.257	theta-wacon
<u>Vadose Zone Layer 2 Characteristics</u>				<i>CRC Care - Silt, Silty Clay</i>
Depth of Layer 2 to Water Table	[m]	vd2	0.3	
Moisture Content	[ml/g]	mocon2	0.22	Estimated for soil type
Organic Carbon Fraction	-	foc2	0.003	Estimated for soil type
Soil Bulk Density	[g/ml]	rhob2	1.367	Estimated for soil type
Density of Solids	[g/ml]	sd2	2.65	default
Total Soil Porosity	[ml/ml]	theta2	0.48	1 - (rhob2/sd2)
Volumetric Water Content	[ml/ml]	wacon2	0.301	mocon2*rhob2
Volumetric Air Content	[ml/ml]	acon2	0.183	theta2-wacon2
<u>Capillary Fringe</u>				
Volumetric Water Content	[ml/ml]	cfwacon	0.45	Value representative of capillary fringe, ASTM (2002)
Volumetric Air Content	[ml/ml]	cfacon	0.03	theta2-cfwacon

Receptor Specific Input Parameters	Units	Abbrev.	Value	Comments
Building Characteristics				Residential - Basement
Depth of Basement	[m]	basement	3	Depth of basement below ground level
Width of Building	[m]	bwidth	40	Site specific assumption
Length of Building	[m]	blength	160	Site specific assumption
Area of Emission - Building Area	[m ²]	emarea	7600	Assume whole building above source
Foundation/wall thickness	[m]	fthick	0.25	Site specific assumption
Height of Room	[m]	boxh	2.7	Assumption for basement
Hourly Volume Exchange of Fresh Air	[exch/hr]	exchanges	1.5	
Fraction of Cracks in Walls and foundation	-	cracks	0.005	Max from CRC CARE 2011
Qbuilding	[cm ³ /s]	Qb	7200000	Calculated from building volume and exchange rate
Qsoil	[cm ³ /s]	Qs	36000	Calculated from default of Qs:Qb (CRC Care 2010)
Ratio of Qs:Qb	-	Qs/Qb	0.005	Defaults are 0.005 (Res) and 0.001 (Comm) (CRC CARE)
Area of Cracks (ACrack)	[cm ²]	Ac	380000	Calculated from building area and crack ratio, USEPA 2003
Volumetric Water Content in foundation/wall cracks	[ml/ml]	fwacon	0.12	Default Value ASTM 1739-95
Volumetric Air Content in foundation/wall cracks	[ml/ml]	facon	0.26	Default Value ASTM 1739-95
Outdoor Air Characteristics				
Length of Contaminated Area	[m]	length	10	site-specific assumption
Width of Contaminated Area	[m]	width	10	site-specific assumption
Wind Speed Outdoors	[m/s]	wspd	4	site-specific assumption
Height of Outdoor Mixing Zone	[m]	outboxh	1.5	Default Value

Chemical Specific Parameters	Water Solubility (mg/L)	MW (g/mol)	Koc (cm ³ /g)	Air Diffusion Coefficient (cm ² /s)	Water Diffusion Coefficient (cm ² /s)	Vapour Pressure (mmHg)	Henry's Law Constant (unitless)
C10-C16 Aromatic	31.26	140.00	3.16E+03	6.00E-02	8.00E-06	0.714	3.40E-01
C10-C16 Aliphatic	0.1	160.00	3.16E+05	5.00E-02	6.00E-06	0.55	1.60E+02

Vapour Transport Calculations	Deff Layer 1 (cm ² /s)	Deff Layer 2 (cm ² /s)	Deff Foundations and Cracks (cm ² /s)	Deff Capillary Fringe (cm ² /s)	Total Effective Diffusion (cm ² /s) to indoor air
C10-C16 Aromatic	4.32E-3	8.99E-4	4.50E-3	9.38E-6	1.25E-5
C10-C16 Aliphatic	3.60E-3	7.48E-4	3.75E-3	1.80E-6	2.40E-6

Phase Partitioning Results	Dissolved Phase Concentration (mg/L)	Vapour Phase Concentration (g/cm ³)	Saturated Vapour Concentration (g/cm ³)	Free Phase Mole Fraction (mol/mol)	Concentration above Free Phase (g/cm ³)	Calculation Vapour Phase Concentration Adopted (g/cm ³)
C10-C16 Aromatic	0.055	1.9E-08	5.4E-06			1.9E-08
C10-C16 Aliphatic	0.055	8.8E-06	4.7E-06			4.7E-06

Calculated Air Concentrations (with advection)	Vapour Phase Concentration at Source (ug/m ³)	Vapour Phase Concentration at Source (mg/m ³)	JE Attenuation Coefficient (unitless)	Indoor Air Concentration (mg/m ³)
C10-C16 Aromatic	1.9E+04	1.9E+01	6.6E-07	1.2E-05
C10-C16 Aliphatic	4.7E+06	4.7E+03	1.3E-07	6.0E-04

[illegible]

C = calculated from chronic value, Ch = chronic value adopted

C = calculated from chronic value, Ch = chronic value adopted

[illegible]

Toxicity and Derma

C = calculated from chronic va

[illegible]

Chronic Exposures

<p><i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i></p> <p><i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i></p> <p><i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i></p>	
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Add comments regarding concentrations here

Chronic Exposures

<p><i>Inhalation Exposure Concentration = Concentration in Air x Intake Factor (ref: USEPA 2009)</i></p> <p><i>NonThreshold Risk = Inhalation Exposure Concentration x Unit Risk</i></p> <p><i>Hazard Quotients = (Inhalation Exposure Concentration/Allowable TC air)</i></p>	
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Add comments regarding concentrations here

Chronic Exposures

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