APPENDIX 4

Draft Human Health Risk Assessment and Ecological Risk Assessment (HHERA)

Human Health Risk Assessment

DRAFT

Barangaroo Delivery Authority

Barangaroo Headland Park
Hickson Road, Sydney, NSW

February 2011
JBS41181–16411 Revision D
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Human Health Risk Assessment

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Table of Contents

List of Abbreviations viii

Executive Summary x

1 Introduction 1

1.1 Introduction and Background 1

1.2 Objectives 1

1.3 Risk Assessment Process 1

2 Summary Site Condition/Surrounding Environment 3

2.1 Site Identification 3

2.2 Current Site Condition 4

2.3 Proposed Site Condition 4

2.4 Surrounding Land use 5

2.5 Topography 5

2.6 Hydrology 5

2.7 Geology 7

2.8 Hydrogeology 9

2.9 Meteorology 9

3 Summary Site History/Previous Assessments 10

3.1 Barangaroo Project Site 10

3.2 Headland Park Site 10

3.3 Previous Site Assessments 11

3.3.1 Environmental Site Assessment (ERM 2007) 11

3.3.2 Additional Investigation Works (ERM 2008a) 12

3.3.3 Stage 2 Remedial Action Plan (ERM 2008b) 13

3.3.4 AECOM Data Gap Investigation Remediation Works (South) Area (AECOM 2010a) 13

3.3.5 AECOM Data Gap Investigation EPA Declaration Area (AECOM 2010b) 13

3.3.6 AECOM Data Gap Investigation Remediation Works (North) Area (AECOM 2010c) 14

3.3.7 AECOM Additional Analysis 14

3.3.8 AECOM Intertidal Study (AECOM 2010d) 14

3.3.9 Douglas Partners Sampling and Analysis 14

3.3.10 Data Quality 15

4 Conceptual Site Model 16

4.1 Geology 16

4.2 Hydrogeology and Water Balance 17

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4.3 Constituents of Potential Concern 17
4.4 Known On-Site Occurrences of COPCs 18
4.5 Potential Off-Site Sources of COPCs 19
4.6 Preferential Pathways 19
4.7 Potential Leaching of Environmental Impact 19
4.8 Exposure Pathways 20
4.9 Receptors 20
5 Issue Identification 21
5.1 Issue Identification 21
5.2 Identification of Environmental Hazards 21
5.3 Environmental Sampling and Analysis 22
5.4 Putting Hazards into their Environmental Health Context 22
5.5 Identification of Potential Interactions between Agents 23
5.6 Why is Risk Assessment Needed? 23
5.7 Limitations and Uncertainties 23
6 Selection of Constituents of Potential Concern 25
6.1 Selection of Screening Criteria 25
6.2 Selection of COPCs in Soils 27
6.3 Selection of COPCs in Groundwater 29
7 Toxicological Review 32
7.1 Hazard Identification 32
7.2 Dose-Response Assessment 33
7.3 Threshold Approaches 33
7.4 Non-Threshold Approaches 34
7.5 Sources of Toxicological and Tolerable Intake Data 35
7.6 Review of Published Hazard Data 36
7.6.1 Arsenic 36
7.6.2 Cadmium 38
7.6.3 Chromium 40
7.6.4 Lead 43
7.6.5 Nickel 45
7.6.6 Ammonia (as N) 47
7.6.7 Cyanide 48
7.6.8 Total Petroleum Hydrocarbons 49
7.6.9 Benzene 51

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7.6.10 Toluene 54
7.6.11 Ethylbenzene 56
7.6.12 Xylene 57
7.6.13 1,2,4-Trimethylbenzene 60
7.6.14 Polycyclic Aromatic Hydrocarbons 60
7.6.15 Phenols 68
7.6.16 Dibenzofuran 71
7.6.17 Asbestos 71
7.7 Summary and Evaluation of Toxicological Data 75
7.8 Odour Thresholds 76
7.9 Background Concentrations 81
8 Human Exposure Assessment 83
8.1 Exposure Scenario(s) Requiring Risk Assessment 83
8.2 Discussion of Exposure Scenarios 83
8.2.1 Headland Park 83
8.2.2 Car Park 85
8.2.3 'Cultural Space' 85
8.3 Exposure Parameters 86
8.4 Estimation of Inhalation Exposure 88
8.5 Estimation of Oral and Dermal Exposure 89
8.6 Estimation of Airborne Concentration 89
8.6.1 Vapour 89
8.6.2 Particulates 90
8.7 Use of RISC Modelling Package 90
8.8 Characterisation of Outdoor Area of Headland Park 91
8.9 Characterisation of Sub-Surface Maintenance Trench 91
8.10 Characterisation of Indoor Spaces 91
8.10.1 Car Park 91
8.10.2 Seepage Water Accumulation in the Car Park 92
8.10.3 'Cultural Space' 93
8.10.4 Vapour Flow into Buildings 93
8.11 Characterisation of Inhalation Exposure from Seepage Water Used for Irrigation 95
8.11.1 Irrigation Water Pre-Treatment 96
8.12 Characterisation of Site Geology and Hydrogeology 96
8.12.1 Growing Medium 96

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8.12.2 General Fill 96
8.12.3 Sandstone Retaining Wall 96
8.12.4 General Fill Underlying Car Park 97
8.12.5 Clay Liner 97
8.12.6 In-situ Soils 97
8.12.7 Summary of Geological Properties 97
8.12.8 Hydrogeology 98
8.12.9 Leaching 98
8.13 Assessment of Total Petroleum Hydrocarbons 99
8.14 Characterisation of Physical and Chemical Properties of COPCs 100
8.15 Asbestos Exposure 102
8.15.1 Characterisation of Potential Occurrence of Asbestos 102
8.15.2 Identification of Potential Exposure Pathways 102
8.15.3 Estimation of Exposure Concentration for Pathways 102
8.15.4 Occurrence of Free Asbestos Fibres at Barangaroo 103
8.15.5 Occurrence of ACM at Headland Park 103
8.15.6 Generation of Asbestos Fibres from Asbestos Cement Materials 104
8.15.7 Estimate of Free Asbestos Fibre Generation Rate from ACM 106
8.15.8 Generation of Asbestos Fibres from Asbestos Fibre Contaminated Soils 106
8.15.9 Dispersion of Asbestos Fibres between Soil Surface and Human Exposure 109
8.15.10 Estimation of Contaminant Intakes for Pathways 109
8.15.11 Intake Estimation 109
8.16 Risk Modelling 110
8.17 Models 111
9 Assessment of Human Health Risk 113
9.1 Risk Measurement 113
9.2 Adopted Risk Criteria 114
9.3 Assessment of Background Contributions 114
9.4 Estimation of Risk 115
9.5 Asbestos 123
9.6 Assessment of Current Groundwater Impact under Headland Park 123
10 Sensitivity Analysis 124
10.1 Sampling Programs 124
10.2 Toxicological Parameters 125
10.3 Land-Use 125

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10.4 Exposure Parameters 126
10.5 Building Parameters 126
10.6 Modelling Equations 126
10.6.1 Application of Johnson & Ettinger Relationships 127
10.6.2 Biodegradation 127
10.7 Geological Parameters 128
10.8 Potential Synergistic / Additive Effects 128
10.9 Conclusion 129
11 Conclusions and Recommendations 130
12 References 132
13 Limitations 138

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Figures

Figure 1 – Site Location

Figure 2 – Site Layout

Figure 3A – Barangaroo Headland Park Plan

Figure 3B – Barangaroo Headland Section 1

Figure 3C – Barangaroo Headland Section 2

Figure 3D – Barangaroo Headland Section 3

Figure 3E – Barangaroo Headland Section 4

Figure 3F – Barangaroo Headland Section 5

Figure 4 – Headland Park Slope Stabilization Section

Figure 5 – Current Site Layout showing Current Site Features

Figure 6 – Fill Batter Typical Section

Figure 7 – Historical Soil Sample Locations as Overlaid on Approximate Proposed Park Dimensions

Figure 8 – Historical Groundwater Monitoring Well Locations as Overlaid on Approximate Proposed Park Dimensions

Figure 9 – Depth to Base of Fill Contours Overlaid on Proposed Site Dimensions and Soil Sample Locations

Figure 10 – AECOM Soil Sampling Locations, Southern Portion

Figure 11 – AECOM Sampling Locations, Declaration Area

Figure 12 – Douglas Partners Sampling Locations

Figure 13 – Proposed Complete Park Section

Figure 14 – Proposed Park Cross-Section on Slope

Figure 15 – Proposed Cross Section Adjoining Car Park

Figure 16 – Proposed Complete Park Section and Soil Zones for Derivation of Risk Based Soil Criteria

Appendices

Appendix A – Historical Soil and Groundwater Results Summary Tables

Appendix B – Proposed Headland Park Water Balance

Appendix C – RISC Modelling Equations

Appendix D – Risk Modelling Spreadsheets and Summary

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List of Abbreviations

A list of the common abbreviations used throughout this report is provided below.

- ACL added contaminant level
- As Arsenic
- Cd Cadmium
- Cr Chromium
- Cu Copper
- BDA Barangaroo Delivery Authority
- BTEX Benzene, Toluene, Ethylbenzene and Xylenes
- B(a)P Benzo (a) pyrene
- COPCs Constituents of Potential Concerns
- DECCW NSW Department of Environment Climate Change and Water
- DQO Data Quality Objectives
- DP Deposited Plan
- EPA NSW Environment Protection Authority
- HHERA Human Health and Ecological Risk Assessment
- Hg Mercury
- HI Hazard Index
- HIL Health Based Investigation Level
- LOR Limit of Reporting
- LTEMP Long Term Environmental Management Plan
- MAH Monocyclic Aromatic Hydrocarbon
- Ni Nickel
- OCP Organochlorine Pesticide
- OoW NSW Office of Water
- SAR Site Audit Report
- SAS Site Audit Statement
- PAH Polycyclic Aromatic Hydrocarbons
- Pb Lead
- PIL Phytotoxicity Based Investigation Level
- PCB Polychlorinated Biphyenyls
- PQL Practical Quantitation Limit
- PSH Phase Separated Hydrocarbons
- QA/QC Quality Assurance/Quality Control
- REMP Remediation Environmental Management Plan

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- RME Reasonably Maximum Exposed
- ROHSMP Remediation Occupational Health and Safety Management Plan
- RPD Relative Percentage Difference
- SWC Sydney Water Corporation
- TPH Total Petroleum Hydrocarbons (C_6-C_9 and C_{10}-C_{36})
- Zn Zinc

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Executive Summary

JBS Environmental Pty Ltd (JBS) was engaged by the Barangaroo Delivery Authority (BDA) to complete a human health risk and ecological risk assessment for the portion of the Barangaroo project site known as the Barangaroo Headland Park and Northern Cove. It is proposed that surplus materials from the central and southern portions of the Bangaroo Site will be used within the development of the proposed Headland Park and Northern Cove, consistent with the zero waste and ecological sustainability objectives of the proposed development. It is estimated that up to 500 000m^3 of materials will be required to develop the proposed final landform of the park and cove.

A number of environmental assessments have been completed for the Barangaroo Site, which have identified environmentally impacted material present across the site. Constituents of potential concern have been identified by a review of the previous environmental assessments. Human health and ecological risk assessment (HHERA) has been undertaken for the proposed Headland Park and Northern Cove for each of the identified constituents of potential concern, to determine the levels of acceptability for the environmentally impacted materials.

A human health risk assessment has been completed for the proposed Barangaroo Headland Park. The risk assessment has considered a range of human health exposure scenarios for the proposed development of the Headland Park. The key facets of the proposed Headland Park development that have been considered in the risk assessment include:

- Construction of the Park boundary with a sloped foreshore which extends laterally over the high tide and low tide points;
- Incorporation of a Car Park and a ''Cultural Space'' substantially buried within the central and western portions of the Headland Park Site; and
- Sub-surface drainage infrastructure over the area of the Park typically to a maximum depth of 0.5m.

On the basis of these land-use parameters, the conceptual plans for the Headland Park, consideration of human exposure scenarios only, consideration of existing levels of exposure of human receptors to background levels of constituents and the limitations provided in **Section 13**, the following risk based criteria have been derived for use on the site as summarised in **Table E.1**. **Table E.1** should be reviewed with **Figure 16** of this HHRA. Risk based criteria have not been presented where the derived criterion has exceeded the historical maximum reported concentration of the constituent as reported in previous environmental assessments completed for the Barangaroo Site.

It has also been found that existing maximum levels of groundwater impact do not pose an unacceptable human health risk.

It has also been found that unacceptable human health risks are posed by the maximum levels of groundwater impact, where it infiltrates into the proposed Car Park as seepage water. It is recommended that future groundwater monitoring be undertaken that levels of groundwater impact in proximity of the proposed car park are below these levels.

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Table E1: Summary of Risk Based Criteria

Constituent	Zone 1 Risk Based Criteria (mg/kg)	Zone 2 Risk Based Criteria (mg/kg)		Zone 3 Risk Based Criteria (mg/kg)	Zone 4 Risk Based Criteria (mg/kg)	Zone 5 Risk Based Criteria (mg/kg)	Zone 6 Risk Based Criteria (mg/kg)	Irrigation Water Risk Based Criteria (mg/L)
		Unsaturated Soil	Saturated Soil					
Ammonia	5100	>MAX	>MAX	580	750	2500	>MAX	72
Arsenic	140	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	45.5
Cadmium	7.7	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.077
Chromium	450	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.29
Lead	130	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	460
Nickel	600[1]	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	23
Cyanide	220	>MAX	>MAX	950	>MAX	2500	3400	8.8
Benzene	1.0	0.4	810	0.1	0.1[1]	0.3[1]	2.3	0.14
Toluene	>MAX	460	>MAX	180	260[1]	950[1]	690	157
Ethylbenzene	>MAX	47	>MAX	25	36[1]	140[1]	80	36
Xylenes	1800	130	>MAX	64	86[1]	310[1]	180	78
1,2,4-trimethylbenzene	21	44	>MAX	0.8	1.2[1]	5[1]	46	0.51
TPH C_6-C_9	5100	6000	>MAX	100	130[1]	430[1]	3500	150
TPH C_{10}-C_{14}	3500	5600	>MAX	107.5	1391	4551	3800	5.6
TPH C_{15}-C_{28}	65950	25000[2]	>MAX	<MAX	<MAX	<MAX	<MAX	1.15[3]
TPH C_{29}-C_{36}			>MAX					
Benz(a)anthracene	31	95	>MAX	39	73	>MAX	>MAX	0.0043
Benzo(a)pyrene	3.1	810	810	810	>MAX	>MAX	>MAX	0.0015
Benzo(b)fluoranthene	31	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.026
Benzo(k)fluoranthene	31	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.015
Chrysene	310	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.18
Dibenz(a,h)anthracene	3.1	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.0011
Dibenzofuran	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	21
Fluoranthene	670	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.91
Fluorene	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	8.0
Indeno(1,2,3-c,d)pyrene	31	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.0083
2-methylnaphthalene	2600	1100	>MAX	610	940	4300	2500	9.6
Naphthalene	880	610	>MAX	12	17[1]	73[1]	>MAX	3.3
Pyrene	1600	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	3.3
Phenol	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	32
2,4-dimethylphenol	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	42
Cresols	3100	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	150

Note: 1. Criteria based on exposure of Cultural Space Receptors

2. Concentration based on risk based criteria from TPH $C_{>16}$ aromatic concentration only, risk based criterion TPH $C_{>16}$ aliphatic concentration >MAX

3. Concentration based on risk based criteria from TPH $C_{>16}$ aromatic concentration only, risk based criterion TPH $C_{>16}$ aliphatic concentration >MAX

Zone 1 – 0-0.5m below open area of Park

Zone 2 – Below Car Park

Zone 3 – 0-1m away from 'Cultural Space'

Zone 4 – >1-10m below / away from 'Cultural Space' and 0-10m away from Car Park

Zone 5 – >10-30m below / away from 'Cultural Space' and away from Car Park

Zone 6 – >30m lateral distance from western portion of 'Cultural Space' and >0.5m below Park surface

<SOL - Above solubility limit <MAX – risk based criteria exceeds maximum detected concentration on site

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1 Introduction

1.1 Introduction and Background

JBS Environmental Pty Ltd (JBS) was engaged by the Barangaroo Delivery Authority (BDA) to complete a human health risk risk assessment for the portion of the Barangaroo development site known as the Barangaroo Headland Park. It is proposed that surplus materials from the central and southern portions of the Barangaroo site, with surplus materials from the proposed shoreline re-alignment of the Headland Park and construction of Northern Cove, will be used to form the proposed profile of the proposed Headland Park, consistent with the zero waste and ecological sustainability objectives of the proposed development. It is estimated that up to 500 000 m^3 of materials will be required to develop the proposed final landform of the park and cove.

A number of environmental assessments have identified environmentally impacted material across the Barangaroo Site. Human health risk assessment (HHRA) is required to determine the suitability of environmentally impacted material from the Baragaroo Site to be used in the development of Headland Park; and to assess the suitability of current in-situ soils on the Headland Park site to remain in the future.

The risk assessment has been undertaken by the methodology outlined in Department of Health and Ageing and enHealth Council (2002) 'Environmental Health Risk Assessment Guidelines for Assessing Human Health Risks from Environmental Hazards' (enHealth, 2002). The findings of the risk assessment shall be used to determine future site management requirements for the Site and off-site areas potentially affected by sub-surface impact present on the Site.

1.2 Objectives

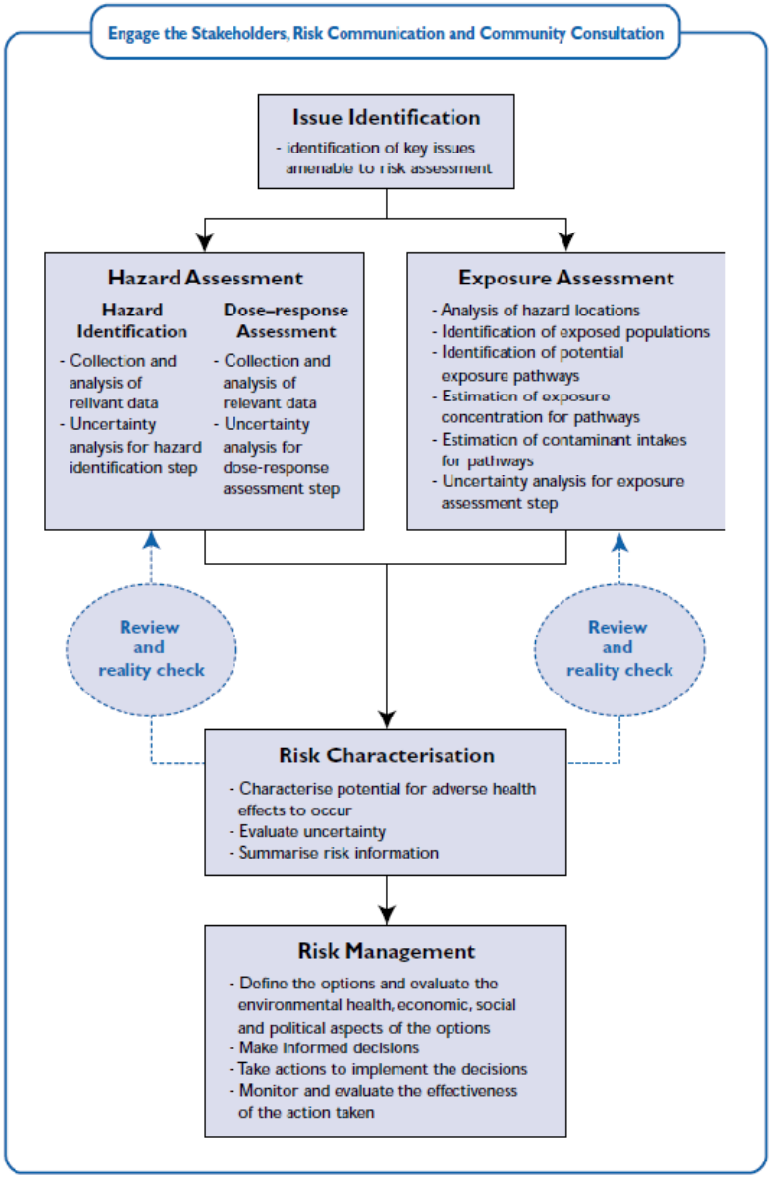
The Barangaroo Headland Park Site consists of Parkland being developed for principally recreational uses within a former industrial site. The Headland Park is proposed to be substantially constructed using surplus soils as available from the overall Barangaroo development. The objective of the HHRA is to determine the suitability of levels of a range of environmental constituents identified as being present in soils and groundwater across the Barangaroo Site, including in-situ soils as present on the former industrial site and surplus soils to be used as fill materials form the proposed headland profile of the Park, for future use in the area of the proposed Headland Park. The HHRA further requires to provide a set of quantitative criteria to facilitate the rapid assessment of the suitability of soils during the construction works phase.

1.3 Risk Assessment Process

Risk assessment is the process of estimating the potential impact of a chemical, physical, microbiological or psychosocial hazard on a specified human population or ecological system under a specific set of conditions and for a certain timeframe. A schematic of the risk assessment process is shown the diagram below (source: enHealth 2004).

- Issue Identification identifies issues amenable to risk assessment and assists in establishing a context for the risk assessment by a process of identifying the problems that the risk assessment needs to address. This includes the selection of Constituents of Potential Concern (COPC's) for the site and each identified potential exposure population.

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- Hazard Assessment including toxicological assessment and dose-response assessment. Toxicological assessment involves determining what types of (adverse) health effects might be caused by the agent; and how quickly the adverse health effects might be experienced and their duration. Dose-response assessment considers both qualitative and quantitative toxicity information to determine 'the incidence of adverse effects occurring in humans at different exposure levels'.
- Exposure Assessment involves the determination of the frequency, extent, duration and character of exposures in the past, currently, and in the future. There is also the identification of exposed populations, particularly sensitive sub populations, and potential exposure pathways.
- Risk Characterisation provides a qualitative and / or quantitative estimate, including attendant uncertainties, of the nature, severity and potential incidence of effects in a given population, based on the hazard identification and exposure assessments.

The risk assessment has specifically considered a range of potential human receptors who may use the site in the future.

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2 Summary Site Condition / Surrounding Environment

2.1 Site Identification

The Barangaroo Project Site is located at Hickson Road, Sydney, NSW and is legally referred to as Lots 1, 3, 5 and 6 Deposited Plan (DP) 876514 and includes the adjacent parts of Sussex Street, Hickson Road and Towns Place, as shown in **Figure 1**. The Barangaroo Project Site details are summarised in **Table 2.1** and described in more detail in the following sections.

Table 2.1 Summary Details for the Barangaroo Project Site

Lot/DP	Lots 1, 3, 5 and 6 of Deposited Plan 876514, including adjacent parts of Sussex Street, Hickson Road and Towns Place
Address	Hickson Road Millers Point NSW
Local Government Authority	City of Sydney
Site Zoning	Zone B4 Mixed Use and RE1 Pubic Recreation
Current Use	Vacant/Roadway
Geographical Co-ordinates, Elevation	Easting – 333643m E, Northing – 6251851m S, 2-3m AHD
Site Area	Approximately 22 ha

The Headland Park Site is located at the northern part of the Barangaroo Project Site and the details are summarised in **Table 2.2** and described in more detail in the following sections.

Table 2.2 Summary Details for the Headland Park Site

Lot/DP	Lot 1 and Part Lot 5 of Deposited Plan 876514, including adjacent parts of Hickson Road and Towns Place
Address	Hickson Rd Millers Point NSW
Local Government Authority	City of Sydney
Site Zoning	Zone B4 Mixed Use and RE1 Pubic Recreation
Current Use	Vacant
Geographical Co-ordinates, Elevation	Easting – 333547m E, Northing – 6252278m, 2-3m AHD
Site Area	Approximately 8 ha

For the purposes of the environmental assessment and the ensuing Site Audit, the final site as intended to be described in the Site Auditor sign off consists of the site as defined by the high water mark boundary. A plan view of the proposed site is shown as **Figure 2**. Proposed sections are shown as **Figures 3A** to **3F** and **4**.

It is noted that a substantial area of the current Lots 1, 3, 5 and 6 are proposed to be inundated with the proposed site development. These inundated areas are understood to be excluded from the area of the final site audit (and excluded from consideration in this HHRA). Approximate dimensions and locations of the future site boundary can be identified as the 1m AHD contour as shown on **Figure 2**.

Soils as contained within the proposed inundated area will be excavated to a maximum likely depth of approximately -4m AHD. The majority of these soils are proposed to be used as fill material in the creation of the headland landform on the Headland Park Site.

With the proposed finished landform of the Headland Park it is noted that two small portions have been excluded from the Barangaroo Project Site for the purposes of environmental assessment and remediation planning including:

- Moore's Wharf (in the far north eastern section of the Headland Park Site); and
- The area immediately surrounding the Port Control Tower.

The location of these areas relative to the Barangaroo Project Site is shown on **Figure 5**, which also shows the location of former structures that were present during the former commercial/industrial site use.

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2.2 Current Site Condition

The Headland Park Site has an approximate rectangular shape, with the longest boundary in a north-south direction. The far north-eastern portion of the Headland Park Site, known as Moores Wharf (Ports Services), was reported to contain a large heritage listed sandstone building and this section of the Headland Park Site was recently utilised as a base for marine operations by Sydney Ports Marine Services.

The remainder of the Headland Park Site was previously used for wharfage and storage of materials and was last occupied by Patrick Stevedoring. The large warehouse buildings associated with this former use have been demolished. The surface of the Headland Park Site is generally covered with areas of concrete and asphaltic pavement. The pavement surfaces have been reported as being in generally reasonable condition (ERM 2008a). The Sewage Pumping Station at the north of the Headland Park Site is still present.

The main vehicular access to the Headland Park Site is from a number of gates on Hickson Road on the eastern boundary of the Barangaroo Site, in addition to gates off Towns Place.

2.3 Proposed Site Condition

The Headland Park Site is proposed to be developed into a naturalistic headland that will simulate the shoreline as it was in 1836. Establishment of the naturalistic headland will involve shaping of the shoreline through the extraction of approximately 150,000 m^3 of fill materials within or behind the existing caissons and seawall that form the current western and northern boundaries of the site.

The proposed Headland Park Site development can be observed on **Figure 2,** and cross sections as shown on **Figures 3A to 3F** and **4**. The Headland Park Site is proposed to include the following elements:

- A substantial open area of sloped parkland over the majority of the site provided with a network of pathways and plantings formed by a substantial filling program;
- A submerged area at the south known as Northern Cove and a modified shoreline throughout the perimeter of the site resulting in the excavation of approximately 150,000m^3 of fill based soils;
- A void to a depth of -7.6m AHD as created by a proposed sandstone extraction program located within the central portion of the site, comprise dimensions of 85m (east-west) and 70m (north-south) resulting in the excavation of approximately 60,000m^3 of sandstone and approximately 5,000m^3 of overlying fill materials;
- A multi-level Car Park as constructed within the void, partially contained within the area of proposed sandstone extraction and extending within an excavation placed to a depth of -2m AHD within the central to southern portion of the site. The proposed dimensions of the car park are 40m (east-west) and 165m (north-south). In addition to the surplus soils as generated by the sandstone excavation, an additional 5,000m^3 of fill based and natural soils (alluvium and potential sandstone) will be generated by this proposed excavation outside the designated area of sandstone extraction;

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- A "Cultural Space" as constructed above the Car Park and substantially contained within a void created within the fill forming the Headland Park Site; and
- A system to control seepage water movement, collection and re-use, as constructed with the filling and formation of the headland profile of the Park.

Geological and hydrological characteristics of the proposed Headland Park and Northern Cove are described further in **Sections 2.5** to **2.8** and within the conceptual site model as **Section 4**.

2.4 Surrounding Land use

The surrounding uses of land adjacent to the Headland Park Site have been previously reported as follows (ERM 2008b[1]):

- North: Immediately to the north is Sydney Harbour;
- East: Immediately to the east is the residential and commercial area of Millers Point (NE), in addition to Hickson Road (SE);
- South: Immediately to the south is the temporary overseas passenger terminal, beyond which lies the Stage 1 Development; and
- West: Immediately to the west is Darling Harbour.

A former gasworks is known to have operated until the 1920s over part of the Stage 1 Development, as shown on **Figure 5**. The former gasworks location is known to continue to the east beneath Hickson Road, and the contaminated gasworks waste material in this area has been identified to contaminate soils and groundwater on the south-eastern portion of the Barangaroo Project Site. This part of the Stage 1 Development, referred to as the Declaration Area in this RAP, has been declared a Remediation Site by NSW DECCW (Declaration No. 21122, Area No. 3221) under the CLM Act 1997. It is understood that environmental assessment programs are being undertaken on the Stage 1 Development in preparation for remediation.

2.5 Topography

The topography of the current area of the Headland Park Site is relatively flat, having been cut and filled for its previous use as a stevedoring facility (ERM 2008b). The Headland Park Site abuts a man-made cliff face on the north-eastern boundary.

The proposed topography will be heavily modified as can be observed from **Figures 2**, **3A** to **3F** and **4**. This will be achieved by the importation of fill material to create a mound over the central portion of the site, and excavation at the north-western and southern areas of the site to form inundated areas. The site elevation will range from the level of surface water in Darling Harbour to a height of 20m in the central eastern portion of the site. Several steep slopes will occur across the site, consistent with a 'headland' topography.

2.6 Hydrology

The closest surface water body to the Headland Park Site is Darling Harbour, located immediately adjacent to the west and north of the Headland Park Site (ERM 2008b). Surface water from the Headland Park Site is currently collected via a sub-surface

[1] *Draft Stage 2 Remedial Action Plan for Barangaroo*, Hickson Road, Sydney, ERM, September 2008 (ERM 2008b)

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drainage network, which generally flows toward the Harbour. The current drainage network is shown on **Figure 5**.

Hydrology on the proposed Headland Park will be substantially modified with the amended topography. Sub-surface drainage will be controlled on the proposed Park. This is shown on a proposed Park section as provided as **Figure 6** and the sketch provided to **Appendix B**. As can be partially observed from **Figure 6** and the sketch to **Appendix B** two drainage systems are proposed over the majority of the proposed Park area with the site redevelopment:

- A shallow drainage system comprising a series of bioswales will be used to collect shallow seepage water in surface soils, used as a growing medium (not shown on **Figure 6** but shown in the sketch in **Appendix B**); and
- A deep drainage system with a clay bottom liner which will be placed under the majority of the proposed area of filling over the Park. The drain will be located below the depth of the current site surface. The clay liner will rise from the location of the drain at a reported slope of 1°. The most recent advice provided to JBS is that the clay liner will commence at a depth of approximately 2.5m AHD at the boundary of the Headland Park. The indicative lateral extent of the clay liner, consistent with the pathway proposed at the boundary of the Headland Park Site is shown on **Figure 9**.

The movement of water within the Proposed Park development has been described in AgEnviro Solutions (29th September 2010) 'Barangaroo Water Balance', included as **Appendix B**. The hydrological regime of the proposed Park has been described as follows:

- 64.46 ML of rainfall falling over the area of the Park annually;
- 9.4 ML of run-on water entering the Headland Park site from surface water flows from adjoining sites;
- 24.46 ML of water lost by evapotranspiration from plants on the Park;
- 10.8 ML of water lost as surface water run-off and discharged into the Harbour;
- 40.91 ML of water placed on the surface of the Park collected in a near surface drainage system consisting of bioswales;
- 12.05 ML seeping into deeper soils (below the depth of influence of the bioswale drainage system) of which 7.3 ML is captured by a deep drain, 1.6ML seeping through the clay bottom liner provided to the deep drain into underlying groundwater, and 3.15ML seeping into deeper soils at the northern, western and southern extremities of the site outside of the area of the proposed deep drainage system and discharge into Darling Harbour as seepage water / groundwater outflows;
- 19.56 ML of collected water from the near surface drains (bioswales) and deep drain system is re-used as irrigation water on the Park;
- 3.72 ML of water as placed on the surface in areas concentrated to the northern, western and southern extremities of the site outside of the area of the proposed bioswale system, infiltrating into near surface soils only and discharging into Darling Harbour by shallow seepage water discharge;
- 2.91 ML per year of water re-used as irrigation is lost by evaporation; and
- The remaining 23.64 ML of surplus water (collected water in the sub-surface drainage systems that is in excess of the Parks irrigation / waters re-use requirements) requires to be discharged from the site.

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By observation of **Figure 6**, the deep drain system will be present underlying all soils imported onto the Headland Park site, apart from a thin layer of materials to be placed underlying the clay liner to achieve the drain slope (immediately above the current site surface). No drainage controls are known to be proposed for soils to the south of Northern Cove. No significant filling works are proposed in this area of the site.

2.7 Geology

According to the 1:100 000 Geological Survey of NSW (Sydney) Sheet 9130 (Ed 1) 1983, the Headland Park Site is generally underlain by man-made fill that has been placed over marine sands and Hawkesbury Sandstone, which is described as follows (ERM 2008b):

- Man-made fill may consist of "dredged estuarine sand and mud, demolition rubble, industrial and household waste"; and
- Hawkesbury Sandstone is characterised as "medium to coarse-grained quartz sandstone with very minor shale and laminite lenses".

A substantial network of soil sample locations has been previously placed across the Barangaroo Project Site. The general geological profile observed at the Headland Park Site, as reported by previous investigations, is summarised in **Table 2.3**.

Table 2.3 Summary of Observed Site Geology

Lithological Unit	Description	Depth (mbgl)
Hardstanding	Asphalt, bitumen or concrete, generally in good condition with no staining.	0 – 0.46
Road base fill	Very dark grey, dry, loose, medium grained sand to fine gravel, poorly sorted, sub angular, no odours or staining noted.	0 – 0.5
Fill	Silty, gravelly sand, olive brown, grey brown, light yellowish brown, dry to wet, fine to coarse sand, sandstone floaters. Fill material including building rubble, bricks, concrete. Black staining and a hydrocarbon odour and significant contamination have been identified in some boreholes, particularly within and around the former gasworks area.	0 – 18.0
Marine Clay/Sand	Interbedded clayey sand and sandy clay, dark greyish brown, saturated, some shell fragments and organic matter. Sandy clay – soft, high plasticity. Clayey Sandy – loose to dense, fine to coarse sand, low to no plasticity. Contamination has been identified within and around the former gasworks area.	3.0 – 18.4
Marine Clay/Sand	Interbedded clayey sand, sandy clay and sand, light yellowish brown, white, reddish brown or dark greyish brown, saturated. Sandy clay – stiff to hard, medium to high plasticity. Clayey Sandy and sand – loose to dense, fine to coarse sand, low to no plasticity.	4.9 – 32.75
Bedrock	Weathered sandstone, white, light yellowish brown, olive brown and reddish brown, wet, fine to coarse grained, some fracturing noted. Contamination has been identified within and around the former gasworks area.	1.3 – 32.75

It was further reported that some areas along the western foreshore and building footprints were covered by concrete with a thickness up to 0.5 m. A layer of fill was observed in all boreholes and ranged in thickness from 1.3 m on the eastern portion of the Barangaroo Project Site to 18 m on the western portion of the Barangaroo Project Site.

The current site geology is described in more detail in the site conceptual model provided as **Section 4**. The most significant changes proposed to the site geology of the final Headland Park site (excluding areas to the north-west and south below the high water mark) include:

- Excavation of soils at the proposed boundaries of the Headland Park to form the proposed grades along the length of the site boundary to the edge of Darling Harbour;
- Placement of substantial quantities of imported fill over the majority of the proposed Park area so as to form the proposed Headland; and

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- Excavation of 60,000m^3 of sandstone and overlying fill based soils from the central portion of the eastern site. Backfilling of the subsequent void by imported soils.

Sydney Environmental & Soil Laboratory (undated) 'Soil Requirements for Barangaroo A Preliminary Scoping Paper' and conceptual plans have been provided to JBS as the basis of the soil design of the Headland Park. Four soil horizons are nominated in this correspondence as listed following:

- A Horizon – topsoil, with the highest fertility, organic matter and biological activity of the layers. It is always sandy and is not anticipated to have a silt / clay content in excess of 5%;
- B Horizon – a subsoil layer that is typically yellow clayey sand containing little if any organic matter. It is of low fertility. In the oldest profile type, the Podsolic, it contains the maximum clay content in the profile (15-30% silt plus clay). Clay content is also reported to increase with depth;
- C Horizon – decomposed rock with little structure, but allows some root penetration as it is not solid rock. Reported as being typically a clayey sand to sandy clay in texture; and
- R Horizon – described as solid rock, highly compacted engineered material or concrete.

Upper soils on the parkland site, to be used as growing medium, are reported to most likely consist of A and B horizons soils and are proposed to be manufactured with soils available from the development and selected imported materials (i.e. compost). The most recent advice received as to intended depths of soils to be used as growing medium on the Park has been provided in an email from BDA (23/11/2010) and includes provisions for growing soils to a maximum depth of 1.5m below ground surface (bgs) with a typical depth of 0.5m. It has been reported that irrigation lines and subsoil drains will be located within the upper 0.45m of the growing medium.

The surface soils will be drained by the bioswale system as described in the water balance in **Section 2.6**. Drop pits associated with the drainage system are reported to be placed at depths of 2m bgs.

Further advice from Sydney Environmental & Soil Laboratory (SESL) as emailed to JBS (9/7/2010), advised that soils below the depths of the growing medium would be compacted to "*prevent root penetration virtually completely*". A further email from SESL to JBS (14/7/2010) advised that surface soils used as growing medium will contain organic content consequent of blending. It was advised that a total organic carbon content of at least 3% should be anticipated for the surface soils / growing medium.

The majority of the in-situ geology, within the boundaries of the Headland Park will remain undisturbed, though for the most part substantially buried under imported fill materials.

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2.8 Hydrogeology

As previously reported (ERM 2008b), information obtained from the Department of Natural Resources (DNR) indicated that 32 registered groundwater bores were situated within a 4 kilometre (km) radius of the Headland Park Site. Review of the groundwater bore information indicated that the bores were used for the following purposes: recreation (8), irrigation (3), and monitoring (22). None of the listed bores were reported to be registered for drinking water purposes. No registered groundwater bores have been reported to be present on or adjacent to the Headland Park Site.

The quality of groundwater has been reported to have been assessed via a network of monitoring wells installed across the Headland Park Site (ERM 2008b). Locations of groundwater monitoring wells are shown on **Figure 8**. Hydrogeological data indicated that groundwater on the Headland Park Site was strongly influenced by tidal fluctuations, suggesting that the substantial hydraulic connection with the Harbour potentially associated with conduits in the fill material.

The hydrogeological data suggest that much of the Headland Park Site is likely to be subject to significant seawater flushing. Under typical conditions there is reported to be a likely net groundwater flux towards the Harbour, at a velocity of between 0 and 7.6 m/day (ERM 2008b).

It is not anticipated that the current hydrogeological regime would change substantially with the proposed Park development. The current rate of surface water recharge over the area of the site is unknown as it is controlled by cracks / penetrations in site pavement. Based on the water balance modelling, it has been estimated that 4.75 ML of seepage per year will infiltrate to groundwater from the Headland Park. It is reported that 1.6ML of this vertical seepage recharge will be derived from contained soils as placed above the current site surface forming the Headland profile.

2.9 Meteorology

The Sydney area has a humid to temperate climate with a seasonal rainfall maximum during the summer and autumn months. Annual mean rainfall recorded at Sydney (Observatory Hill) is 1212 mm[2].

The area has a history of droughts, which are broken by periods of heavy rainfall resulting in significant recharges to groundwater resources. The 1940s and 1980s and the current decade are observed to be dry periods, while the early 1970s and 1990s were wet periods.

Summer winds are predominantly northeasterly with southerly thunderstorms common. Winter winds are predominantly westerly.

[2] http://www.bom.gov.au/climate/averages/tables/cw_066062.shtml visited 7th May 2010

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3 Summary Site History / Previous Assessments

3.1 Barangaroo Project Site

The Barangaroo Project Site was a large precinct occupied by shipping and related merchants over the 1900s. A gasworks operated by The Australian Gas Light Company (AGL) over the period of 1840 to 1925 was located on part of the Barangaroo Project Site, within the Stage 1 Development, and extended across what is now Hickson Road. During the use of the Barangaroo Project Site for these purposes, the original shoreline was altered to enable the constitution of a number of finger wharves and associated activities, with these reclaimed over the period spanning the 1950s to 1970s. Over the past 20 years, the Barangaroo Project Site was used for principally stevedoring purposes until the majority of buildings were demolished and the land prepared for redevelopment in the past 5 years.

3.2 Headland Park Site

A summary of the Headland Park Site history has been provided in the previous reports (ERM 2008b). A chronological list of activities at the Headland Park Site is summarised below:

- 1840 to 1910: The Headland Park Site was owned by merchants, compositors, manufacturers and various shipping companies and was also used for ship berthing and associated activities. Ownership was largely transferred to Sydney Harbour Trust Commissioners (SHTC) in approximately 1910.
- 1910 to 1936: The majority of the Headland Park Site continued to be owned by the SHTC and was used for ship berthing and associated activities such as workshops and stores.
- 1936 to 1998: Ownership was transferred to the Maritime Services Board of NSW and subject to various commercial leases. Part of the Headland Park Site initially consisted of finger wharves, which were removed over time with a significant portion of land reclaimed from the Harbour with unclassified fill between 1951 and 1972.
- 1998: Marine Ministerial Holding Corporation was the proprietor of Lot 1. Sydney Ports Corporation was proprietor of Lots 2, 4 and 5.
- 1996-2007: A number of environmental investigations were conducted on the Headland Park Site; and
- 2007 - 2008: The Headland Park Site was vacated by Patrick Stevedores Operations. The warehouses were demolished and the land was cleared and leveled in preparation for future redevelopment.

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3.3 Previous Site Assessments

A number of previous site investigations have been undertaken which provide relevant environmental data for remediation planning. Environmental Assessments that have been made available to JBS include:

- ERM (June 2007) 'Environmental Site Assessment, East Darling Harbour, Sydney, NSW' (ERM 2007);
- ERM, (July 2008) 'Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW' (ERM 2008a);
- ERM (September 2008) 'Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney' (ERM 2008b);
- Douglas Partners (14 May 2010) 'Barangaroo Draft Factual Environmental Site Investigation Report' (DP 2010a);
- AECOM Australia (27 May 2010) 'Data Gap Investigation, Other Remediation Works (South) Area Hickson Road, Millers Point NSW' (AECOM 2010a);
- AECOM (23 September 2010) 'Data Gap Investigation EPA Declaration Area (Parts of Barangaroo Site and Hickson Road), Millers Point, NSW' (AECOM 2010b); and
- AECOM (20 October 2010) 'Data Gap Investigation Other Remediation Works North, Hickson Road, Millers Point, NSW' (AECOM 2010c).
- AECOM (3 November 2010) 'Groundwater Discharge Study Stage 1 Barangaroo Development' (AECOM 2010d); and
- Douglas Partners (17 December 2010) 'Factual Report – Pre Early Works Additional Environmental Assessment – Soils Barangaroo Headland Park' (DP 2010b).

The works and findings of each of these assessments is summarised following.

3.3.1 Environmental Site Assessment (ERM 2007)

This investigation (ERM 2007[3]) comprised a desktop study of existing and previous land uses, the placement of 161 soil sample locations across the site and the assessment of groundwater from 25 groundwater monitoring wells. Soil sample locations are shown as BH001 to BH161 on **Figure 7**. Groundwater monitoring well locations are shown as MW01 to MW25 on **Figure 8**.

The investigations reported encountering a layer of silty / gravelly sand fill in all boreholes, raging in thickness from 0.5 to 21m. Boreholes drilled in the northern and eastern portion of the Barangaroo Project Site were reported as being generally devoid of a layer of natural sediment, with fill underlain by the sandstone bedrock. In the central portion of the Barangaroo Project Site the fill layer was found to be underlain by natural marine sediments generally comprising silty clays underlain by sandstone. An underground storage tank (UST) was identified at the north-eastern corner of the Barangaroo Project Site.

Soils were reported to be sampled and analysed for a wide range of contaminants commonly associated with former gasworks and industrial sites including heavy metals (As, Cd, Cr, Cu, Pb, Hg, Ni and Zn), cyanides, sulphates, total petroleum hydrocarbons

[3] *Environmental Site Assessment, East Darling Harbour*, Sydney, NSW, ERM, June 2007 (ERM 2007)

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(TPH), monocyclic aromatic hydrocarbons (including benzene, toluene, ethylbenzene and xylene – collectively referred to as BTEX), polycyclic aromatic hydrocarbons (PAHs), phenols, polychlorinated biphenyls (PCBs), organochlorine pesticides (OCPs) and organophosphorus pesticides (OPPs).

Two primary areas were identified which had levels of contaminants above the adopted investigation criteria. These areas were described as being located in the proximity of the former gasworks (see **Figure 2**) and in the north-western portion of the site adjacent to Warehouse 3. The primary COPCs were identified as copper, lead, PAHs, TPH, BTEX and sulphates.

Isolated areas of soil impact were also identified including the western portion of Wharf 8, the eastern boundary of north of Warehouse 5 and the western edge of Warehouse 4. Impact at these locations was found to consist of PAHs including benzo(a)pyrene and lead. Impact was found to occur within a fill layer present to a maximum reported depth of 3.5m bgl.

Widespread elevated levels of heavy metals were also reported across the Barangaroo Project Site. The potential for asbestos containing materials (ACM) to be present was also identified across the Barangaroo Project Site. However, the consultant (ERM 2007) noted that the sampling methods employed as part of the assessment were not considered appropriate to identify ACM.

Groundwater underlying the Barangaroo Project Site was found to be subject to strong tidal influence. Groundwater impact was identified as consistent with the constituents identified as soil impact. The majority of groundwater impact was identified in the proximity of the former gasworks, with localised impact in other areas of the Barangaroo Project Site, such as in the proximity of the UST. Groundwater constituents identified at elevated levels included PAHs, TPH, BTEX cadmium, copper, lead, zinc and free cyanide.

3.3.2 Additional Investigation Works (ERM 2008a)

This additional investigation (ERM 2008a) consisted of additional soil and groundwater assessment to address perceived data gaps in the initial site assessment (ERM 2007).

A total of 55 soil sample locations were placed across the Barangaroo Project Site, consisting of 34 grid based locations and 21 targeted locations. Sandstone bedrock was additionally cored at 13 locations. Sample locations are shown as BH162 to BH215 on **Figure 7**.

A total of 23 existing wells and 13 newly installed wells were assessed across the site. The additional wells are referred to as sample locations MW179, MW198, MW200, MW204S, MW204D, MW205, MW206, MW209, MW210 and MW212 to MW215 on **Figure 8**.

Soil and groundwater were analysed for the COPCs identified in the initial site assessment (ERM 2007). The following results were reported (ERM 2008a):

- Localised levels of lead, TPH, BTEX, PAHs and sulphate exceeded the adopted assessment criteria. The highest levels were located within the area of the former gasworks;
- The highest levels of groundwater impact, occurring as TPH, BTEX and PAHs were located within the area of the former gasworks. Groundwater impact was identified in this area as occurring in fill materials, natural clayey sands and sandstone;

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- Groundwater was found to be substantially influenced by tidal movements with very high hydraulic conductivities recorded for the fill material. It was considered that substantial tidal flushing of the aquifer had occurred which had resulted in a relatively small migration of impact from the area of the former gasworks; and
- Phase separated hydrocarbon (PSH) impact was identified at monitoring well MW204D in the area of the former gasworks.

The same limitations with the sampling methodology to identify ACM were present in both ERM 2007 and ERM 2008a investigations.

3.3.3 Stage 2 Remedial Action Plan (ERM 2008b)

A remedial strategy for the whole of the Barangaroo Project Site was prepared in ERM (2008b). The preferred remedial approach for the former gasworks portion of the site, currently subject to the DECCW regulation and proposed for future mixed use, was determined to be source removal via either excavation and off-site treatment and disposal (for the most heavily impacted materials) or excavation and on-site stabilisation / reuse (for less heavily impacted materials). Re-use of materials was proposed to occur in any appropriate area of the site, including the proposed Headland Park.

The remaining areas of the Barangaroo Project Site (including the area of the Headland Park) were proposed to be made suitable for the proposed developments by on-site management involving capping of impacted materials and hotspot removal of materials exceeding risk based clean-up levels.

3.3.4 AECOM Data Gap Investigation Remediation Works (South) Area (AECOM 2010a)

Targeted sampling and analysis was completed by AECOM in the area of Blocks 1, 2 and 3 within Stage 1 of the Barangaroo Project Site. The investigations were undertaken to obtain additional contaminant data in these areas. The works comprised the placement of 35 soil sample locations, seven groundwater monitoring wells, four soil vapour wells and additional sampling and analysis of selected existing groundwater monitoring wells. Sample locations are shown on **Figure 10** and analytical data are summarised in **Appendix A**.

Hot-spots of environmental impact were recorded throughout the fill materials and in the proximity of the former gasworks on the site. Constituents identified included lead, total petroleum hydrocarbons, benzene, xylenes, polycyclic aromatic hydrocarbons and sulphate.

Of the limited number of soils analysis for acid sulphate soils, potential acid sulphate soils were generally recorded in the natural soils.

3.3.5 AECOM Data Gap Investigation EPA Declaration Area (AECOM 2010b)

Targeted sampling and analysis was undertaken by AECOM in the area of Blocks 3, 4 and 5 of the Barangaroo Project Site, part of the proposed Southern Cove and part of Hickson Rd adjacent to the Barangaroo Site. The investigations were undertaken to obtain additional contaminant data in these areas. The works comprised the placement of 25 soil sample locations, nine groundwater monitoring wells, seven soil vapour wells and additional sampling and analysis of selected existing groundwater monitoring wells. Sample locations are shown on **Figure 11** and analytical data are summarised in **Appendix A**.

The additional sampling and analysis confirmed the findings of previous assessments that substantial environmental impact is present in the proximity of the former gasworks

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infrastructure. Soil vapour, principally consisting of naphthalene, was identified in the proximity of the former gasworks.

Of two samples analysed for acid sulphate soils, one sample consisting of clayey sand from a depth of 7.3-7.5m recorded potential acid sulphate soils. The other sample consisting of sandy gravelly clay fill did not report acid sulphate soils

Samples submitted for 'neutral water leach' (by ASLP leaching) reported some potentially leachable levels of lighter PAHs and heavy metals.

3.3.6 AECOM Data Gap Investigation Remediation Works (North) Area (AECOM 2010c)

Targeted sampling and analysis was undertaken by AECOM in the area of the proposed Blocks 4, 5, Southern Cove and the Public Domain of the Barangaroo Project Site. The investigations were undertaken to obtain additional contaminant data in these areas. The works comprised the placement of 13 soil sample locations, five groundwater monitoring wells, one soil vapour wells and additional sampling and analysis of selected existing groundwater monitoring wells. Sample locations are shown on **Figure 11** and analytical data are summarised in **Appendix A**.

Elevated levels of hydrocarbon constituents were identified at some sample locations, including monocyclic aromatic hydrocarbons and polycyclic aromatic hydrocarbons. The highest levels of soil impact were identified in Blocks 4 and 5 in close proximity of the former gasworks. Naphthalene was identified in soil vapour. Some elevated levels of heavy metals were identified in groundwater, with the highest levels being recorded in wells screened at deeper depths.

Samples submitted for 'neutral water leach' (by ASLP leaching) reported some potentially leachable levels of lighter PAHs and heavy metals.

3.3.7 AECOM Additional Analysis

Limited additional analysis of AECOM samples was undertaken by JBS to assist with the interpretation of the leachability data. Analytical reports from these analyses are provided in **Appendix A**.

3.3.8 AECOM Intertidal Study (AECOM 2010d)

AECOM undertook a study of groundwater discharge from the Barangaroo Central and South Sites. It was found that an attenuation factor of five could be applied to groundwater constituents as present in groundwater underlying the site as discharging to Darling Harbour. This factor is intended to be applied to predict the dilution of leachate in saturated soil to the receining environment (i.e. Darling Harbour). AECOM have advised JBS that the results of the study are applicable to groundwater discharge on the Headland Park site.

3.3.9 Douglas Partners Sampling and Analysis

Targeted sampling and analysis works were completed by Douglas Partners (DP2010a & 2010b) across the majority of the Barangaroo Project Site in April, May, November and December 2010. Sample locations are shown on **Figure 12**. Soil analyses included analysis of total and ASLP leachable concentrations.

A comparison of total and leachable levels of constituents as generated by the copmpletion of the DP (2010a & 2010b) works has been provided in JBS Environmental (10 January 2011) 'Summary of Results of Soil Analysis of Chemical Constituent Leachability Barangaroo'.

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Two additional groundwater monitoring wells were also installed within the Headland Park site during the November and December 2010 works and all monitoring wells (new and existing) within the Headland Park site were sampled and analysed.

3.3.10 Data Quality

Each of the respective assessments identified in Section 3.3.1 to 3.3.9 have concluded that the data presented in adequately reliable to be used in decision making on the Barangaroo site. JBS has undertaken no further assessment of the data and it is assumed that all data is reliable for use in the HHRA.

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4 Conceptual Site Model

A conceptual site model (CSM) has been prepared to document the constituents of potential concern (COPCs), sources of COPCs, pathways, and potential receptors. The CSM is considered to be an essential pre-requisite prior to the consideration of the scope of the HHRA.

It is noted that the CSM has not focussed extensively on existing pathways or contaminant distribution. Substantial earthworks are proposed for the Headland Park Site which will result in the movement of soils about the site. The CSM has instead focussed on potential interactions with soils with the future development of the site, focussed to the Headland Park and Northern Cove.

4.1 Geology

As described in detail in **Section 2.7** the proposed Headland Park geology can be described as:

- Soils in accessible parts of the site to a maximum depth of 1.5m consisting of top-soils. These are characterised as being well aerated and having high levels of organic carbon;
- Sub-surface services typically restricted to the upper 0.5m of the soils profile, apart from large drainage pits associated with the sub-surface drainage system;
- Fill based soils as sourced from shoreline reclamation, Northern Cove excavation and surplus soils from Barangaroo Central and South used to form the Headland profile of the park. Limited descriptions provided for these materials indicate that they will be well compared and have low levels of oxygen;
- Clay liner placed at an approximate elevation of 3m AHD underlying the majority of the site as associated with the retention of seepage water formed in the filled portion of the site;
- Existing in-situ soils, as consisting of a shallow depth of fill materials overlying naturally occurring clayey sand soils or sandstone, as present at the Park boundaries and underlying the clay liner in the remaining Park area. These soils are not anticipated to be substantially modified from the current condition.

Further details on the composition of sub-surface soils on the propose Headland Park can be determined from review of **Figures 13** to **15**.

Figures 13 and **15** show a wedge of cement stabilised sandstone that is proposed to be placed adjoining the walls of the proposed Car Park structure and the majority of the lower walls of the overlying 'Future 'Cultural Space'' Building Space. This has been advised by BDA to consist of crushed sandstone blended with cement. The cement is generally used to fill the voids in the crushed sandstone and is hydrated so to achieve the strength characteristics required. The voids between the hydrated cement would be anticipated to minimise vapour and seepage water movement through this material, in a similar manner to a low permeability soil.

It is understood that the remainder of the backfill in the vicinity of the Car Park, including a potential void underlying the Car Park, as shown in **Figures 13** to **15** will consist of general fill materials. No engineering specification has been provided for these materials.

Limited analysis of geological parameters of existing soils on the Barangaroo Site has been undertaken in AECOM (2010a and 2010b), DP (2010) and/or the additional analysis of AECOM (2010) samples as reported in **Appendix A**. Levels of organic carbon in site soils have been found to range from 0.15% to 2.8%.

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On this basis, for the purposes of risk assessment and fate and transport modelling, there is considered to be four distinct soil types that will be present in the majority of the Park:

- Soils present at near surface depths (reported to be 0.5-1.5m bgs dependent on plat life being supported) to be used as growing medium;
- Soils to be present in the sandstone retaining wall as shown on **Figure 15**;
- Soils to be present as general fill material throughout the bulk of the Park; and
- In-situ soils as will be present below the capping layer as provided to the Park.

4.2 Hydrogeology and Water Balance

As described in **Sections 2.6** and **2.8**, surface and sub-surface water movement on the proposed Headland Park can be broadly described as:

- Surface water flows over the majority of the park surface will be collected and controlled by a system of shallow 'bioswale' drains;
- Deeper surface water which infiltrates into the Headland profile of the Park is anticipated to infiltrate to the depth of an underlying clay liner as part of a deep seepage water collection system;
- Existing groundwater as present underlying the site (within in-situ soils) which is substantially tidally influenced;
- Minor leakage of seepage water out of the Headland portion of the site into the underlying in-situ soils; and
- Substantial re-use of collected seepage waters as irrigation water on the Park subsequent to treatment, otherwise disposal off-site.

There is anticipated to be very limited interaction between seepage water as will occur within the headland portion of the site, and the existing and continuing tidally influenced groundwater underlying the site.

No information is available on a likely depth of a seepage water table that may occur within the Headland portion of the site. Noting the extent of compaction proposed with soils below the depth of the 'growing medium' (0.5-1.5m bgs) there is a potential that a seepage water horizon (as associated with a significant area of connected saturated soils) may occur above this depth, however the Park is being designed to ensure the rapid drainage of this seepage water. Depending on the effectiveness of the deep drain as will be installed above the clay liner, there is also a potential that a seepage water horizon may also establish at depth underlying the headland.

Advice on groundwater flows in the current sub-surface underlying the area of the Park has been provided in emails from John Braybrooke of Douglas Partners (28/7/2010). It has been advised:

- Groundwater inflow /outflow into the proposed excavation underlying the Car Park is anticipated to be very low and less than 1 litre/minute; and
- The majority of groundwater movement underlying the site consists of water movement through the high permeability fill materials that are currently present overlying the natural sandstone at the boundaries of the Park site. It has been estimated that groundwater fluxes of 100-150 ML per day may move in and out of the highly permeable sub-surface zone.

4.3 Constituents of Potential Concern

COPCs identified as adversely impacting soils and/or groundwater have been found to include:

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- Heavy metals including copper, lead and zinc;
- Total petroleum hydrocarbons (TPH);
- Monocyclic aromatic hydrocarbons including benzene, toluene, ethylbenzene and xylenes;
- Polycyclic aromatic hydrocarbons (PAHs);
- Phenols;
- Cyanides;
- Ammonia;
- Sulphates; and
- Asbestos.

Other COPCs that may also be present that have not been previously tested for include:

- Other volatile organic compounds, particularly including other monocyclic aromatic hydrocarbons (e.g. trimethylbenzenes).

4.4 Known On-Site Occurrences of COPCs

The principal area of impact in the proximity of the proposed Headland Park and Northern Cove is located at the footprint of the former gasworks (ERM 2008b). COPCs including PAHs, BTEX, TPH, phenols, cyanide, lead and zinc have been identified in this area of the Barangaroo Project Site. Highest levels of hydrocarbon constituents are co-incident with former gasworks infrastructure (AECOM 2010b and 2010c), with the depth of impact below the site surface generally increasing with further distance away from the former infrastructure.

Elevated levels of lead have also been identified throughout the area of the former gasworks, generally associated with near surface fill material generally described as consisting of sand and silty sand soils. These fill materials are present throughout the site and the lead impact does not appear co-incident with this or any particular type of fill.

Hydrocarbon impacts have been identified in fill based soils, underlying natural soils and within deeper sandstone occurring within rock fractures within the area of the former gasworks. There is evidence of the lateral and downward migration of hydrocarbon impact.

Several hot-spots are located over the remainder of the Barangaroo Project Site including the proposed location of the Headland Park and Northern Cove. These hot-spots generally consist of lead impacted fill materials, or PAH impacted fill materials. These specifically include:

- Lead hot-spots at the south-west of the Barangaroo Project Site and the centre of the eastern boundary; and
- Several hot-spots of PAH impact generally present in fill materials across the Barangaroo Project Site including hot-spots at the perimeter of the former gasworks, extensive impact in fill materials at the north-western portion of the Barangaroo Project Site and localised hot-spots over the central and southern portions of the Barangaroo Project Site.

Common fill types are identified by the review of borelogs across the site. It is noted that for the extent of fill material across the Barangaroo Project Site, that a broad program of

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sampling and analysis has been undertaken. It is likely that localised lead, and particularly PAH/TPH impacts, may be present in other areas of the site due to the heterogeneous nature of the fill materials.

It is also noted that the highest levels of hydrocarbon impacts (PAHs, TPH and BTEX) have been coincident with aesthetic impacts including odours and observations of tar. This indicates that where areas of gross impacts have not been identified by the sampling and analysis works completed to date, they will be identified by aesthetic indicators during the proposed future earthworks.

Groundwater at the northern portion of the site in the proximity of the proposed Headland Park and Northern Cove is currently found to be free of substantial environmental impact.

4.5 Potential Off-Site Sources of COPCs

The remnant gasworks infrastructure beneath Hickson Rd has been identified as a potential off-site source of COPCs. This is hydrogeologically upgradient of the central and southern portion of the Barangaroo Site. No potential off-site sources of COPCs have been identified at the north of the Barangaroo Site in the proximity of the Headland Park and Northern Cove.

4.6 Preferential Pathways

For the purpose of this assessment, preferential pathways have been identified as natural and/or manmade pathways that result in the preferential migration of COPCs as either liquids or gasses.

Man-made preferential pathways are present at the north of the Barangaroo Project Site, generally associated with extensive sand and gravel based fill materials. As indicated by estimates of hydraulic conductivity and extent of tidal influence observed in groundwater monitoring wells, these fill materials are found to be have a high permeability.

Fill materials sourced from on-site and comprising sand based soils potentially with crushed sandstone, will form the basis of the geology of the Headland Park. The geological profile of the area of the Headland Park, in particular, will be substantially altered by these proposed filling works. As such, the geology of the Headland Park formed by the filling and raising of the site profile, is also likely to be very permeable. There is potential that a perched / localised aquifer, recharged by surface infiltration and potential shallow sub-surface flows from the east of the site, will occur within the fill materials.

4.7 Potential Leaching of Environmental Impact

Impacted soils are present across the area of the proposed Headland Park and Northern Cove. These are generally present within fill materials as hot-spots. Low levels of environmental impact have been identified in groundwater underlying the proposed area of the Park and Cove. The low levels of impact in groundwater, compared to the potential leaching potential of the impacted fill materials, have been indicated in previous assessments to be consequent of extensive tidal flushing of marine water occurring in the high permeability sub-surface soils.

The excavation and handling of soils during the development of the Headland Park may expose areas of environmental impact to future leaching processes. Fill materials from the Barangaroo Project Site used to raise the surface of the Park may be subject to levels of environmental impact. The hydrogeological regime of the redeveloped park has been

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defined in AgEnviro (2010) and summarised in **Section 4.2**. Seepage water flows will occur in upper depth permeable soils and through deeper less permeable fill based soils. Constituents present in each of the soils will potentially be impacted by leaching from fill materials used to form the soils.

4.8 Exposure Pathways

The exposure pathways considered to be potentially complete include:

- Inhalation of COPC vapours migrating upwards from impacted soils and/or from shallow seepage water occurring after filling of the Headland Park Site and/or from deeper groundwater present underlying the Park. Vapours may occur in outdoor areas, potential future sub-surface excavations, within the Car Park or within the 'Cultural Space' overlying the Car Park;
- Dermal and oral exposure to impacted soils used to form the park and present at shallow depths and so accessible by future service / maintenance excavations;
- Dermal and oral exposure with seepage water infiltrating into future service / maintenance excavations;
- Inhalation and dermal exposure with collected seepage water as irrigated over the Headland Park Site by sprinklers; and
- Inhalation and dermal exposure with seepage water which may potentially infiltrate into the Car Park structure.

It is anticipated that groundwater extraction, below the depth of the clay liner, will not occur over the area of the Headland Park site. Groundwater below this depth is found to be saline and unsuitable for any beneficial uses. Therefore, this has not been considered as a complete exposure pathway.

4.9 Receptors

Potential receptors of COPCs include:

- Future recreational users of the Park;
- Excavation / construction / maintenance workers conducting activities at or in the vicinity of the Headland Park Site, who may potentially be exposed to COPCs through inhalation of vapours or via direct dermal contact with impacted soils and/or seepage water present within excavations;
- Commercial / industrial workers occupationally engaged within the Car Park or 'Cultural Space';
- Recreational users of the 'Cultural Space'; and
- Customers of the Car Park.

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5 Issue Identification

Issue identification is the first step of the risk assessment process.

5.1 Issue Identification

Issue identification determines whether risk assessment is useful, and establishes a context for the risk assessment by a process of identifying the concerns the risk assessment needs to address. Issue identification draws on all relevant lines of information.

Issue identification comprises several phases:

1. Identification of environmental health issues (or an individual issue) and determining whether there are hazards amenable to risk assessment. This will involve demarcating 'hazards' from 'issues' and may require environmental sampling;
2. Putting the hazards into their environmental health context (clarification and prioritising of problems and hazards);
3. Identification of potential interactions between agents; and
4. Stating clearly why risk assessment is needed and the scope and objectives of the risk assessment. This will involve identifying problems for which information is, or can be, available to undertake adequate risk assessments and problems which risk assessment cannot assist.

5.2 Identification of Environmental Hazards

Environmental health hazards may be caused by physical, chemical, biological or social factors in the environment. Physical factors include heat, cold, noise, mechanical hazards etc. Chemical factors include synthetic and naturally occurring substances. Biological factors include viruses, prions, bacteria, parasites and vermin.

The proposed Headland Park is the subject of this assessment. Environmental impact is currently present in isolated areas of the Barangaroo Project Site, reported to be consequent of historical placement of fill materials associated with the former industrial use of the Headland Park Site and surrounding area.

The fill materials currently present in the portion of the Barangaroo Project Site to be developed as the Headland Park are impacted with elevated levels of heavy metals, petroleum hydrocarbons and monocyclic and polycyclic aromatic hydrocarbons (MAHs and PAHs).

Surplus materials from the remainder of the Barangaroo Project Site will potentially be used as fill materials in the construction of the Headland Park. A range of industrial uses and associated filling activities have occurred across the Barangaroo Project Site. Most significantly a former gasworks operated within the southern portion. A range of environmental contaminants have been identified within soil and groundwater in the proximity of the former gasworks including heavy metals, petroleum hydrocarbons, MAHs, PAHs, cyanides and phenols. The highest levels of these constituents have generally been associated with observations of tar within soils and groundwater.

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5.3 Environmental Sampling and Analysis

Environmental sampling and analysis are a key factor in identifying the agents that may be present, their concentrations and distributions. Environmental sampling and analysis require to be targeted to address the identified potential environmental hazards.

Environmental sampling and analysis have been detailed in the previous investigations listed in **Section 3**. Within the area of the proposed Headland Park a range of environmental constituents including heavy metals, petroleum hydrocarbons, MAHs and PAHs have been identified in soils at levels exceeding NSW DECCW published and/or endorsed investigation criteria. Across the broader area of the Barangaroo Project Site, where fill materials may potentially be sourced from to create the proposed landform of the Park, significantly elevated levels of heavy metals, petroleum hydrocarbons, MAHs, PAHs, cyanides and phenols have been reported in soils and/or groundwater, in particular, associated with tar impacted materials identified in the proximity of the former gasworks.

5.4 Putting Hazards into their Environmental Health Context

Putting the hazards into their environmental context entails a consideration of:

- Whether the hazard has single or multiple sources;
- Whether the type of environmental impact affects multiple environmental media;
- How stakeholders perceive the problem including the consideration of different groups; and
- How do the hazards compare to other environmental hazards affecting the community.

The environmental hazards across the Barangaroo Project Site may have multiple sources arising from the former commercial / industrial processes undertaken (including operation of a gasworks) and the anticipated significant generation and potential on-site placement of waste materials / by-products. Human health risks associated with tar-based contaminants including potential dermal and oral contact with tar containing materials and potential inhalation of volatile constituents of tars (i.e. benzene and naphthalene). These materials may also pose potential ecological impacts, particularly in locations where leaching of impact may enter waterways, or in soils used as growing media. This risk becomes greater where more sensitive site uses and longer exposure periods occur.

The risk assessment requires consideration of the redevelopment of the northern portion of the Barangaroo Project Site as the Headland Park, as well as the underground Car Park and a 'Cultural Space'. The major human stakeholders identified for the Headland Park and Northern Cove include recreational users of open space facilities and commercial / industrial workers within the proposed Car Park and 'Cultural Space'.

As the environmental hazards present on the Barangaroo Project Site are related to commonly occurring commercial / industrial contaminants, including heavy metals, petroleum hydrocarbons, monocyclic hydrocarbons and polycyclic hydrocarbons, that previously had widespread use throughout Australia, it can be assumed that the environmental hazard does not pose a unique hazard to the community. However, the presence of these contaminants in uncontrolled locations, potentially accessed by sensitive populations, may serve to increase the exposure of the community and/or the environment to the environmental hazard.

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5.5 Identification of Potential Interactions between Agents

There may be interactions between the physical, chemical, biological and social hazards that require identification and consideration as part of a risk assessment. There are several potential types of interactions between hazardous agents which include: additive effects; synergistic effects; potentiation effects and antagonistic effects.

It is widely acknowledged that activities such as smoking can increase the susceptibility of a person to the potential effects of some carcinogens. To this effect, it will be required to be ensured that conservatively derived data and reasonably maximum exposed receptors are used as the basis for any risk assessment.

5.6 Why is Risk Assessment Needed?

The occurrence of environmental hazards in a site sub-surface is unique for every site and location. Further, the particular populations exposed to an environmental hazard are unique for every occurrence of the environmental hazard. Regulatory authorities within NSW do not provide comprehensive guidance for the assessment as an environmental hazard of the range of contaminants identified within the proposed Headland Park and Northern Cove, or present within the wider Barangaroo Project Site, where fill materials to construct the Park may be sourced. The limited guidance available is considered unsuitable to be solely applied to the development of the proposed Headland Park and Northern Cove.

The requirement for, and/or the method of remediation/management for an environmental hazard needs to be determined. The extent of this requirement, if there is a requirement, must be determined by the assessment of the presence of an environmental hazard; the degree of potential harm posed by the environmental hazard (in an isolated environment); and the likely exposure of the surrounding community and environment to the environmental hazard. Only through the assessment of all these factors can the true impact of the environmental hazard be assessed. The risk assessment process is designed to include all of these factors to determine a site specific requirement and associated acceptance criteria for a range of environmental constituents, which may be present in soils and/or sediments and/or seepage water and/or groundwater which will occur on the Site.

5.7 Limitations and Uncertainties

Potential limitations and uncertainties that may occur in the risk assessment process include:

- Information gaps, e.g. effects of mixtures, low level and variable exposures over time, relative contribution of 'lifestyle' factors;
- Poor exposure information, e.g. complex mixtures of hazards with complex behaviours in the environment; limited knowledge about the actual or potential sub-population;
- Limitations of toxicological or epidemiological research, e.g. small populations and limited exposure information, multifactorial causes of many diseases on health impacts; 'background noise' affecting research into common diseases or symptoms; population heterogeneity;
- Complexity, e.g. large numbers of combinations of hazards, exposures and health states;

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- Confidentiality of health and commercial information;
- Charged atmosphere of fear, antagonism and distrust; and
- Value conflicts.

The risk assessment requires a thorough sensitivity analysis subsequent to the provision of the risk outcomes. The sensitivity analysis will be required to take these matters into account, testing the outcome of the risk assessment of reasonable upper and lower bounds of each. Sensitivity analysis of all assumptions has been undertaken throughout the risk assessment. Risk assessment outcomes may require to be modified where sensitive parameters are observed to have large reasonable potential deviations.

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6 Selection of Constituents of Potential Concern

Extensive soil and groundwater data have been collected from underlying the Barangaroo Project Site. Surplus soils may potentially be received from the Barangaroo Project Site and used in the development of the Headland Park (subject to environmental suitability). Existing soils will be retained where possible for use on the site.

Soils as received on the site and used to form the Headland profile may leach contaminants and impact sub-surface seepage water, which may potentially occur at shallow depths within the area of the Headland Park. Sub-surface seepage water collection, proposed as part of remedial planning for the Park, is proposed to facilitate re-use of seepage water on the Headland Park site. Consequently, the proposed Headland Park Site development will potentially alter the exposure patterns to current site groundwater.

A screening assessment is required to select constituents of potential concern (COPCs) so as to distinguish between chemical constituents which pose little or no risk to human health and those constituents which may pose a risk. The screening assessment has been undertaken by a comparison of measured constituent concentrations with adopted screening criteria. Constituent concentrations across the whole of the Barangaroo Project Site have been considered.

Where constituent concentrations in the soil at the Barangaroo Project Site or the groundwater on the proposed extent of the Headland Park site do not exceed the screening criteria, it may be concluded with a high degree of confidence that those constituents do not pose a significant risk to human health. Constituents exceeding screening criteria are set as COPCs for further risk assessment.

6.1 Selection of Screening Criteria

Assessment criteria for sensitive land-uses are provided by regulatory authorities in Australia and internationally. Though these assessment criteria are not strictly applicable to the exposure scenarios and occurrence of site impact within the study area, they can be used to select constituents of potential concern (COPC's) requiring further assessment. The published assessment criteria used include:

- Soil criteria published in NSW DEC (2006) 'Contaminated Sites: Guidelines for the NSW Site Auditor Scheme 2nd Edition'. 'Parks, recreational open space, playing fields (NEHF E)' criteria have been used;
- Soil criteria published in NSW EPA (1994) 'Contaminated Sites: Guidelines for Assessing Service Station Sites';
- Drinking water criteria provided in NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines';
- Human health based groundwater (i.e. drinking water) criteria published in NEPC (1999) 'National Environmental Protection (Assessment of Contamination) Measure';
- Human health based drinking water criteria published in WHO (2005) 'Petroleum Products in Drinking Water';
- US EPA (November 2010) Residential Soils Regional Screening Levels. Residential soil criteria have been used as these are the most conservative criteria provided in this document;

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- US EPA (November 2010) Tap Water Regional Screening Levels;
- The Dutch Intervention Level for soils and groundwater provided to Ministry of Housing, Spatial Planning and the Environment (2000) 'Circular on target and intervention values for soil remediation'. Though the Netherlands is a signatory to the World Health Organisation, and WHO sources of toxicity data are preferred by enHealth and NEPC (1999), Dutch criteria have not been used in preference to US EPA criteria. US EPA criteria have been preferred as these are found to be more recent. Dutch criteria have only been used for constituents where no other agency provides definitive guidance.

The criteria selected from the above sources are summarised in **Table 6.1**, following, for soils and **Table 6.2** for groundwater, for each constituent recorded above detection limits in the analytical data sets.

Table 6.1: Summary of Soil Screening Criteria (mg/kg)

Constituent	Human Health Based Criteria
Heavy metals	
Aluminum	77 000[6]
Arsenic	200[1]
Barium	15 000[6]
Berrylium	40[1]
Cadmium	40[1]
Chromium	200[1,2]
Cobalt	200[1]
Copper	2,000[1]
Lead	600[1]
Manganese	3000[1]
Mercury	30[1]
Nickel	600[1]
Tin	47 000[6]
Vanadium	390[6]
Zinc	14,000[1]
Other Inorganics	
Sulphate	NC
Cyanide (total)	500[1, 3]
Total Petroleum Hydrocarbons	
TPH C_6-C_9	65[5]
TPH C_{10}-C_{14}	1,000[5]
TPH C_{15}-C_{28}	
TPH C_{29}-C_{36}	
Monocyclic Aromatic Hydrocarbons	
Benzene	1[5]
Toluene	1.4[5]
Ethylbenzene	3.1[5]
Xylene (total)	14[5]
1,2,4-trimethylbenzene	62[6]
1,3,5-trimethylbenzene	780[6]
Styrene	6 300[6]
Polycyclic Aromatic Hydrocarbons	
Total PAHs	40[1]
Acenaphthene	3,400[6]
Acenaphthylene	NC
Anthracene	17,000[6]
Benz(a)anthracene	0.15[6]
Benzo(a)pyrene	2[1]
Benzo(b)fluoranthene	0.15[6]
Benzo(g,h,i)perylene	NC
Benzo(k)fluoranthene	1.5[6]
Chrysene	15[6]
Dibenz(a,h)anthracene	0.015[6]
Fluoranthene	2,300[6]
Fluorene	2,300[6]
Indeno(1,2,3-c,d)pyrene	0.15[6]
2-methylnaphthalene	310[6]
Naphthalene	3.6[6]

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Constituent	Human Health Based Criteria
Phenanthrene	NC
Pyrene	1,700[6]
Other SVOCs	
Phenol	17,000[1]
2,4-dimethylphenol	1,200
2-methylphenol	5[4, 7]
3- & 4-methylphenol	
2-picoline	NC
Azobenzene	5.1[6]
Carbazole	NC
Dibenzofuran	78[6]
Ethion	31[6]
Bis(2-ethylhexyl) phthalate	35[6]

Notes: 1. DEC (2006) 'Parks, Recreation, Open Space (NEHF E) criteria
2. Value for Cr(VI)
3. Based on cyanides (free)
4. Netherlands Ministry for Housing, Spatial Planning and the Environment (2000) intervention value
5. NSW EPA (1994)
6. US EPA (November 2010) Residential Soil Screening Level
7. Criteria for sum of cresols
NC no criteria

Table 6.2: Summary of Groundwater Screening Criteria (µg/l)

Constituent	Human Health Based Criteria
Heavy metals	
Arsenic	7[1]
Cadmium	2[1]
Chromium (total)	50[1]
Copper	2,000[1]
Lead	10[1]
Mercury	1[1]
Nickel	20[1]
Zinc	3,000[1, 6]
Other Inorganics	
Ammonia	0.5[1, 6]
Cyanide (total)	80[1]
Total Petroleum Hydrocarbons	
TPH C_{15}-C_{28}	90[2]
TPH C_{29}-C_{36}	
Monocyclic Aromatic Hydrocarbons	
Benzene	1[1]
Xylenes	600[1]
1,2,4-trimethylbenzene	15[4]
Polycyclic Aromatic Hydrocarbons	
Benz(a)anthracene	0.029[4]
Benzo(a)pyrene	0.01[1]
Benzo(b)fluoranthene	0.029[4]
Benzo(g,h,i)perylene	0.05[3, 5]
Benzo(k)fluoranthene	0.29[4]
Chrysene	2.9[4]
Fluoranthene	1,500[4]
Indeno(1,2,3-c,d)pyrene	0.029[4]
Naphthalene	0.14[4]
Phenanthrene	NC
Pyrene	1,100[4]

Notes: 1. NHMRC/NRMMC (2004) health based drinking water guideline
2. WHO (2005) value provided for TPH >EC16—EC21 and >EC21-EC35 aromatic fraction
3. Netherlands Ministry for Housing, Spatial Planning and the Environment (2000) intervention value for mineral oil. Mineral oil adopted for assessment of total petroleum hydrocarbons.
4. US EPA (November 2010) Tap Water Screening Level
5. Used in lieu of other published value
6. Criteria based on aesthetic considerations used in lieu of other criteria
NC no criteria

6.2 Selection of COPCs in Soils

Environmental data for the Barangaroo Project Site have been reviewed and the maximum concentration of each constituent determined.

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It is noted that on the basis of the total PAH criteria as published by Australian jurisdictions that all PAH constituents require to be selected as COPCs in soils. Where speciated criteria are available from international agencies these have also been referred to in the refinement of the selection of PAH constituents for detailed risk assessment. These speciated criteria were also included in **Table 6.1**. This has resulted in the reduction of the number of PAH constituents for detailed consideration for human health assessment.

Maximum concentrations have been compared to the screening criteria and selected as a COPC where the screening criteria are exceeded, as summarised in **Table 6.3**, following.

Table 6.3: Summary of Selection of COPCs for Soils

Constituent	Maximum Concentration (mg/kg)	COPC Selection
		Human Health (soils)
Heavy Metals		
Aluminum	3340	
Arsenic	94	
Barium	690	
Berrylium	4	
Cadmium	5	
Chromium	1,600	X
Cobalt	39	
Copper	1,480	
Lead	13,600	X
Manganese	864	
Mercury	14.7	
Nickel	470	
Tin	12	
Vanadium	248	
Zinc	4,770	
Other Inorganics		
Sulphate	31,500	
Cyanide (total)	6,900	X
Total Petroleum Hydrocarbons		
TPH C_6-C_9	10,282	X
TPH C_{10}-C_{14}	89,207	X
TPH C_{15}-C_{28}	166,423	X
TPH C_{29}-C_{36}	25,800	X
Monocyclic Aromatic Hydrocarbons		
Benzene	1510	X
Toluene	2650	X
Ethylbenzene	261	X
Xylene (total)	2629	X
1,2,4-trimethylbenzene	220	X
1,3,5-trimethylbenzene	100	
Styrene	241	
Polycyclic Aromatic Hydrocarbons		
Acenaphthene	511	
Acenaphthylene	2,569	
Anthracene	2,150	
Benz(a)anthracene	1,870	X
Benzo(a)pyrene	908	X
Benzo(b)fluoranthene	975[1]	X
Benzo(g,h,i)perylene	305	
Benzo(k)fluoranthene	975[1]	X
Chrysene	1,009	X
Dibenz(a,h)anthracene	110	X
Fluoranthene	2,569	X
Fluorene	2100[2]	X
Indeno(1,2,3-c,d)pyrene	404	X
2-methylnaphthalene	7650	X
Naphthalene	17,064	X
Phenanthrene	5,180	
Pyrene	2640	X
Other SVOCs		
Phenol	1,720	
2,4-dimethylphenol	901	

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Constituent	Maximum Concentration (mg/kg)	COPC Selection
		Human Health (soils)
2-methylphenol	1,160	X
3- & 4-methylphenol	2,290	X
2-picoline	33.9	
Azobenzene	3	
Carbazole	186	
Dibenzofuran	327	X
Ethion	2.6	
Bis(2-ethylhexyl) phthalate	13.1	

Note: 1. Highest combined (b) and (k) result
2. Selected on the basis of Total PAHs exceeding the screening criteria and found to be potentially volatile

It is noted that no screening criteria were available for benzo(g,h,i)perylene, phenanthrene, 2-picoline and carbazole. The unitless Henry's Law constants for these constituents have been reviewed and are summarised following:

- Benzo(g,h,i)perylene – $1.35*10^{-5}$;
- Phenanthrene – $1.73*10^{-3}$;
- 2-picoline – $4.07*10^{-4}$; and
- Carbazole – $4.74*10^{-6}$.

Each of the constituents is found to be relatively non-volatile and would be anticipated to not pose a significant risk via an inhalation exposure. The highest concentrations of these constituents are generally coincident with substantial concentrations of other PAH constituents which have been selected as COPCs. It is considered that assessment of the other PAH constituents will be protective of the potential impacts of these other constituents.These constituents have not been selected as COPCs for human health assessment.

6.3 Selection of COPCs in Groundwater

Environmental data for the Headland Park, Northern Cove and area of the overall Barangaroo site have been reviewed and the maximum concentration of each constituent determined. This has restricted the assessment of groundwater to results from monitoring wells MW01 to MW07, MW19, MW25 and MW215 as reported in ERM (2007 and 2008). Maximum concentrations have been compared to the screening criteria and selected as a COPC where the screening criteria are exceeded, as summarised in **Table 6.4**, following.

Table 6.4: Summary of Selection of COPCs for Groundwater

Constituent	Maximum Concentration (µg/l)	COPC Selection
		Human Health
Heavy metals		
Arsenic	13	X
Cadmium	43.2	X
Chromium (total)	1.9	
Copper	153	
Lead	65	X
Mercury	0.1	
Nickel	303	X
Zinc	392	
Other Inorganics		
Ammonia	4,320	X
Cyanide (total)	11.8	
Total Petroleum Hydrocarbons		
TPH C_{15}-C_{28}	400	X
TPH C_{29}-C_{36}	200	X
Monocyclic Aromatic Hydrocarbons		
Benzene	3	X
Xylenes	3	
1,2,4-trimethylbenzene	1.2	
Polycyclic Aromatic Hydrocarbons		

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Constituent	Maximum Concentration (µg/l)	COPC Selection
		Human Health
Benz(a)anthracene	2.2	X
Benzo(a)pyrene	2.7	X
Benzo(b)fluoranthene	2.8	X
Benzo(g,h,i)perylene	2[1]	X
Benzo(k)fluoranthene	1.6	X
Chrysene	2.4	
Fluoranthene	5.5	
Indeno(1,2,3-c,d)pyrene	1.8	X
Naphthalene	7.7	X
Phenanthrene	2.5	
Pyrene	6.5	

Note: 1. Not selected as COPC as criteria not directly applicable to constituent. Several other PAH constituents assessed are considered sufficient to be protective of co-incident PAHs that occur with benzo(g,h,i)perylene

On the basis of **Tables 6.3** and **6.4** the COPCs to be considered for each media requiring risk assessment are summarised in **Table 6.5** to **6.7**, following.

Table 6.5: Summary of COPCs for Soils

Soils (Headland Park – potential human exposure)
Chromium
Lead
Cyanide
TPH
Benzene
Toluene
Ethylbenzene
Xylene
1,2,4-trimethylbenzene
Benz(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Chrysene
Dibenz(a,h)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-c,d)pyrene
2-methylnaphthalene
Naphthalene
Pyrene
2-methylphenol
3-&4-methylphenol
Asbestos
Dibenzofuran

Asbestos has been selected as a COPC for soils based on DEC (2006) guidance instructing that asbestos requires specific risk assessment on a site by site basis; and detections of asbestos containing materials on-site in previous ERM and AECOM investigations.

Table 6.6: Summary of COPCs for Groundwater

Groundwater (existing – human health)
Arsenic
Cadmium
Lead
Nickel
Ammonia (as N)
TPH (C_{15}-C_{28})
TPH (C_{29}-C_{36})
Benzene
Benz(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Indeno(1,2,3-c,d)pyrene
Naphthalene

Table 6.7: Summary of COPCs for Potential Future Seepage Water

Seepage Water (future – human health)
Arsenic

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Seepage Water (future – human health)
Cadmium
Chromium
Lead
Nickel
Ammonia (as N)
Cyanide
TPH
Benzene
Toluene
Ethylbenzene
Xylene
1,2,4-trimethylbenzene
Benz(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Chrysene
Dibenz(a,h)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-c,d)pyrene
2-methylnaphthalene
Naphthalene
Pyrene
2-methylphenol
3-&4-methylphenol
Asbestos
Dibenzofuran

The selection of COPC's for seepage water have included the COPC's selected by comparison to human health soil and groundwater screening criteria, as these are indicative of the constituents that may leach from site soils and cause potential human health impacts in seepage water.

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7 Toxicological Review

There are two elements to the toxicological review for the human health risk assessment: hazard identification (using toxicological studies); and dose-response assessment. The Australian approach to each is discussed in detail following.

7.1 Hazard Identification

Hazard identification examines the capacity of an agent to cause adverse health effects in humans and other animals.

Hazard identification uses:

- Animal data. These are usually assessed by toxicological methods;
- Human data. These are usually assessed by epidemiological methods when groups of people are involved, or by toxicological methods when using case studies and acute chamber studies; and
- Other data. These include structure data such as structure activity data or in vitro data assessed by toxicologists.

Hazard identification mostly relies on the results of in vitro toxicity studies conducted according to standard protocols (e.g. OECD Test Guidelines). The following types of studies are defined:

- Acute toxicity studies are studies which investigate the effects of single doses of a substance. The standard acute toxicity studies include tests for: acute, oral, dermal and inhalational toxicity; eye irritation; skin irritation; and skin sensitisation;
- Sub-chronic toxicity studies are short term repeat-dose studies. The main purpose of sub-chronic testing is to identify any target organs and to establish dose levels for chronic exposure studies;
- Chronic toxicity studies, or long-term studies, are defined as studies lasting for the greater part of the lifespan of the test animals. The protocol for these studies may cover the investigation of chronic toxicity or carcinogenicity, or both;
- Reproductive toxicity studies are studies designed to provide general information about the effects of a test substance on reproductive performance in both male and female animals;
- Developmental toxicity studies are studies which examine the spectrum of possible in-utero outcomes for the conceptus, including death, malformations, functional deficits and developmental delays; and
- Genotoxicity studies are designed to determine whether test chemicals can perturb genetic material to cause gene or chromosomal mutations.

The essential purpose of toxicity studies is the detection of valid biological evidence of the hazard potential of the substance being investigated. The evaluation of the weight of evidence from toxicity studies is by a process which considers the cumulative data pertinent to arriving at a level of concern about the potential adverse effects of a substance. In assessing toxicological studies and hazard analysis, judgement and supporting rationale are provided for:

- The acceptability of the study and its database;

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- The existence of biologically important adverse effects;
- The relevance of any factors noted during the evaluation which might have had some bearing on the outcomes of the study and modified the findings in some way; and
- The likelihood that any of the observed effects were induced by the administered substance.

Toxicology assessments are often complemented with epidemiological studies in hazard assessment. Epidemiology is the direct human evidence component of the assessment. Epidemiological studies are used to investigate the cause of adverse health effects; the natural history of health conditions; the description of the health status of populations; to evaluate the health status of populations; and to evaluate health related interventions.

7.2 Dose-Response Assessment

The dose-response assessment examines the quantitative relationships between exposure and the effects of concern. There are different ways of characterising dose-response relationships including:

- Effect levels (e.g. LD_{50}, LC_{50}, ED_{10}) and no observed adverse effect levels (NOELs);
- Margins of safety;
- Therapeutic indices; and
- Models to interpolate high dose experimental data to the low doses likely to be experienced in the environment.

There are often limited human exposure data, and animal bio-assay data are most often used for dose-response assessment. The use of these data requires extrapolations from animals to humans and interpolations from high doses to low doses.

Dose-response assessments and calculations are generally undertaken by either of a threshold approach or a non-threshold approach. Each is described in further detail following.

7.3 Threshold Approaches

A threshold is considered to occur because of biological mechanisms such as the ability to metabolise or excrete a toxin to repair damage up to a certain dose.

The approach with these models is to derive exposure limits such as an allowable daily intake (ADI), Tolerable Daily Intake (TDI) or reference dose (R*f*D). This approach makes no attempt to calculate a level of risk at low exposures. Rather, it derives a dose which is apparently without effect in a human population or suitable animal model, and then applies a factor to derive an exposure which has a high likelihood that no effect will occur in the general human population.

These exposure limits are derived by first determining the No Observed Adverse Effect Level (NOAEL) or, if the NOAEL cannot be determined, the Lowest Observed Adverse Effect Level (LOAEL) and dividing the value by factors to account for:

- Interspecies differences (extrapolating from animals to humans);
- Intraspecies differences (differing sensitivities between individuals);
- The severity of the adverse effect; and

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- The quantity and quality of the scientific data.

Traditionally, safety factors for intraspecies and interspecies differences have each been assigned values of ten, and the other two have been assigned values between 1 and 10. An additional factor of ten is sometimes used if the NOAEL was not established in the study. The individual factors are then multiplied to determine an overall safety factor by which the NOAEL is divided to give the ADI, TDI or R*f*D.

Historically, the most common overall factor used by a number of regulatory bodies is 100, if a large toxicological database has been assessed, although the overall factor can range from 10 to 10,000. From the data available on humans and experimental animals, it appears that interspecies and intraspecies differences are in general less than 10; hence the often used safety factor of 100 for these two factors is conservative and adequately protective of public health.

7.4 Non-Threshold Approaches

These approaches do not recognise the possibility of a threshold effect and are appropriate for radiation and some genotoxic carcinogens. It is, as a science policy decision, applied to all carcinogens by the US EPA.

Non-threshold models assume linearity between the lowest experimentally derived dose and the zero dose (the origin). This implies that there is a calculable probability of an adverse effect (risk) no matter how small the dose. This does not mean that there is no dose that could be considered safe unless safety must be equated with zero risk.

Numerical estimates of risk probabilities are generated by fitting one or more mathematical models to the data in the experimental dose range and extrapolating to the low environmental exposure doses. For example, low-dose extrapolation using a linear model is a default approach for cancer risk assessment in the USA and is one approach which has been used by the WHO for genotoxic carcinogens in deriving water quality guidelines.

The outcomes are estimates of either:

- The dose at a predetermined acceptable risk level (note that this requires some judgement on what constitutes an acceptable level of risk); or
- The estimated risk level at any particular dose.

It has been recognised by IARC and other European based agencies that not all carcinogens have genotoxicity as their prime mode of action. The dose-response curve is assumed to be non-threshold for genotoxic carcinogens and threshold for non-genotoxic carcinogens. Accordingly, the Australian approach is to apply non-threshold and threshold models to genotoxic and non-genotoxic carcinogens.

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7.5 Sources of Toxicological and Tolerable Intake Data

Enhealth (2002) provides advice as to the quality of toxicological data that is available to be used in risk assessments. Data is categorised as Level 1, 2 or 3 data. Level 1 sources are recommended as the preferred sources of chemical data. Level 1 sources, in the order of preference for which they are recommended to be used, include:

1. National Health and Medical Research Council documents and documents from other joint Commonwealth, State and Territory Health organisations. These may be a source of Australian guidance values. Publications prepared by the former Australian and New Zealand Environmental and Conservation Council are considered a suitable Commonwealth source to be included here;
2. ADI list from the Therapeutic Goods Administration;
3. World Health Organisation (WHO) documents. Australia is a party to the WHO process and has incorporated their material in a variety of environmental health criteria. A range of documents include those from the WHO/ILO/UNEP International Programme on Chemical Safety (IPCS) which produces Environmental Health Criteria monographs and Concise International Chemical Assessment documents (CICADs). Documents detailing international Acceptable Daily Intakes (ADI's), Tolerable Daily Intakes (TDI) or Tolerable Weekly Intakes (TWI) may be found in evaluations by the WHO/FAO Joint Meeting on Pesticide Residues (JMPR) and by the Joint FAO/WHO Expert Committee on Food Additives (JECFA);
4. enHealth Council documents;
5. National Environmental Health Forum documents distributed by the Commonwealth Department of Health and Ageing;
6. International Agency for Research on Cancer (IARC) Monographs;
7. WHO/FAO Joint Meeting on Pesticide Residues (JMPR) Monographs;
8. NICNAS Priority Existing Chemical (PEC) reports;
9. US Agency for Toxic Substances and Disease Registry (ATSDR) documents for general toxicological reviews and Reference Doses;
10. National Toxicology Program (NTP) carcinogenicity appraisals which report in detail the results of carcinogenicity tests on a wide range of chemicals;
11. OECD Standard Information Data Sets (SIDS) and SIDS Initial Assessment Reports (SIAR); and
12. US EPA Reference Doses.

Where a rare substance is being assessed, or insufficient data are available within Level 1 sources, then Level 2 sources may require to be researched. Level 2 sources include:

1. European Centre of Ecotoxicology and Toxicology of Chemicals (ECETOC): Monographs, JACC reports and Technical Reports;
2. Chemical Institute of Toxicology (CIIT) reports; and
3. Unpublished industry reports submitted for regulatory purposes. These may have restricted availability but information may be available in evaluation reports from regulatory agencies that have reviewed individual reports.

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Level 2 sources may also include peer-reviewed journals.

7.6 Review of Published Hazard Data

Available toxicological, epidemiological studies and dose-response studies have been reviewed for each of the COPC's (identified in **Section 6**) by the protocols established in **Section 7.5**. Consequently, citing the authority of the Level 1 agencies, there has been no requirement in this risk assessment to further review and comment upon the hazard studies reviewed by each organisation, or those that may be available elsewhere that are not endorsed by these organisations.

Instead, the pertinent toxicological effects identified for each of the COPC's by the Level 1 agencies has been reviewed and summarised for each identified COPC. Risk / hazard factors and guideline values have also been identified from these sources. The most current guidance only has been referenced for each of the sources. It is noted that some agencies have removed historical assessments of some chemicals in most recent guidance.

A brief summary of the toxicological endpoints of each of the identified COPCs is provided in the following sections. The summaries have been generated by a review of the available data held by the Level 1 agencies. Level 2 sources have been required to be reviewed in some cases where no Level 1 data are available, or where recommended in the case of the assessment of PAHs by DECCW officers.

7.6.1 Arsenic

Arsenic has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for arsenic has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.1**.

Table 7.1: Summary of Published Level 1 Hazard Data for Arsenic

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Arsenic in Drinking Water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 6.1)
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	IARC Monographs (1987)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (August 2007) 'Toxicological Profile for Arsenic'
NTP	YES	US Department of Health and Human Services (2009) '11th Report on Carcinogens'
OECD SIDS SIAR	No	
EPA	YES	IRIS database (1998)

NHMRC

NHMRC/NRMMC (2004) recommends the use of a maximum tolerable daily intake (TDI) for arsenic of 0.002mg/kg body weight per day as based on the WHO (1998) guideline value. It is reported that the WHO data were based on the estimated additional lifetime risk of six skin cancers per 10 000 people.

It is estimated in NHMRC/NRMMC (2004) that the average Australia adult dietary intake of arsenic is approximately 0.04mg/day.

WHO

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Arsenic in drinking water is noted to be classified by IARC as a carcinogen. The guideline value by WHO (2003), of 10µg/l is reported to be based on the maximum likelihood estimates, using linear extrapolation, for bladder and lung cancer for US populations exposed to 10µg of arsenic per litre in drinking water of 12 and 18 per 10 000 population for females and 23 and 14 per 10 000 population for males. It is also reported to be based on the practical quantification limit for arsenic and extent to which arsenic can be removed from drinking water.

Arsenic is classified as a human carcinogen in WHO (2000). Risk estimates have been derived from studies in exposed human populations in the United States and Sweden. At an air concentration of 1µg/m^3 an estimate of lifetime risk of $1.5*10^{-3}$ is reported.

enHealth

enHealth (2001) reports a WHO provisional tolerable weekly intake (PTWI) of 0.015mg/kg/week for arsenic. It is reported that there is a narrow margin between the WHO PTWI and intakes reported to have toxic effects in other studies. It is reported that dietary exposure of children could account for 50% of the PWTI.

IARC

Arsenic and arsenic compounds are classified by the IARC as a Group 1 carcinogen.

ATSDR

ATSDR reports that no minimal risk level (MRL) has been derived for exposure to inorganic arsenic by inhalation.

An oral MRL of 0.005 mg As/kg/day has been derived for acute-duration (14 days or less) oral exposure to inorganic arsenic. This is based on an assessment of poisoning cases associated with an episode of arsenic contamination of soy sauce in Japan. The MRL is reported to have been derived on the basis of an LOAEL of 0.05 mg As/kg/day with an uncertainty factor of 10.

An MRL of 0.0003 mg As/kg/day has been derived for chronic-duration (365 days or more) oral exposure to inorganic arsenic. This is reported to have been on the incidence of Blackfoot Disease and dermal lesions (hyperkeratosis and hyperpigmentation) in a large number of poor farmers (both male and female) exposed to high levels of arsenic in well water in Taiwan. The MRL is derived by applying an uncertainty factor of 3 (for human variability) to the NOAEL of 0.0008 mg/kg/day.

NTP

NTP reports that inorganic arsenic compounds are known to be human carcinogens based on sufficient evidence of carcinogenicity in humans. Epidemiological studies and case reports of humans exposed to arsenic compounds for medical treatment, in drinking water, or occupationally have demonstrated that exposure to inorganic arsenic compounds increases the risk of cancer. Cancer tissue sites include the skin, lung, digestive tract, liver, bladder, kidney, and lymphatic and hematopoietic systems (organs and tissues involved in production of blood).

US EPA

Arsenic is classified as a human carcinogen (Classification A) by the US EPA based on increased lung cancer mortality observed in multiple human populations exposed primarily through inhalation. Increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic.

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An oral slope factor of 1.5 per (mg/kg)/day is provided by the US EPA on the basis of studies of persons exposed to arsenic in drinking water.

An oral RfD of $3*10^{-4}$ mg/kg/day is provided for arsenic on the basis of studies of effects and dose-response relationships of skin cancer and blackfoot disease with arsenic and the prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. The RfD has been based on the lowest of the report NOAELs with an uncertainty factor of 3 to account for lack of data to preclude reproductive toxicity and sensitive individuals.

An inhalation unit risk of $4.3*10^{-3}$ $(\mu g/m^3)^{-1}$ is provided by US EPA on the basis of studies of lung cancers in male humans occupationally exposed by inhalation. The unit risk is the geometric mean of the unit risk derived in several studies.

Level 2 Sources

It is noted that the US EPA (November 2010) 'Regional Screen Levels' adopt a Californian EPA health based RfC of $1.5*10^{-5}mg/m^3$ for assessment of inhalation exposure to arsenic.

7.6.2 Cadmium

Cadmium has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for cadmium has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.2**.

Table 7.2: Summary of Published Level 1 Hazard Data for Cadmium

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2004) 'Cadmium in Drinking Water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 6.3)
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	IARC Monographs (1993)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (September 2008) 'Draft Toxicological Profile for Cadmium'
NTP	YES	US Department of Health and Human Services (2009) '11th Report on Carcinogens'
OECD SIDS SIAR	No	
EPA	YES	IRIS database (1994)

NHMRC

NHMRC/NRMMC (2004) recommends that cadmium intake should be reduced to less than 0.0007mg/kg body weight per day to ensure that over a 70 year lifetime, cadmium in the body is kept below the critical amount of 200mg/kg renal cortex tissue. The guidance derived by NHMRC/NRMMC (2004) is reported to have taken into account an absorption rate of 5%, a daily excretion rate of 0.005% and a safety factor.

The guideline is also reported to take into account potentially higher intake rates of infants and children.

NHMRC/NRMMC (2004) estimates the average Australian adult dietary intake of cadmium to be 0.03mg/day.

WHO

WHO (2004) reports that for chronic oral exposure to cadmium that the kidney is the most sensitive organ. Cadmium affects the resorption function of the proximal tubules,

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the first symptom reported being an increase in the urinary excretion of low-molecular-weight proteins. Intakes of 140–255 µg of cadmium per day have been reported to be associated with low-molecular-weight proteinuria in the elderly. The minimum (critical) level of cadmium in the human renal cortex, related to the first sign of tubular dysfunction, ranged from 100 to 450 mg/kg wet weight.

The WHO guideline value for drinking water is based on the absorption rate for dietary cadmium of 5% and a daily excretion rate of 0.005% of body burden levels, and the requirement that levels of cadmium in the renal cortex are not to exceed 50 mg/kg. On this basis it was found that the total intake of cadmium should not exceed 1 µg/kg of body weight per day.

WHO (2000) reports that IARC has classified cadmium and cadmium compounds as group 1 human carcinogens, having concluded that there was sufficient evidence that cadmium can produce lung cancers in humans and animals exposed by inhalation.

Cadmium is reported to give rise to various renal alterations, whether absorbed by inhalation or via contaminated food. It is reported that the lowest estimate of the cumulative exposure to airborne cadmium in industrial workers leading to an increased risk of renal dysfunction (low-molecular-weight proteinuria) or lung cancer is 100 µg/m3-years for an 8-hour exposure. Extrapolation to a continuous lifetime exposure gives a value of around 0.3µg/m^3. A 1 year guidance value of $5*10^{-3}$ µg/m^3 is recommended by WHO.

enHealth

enHealth (2001) reports a WHO PTWI of 7µg/kg/week for cadmium. It is further reported that a relatively small margin of safety exists between the PWTI and exposures that produce deleterious effects. Estimates of exposure from background sources are reported as 30% of the PWTI.

IARC

Cadmium and cadmium compounds are classified by the IARC as a Group 1 carcinogen.

ATSDR

ATSDR has reported an acute duration inhalation exposure MRL of $3*10^{-5}$ mg Cd/m^3 for exposure less than 14 days to cadmium. This guideline is based on occurrence of lung damage. The MRL is reported to have derived from a duration adjusted LOAEL of 0.01mg Cd/m^3 adjusted by an uncertainty factor of 300.

A chronic duration inhalation exposure MRL of 0.01 µg Cd/m^3 is reported by ATSDR. This is reported to be based on studies of the renal toxicity of cadmium in workers chronically exposed to high levels of cadmium. The MRL has been derived based on levels of urinary cadmium requiring to be 0.5 µg/g creatinine with an uncertainty factor of 3 for human variability and a modifying factor of 3 for a chronic duration inhalation.

An intermediate duration (5 to 364 days) oral exposure MRL of 0.5µg Cd/kg/day has been reported for cadmium. This is reported to be based on studies of decreased bone mineral density. A benchmark dose was derived for skeletal alterations and divided by an uncertainty factor of 100.

A chronic duration oral exposure MRL of 0.1 µg/kg/day has been reported. This is based on urinary concentrations on cadmium levels, with a uncertainty factor of 3 incorporated for potential exposure of diabetics.

NTP

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NTP reports that cadmium and cadmium compounds are known to be human carcinogens based on sufficient evidence of carcinogenicity in humans, including epidemiological and mechanistic information that indicate a causal relationship between exposure to cadmium and cadmium compounds and human cancer. Cadmium exposure is associated with elevated lung cancer risk under some industrial circumstances. Epidemiological evidence (including case control studies and geographic distribution studies) suggests an association between cadmium exposure and cancer of the prostate, kidney and bladder.

US EPA

The US EPA classifies cadmium as a probable human carcinogen (classification B1). This is based on limited evidence from occupational epidemiologic studies of cadmium and sufficient evidence of carcinogenicity in rats and mice by inhalation and intramuscular and subcutaneous injection.

It is also reported that these is no evidence of carcinogenicity by oral ingestion, with seven studies in rats and mice, wherein cadmium salts (acetate, sulfate, chloride) were administered orally, showing no evidence of carcinogenic response.

An inhalation unit risk of $1.8*10^{-3}$ $(\mu g/m^3)^{-1}$ is provided by US EPA on the basis of studies on lung, trachea and bronchus cancer deaths in occupational studies of cadmium inhalation.

An oral RfD of $5*10^{-4}$ mg/kg/day is provided by the US EPA, on the basis of exposure to cadmium in water. This has been derived by the reported NOAEL of significant proteinuria and incorporating an uncertainty factor of 10.

An oral RfD of $1*10^{-3}$ mg/kg/day is provided by the US EPA, on the basis of exposure to cadmium in food. The higher RfD than water is on the basis of a reduced absorption of cadmium through food.

7.6.3 Chromium

Chromium has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for chromium has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.3**.

Table 7.3: Summary of Published Level 1 Hazard Data for Chromium

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Chromium in Drinking Water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 6.4)
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	IARC Monographs (1990)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (February 2009) 'Draft Toxicological Profile for Chromium'
NTP	YES	US Department of Health and Human Services (2009) '11th Report on Carcinogens'
OECD SIDS SIAR	No	
EPA	YES	Iris Database (1998)

NHRMC

NHMRC/NRMMC (2004) reports that the chromium drinking water guideline has been adopted from the WHO guideline.

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NHMRC/NRMMC (2004) reports that total concentrations of chromium in Australian drinking water are usually less than 0.005mg/l.

WHO

WHO (2003) reports that IARC has classified Cr(VI) in Group 1 (carcinogenic to humans) and metallic chromium and Cr(III) in Group 3 (not classifiable as to their carcinogenicity to humans). A guideline value has been derived for total chromium. It is reported that the criteria for chromium has been set at 0.05mg/l as a practical measure. This is considered to be unlikely to give rise to significant risks to health.

WHO (2000) reports that only hexavalent chromium is carcinogenic in humans by inhalation. An air concentration of Cr(VI) of 1µg/m^3 is reported to cause a lifetime risk of $4*10^{-2}$. This is based on studies of lung cancer occurrence in occupationally exposed workers.

enHealth

enHealth (2001) reports the US EPA chronic RfD for Cr(III) as being 1mg/kg/day as based on a NOAEL of 1.46mg/kg/day from a chronic feeding study in rats.

It is reported that Cr(VI) assessment has been undertaken on the basis of a skin sensitivity study. It is further reported that the inhalation exposure route to chromium is relatively unimportant in comparison to the oral and dermal pathways.

IARC

Cr(VI) is classified by the IARC as a Group 1 carcinogen. Cr(III) is classified as a Group 3 chemical, not classifiable as to its carcinogenicity to humans.

ATSDR

An intermediate duration inhalation exposure MRL of $5*10^{-6}$ mg Cr(VI)/m^3 is derived for exposure to dissolved hexavalent chromium aerosols and mists. The primary respiratory effects of inhaled chromic acid mists are observed in the nose, while the effects of inhaled particulate Cr(VI) compounds occur throughout the respiratory tract. Upper respiratory effects include nasal irritation, ulceration, and mucosal atrophy and rhinorrhea. The MRL was derived from a benchmark concentration estimated for alterations in lactate dehydrogenase levels in BAL fluid with division by an uncertainty factor of 30 to account for extrapolation from humans to animals and human variability.

An intermediate duration inhalation exposure MRL of 0.005mg Cr(III)/m^3 was derived for exposure to insoluble trivalent chromium particulate compounds. This was based on septal cell hyperplasia and chronic interstitial inflammation of the lung in male rats. A human equivalent LOAEL derived from this study was divided by an uncertainty factor of 90 to account for use of a minimal LOAEL, extrapolation from animals to humans and human variability.

An intermediate duration inhalation exposure MRL of 0.0003mg Cr(VI)/m^3 was derived for exposure to hexavalent chromium particulate compounds. This is based on an LOAEL of rats which showed adverse respiratory effects including obstructive respiratory dyspnea, increased lung weights, hyperplasia of the lung, focal inflammation of the upper airway, and alterations to BAL fluid concentrations of lactate dehydrogenase, protein, and albumin. A benchmark dose has been derived from the LOAEL and divided by a factor of 30 to account for extrapolation from humans to animals and human variability.

A chronic duration inhalation exposure MRL of $5*10^{-6}$ mg Cr(VI)/m^3 is derived for exposure to dissolved hexavalent chromium aerosols and mists. This is based on an

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LOAEL value derived for respiratory, renal and gastrointestinal effects in workers divided by an uncertainty factor of 100 to account for human variability and extrapolation from a LOAEL. It is reported that no chronic inhalation MRL is available for chromium particulates.

An intermediate duration oral exposure MRL of 0.005mg Cr(VI)/kg/day has been reported by ATSDR. This was derived on the basis of hematological effects (microcytic, hypochromic anemia) in male rats observed after exposure for 22 days. A benchmark dose was derived from this study and divided by an uncertainty factor of 100 to account for extrapolation from animals to humans and human variability.

A chronic duration oral MRL of 0.001mg Cr(VI)/kg/day has been reported by ASTDR. This was based on the occurrence of nonneoplastic lesions of the duodenum observed in mice in an chronic drinking water. A benchmark dose was derived from this study and divided by an uncertainty factor of 100 to account for extrapolation from humans to animals and human variability.

No acute, intermediate, or chronic duration oral MRLs were derived by ATSDR for Cr(III) because studies evaluating the effects of Cr(III) in humans and animals following acute, intermediate, and chronic oral exposure were considered to be inadequate for establishing the exposure concentrations associated with adverse health effects.

NTP

NTP reports that chromium hexavalent Cr(VI) compounds are known to be human carcinogens based on sufficient evidence of carcinogenicity in humans. Epidemiological studies in various geographical locations have consistently reported increased risks of lung cancer among workers engaged in chromate production, chromate pigment production, and chromium plating.

US EPA

The US EPA classifies Cr(VI) as a known human carcinogen by the inhalation route of exposure. It is reported that carcinogenicity by the oral route of exposure cannot be determined.

An inhalation unit risk of $1.2*10^{-2}$ $(\mu g/m^3)^{-1}$ is provided by US EPA on the basis of the occupational studies of the occurrence of lung caners in humans exposed by inhalation.

An Oral RfD of $3*10^{-3}$ mg/kg-day is provided for Cr(VI) on the basis of a NOAEL derived by a study of rats exposed to chromium through drinking water. Levels of chromium in tissues were found to increase with increasing exposure to chromium. The oral RfD was derived by applying an uncertainty factor of 300 to the NOAEL to account for interspecies, intraspecies variability and less than lifetime exposure duration of the supporting study.

An inhalation RfC of $8*10^{-6}$ mg/m^3 for exposure to chromic acid mists and dissolved aerosols and an inhalation RfC of $1*10^{-4}$ mg/m^3 for exposure to particulates have been reported by the US EPA. These RfC's are based on studies reporting nasal mucosal irritation, atrophy, and perforation following occupational exposures to chromic acid mists and dissolved hexavalent chromium aerosols. The particulates RfC has also considered lower respiratory effects following inhalation of Cr(VI) particulates in rats including obstructive respiratory dyspnea and reduced body weight.

Ther mist and aerosols RfC has been based on a LOAEL with an uncertainty factor of 90. The particulates RfC is based on a benchmark dose with an uncertainty factor of 300.

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7.6.4 Lead

Lead has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for lead has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.4**.

Table 7.4: Summary of Published Level 1 Hazard Data for Lead

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Lead in Drinking Water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 6.7)
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	IARC Monographs (1987 and 2006)
WHO/FAO JMPR	No	
NICNAS PEC	YES	NICNAS (September 2007) 'Lead Compounds in Industrial Surface Coatings & Inks'
ATSDR	YES	ATSDR (August 2007) 'Toxicological Profile for Lead'
NTP	YES	US Department of Health and Human Services (2009) '11th Report on Carcinogens'
OECD SIDS SIAR	No	
EPA	YES	IRIS data base (2004)

NHMRC

NHMRC/NRMMC (2004) has recommended a daily intake of 0.0035mg/kg body weight per day of lead as based on a level which has been demonstrated to not result in an increase in lead retention in metabolic studies with infants. The recommended daily intake is reported to have been based on a WHO value.

NHMRC/NRMMC (2004) estimates that average Australian adult dietary intake of lead to be approximately 0.1mg/day. It is estimated that approximately 80% of the daily intake of lead is from the ingestion of food, dirt and dust.

WHO

It is reported in WHO (2003) that the evidence for the carcinogenicity of lead in humans is inconclusive because of the limited number of studies, the small cohort sizes, and the failure to take adequate account of potential confounding variables. However, an association has been demonstrated experimentally between the ingestion of lead salts and renal tumours. However as there is evidence from human studies that adverse effects other than cancer may occur at very low lead levels, the WHO drinking water guideline has been derived using the TDI approach.

The WHO (2003) drinking water guideline is based on a provisional tolerable weekly intake (PTWI) of 25 µg of lead per kg of body weight (equivalent to 3.5 µg/kg of body weight per day) for infants and children which took account of the fact that lead is a cumulative poison so that any increase in the body burden of lead should be avoided.

WHO (2000) reports that the guideline for lead in air has been based on the concentration of lead in blood. Critical effects in adults include elevation of free erythrocyte protoporphyrin. For children, cognitive deficit, hearing impairment and disturbed vitamin D metabolism are taken as the decisive effects. The guideline is based on a critical level in blood of 100µg/l, based on a child exposure. It is recommended that an annual average lead level in air should not exceed 0.5µg/m^3.

enHealth

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enHealth (2001) describes the adopted approaches for assessing lead being the assessment for potential impacts to children by the use of a WHO PTWI of 25µg/kg/week. It was also noted that background exposures may contribute approximately 50% of the PWTI.

IARC

IARC classifies lead compounds as Group 2A chemicals, probably carcinogenic to humans. IARC classified lead as a Group 2B chemical, possibly carcinogenic to humans.

NICNAS

Lead and inorganic lead compounds are reported to have diverse effects on multiple body systems including neurological, gastrointestinal, reproductive and cardiovascular systems.

Few data were reported to be available from acute exposure in humans to lead. Most data was derived from cases of accidental or intentional ingestion of dirt containing lead or lead-based paint. High acute exposure had resulted in encephalopathy, gasterointestinal and renal effects.

It was reported that lead had been shown in animals to produce a variety of cardiovascular effects. The endpoint of greatest concern to humans was possible changes in blood pressure. Although there have been numerous epidemiological studies examining the effect of low concentrations of lead on blood pressure (amongst other endpoints) no causal relationship is reported to have been demonstrated between blood pressure and low blood lead concentration in humans.

The most important confirmed effects of long term exposure to lead were reported to be neurological, including encephalopathy and neurobehavioural changes. Neurological effects were reported to be particularly important in the foetus and in children. Lead was reported to be a known developmental toxicant in humans. Blood lead levels greater than 10 µg/dL can result in decline in IQ and neurobehavioural deficits. Peripheral neuropathy has been observed in children at blood levels between 60 and 130µg/dL

The report recommended that lead is not used in industrial coatings.

ATSDR

ATSDR reports that MRLs were not derived for lead because a clear threshold for some of the more sensitive effects in humans has not been identified and data suggest that certain subtle neurobehavioral effects in children may occur at very low lead blood levels.

It is reported that blood levels as low as <10µg/dL can cause depressed aminolevulinic acid dehydratase (i.e. anemia). A range of other effects are reported at higher concentrations.

NTP

NTP reports that lead and lead compounds are reasonably anticipated to be human carcinogens based on limited evidence from studies in humans and sufficient evidence from studies in experimental animals. Lead exposure has been associated with increased risk of lung, stomach, and bladder cancer in diverse human populations. The strongest epidemiological evidence is reported to be for lung and stomach cancer, which are consistently but weakly associated with occupations and industries entailing lead exposure and with indices of individual lead exposure, including job history and biological monitoring of occupationally exposed and general populations.

US EPA

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The US EPA has classified lead as a probable human carcinogen (Class B2) on the basis of ten rat bioassays and one mouse assay that have shown statistically significant increases in renal tumors with dietary and subcutaneous exposure to several soluble lead salts. Short term studies are also reported to show that lead effects gene expression. Human evidence is described as being inadequate.

US EPA further reports that health effects associated with exposure to inorganic lead and compounds include, but are not limited to, neurotoxicity, developmental delays, hypertension, impaired hearing acuity, impaired hemoglobin synthesis, and male reproductive impairment. Lead is reported to have particularly significant effects in children, well before the usual term of chronic exposure can take place.

US EPA does not provide an oral RfD for lead on the basis that some of the effects of lead exposure, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at blood lead levels so low as to be essentially without a threshold.

An RfC is not provided for lead for the same reasoning.

7.6.5 Nickel

Nickel has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for nickel has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.5**.

Table 7.5: Summary of Published Level 1 Hazard Data for Nickel

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2005) 'Nickel in Drinking Water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 6.10)
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	IARC Monographs (1990)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (August 2005) 'Toxicological Profile for Nickel'
NTP	YES	US Department of Health and Human Services (2009) '11th Report on Carcinogens'
OECD SIDS SIAR	No	
EPA	YES	IRIS database (1996 & 2006)

NHMRC

NHMRC/NRMMC (2004) has recommended a daily intake of 5 mg/kg body weight per day based on a no effect level for altered organ to body weight ratios in a 2 year study with rats. The rats were orally exposed to high nickel doses. It is also recommended that a 1,000 safety factor be used with this daily intake (TDI of 0.005 mg/kg body weight per day) to account for interspecies variations, intraspecies variations and to compensate for a lack of adequate studies on chronic effects and for increases in intestinal absorption on an empty stomach.

NHMRC/NRMMC (2004) estimates that average Australian adult dietary intake of nickel to be between 0.1 and 0.3mg/day generally through food consumption.

WHO

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WHO (2005) reports a two-generation study on rats where it was found that a NOAEL of 2.2 mg of nickel per kg of body weight per day was identified for all the end-points studied, including the variable of post-implantation/perinatal lethality. An uncertainty factor of 100 (10 to account for interspecies variation and 10 to account for intraspecies variation) gives a TDI of 22 µg/kg of body weight. This study is found to be more recent that the background to the NHMRC value.

However it was found this general toxicity value may not be sufficiently protective of individuals sensitised to nickel. The guideline value for nickel in drinking-water is reported to have been derived using the LOAEL of 12 µg/kg of body weight established after provocation of fasted patients with an empty stomach.

WHO (2000) reports that nickel compounds are human carcinogens by inhalation exposure on the basis of studies in occupationally exposed human populations. It is reported that an incremental risk of $3.8*10^{-4}$ can be given for a concentration of nickel in air of $1\mu g/m^3$.

enHealth

enHealth (2001) reports a US EPA chronic oral RfD of 0.02mg/kg/day as based on a NOAEL derived from a chronic feeding study in rats. The potential for sensitisation to nickel was also reported in enHealth (2001). Risk based calculations were adjusted by a factor of approximately 2 to account for potential sensitisation of susceptible receptors by dermal exposure.

IARC

IARC classifies nickel compounds as a Group 1 carcinogen. Nickel is classified as a Group 2B chemical, possibly carcinogenic to humans.

ATSDR

ATSDR reports an intermediate duration inhalation exposure MRL of 0.0002mg Ni/m^3. The MRL has been derived by a human equivalent NOAEL derived from a study of alveolar macrophage hyperplasia as observed in rats. The NOAEL was divided by an uncertainty factor of 30 to account for species to species extrapolation and human variability.

A chronic duration inhalation exposure MRL of $9*10^{-5}$mg Ni/m^3 has been derived. This is reported to have been based on a human equivalent NOAEL as derived from inhalation studies of rats. Effects of the inhalation studies are reported to have included chronic lung inflammation and bronchialisation, alveolar epithelium hyperplasia, fibrosis and rapid and shallow breathing. The NOAEL was divided by an uncertainty factor of 30 to account for species to species extrapolation and human variability.

No oral exposure MRLs are provided for nickel. It is reported that data on the chronic toxicity of ingested nickel (oral exposure) are limited to one animal study that found significant decreases in body weight and liver weights in rats. This was considered inadequate for MRL derivation.

NTP

NTP reports that nickel compounds are known to be human carcinogens based on sufficient evidence of carcinogenicity from studies in humans, including epidemiological and mechanistic information, which indicates a causal relationship between exposure to nickel compounds and human cancer. The findings of increased risk of cancer in exposed workers are supported by evidence from experimental animals that shows that exposure

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to an assortment of nickel compounds by multiple routes causes malignant tumors to form at various sites in multiple species of experimental animals.

US EPA

The US EPA classified nickel refinery dusts as a carcinogen (Classification A) on the basis of human data, in which exposure to nickel refinery dust caused lung and nasal tumors in sulfide nickel matte refinery workers in several epidemiologic studies in different countries. Animal data have also demonstrated carcinomas produced in rats exposed to nickel refinery dust by inhalation and injection.

An inhalation unit risk of $2.4*10^{-4}$ $(\mu g/m^3)^{-1}$ is provided for nickel on the basis on estimates of lung cancer in occupationally exposed workers.

Nickel and soluble salts have been reported by US EPA to cause body weight decreases in rates exposed by oral pathways. An oral RfD of $2*10^{-2}$ mg/kg/day was derived for nickel on the basis of a NOAEL derived from a study of decreased body and organ weights in rats, adjusted by an uncertainty factor of 300 to account for interspecies extrapolation, to protect sensitive populations and account for inadequacies in the reproductive studies.

7.6.6 Ammonia (as N)

Ammonia (as N) has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for ammonia has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.6**.

Table 7.6: Summary of Published Level 1 Hazard Data for Ammonia

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Ammonia in Drinking Water'
enHealth	No	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	No	
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (September 2004) 'Toxicological Profile for Ammonia'
NTP	No	
OECD SIDS SIAR	No	
EPA	YES	IRIS database (1991)

NHMRC

NHMRC / NRMMC (2004) provide a guideline value for ammonia based on aesthetic considerations only. The aesthetic guideline of 0.5mg/l is based on likelihood of corrosion to copper pipes and fittings. No health based guideline is provided as it is concluded that ammonia is unlikely to occur in drinking water supplies at levels that may cause health effects.

Ammonia is reported to have a toxic effect where the detoxification capacity of the body is exceeded. This is reported to occur at a dose above 32mg ammonium per kg body weight.

WHO

WHO (2003) states that ammonia is not of direct importance for health in the concentrations expected in drinking water. It is reported that the ammonium can have a toxic effect where the intake becomes higher than the capacity to detoxify, which is reported to occur at a dose above 33.7mg ammonium per kg body weight.

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ATSDR

ATSDR provides an MRL of 1.7ppm for the acute duration inhalation exposure to ammonia. The MRL is reported to be based on the LOAEL of 50ppm base don mild irritation in exposed humans.

An MRL of 0.1ppm is provided for chronic duration inhalation exposure to ammonia. The MRL is reported to be based on an a NOAEL of 9.2ppm for the sense of smell and prevalence of respiratory symptoms in occupationally exposed humans. The NOAEL is reported to have been calculated by adjusting the mean TWA (time weighted average) exposure, dividing by an uncertainty factor of 10 and a modifying factor of 3.

No oral MRLs are provided for ammonia by ATSDR based on the lack of suitable toxicological studies and the high doses of ammonium that are anticipated to be required in drinking water / food to allow acceptable levels to be exceeded. It was further noted that oral exposure to ammonia generally consists of ammonium chloride. The anion chloride is reported to assist in the metabolism of the co-occurring ammonium.

US EPA

The US EPA provides a reference concentration (RfC) for ammonia of 0.1mg/m^3. The RfC is reported to be based on studies of occupationally exposed workers and a study of rats which identified significantly increased severity of rhinitis, otitis media, tracheitis and pneumonia, a significant concentration response between observed respiratory lesions and increasing environmental ammonia concentration, gross bronchiectasis and/or pulmonary abscesses and the extent of gross atelectasis. The RfC has been principally derived from a NOAEL derived from the occupational study.

No data was available on the potential toxicity of ammonia by oral exposure or potential carcinogenicity.

7.6.7 Cyanide

Cyanide has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for cyanide has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.7**.

Table 7.7: Summary of Published Level 1 Hazard Data for Cyanide

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2009) 'Cyanide in Drinking Water'
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	No	
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (July 2006) 'Toxicological Profile for Cyanide'
NTP	No	
OECD SIDS SIAR	No	
EPA	YES	IRIS database (1993)

NHMRC

NHMRC/NRMMC (2004) has recommended a daily intake of 1.2mg/kg body weight per day based on the no effect level from 6 month feeding studies using pigs. Exposure to cyanide was reported to increase ambivalence and result in slower response times to

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stimuli of the pigs. It is also recommended that a 100 safety factor be used the recommended daily intake based on interspecies and intraspecies variations.

A background exposure to cyanide was not reported in NHMRC/NRMMC (2004), however it was noted that typical concentrations of cyanides in drinking water are less than 0.02mg/l.

WHO

WHO (2009) reports a cyanide dose of 12.5 mg/kg body weight per day as the LOAEL, based on all the effects on reproductive organs observed in the male rats, and a cyanide dose of 4.5 mg/kg body weight per day as the NOAEL, on the basis of a 13-week study in which rats and mice were administered sodium cyanide in drinking-water.

An uncertainty factor of 100 (based on inter and intraspecies variations) has been applied to the LOAEL to derive a TDI of 12µg/kg of body weight.

enHealth

enHealth reports that the toxicity of complexed cyanides is generally dependent on the release of free cyanides occurring. A WHO (1993) TDI of 0.012mg/kg/day is reported for free cyanide. It is noted that analytical methods for the assessments of free cyanides should include thiocyanates.

The enHealth (2001) soil guideline for complexed cyanides is reported to have been derived on the basis of a subchronic study deriving a NOAEL for complexed cyanides of 25,g/kg/day and a applying a safety factor of 1 000 to derive a TDI of 0.025mg/kg/day.

It is recommended that assessment of cyanides as free or complexed cyanides should be on the basis of the state in which cyanides occur on a site. Criteria presented by enHealth for complexed cyanides are 5 times higher than those for free cyanides.

ATSDR

No inhalation exposure MRLs have been derived by ASTDR.

An intermediate duration oral exposure MRL of 0.05mg CN^-/kg/day is derived by ASTDR. This is reported to be based on studies of animals exposed to sodium or potassium cyanide. The MRL is reported to have been derived from a LOAEL and a NOAEL, as based on the reduced weights of male reproductive system of rats. The NOAEL has been divided by an uncertainty factor of 100 to account for extrapolation from humans to animals and human variability.

A chronic duration oral MRL has not been derived consequent of a lack of appropriate data.

US EPA

The US EPA has not classified free cyanide as a carcinogen (classification D). Feeding studies have showed decreased weight gain and thyroxin levels and myelin degeneration in rats. An oral RfD of $2*10^{-2}$ mg/kg/day is provided by the US EPA. This is based on the NOAEL of a rat chronic oral study, adjusted by a uncertainty factor of 100 and a modifying factor of 5.

7.6.8 Total Petroleum Hydrocarbons

Total petroleum hydrocarbons (TPH) have been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for TPH has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.8**.

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Table 7.8: Summary of Published Level 1 Hazard Data for Total Petroleum Hydrocarbons

Organisation	Availability	Reference
NHMRC	No	
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2005) 'Petroleum Products in Drinking Water'
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	IARC Monographs (1987 and 1989)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	No	Profiles on commercial petroleum products considered inappropriate for TPH principally consequent of coal tar. ATSDR (September 1999) 'Toxicological Profile for Total Petroleum Hydrocarbons' is substantially based on speciated constituents of TPH.
NTP	No	
OECD SIDS SIAR	No	
EPA	No	

WHO

WHO (2005) derives drinking water criteria for a range of TPH fractions on the basis of Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) toxicity criteria for aliphatic and aromatic fractions.

enHealth

enHealth (2001) references the TPHCWG (1997) approach to assessing hydrocarbons. Specific mention is made of the TPHCWG (1997) proposing two approaches to the assessment of petroleum hydrocarbons to be used in a hybrid framework:

- The first approach examines the presence of indicator chemicals which are carcinogenic substances. This generally includes substances such as benzene and polycyclic aromatic hydrocarbons such as benzo (a) pyrene which, if detected, require an appraisal; or
- If indicator chemicals are not present then the second stage is used. The second stage is the TPH fraction stage which assigns toxicity criteria to well defined fractions based on the available toxicity data for constituents, mixtures, solvent streams and whole product

IARC

IARC classifies mineral oils as a mixture containing Group 1 carcinogens. IARC classifies fuel oil, gasoline and diesel fuel as Group 2B mixtures, containing chemicals that are possibly carcinogenic to humans. IARC classifies coal tars as mixtures containing Group 1 carcinogens.

Level 2 Sources

On the basis of TPHCWG (1997) being identified in the WHO and enHealth documents, a further review has been undertaken of TPHCWG. TPH fractions described in TPHCWG are classified as aromatic and aliphatic fractions. Toxicity data are provided for fractions of TPH as based on indicator chemicals that occur within that fraction. This is summarised in **Table 7.9** following.

Table 7.9: Summary of Fraction Specific TPH Toxicity Values (mg/kg/day)

TPH Range	Oral RfD (mg/kg/day)	Inhalation RfC (mg/m^3)	Comments / Source
Aliphatic			
$C_{>6}$-C_8	5.0	18..4	RfD and RfC based on consideration of relative levels of hexane and heptane in petroleum products.
$C_{>8}$-C_{10}	0.1	1.0	RfD based on oral gavage studies using dearomatised

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$C_{>10}$-C_{12}	0.1	1.0	aromatics (C_9-C_{12}) and dearomatised aliphatics (C_{10}-C_{13}) RfC based on inhalation studies for various petroleum streams and JP-8 (jet fuel).
$C_{>12}$-C_{16}	0.1	1.0	
$C_{>16}$-C_{21}	2.0	N/A	RfD based on low molecular weight mineral oils and high molecular weight mineral oils.
$C_{>21}$-C_{35}	2.0	N/A	
Aromatic			
$C_{>7}$-C_8	0.2	0.4	RfD based on toluene. RfC based on toluene
$C_{>8}$-C_{10}	0.04	0.2	RfD based on naphthalene RfC based on inhalation studies using TPH C_9 mixture. Value less conservative than published values for naphthalene and isopropylbenzene.
$C_{>10}$-C_{12}	0.04	0.2	
$C_{>12}$-C_{16}	0.04	0.2	
$C_{>16}$-C_{21}	0.03	N/A	RfD based on pyrene.
$C_{>21}$-C_{35}	0.03	N/A	

7.6.9 Benzene

Benzene has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for benzene has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.10**.

Table 7.10: Summary of Published Level 1 Hazard Data for Benzene

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Benzene in Drinking Water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 5.2)
enHealth	No	
NEHF	YES	NEHF (1997) 'Benzene National Environmental Health Monographs' NEHF (May 2003) 'Benzene Health Review' NEHF (2004) 'National Environment Protection (Air Toxics) Measure'
IARC	YES	IARC Monographs (1987)
WHO/FAO JMPR	No	
NICNAS PEC	YES	NICNAS (September 2001) 'Benzene Priority Existing Chemical Assessment Report No. 21'
ATSDR	YES	ATSDR (August 2007) 'Toxicological Profile for Benzene'
NTP	YES	US Department of Health and Human Services (2009) '11th Report on Carcinogens'
OECD SIDS SIAR	No	
EPA	YES	IRIS Database (2003)

NHMRC

NHMRC/NRMMC (2004) reports that the IARC has concluded that benzene is carcinogenic to humans. The guideline value presented is reported to have been based on a WHO extrapolation model as based on the incidence of leukaemia in humans. The NHMRC/NRMMC (2004) guideline value is further noted to be based on an incremental risk of cancer of 1 in 100 000.

A background exposure to benzene was not reported in NHMRC/NRMMC (2004). It was reported that benzene has not been found in Australian drinking waters.

WHO

WHO (2003) reports that benzene is carcinogenic in mice and rats after both inhalation and oral exposure, producing malignant tumours at many sites. It is considered to be a human carcinogen and is classified by IARC in Group 1. The drinking water guideline has been derived based on a risk estimate using data on leukaemia from epidemiological studies involving inhalation exposure. The epidemiological data was reported to be supported by leukaemia and lymphomas in female mice and oral cavity squamous cell carcinomas in male rats. A slope factor for oral exposure of 0.035 $(mg/kg/day)^{-1}$ is reported to have been used.

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WHO (2000) reports that benzene is carcinogenic to humans. The geometric mean of the range of estimates of the excess lifetime risk of leukaemia at an air concentration of 1µg/m^3 is reported to be $6*10^{-6}$.

NEHF

NEHF (1997) reports a number of effects of benzene exposure including narcotic or anaesthetic effects, deaths of workers, development of severe and sometimes fatal damage to the blood-forming elements of the bone marrow preventing the manufacture of essential blood cells, central nervous system depression, cardiac arrhythmia, respiratory failure, headaches, lassitude and general weakness, increases in the number of chromosomal aberrations, increasing susceptibility to allergens, increased incidence of leukemias (especially non-lymphocytic leukemia) and some evidence of decreased immune function. NEHF (1997) reports that the most commonly found associations have been with increases in non-lymphocytic leukemia.

NEHF (1997) reports that WHO concluded that a time-weighted average of 1 ppm or less over a 40-year working life is not statistically associated with any increase in deaths from leukemia. It is further reported that in the United Kingdom, the Expert Panel on Air Quality Standards determined that a level of 0.5 ppm over a working lifetime would not produce any detectable adverse health effect.

NEHF (2003) contains a review of international sources of benzene toxicological data. This is undertaken to premise the benzene criteria as provided to the NEHF (2004) 'National Environment Protection (Air Toxics) Measure' (Air Toxics NEPM). An annual average of 0.003ppm as an eight year goal is recommended for benzene.

IARC

IARC classifies benzene as a Group 1 carcinogen.

NICNAS

NICNAS reports anecdotal evidence of acute exposure to benzene vapours causes dizziness and other CNS effects at concentrations above 25 ppm and eye, mucous membrane and skin irritation at levels above 30-60 ppm. Aspiration of liquid benzene is reported to have been observed to cause lung oedema and bleeding. Deaths from cardio-respiratory arrest are reported to have occurred following short-term inhalation of 20 000 ppm benzene, or from ingestion of a single dose of 125 mg benzene per kg.

Several studies are reported to demonstrate that repeated exposure to benzene may induce bone marrow depression, cause damage to genetic material and induce leukaemia. Some studies also reported to point to an association between benzene exposure and the risk for lymphoma. For bone marrow depression, the best estimate for a LOAEL is reported to be 7.6 ppm (TWA). An appropriate NOAEL is reported to have not been determined, although studies with various limitations indicate that would be likely to be >0.5 ppm (TWA).

The risk of developing leukaemia is reported to increase with exposure and has been shown to be significantly elevated above, but not below, a cumulative exposure of 50 ppm-years, corresponding to an average occupational exposure of 1.25 ppm (TWA) over 40 years. A potential lack of conservatism is noted in this study.

A national occupational exposure standard of 0.5ppm (TWA) was recommended in the study.

ATSDR

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ATSDR provides an acute duration inhalation exposure MRL of 0.009ppm. The MRL is reported to have been derived from a LOAEL value of 10.2 ppm for reduced lymphocyte proliferation following mitogen stimulation in mice.

An intermediate duration inhalation exposure MRL of 0.006ppm has been reported. This is reported to have been derived from a LOAEL of 10ppm for significantly delayed splenic lymphocyte reaction to foreign antigens evaluated in *in vitro* mixed lymphocyte reaction following the exposure of male mice to benzene vapours.

A chronic duration inhalation exposure MRL of 0.003ppm has been reported by ATSDR. The MRL is reported to be based on statistically significantly decreased counts of B-lymphocytes in workers of shoe manufacturing industries in Tianjin, China. A benchmark dose was derived from this study and adjusted by an uncertainty factor of 10 to account for human variability.

No acute or intermediate duration MRLs have been derived for benzene based on insufficient studies being available.

A chronic duration oral exposure MRL of 0.0005 mg/kg/day has been reported by ATSDR. This is reported to have been based on inhalation studies in workers, as described for the inhalation MRL. A benchmark dose has been derived from this study and adjusted for an oral route of exposure. A further uncertainty factor of 30 has been incorporated to account for human variability and uncertainty in route to route extrapolation.

NTP

Benzene is reported to be a human carcinogen based on sufficient evidence in humans. Case reports and case series have reported leukemia (mostly acute myelogenous leukemia, also known as acute myeloid or myelocytic leukemia) in individuals exposed to benzene. It was also reported that occupational exposure to benzene increased the risk of mortality from leukemia (mainly acute myelogenous leukemia).

US EPA

The US EPA classifies benzene as a known human carcinogen (classification A) for all routes of exposure. Epidemiologic studies and case studies are reported to provide clear evidence of a causal association between exposure to benzene and acute nonlymphocytic leukemia and also suggest evidence for chronic nonlymphocytic leukemia and chronic lymphocytic leukemia. Other neoplastic conditions that are associated with an increased risk in humans are hematologic neoplasms, blood disorders such as preleukemia and aplastic anemia, Hodgkin's lymphoma, and myelodysplastic syndrome. These human data are reported to be supported by animal studies.

US EPA provides an oral slope factor of $1.5*10^{-2}$ to $5.5*10^{-2}$ per (mg/kg)/day based on occurrences of leukaemia in occupational workers exposed by inhalation. An air unit risk of $2.2*10^{-6}$ to $7.8*10^{-6}$ is provided for benzene on the basis of the occurrence of leukaemia in humans.

An oral RfD of $4.0*10^{-3}$ mg/kg/day is also provided by the US EPA. This is reported to have been derived based on a benchmark dose calculated by the modelling of the absolute lymphocyte count (ALC) data from an occupational epidemiologic study in which workers were exposed to benzene by inhalation. Absolute lymphocyte count, white blood cell count, red blood cell count, hematocrit, and platelets were all significantly decreased, and mean corpuscular volume was significantly increased in the exposed workers. The benchmark dose was adjusted by an uncertainty factor of 300.

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The same study has been used by the US EPA to derive a inhalation RfC of $3*10^{-2}$ mg/m^3. The benchmark concentrations has been likewise adjusted by an uncertainty factor of 300.

7.6.10 Toluene

Toluene has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for toluene has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.11**.

Table 7.11: Summary of Published Level 1 Hazard Data for Toluene

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2004) 'Toluene in Drinking Water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 5.14)
enHealth	No	
NEHF	YES	NEHF (May 2003) 'Toluene Health Review' NEPC (2004) 'National Environment Protection (Air Toxics) Measure'
IARC	YES	IARC Monographs (1999)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (2000) 'Toxicological Profile for Toluene'
NTP	No	
OECD SIDS SIAR	No	
EPA	YES	IRIS database (2005)

NHMRC

NHMRC/NRMMC (2004) has recommended a daily intake of 312mg/kg body weight per day as based on a no effect levels derived from a 13 week oral study using rats. Rats and mice exposed via a 13 year gavage study reported increased liver weights at doses from 625 mg/kg body weight per day.

It was also recommended that a safety factor of 1 000 is used with the recommended tolerable daily intake based on interspecies variations, intraspecies variations and to account for the use of a less than lifetime study. A correction factor of 5/7 is also recommended to convert a 5 day per week gavage study to a 7 day week equivalent (TDI of 0.223 mg/kg body weight per day).

A background exposure to toluene was not reported in NHMRC/NRMMC (2004). It was reported that toluene has not been found in Australian drinking waters.

WHO

WHO (2004) reports that the guideline value for toluene has been derived by a TDI approach. A TDI of 223 µg/kg of body weight is reported to have been derived using the LOAEL for marginal hepatotoxicity in mice of 312mg/kg of body weight per day (equivalent to 223 mg/kg of body weight per day for 7 days per week dosing) and applying an uncertainty factor of 1000 (100 for inter- and intraspecies variation and 10 for the short duration of the study and use of a LOAEL instead of a NOAEL).

WHO (2000) reports that the LOAEL for effects on the CNS from occupational studies, is approximately 332mg/m^3. A guideline value of 0.26mg/m^3 is reported to be established from these data adjusting for continuous exposure (dividing by a factor of 4.2) and dividing by an uncertainty factor of 300 (10 for interindividual variation, 10 for use of a lowest-observed-adverse-effect level rather than a no-observed-adverse-effect level, and

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an additional factor of 3, given the potential effects on the developing CNS). It is recommended that this guideline value be applied as a weekly average.

NEHF

NEHF (2003) contains a review of international sources of toluene toxicological data. This is undertaken to premise the toluene criteria as provided to the Air Toxics NEPM. An annual average of 0.1ppm as an eight year goal is recommended for toluene. A 24 hour average of 1ppm is also recommended for toluene as an eight year goal.

IARC

IARC classifies toluene as a Group 3 chemical, not classifiable as to its carcinogenicity to humans.

ATSDR

ATSDR provide an acute duration inhalation exposure MRL of 1mg/kg/day. This is reported to be based on changes in neurological effects of human subjects to short terms exposures. A NOAEL was derived from this study and adjusted for an uncertainty factor of 10 to account for human variability.

A chronic duration inhalation exposure MRL of 0.08mg/kg/day is reported. This is based on studies of Canadian workers occupationally exposed to toluene. A LOAEL was derived from this study on the basis of colour vision impairment. The LOAEL was adjusted to account for affects of age and alcohol exposure. An uncertainty factor of 100 was also used to account for use of an LOAEL and human variability.

An acute duration oral exposure MRL of 0.8mg/kg/day is reported. This is based on the observation of neurological effects in rats. The LOAEL derived from the study was divided by an uncertainty factor of 300 to account for use of an LOAEL, extrapolation from humans to animals and human variability.

An intermediate duration oral exposure MRL of 0.02mg/kg.day has been reported by ATSDR. This is based on significant increases in norepinephrin present in the hypothalamus and in the midbrain in dosed mice. A LOAEL was derived from this study and divided by an uncertainty factor of 300 to account for used of an LOAEL, extrapolation from humans to animals and human variability.

A chronic duration oral MRL is not available.

US EPA

US EPA reports that there is inadequate information to assess the carcinogenic potential of toluene because studies of humans chronically exposed to toluene are inconclusive. Toluene is reported to have not been found to be carcinogenic in adequate inhalation cancer bioassays of rats and mice exposed for life.

An oral RfD of 0.08mg/kg-day is reported by the US EPA as based on a benchmark dose derived from a subchronic study that examined oral exposure to toluene in rodents (rats and mice). The rodents developed increased kidney and liver weights. Histopathologic lesions in the liver consisted of hepatocellular hypertrophy. Nephrosis was observed in rats that died, and damage to the tubular epithelia of the kidney occurred in terminally sacrificed rats. The benchmark dose was derived on the basis of increased kidney weights. This is reported by US EPA to have been supported by several acute oral and inhalation human toxicity studies. The RfD incorporated an uncertainty factor of 3 000 to account for extrapolation for interspecies differences, consideration of intraspecies

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variation, use of a subchronic study to estimate chronic effects and database insufficiencies and contradictions in the immunotoxicity data.

An inhalation RfC of 5mg/m^3 is reported by US EPA as based on an average NOAEL as derived from studies of neurological effects of occupational workers exposed by inhalation. Neurological effects are reported to include impaired colour vision, impaired hearing, decreased performance in neurobehavioral analysis, changes in motor and sensory nerve conduction velocity, headache and dizziness. The RfC incorporated an uncertainty factor of 10 for intraspecies differences.

7.6.11 Ethylbenzene

Ethylbenzene has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for ethylbenzene has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.12**.

Table 7.12: Summary of Published Level 1 Hazard Data for Ethylbenzene

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Ethylbenzene in Drinking Water'
enHealth	No	
NEHF	No	
IARC	YES	IARC Monographs (2000)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (September 2007) 'Toxicological Profile for Ethylbenzene'
NTP	No	
OECD SIDS SIAR	No	
EPA	YES	IRIS Database (1991)

NHMRC

NHMRC/NRMMC (2004) has recommended a daily intake of 136 mg/kg body weight per day as based on a no effect level from a 6 month gavage study using rats. The gavage study found that rats reported enlargement of the liver and kidney at high doses (400 mg/kg body weight per day).

It was also recommended that a safety factor of 1 000 is used with the recommended tolerable daily intake based on interspecies variations, intraspecies variations and to account for the use of a less than lifetime study. A correction factor of 5/7 is also recommended to convert a 5 day per week gavage study to a 7 day week equivalent (TDI of 0.097 mg/kg body weight per day).

A background exposure to ethylbenzene was not reported in NHMRC/NRMMC (2004). It was reported that ethylbenzene has not been found in Australian drinking waters.

WHO

WHO (2003) reports that the guideline value for ethylbenzene has been derived by a TDI approach. The TDI is reported to have been derived using a NOAEL of 136 mg/kg of body weight per day based on hepatotoxicity and nephrotoxicity observed in a limited 6-month study in rats (administration 5 days per week). After application of an uncertainty factor of 1 000 (100 for intra- and interspecies variation and 10 for the limited database and short duration of the study), a TDI of 97.1 µg/kg of body weight is reported to have been used.

Most recent editions of WHO air quality guidelines do not include an assessment of ethylbenzene in air.

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IARC

IARC classified ethylbenzene as a Group 2B chemical, possibly carcinogenic to humans.

ATSDR

ATSDR provide an acute duration inhalation exposure MRL of 10ppm. This is reported to be based on auditory losses of rats. Increased kidney and liver weights have also been reported in exposed rats.

An intermediate duration inhalation exposure MRL of 0.7ppm. This is reported to be based on a loss of cochlear outer hair cells in exposed rats. A human equivalent LOAEL was derived from this studies and divided by an uncertainty factor of 300 to account for extrapolation from animals to humans and human variability.

A chronic duration inhalation exposure MRL of 0.3ppm was reported as based on the human equivalent LOAEL of 75ppm for nephropathy in rats. The MRL has incorporated an uncertainty factor of 300 to account for use of an LOAEL, extrapolation from animals to humans and human variability.

An intermediate duration oral exposure MRL of 0.5 mg/kg/day has been reported by ASTDR as based on a benchmark dose derived for hepatoxocity (centrilobular hepatocyte hypertrophy) in exposed male rats. The benchmark dose was divided by an uncertainty factor of 100 to account for extrapolation from animals to humans and human variability to derive the MRL.

No acute or chronic duration oral exposure MDLs were provided by ASTDR.

US EPA

US EPA reports that ethylbenzene is not classifiable as to human carcinogenicity due to a lack of animal bioassays and human studies.

An oral RfD of 0.1mg/kg/day is reported by US EPA based on a NOAEL derived for a oral bioassay study of rats given ethylbenzene doses in olive oil gavage. Toxic effects on the animals included growth, mortality, appearance and behavior, hematologic findings, terminal concentration of urea nitrogen in the blood, final average organ and body weights, histopathologic findings and bone marrow counts. The RfD incorporated an uncertainty factor of 1 000 for intraspecies and interspecies variability and extrapolation of a subchronic effect level to its chronic equivalent.

An inhalation RfC of 1mg/m^3 is reported based on a NOAEL as derived from inhalation experiments conducted with Wistar rats and New Zealand white rabbits. The principal observation of the exposed animals was a reduced number of live rabbit kittens per litter, an increased incidence of supernumerary and rudimentary ribs and extra ribs in exposed rats and increased liver, kidney, and spleen weights in pregnant rats. The RfC incorporated an uncertainty factor of 300 for unusually sensitive individuals, interspecies conversion and to adjust for the absence of multigenerational reproductive and chronic studies.

7.6.12 Xylene

Xylene has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for xylene has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.13**.

Table 7.13: Summary of Published Level 1 Hazard Data for Xylene

Organisation	Availability	Reference

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Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Xylenes in Drinking Water'
enHealth	No	
NEHF	YES	NEHF (May 2003) 'Xylenes Health Review' NEPC (2004) 'National Environment Protection (Air Toxics) Measure'
IARC	YES	IARC Monographs (1999)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (August 2007) 'Toxicological Profile for Xylene'
NTP	No	
OECD SIDS SIAR	No	
EPA	YES	IRIS Database (2003)

NHMRC

NHMRC/NRMMC (2004) has recommended a daily intake of 250 mg/kg body weight per day as based on a no effect level from a 2 year gavage study using rats and mice. The gavage study found that rats and mice reported decreased growth at high doses (500 mg/kg body weight per day).

It was also recommended that a safety factor of 1 000 is used with the recommended tolerable daily intake based on interspecies variations, intraspecies variations and to account for the use of a less than lifetime study. A correction factor of 5/7 is also recommended to convert a 5 day per week gavage study to a 7 day week equivalent (TDI of 0.179 mg/kg body weight per day).

Background exposure to xylenes was not reported in NHMRC/NRMMC (2004). It was reported that xylenes have not been found in Australian drinking waters.

WHO

WHO (2003) reports that the guideline value for xylene has been derived by a TDI approach. A TDI of 179 µg/kg of body weight is reported to have been derived using a NOAEL of 250 mg/kg of body weight per day based on decreased body weight in a 103-week gavage study in rats with administration 5 days per week (equivalent to 179 mg/kg of body weight per day 7 days per week) and an uncertainty factor of 1000 (100 for intra- and interspecies variation and 10 for the limited toxicological endpoint).

Most recent editions of WHO air quality guidelines do not include an assessment of xylenes in air.

NEHF

NEHF (2003) contains a review of international sources of xylene toxicological data. This is undertaken to premise the xylene criteria as provided to the Air Toxics NEPM. An annual average of 0.2ppm as an eight year goal is recommended for xylene. A 24 hour average of 0.25ppm is also recommended for toluene as an eight year goal.

IARC

IARC classify xylenes as a Group 3 chemical, not classifiable as to its carcinogenicity to humans.

ATSDR

ATSDR report an acute duration inhalation exposure MRL of 2ppm for mixed xylenes. This is based on neurological and respiratory effects of humans. A LOAEL was derived from the study and divided by an uncertainty factor of 30 to account for use of an LOAEL and human variability to derive the MRL.

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An intermediate duration inhalation exposure MRL of 0.6ppm is reported for mixed xylenes. This was based on neurotoxicity effects in rats. A human equivalent LOAEL was derived from the study and divided by an uncertainty factor of 90 to account for use of a LOAEL, extrapolation from humans to animals and human variability.

A chronic duration inhalation exposure MRL of 0.5ppm has been reported for mixed xylenes. The MRL was based on the observation of respiratory and neurological effects in exposed workers. The study derived an LOAEL as the geometric mean of the critical neurological and respiratory effects. The LOAEL was divided by an uncertainty factor of 100 to account for use of an LOAEL and human variability and a modifying factor of three to account for lack of supporting studies evaluating the chronic neurotoxicity of xylene.

An acute duration oral exposure MRL of 1mg/kg/day was reported for mixed xylenes. This was derived from neurotoxicity effects observed in exposed rats. An NOAEL was derived from this study. The NOAEL was divided by an uncertainty factor of 100 to account for extrapolation from animals to humans and human variability to derive the MRL.

An intermediate duration oral exposure MRL of 0.4mg/kg/day was reported for mixed xylenes. This was based on an NOAEL derived from observations of hyperactivity in exposed mice. An uncertainty factor of 100 to account for extrapolation from animals to humans and human variability and a modifying factor of 10 to account for the lack of testing for sensitive neurological end points and lack of developmental and multigenerational data were applied to a duration adjusted NOAEL to derive the MRL.

A chronic duration oral exposure MRL of 0.2 mg/kg/day has been reported for mixed xylenes. This was based on an NOAEL derived from observations of hyperactivity in exposed mice. An uncertainty factor of 100 to account for extrapolation from animals to humans and human variability and a modifying factor of 10 to account for the lack of testing for sensitive neurological end points and lack of developmental and multigenerational data were applied to a duration adjusted NOAEL to derive the MRL.

US EPA

It is reported that data are inadequate for an assessment of the carcinogenic potential of xylenes. Available animal data are reported to be inconclusive.

An oral RfD of 0.2mg/kg/day is reported for xylene on the basis of a NOAEL as based on increased mortality and decreased body weight of rats. It is reported that a study of rats administered mixed xylenes by gavage identified effects of exposure including decreased body weight and decreased survival. Studies of mice have also reported hyperactivity. The RfD incorporated an uncertainty factor of 1 000 for interspecies and intraspecies differences and database uncertainty.

An inhalation RfC of 0.1mg/m^3 is reported for xylenes based on a NOAEL derived from a study of rats exposed to toluene and xylene via inhalation. Exposed rats exhibited statistically significantly decreased rotarod performance and decreased spontaneous activity. Another study of rats reported statistically significant decreases in erythrocyte number and decreased levels of hemoglobin. Rats also reported increased sensitivity to pain. The RfC incorporated an uncertainty factor of 300 for laboratory animal-to-human interspecies differences, intraspecies uncertainty, extrapolation from subchronic to chronic duration and uncertainties in the database.

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7.6.13 1,2,4-Trimethylbenzene

1,2,4-trimethylbenzene has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for 1,2,4-trimethylbenzene has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.14**.

Table 7.14: Summary of Published Level 1 Hazard Data for 1,2,4-trimethylbenzene

Organisation	Availability	Reference
NHMRC	No	
Therapeutic Goods Administration	No	
WHO	No	
enHealth	No	
NEHF	No	
IARC	No	
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	No	
NTP	No	
OECD SIDS SIAR	No	
EPA	YES	US EPA (August 1994) 'Chemical Summary for 1,2,4-trimethylbenzene

Significant information on the toxicity of 1,2,4-trimethylbenzene has only been identified with the US EPA preparation of a chemical summary of 1,2,4-trimethylbenzene of the Level 1 sources. It is reported that direct contact with liquid 1,2,4-trimethylbenzene is irritating to the skin. Inhalation of vapour has been found to cause chemical pneumonitis, headache, fatigue and drowsiness. Long term exposure of humans to trimethylbenzenes has been found to cause nervousness, tension and anxiety, asthmatic bronchitis, anemia, and alterations in blood clotting, based on a study of painters exposed to a solvent containing 50% 1,2,4-trimethylbenzene.

A review of Level 2 sources has been additionally undertaken. The US EPA (November 2010) regional screening level table cites a provisional peer reviewed toxicity value as a an RfC equal to $7*10^{-3}mg/m^3$. Background studies on the derivation of PPRTV's are not available.

7.6.14 Polycyclic Aromatic Hydrocarbons

A range of polycyclic aromatic hydrocarbons (PAHs) have been selected as COPCs for the assessment of potential human health impacts. A brief summary of the toxicological data available for PAHs has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.15**.

Table 7.15: Summary of Published Level 1 Hazard Data for Polycyclic Aromatic Hydrocarbons

Organisation	Availability	Reference
NHMRC	YES	NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines'
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	YES	WHO (2003) 'Polynuclear aromatic hydrocarbons in Drinking-water' WHO (2000) 'Air Quality Guidelines for Europe, 2nd Edition' (chapter 5.9)
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	YES	NEHF (May 2003) 'Polycyclic Aromatic Hydrocarbons (PAHs) Health Review' NEHF (2004) 'National Environment Protection (Air Toxics) Measure' enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	Anthracene, IARC Monograph in preparation (2010) Benz(a)anthracene, IARC Monograph in preparation (2010) Benzo(a)pyrene, IARC Monograph in preparation (2010) Benzo(b)fluoranthene, IARC Monograph in preparation (2010) Benzo(k)fluoranthene, IARC Monograph in preparation (2010)

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Organisation	Availability	Reference
		Chrysene, IARC Monograph in preparation (2010) Dibenz(a,h)anthracene, IARC Monograph in preparation (2010) Fluorene, IARC Monograph in preparation (2010) Indeno(1,2,3-c,d)pyrene, IARC Monograph in preparation (2010) Naphthalene, IARC Monographs (2002) Phenanthrene, IARC Monograph in preparation (2010) Pyrene, IARC Monograph in preparation (2010)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATSDR (August 1995) 'Toxicological Profile for Polycyclic Aromatic Hydrocarbons' ATSDR (August 2005) 'Toxicological Profile for Naphthalene, 1-Methylnaphthalene and 2-Methylnaphthalene'
NTP	YES	US Department of Health and Human Services (2009) '11th Report on Carcinogens'
OECD SIDS SIAR	YES	'Sids Initial Assessment Profile, 2-methylnaphthalene'
EPA	YES	IRIS Database (1991), acenaphthylene IRIS Database (1994), benz(a)anthracene IRIS Database (1994), benzo(a)pyrene IRIS Database (1994), benzo(b)fluoranthene IRIS Database (1990), benzo(g,h,i)perylene IRIS Database (1994), benzo(k)fluoranthene IRIS Database (1994), chrysene IRIS Database (1994), dibenz(a,h)anthracene IRIS Database (1990), fluorene IRIS Database (1994) ,indeno(1,2,3-c,d)pyrene IRIS Database (2003), 2-methylnaphthalene IRIS Database (1998), naphthalene IRIS Database (1994), phenanthrene IRIS Database (1994), pyrene

NHMRC

It is reported in NHMRC (2004) that most of the toxicological literature is specific to benzo(a)pyrene with few studies available for other PAHs. It is reported that the IARC defines benzo(a)pyrene as probably carcinogenic to humans (though recently updated to a confirmed carcinogen as discussed in IARC review).

A guideline value has been presented for benzo(a)pyrene. This is reported to have been based on a WHO linear multistage model as based on the incidence of leukaemia in humans. The NHMRC/NRMMC (2004) guideline value is further noted to be based on an incremental risk of cancer of 1 in 1 000 000.

Background exposure to PAHs were not reported in NHMRC/NRMMC (2004) for Australia. It was reported that benzo(a)pyrene occurs in US drinking waters at a typical concentration of 55ng/l. The intake of PAHs from foods was reported as being at least an order of magnitude higher than from drinking water.

WHO

WHO (2003) reports that benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, Dibenzo(a,h)anthracene, fluoranthene and indeno(1,2,3-c,d)pyrene are classifiable as carcinogens. Relative potencies of PAHs are summarised following:

- Benz(a)anthracene – 0.1;
- Benzo(a)pyrene – 1.0
- Benzo(b)fluoranthene – 0.1;
- Benzo(k)fluoranthene – 0.1;
- Dibenz(a,h)anthracene – 1.0; and

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- Indeno(1,2,3-c,d)pyrene – 0.1.

An earlier WHO publication, WHO / IPCS (1998) 'Environmental Health Criteria Selected Non-Hetrocyclic Polycyclic Aromatic Hydrocarbons' also provides potency factors for an increased list of PAHs that includes chrysene. These are reproduced following.

- Benzo(a)pyrene – 1.0
- Benzo(a)anthracene – 0.1-0.145;
- Benzo(b)fluoranthene – 0.1-0.167;
- Benzo(k)fluoranthene – 0.01-0.02;
- Chrysene – 0.001-0.004;
- Diebnz(a,h)anthracene – 1-1.11; and
- Indeno(1,2,3-c,d)pyrene – 0.055-0.1.

It is reported that evidence that mixtures of PAHs are carcinogenic in humans comes primarily from occupational studies of workers. Cancer associated with exposure to PAH-containing mixtures in humans occurs predominantly in the lung and skin following inhalation and dermal exposure, respectively.

A guideline value has been derived by WHO (2003) for benzo(a)pyrene, described as the most carcinogenic of PAHs. It is reported that an excess lifetime cancer risk of $1*10^{-5}$ was estimated for 0.7µg/l, based on an oral carcinogenicity study and a two-stage birth–death mutation model, which incorporated variable dosing patterns and time of sacrifice. It is further reported that a study on forestomach tumour incidence in mice gave nearly identical results.

A guideline value has also been derived for fluoranthene. This is reported to have been estimated from a 13-week oral gavage study in mice with a NOAEL of 125 mg/kg of body weight per day, based on increased serum glutamate-pyruvate transaminase levels, kidney and liver pathology, and clinical and haematological changes. An uncertainty factor of 10 000 (100 for inter- and intraspecies variation, 10 for the use of a subchronic study and inadequate database, and 10 because of clear evidence of co-carcinogenicity with BaP in mouse skin painting studies) is reported to result in a TDI of 0.0125 mg/kg of body weight per day.

WHO (2000) nominated benzo(a)pyrene as an indicator chemical to represent the carcinogenic potential of PAHs in air. It is noted that that evaluation of benzo(a)pyrene solely probably underestimates the carcinogenic potential of airborne PAH mixtures. Based upon epidemiological data from studies in coke-oven workers, a unit risk for benzo(a)pyrene as an indicator in air of PAH constituents, is estimated to be $8.7*10^{-5}$ $(ng/m^3)^{-1}$. This was reported to be supported by animal data.

<u>enHealth</u>

enHealth (2001) reports that some PAHs are classified as IARC Group 2A and 2B carcinogens and the procedure for these compounds, in the absence of an ADI/PTWI, was to establish their carcinogenic potency, and then estimate a dose associated with a particular increased lifetime cancer risk.

A guideline value based on an exposure to benzo(a)pyrene of 0.8ng/kg/day was reported to have been used to derive soils criteria.

<u>NEHF</u>

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NEHF (2003) contains a review of international sources of PAHs toxicological data. Most of the available toxicological data is found in this document to be available for benzo(a)pyrene. This review has been undertaken to premise the PAHs criteria as provided to the Air Toxics NEPM. An annual average of 0.3ng/m^3 as an eight year goal is recommended for benzo(a)pyrene as a marker for PAHs.

IARC

IARC classifies anthracene as a Group 3 chemical, not classifiable as to its human carcinogenicity.

IARC classifies benz(a)anthracene as a Group 2B chemical, possibly carcinogenic to humans.

IARC classifies benzo(a)pyrene as a Group 1 carcinogen.

IARC classifies benzo(b)fluoranthene and benzo(k)fluoranthene as Group 2B chemicals, possibly carcinogenic to humans.

IARC classifies chrysene as a Group 2B chemical, possibly carcinogenic to humans.

IARC classifies dibenz(a,h)anthracene as a Group 2A chemical, possibly carcinogenic to humans.

IARC classifies fluorene as a Group 3 chemical, not classifiable as to its human carcinogenicity.

IARC classifies indeno(1,2,3-c,d)pyrene as a Group 2B chemical, possibly carcinogenic to humans.

IARC classifies naphthalene as a Group 2B chemical, possibly carcinogenic to humans.

IARC classifies phenanthrene as a Group 3 chemical, not classifiable as to its human carcinogenicity.

IARC classifies pyrene as a Group 3 chemical, not classifiable as to its human carcinogenicity.

ATSDR

ATSDR report that no inhalation exposure MRLs have been derived for PAHs (apart from naphthalene and isomers) consequent of lack of dose-response data that identify noncancer health effects for humans or animals.

No acute or chronic duration oral exposure MRLs are reported to be provided for PAHS, also consequent of a lack of data.

A chronic duration inhalation exposure MRL of 0.0007ppm has been reported for naphthalene. The MRL has been based on an LOAEL derived for nonneoplastic lesions in nasal olfactory epithelium (metaplasia in mice, and hyperplasia, atrophy, and chronic inflammation in rats) and respiratory epithelium (hyperplasia in mice, and hyperplasia, metaplasia, hyaline degeneration, or gland hyperplasia in rats). Exposed rats were also reported to show increased incidences of nasal tumours. A human equivalent LOAEL was derived and divided by an uncertainty factor of 300 to account for use of an LOAEL, extrapolation from animals to humans and human variability.

An intermediate duration oral exposure MRL of 0.6mg/kg.day has been reported for acenaphthene. This is reported to be based on an LOAEL for liver weight changes in exposed mice. The MRL has been obtained by dividing the LOAEL by an uncertainty

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factor of 300 to account for use of an LOAEL, extrapolation of animals to humans and human variability.

An intermediate duration oral exposure MRL of 0.4mg/kg/day has been reported for fluoranthene. This is reported to be based on an LOAEL for liver weight changes in exposed mice. The MRL has been obtained by dividing the LOAEL by an uncertainty factor of 300 to account for use of an LOAEL, extrapolation of animals to humans and human variability.

An intermediate duration oral exposure MRL of 0.4mg/kg/day has been reported for fluorene. This is reported to be based on an LOAEL for liver weight changes in exposed mice. The MRL has been obtained by dividing the LOAEL by an uncertainty factor of 300 to account for use of an LOAEL, extrapolation of animals to humans and human variability.

An intermediate duration oral exposure MRL of 10mg/kg/day has been reported for anthracene. This is reported to be based on an NOAEL for potential liver effects in exposed mice. The MRL has been obtained by dividing the LOAEL by an uncertainty factor of 100 to account for extrapolation of animals to humans and human variability.

An acute and intermediate duration oral exposure MRL of 0.6mg/kg/day was reported for naphthalene. This is reported to be based on decreased body weights in exposed rats, to derive an NOAEL. The NOAEL has been divided by an uncertainty factor of 100 to account for extrapolation from animals to humans and human variability to derive the MRL.

A chronic duration oral exposure MRL of 0.6mg/kg/day has been reported for naphthalene. This was based on a rat developmental study. Effects observed included slow respiration, lethargy, or prone body posture in most rats following dose administration on the first and second day of dosing. The MRL was calculated from the LOAEL derived for these effects and an uncertainty factor of 90 to account for use of an LOAEL, extrapolation from animals to humans and human variability.

The ATSDR has set a chronic-duration MRL of 0.04 mg/kg/day for 2-methylnaphthalene based on a study on pulmonary alveolar proteinosis in male mice, with an uncertainty factor of 100.

NTP

NTP reported polycyclic aromatic hydrocarbons including benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,h)anthracene and indeno(1,2,3-c,d)pyrene to be reasonably anticipated to be human carcinogens based on sufficient evidence of carcinogenicity in experimental animals.

Benz(a)anthracene is reported to have induced papillomas of the forestomach in mice, lung adenomas and hepatomas in mice, skin papillomas in mice sarcomas in adult mice and pulmonary adenomas and adenocarcinomas in newborn mice and local carcinomas in mice (by bladder implantation).

Benzo(a)pyrene is reported to induce malignant and benign forestomach tumors in mice and hamsters, and mammary tumors in female rats, increase the incidence of forestomach tumors and induced lung adenomas in mice, induced skin carcinomas and papillomas in mice, rats, guinea pigs, and rabbits, tracheal papillomas and carcinomas in hamsters and squamous cell carcinomas of the lung in rats, lung tumors in rats, tracheobronchial tumors in hamsters, and squamous carcinomas of the lung in two of six subhuman primates, local sarcomas in rats, hamsters, guinea pigs, newts, subhuman primates, and adult mice, abdominal fibrosarcomas in mice of both sexes, and mammary

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and uterine carcinomas in rats, mammary carcinomas in female rats, local tumors in rats, increased incidence of lung adenomas and initiated skin carcinogenesis in the offspring.

Benzo(b)fluoranthene is reported to have induced skin tumours in mice and local sarcomas in mice.

Dibenz(a,h)anthracene is reported to have induced local sarcomas in mice, squamous cell carcinomas and papillomas of the forestomach in mice, alveologenic carcinomas of the lung and hemangioendotheliomas in mice of both sexes and mammary carcinomas in female mice, lung squamous cell carcinomas in rats, local sarcomas in rats, guinea pigs, pigeons, fowl, adult mice, and newborn mice, lung adenomas and renal adenocarcinomas

NTP reports that that exposure to coke oven emissions, which contain a variety of PAHs, has been demonstrated to cause increased incidences of lung and genitourinary cancer mortality in coke oven workers. Workers exposed to creosote containing numerous PAHs developed skin tumors. Exposures to other chemical mixtures that contain PAHs, such as cigarette smoke, coal tar, coal tar pitch, and bitumens, have been associated with increased incidences of lung cancer in humans. Dermal exposure to coal tar and shale oils containing PAHs have been associated with increased incidences of skin tumors in humans.

US EPA

Acenaphthylene

Acenaphthylene has been reported as being non classifiable as to human carcinogenicity, based on no human data and inadequate data from animal bioassays.

Benz(a)anthracene

Benz(a)anthracene has been reported by US EPA to be a probable human carcinogen (classification B2) based on data from animal bioasays. Benz[a]anthracene administration has been reported to cause an increase in the incidence of tumors in animals by gavage, dermal application and both subcutaneous injection and intraperitoneal injection.

Benzo(a)pyrene

Benz(a)anthracene has been reported by US EPA to be a probable human carcinogen (classification B2) based on human data from multiple animal studies in many species demonstrating benzo(a)pyrene to be carcinogenic following administration by numerous routes. Benzo(a)pyrene is also reported to have produced positive results in numerous genotoxicity assays.

Benzo(a)pyrene administered in the diet or by gavage to mice, rats and hamsters has produced increased incidences of stomach tumours. Intratracheal instillation and inhalation studies in guinea pigs, hamsters and rats have resulted in elevated incidences of respiratory tract and upper digestive tract tumours. Intraperitoneal BAP injections have caused increases in the number of injection site tumours in mice and rats.

US EPA provides an oral slope factor for benzo(a)pyrene of 7.3 per (mg/kg)/day. This data has been derived on the extrapolation of animal studies that resulted in forestomach, larynx and esophagus, papillomas and carcinoma type tumours. The slope factor has been set by the calculation of a geometric mean of a range of slope factors.

Benzo(b)fluoranthene

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Benzo(b)fluoranthene has been reported by US EPA to be a probable human carcinogen (classification B2) based on data from animal bioasays. Benzo[b]fluoranthene is reported to have produced tumors in mice after lung implantation, intraperitoneal or subcutaneous injection, and skin painting.

Benzo(g,h,i)perylene

Benzo(g,h,i)perylene has been reported as being non classifiable as to human carcinogenicity, based on no human data and inadequate data from animal bioassays.

Benzo(k)fluoranthene

Benzo(k)fluoranthene has been reported by US EPA to be a probable human carcinogen (classification B2) based on data from animal bioasays. Benzo(k)fluoranthene is reported to have produced tumours after lung implantation in mice and when administered with a promoting agent in skin-painting studies. Equivocal results have reported to have been found in a lung adenoma assay in mice. Benzo[k]fluoranthene is also reported to have been shown to be mutagenic in bacteria.

Chrysene

Chrysene has been reported by US EPA to be a probable human carcinogen (classification B2) based on data from animal bioasays. Chrysene is reported to have produced carcinomas and malignant lymphoma in mice after intraperitoneal injection and skin carcinomas in mice following dermal exposure. Chrysene is reported to have produced chromosomal abnormalities in hamsters and mouse germ cells after gavage exposure, positive responses in bacterial gene mutation assays and transformed mammalian cells exposed in culture.

Dibenz(a,h)anthracene

Dibenz(a,h)anthracene has been reported by the US EPA to be a probable human carcinogen (classification B2) based on data from animal bioassays.
Dibenz(a,h)anthracene is reported to have produced carcinomas in mice following oral or dermal exposure and injection site tumors in several species following subcutaneous or intramuscular administration and induced DNA damage and gene mutations in bacteria as well as gene mutations and transformation in several types of mammalian cell cultures.

Fluorene

Fluorene has been reported as being non classifiable as to human carcinogenicity, based on no human data and inadequate data from animal bioassays.

An oral RfD of $4*10^{-2}$mf/kg/day is reported by the US EPA on the basis of a NOAEL and LOAEL as reported from a gavage study of mice. A significant decrease in red blood cell count and packed cell volume were observed in the mice. Decreases in erythrocyte count, packed cell volume, and haemoglobin concentration were all observed in the mice. A significant decreasing trend in blood urea nitrogen and a significant increasing trend in total serum bilirubin were observed in both high-dose subjects. Dose-related increases in liver, spleen and kidney weights were also observed. The LOAEL and NOAEL were derived on the basis of the observed haematological effects.

The RfD has also incorporated an uncertainty factor of 3,000 to account for intra- and interspecies variability, the use of a subchronic study for chronic RfD derivation and to account for the lack of adequate toxicity data in a second species and reproductive / developmental data.

Indeno(1,2,3-c,d)pyrene

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Indeno(1,2,3-c,d)pyrene has been reported by US EPA to be a probable human carcinogen (classification B2) based on data from animal bioassays. Indeno(1,2,3-c,d)pyrene is reported to produce tumours in mice following lung implants, subcutaneous injection and dermal exposure. Indeno(1,2,3-c,d)pyrene is reported to have tested positive in bacterial gene mutation assays.

2-methylnaphthalene

The EPA gives an oral RfD of 0.004 mg/kg-day, derived from a value of 3.5 mg/kg-day for a 95% lower confidence limit on a dose associated with 5% extra risk (BMDL05) for pulmonary alveolar proteinosis in mice exposed to 2-methylnaphthalene in the diet.

Naphthalene

Naphthalene is classified by the US EPA as a possible human carcinogen (classification C). This is based on limited evidence of carcinogenicity in animals via the inhalation route. Mice exposed to naphthalene vapours were found to have increased rates of mortaility. Increases in incidences of nonneoplastic lesions were found in the lung and nose and alveolar/bronchiolar adenomas were also observed.

An oral RfD of $2*10^{-2}$mg/kg/day is reported to have been derived on the basis of the NOAEL as derived from a gavage study of rats. Rats of both sexes were reported to have displayed diarrhoea, lethargy, hunched posture, and rough coats at intermittent intervals throughout the study. Decreases in mean body weight and depression were also reported. A LOAEL and NOAEL were derived on the basis of the decrease in body weight.

The oral RfD has incorporated an uncertainty factor of 3 000 to account for extrapolation from rats to humans, sensitive humans, extrapolation from subchronic to chronic exposure and the lack of chronic oral exposure studies and 2-generation reproductive toxicity studies.

An inhalation RfC of $3*10^{-3}$mg/m^3 is reported to have been derived on the basis of LOAEL human equivalent concentration as derived from a inhalation study of mice. Inflammation, metaplasia of the olfactory epithelium, and hyperplasia of the respiratory epithelium were reported to have occurred in the noses of virtually all exposed mice. The LOAEL was derived on the basis of naphthalene-related effects on the nasal epithelium.

The inhalation RfC has incorporated an uncertainty factor of 3 000 to account for extrapolation from mice to humans, sensitive humans, extrapolation from a LOAEL to a NOAEL and database deficiencies including the lack of a 2-generation reproductive toxicity study and chronic inhalation data for other animal species.

Phenanthrene

Phenanthrene has been reported as being non classifiable as to human carcinogenicity, based on no human data and inadequate data from animal bioassays.

Pyrene

Pyrene has been reported as being non classifiable as to human carcinogenicity, based on no human data and inadequate data from animal bioassays. An oral RfD of $3*10^{-2}$ mg/kg/day is provided for pyrene on the basis of the average of the NOAEL and the LOAEL as determined by a gavage study of mice. Nephropathy, characterised by the presence of multiple foci of renal tubular regeneration, often accompanied by interstitial lymphocytic infiltrates and/or foci of interstitial fibrosis, was reported to be present in the mice. Kidney lesions were also reported. An NOAEL and LOAEL were derived from the study on the basis of nephropathy and decreased kidney weights. The RfD has also

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incorporated an uncertainty factor of 3 000 to account for intra- and interspecies variability, the use of a subchronic study for chronic RfD derivation and to account for the lack of both toxicity studies in a second species and developmental / reproductive studies.

Order of Potency of PAHs

US EPA (1993) 'U.S. Environmental Protection Agency. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons' provides an order of potency for PAHs on the basis of equivalent toxicity to benzo(a)pyrene. This is summarised following:

- Benzo(a)pyrene – 1.0
- Benzo(a)anthracene – 0.1
- Benzo(b)fluoranthene – 0.1
- Benzo(k)fluoranthene – 0.01;
- Chrysene – 0.001;
- Dibenz(a,h)anthracene – 1.0; and
- Indeno(1,2,3-c,d)pyrene – 0.1.

Level 2 Sources

Discussions with the NSW DECCW have advised that consideration should be given to Knafla A, Phillipps KA, Brecher RW, Petrovic S and Richardson M (2006) 'Development of a dermal cancer slope factor for benzo(a)pyrene' in Regulatory Toxicological and Pharmacology. It is recommended in this paper that a dermal slope factor of 25 $(mg/kg/day)^{-1}$ be adopted for human health risk assessment of benzo(a)pyrene.

7.6.15 Phenols

Phenol, methyl-phenols (cresols) and 2,4-dimethylphenol have been selected as COPCs for the assessment of potential human health impacts. A brief summary of the toxicological data available for each of the phenols has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.16**.

Table 7.16: Summary of Published Level 1 Hazard Data for Phenols

Organisation	Availability	Reference
NHMRC	No	
Therapeutic Goods Administration	No	Full review of safety alerts and advisory statements, no information
WHO	No	
enHealth	YES	enHealth (2001) 'Health-based Soil Investigation Levels'
NEHF	No	enHealth reported by the Australian Government Department of Health and Ageing to have replaced NEHF. Refer to enHealth (2001)
IARC	YES	IARC Monographs (1999)
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	YES	ATDSR (September 2008) 'Toxicological Profile for Phenol' ATDSR (September 2008) 'Toxicological Profile for Cresols'
NTP	No	
OECD SIDS SIAR	No	
EPA	YES	IRIS Database (2002), phenol IRIS Database (1992), 2-methylphenol IRIS Database (1992), 3-methylphenol IRIS Database (1993), 4-methylphenol IRIS Database (1990), 2,4-dimethylphenol

enHealth

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enHealth (2001) reports a US EPA oral RfD for phenol of 0.6mg/kg/day. Potentially significant differences in toxicities between substituted phenolic compounds are identified in the discussion of phenol toxicity.

IARC

IARC classifies phenol as a Group 3 chemical, not classifiable as to its human carcinogenicity.

ATSDR

Inhalation exposure MRLs are reported to not be available for phenols or cresols (methylphenols) due to a lack of data. No intermediate or chronic duration MRLs are available for oral exposure to phenol.

An acute duration oral exposure MRL of 1mg/kg/day is provided for phenol. This is reported to be based on decreased maternal and foetal body weights as observed in a rat development study. A NOAEL derived from this study was used to derive the MRL by dividing by an uncertainty factor of 100 to account for animal to human extrapolation and human variability.

An intermediate duration oral exposure MRL of 0.1mg/kg/day has been reported for cresols. The MRL has been based on the occurrence of nasal respiratory epithelium in rats and mice dosed with p-cresol or a mixture of m- and p-cresol. A benchmark dose was derived and divided by an uncertainty factor of 100 to account for extrapolation for animals to humans and human variability to derive the MRL.

A chronic duration inhalation exposure MRL of 0.1 mg/kg/day has been reported for cresols. As with the shorter term term MRL, the chronic MRL has been derived based on the occurrence of nasal respiratory epithelium in rats and mice dosed with p-cresol, or a mixture of m- and p-cresol. An LOAEL has been derived from the study, which has been divided by an uncertainty factor of 1000 to account for use of an LOAEL, extrapolation for animals to humans and human variability to derive the MRL.

US EPA

Phenol

Phenol is not classified as to its carcinogenicity (classification D) on the basis of inadequate human and animal data.

An oral RfD of 0.3mg/kg-day is provided for phenol on the basis of a benchmark dose derived from a developmental study of rats. Statistically significant decreases in body weight gain and decreases in food consumption were also observed during the dosing period. Lower foetal body weights were also reported. The benchmark dose was derived on the basis of decreases in maternal body weight gain, decreased foetal body weight and delayed ossification.

The oral RfD has incorporated a uncertainty factor of 10 to account for sensitive human subpopulations, extrapolate from animals to humans and uncertainties regarding the immunological and haematological effects in mice.

2-methylphenol

2-methylphenol is classified by the US EPA as a possible human carcinogen (classification C) based on three cresol isomers producing positive results in genetic toxicity studies both alone and in combination. This was reported as an increased incidence of skin papillomas in mice in an initiation-promotion study.

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An oral RfD of $5*10^{-2}$ mg/kg/day has been provided for 2-methylphenol on the basis of a NOAEL of a gavage study of rats. Rats dosed with 2-methyphenol were reported to have increased mortality, reduced body weight and reduced food consumption. Tremors were also reported.

A separate neurotoxicity study produced significant neurological events, such as increased salivation, urination, tremors, lacrimation, palpebral closure, and rapid respiration. High dosed animals were further reported to show abnormal patterns in the neurobehavioral tests.

The oral RFD has incorporated an uncertainty factor of 1 000 to account for interspecies and intraspecies variability and uncertainty in extrapolation of subchronic data to levels of chronic effects.

3-methylphenol

3-methylphenol is classified by the US EPA as a possible human carcinogen (classification C) based on three cresol isomers producing positive results in genetic toxicity studies both alone and in combination. This was reported as an increased incidence of skin papillomas in mice in an initiation-promotion study.

An oral RfD of $5*10^{-2}$ mg/kg/day has been provided for 3-methylphenol on the basis of a NOAEL of a gavage study of rats. Rats dosed with 3-methyphenol were reported to have increased mortality, reduced body weight and reduced food consumption. Tremors were also reported.

A separate neurotoxicity study produced significant neurological events, such as increased salivation, urination, tremors, lacrimation, palpebral closure, and rapid respiration. High dosed animals were further reported to show abnormal patterns in the neurobehavioral tests.

The oral RFD has incorporated an uncertainty factor of 1 000 to account for interspecies and intraspecies variability and uncertainty in extrapolation of subchronic data to levels of chronic effects.

4-methylphenol

4-methylphenol is classified by the US EPA as a possible human carcinogen (classification C) based on three cresol isomers producing positive results in genetic toxicity studies both alone and in combination. This was reported as an increased incidence of skin papillomas in mice in an initiation-promotion study.

2,4-dimethylphenol

An oral RfD of $2*10^{-2}$mg/kg/day is provided for 2,4-dimethylphenol on the basis of a NOAEL as derived from a gavage study of rats. Toxicologically relevant clinical signs observed during the study included squinting, lethargy, prostration, and ataxia, with onset shortly after dosing. Statistically significant haematological changes included lower mean corpuscular volume and mean corpuscular haemoglobin concentration in females. The NOAEL was derived on the basis of the clinical signs and haematological changes.

The RfD has incorporated an uncertainty factor of 3 000 based on inter- and intraspecies variability and lack of chronic toxicity data, data in a second species and reproductive/developmental studies.

Level 2 Sources

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In assessing phenol, US EPA (November 2010) is observed to adopt a Californian EPA RfC of 0.2mg/m^3 for the assessment of inhalation effects of phenol.

7.6.16 Dibenzofuran

Dibenzofuran has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for dibenzofuran has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.17**.

Table 7.17: Summary of Published Level 1 Hazard Data for Dibenzofuran

Organisation	Availability	Reference
NHMRC	No	
Therapeutic Goods Administration	No	
WHO	No	
enHealth	No	
NEHF	No	
IARC	No	
WHO/FAO JMPR	No	
NICNAS PEC	No	
ATSDR	No	
NTP	YES	Summary of Data for Chemical Selection: Dibenzofuran (2000)
OECD SIDS SIAR	No	
EPA	YES	IRIS Database (2010) Dibenzofuran

NTP

Dibenzofuran has been nominated as a high priority chemical for action by the NTP. This is based on widespread human exposure and the potential for carcinogenicity via epigenetic mechanisms unrelated to TCDD (dioxin) toxicity. Studies for carcinogenicity and short term chromosomal aberrations have been requested.

US EPA

The US EPA classifies dibenzofuran as class D, not classifiable as to its carcinogenicity to humans. No other data is available as to the toxicity of dibenzofuran.

Level 2 Sources

A PPRTV is provided to the US EPA (November 2010) Regional Screening Level tables as an RfD of $1*10^{-3}$mg/kg-day.

7.6.17 Asbestos

Asbestos has been selected as a COPC for the assessment of potential human health impacts. A brief summary of the toxicological data available for asbestos has been provided following. The summary has been generated by a review of the available data held by the Level 1 agencies, as summarised in **Table 7.18**.

Table 7.18: Summary of Published Level 1 Hazard Data for Asbestos

Organisation	Availability	Reference
NHMRC	YES	'Lung Cancer', Section 1, Epidemiology. http://www.nhmrc.gov.au/publications/synopses/_files/cp97_1.pdf 'Asbestos Related Diseases' http://www.nhmrc.gov.au/your_health/issues/asbestos.htm
ANZECC	NO	
Therapeutic Goods Administration	NO	
WHO	YES	'Elimination of Asbestos Related Diseases' http://whqlibdoc.who.int/hq/2006/WHO_SDE_OEH_06.03_eng.pdf 'Asbestos in Drinking Water' http://www.who.int/water_sanitation_health/dwq/asbestos.pdf

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Organisation	Availability	Reference
		Air Quality Guidelines, 2nd Edition, Section 6.2, 'Asbestos'. http://www.euro.who.int/document/aiq/6_2_asbestos.pdf 'Environmental exposure to asbestos and the exposure–response relationship with mesothelioma' http://www.emro.who.int/publications/emhj/1501/PDF/03.pdf
enHealth	YES	'Management of Asbestos in the Non-Occupational Environment' http://www.nphp.gov.au/enhealth/council/pubs/pdf/asbestos.pdf
NEHF	NO	
IARC	NO	
WHO/FAO JMPR	NO	
NICNAS PEC	YES	'Chrysotile Asbestos Priority Existing Chemical No. 9' http://www.nicnas.gov.au/publications/CAR/PEC/PEC9/PEC_9_Full_Report_PDF.pdf
ATSDR	YES	'ToxFAQs™ for Asbestos' http://www.atsdr.cdc.gov/tfacts61.html 'Regulations and Advisories' http://www.atsdr.cdc.gov/toxprofiles/tp61-c8.pdf
NTP	YES	Lifetime Carcinogenesis Studies of Amosite Asbestos in Syrian Golden Hamsters http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr249.pdf Toxicology and Carcinogenesis Studies of Crocidolite Asbestos in F344/N Rats http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr280.pdf Toxicology and Carcinogenesis Studies of Chrysotile Asbestos in F344/N Rats http://ntp.niehs.nih.gov/ntp/htdocs/LT_rpts/tr295.pdf
OECD SIDS SIAR	NO	
EPA	YES	'Asbestos (CASRN 1332-21-4)' http://www.epa.gov/NCEA/iris/subst/0371.htm

NHMRC

NHMRC define asbestos as a carcinogen with no clearly delineated limiting threshold, and support a cumulative exposure model for risk as defined by exposure. Asbestos has been found to cause pleural disease, asbestosis, lung cancer and mesothelioma.

WHO

WHO classify asbestos (actinolite, amosite, anthophyllite, chrysotile, crocidolite and tremolite) as carcinogenic, based on a statement by the IARC. Exposure to amosite, anthophyllite, chrysotile or crocidolite result in the increased risk of lung cancer, while occupational exposure to crocidolite, amosite, tremolite and chrysotile has resulted in mesotheliomas. The risk of bronchial cancer also increases, as may that of cancers of the larynx and gastrointestinal tract.

WHO finds that the occurrence of asbestos-related diseases is related to fibre type, size and dose, and to the industrial procession of that asbestos, while cigarette smoking increases the associated risk. Fibres with a diameter greater than 3 µm are not respirable; fibres shorter than 5 µm and thicker than 2 µm elicit little response, while those longer than 10 µm and thinner than 0.5 µm yield the highest response.

Asbestosis has only been found related to occupational asbestos exposure, while non-occupational asbestos exposure does not appear sufficient. The incidence of mesothelioma has been shown to increase with increased exposure.

WHO studies have not found asbestos to be teratogenic or mutagenic in mice, while there is no conclusive evidence that ingested asbestos is carcinogenic. Drinking water containing high levels of asbestos has not been shown to be carcinogenic.

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WHO (2000) provides estimates of mesothelioma risk resulting from lifetime inhalation exposure to asbestos with a best estimate of a risk of $2 * 10^{-5}$ for a lifetime exposure to 100 f/m^3 ($1 * 10^{-4}$ f/ml). WHO (2000) further provides an estimate of $2.2 * 10^{-5}$ risk of lung cancer for a non-smoker exposed to a fibre concentration of 100 f/m^3. These values are each equivalent to an approximate unit risk of 0.2 (f/ml)$^{-1}$. The unit risk is a measure of the incremental lifetime risk of cancer associated with lifetime exposure to a unit concentration (1 f/ml)$^{-1}$ of asbestos in air.

enHealth

enHealth defines asbestos as a carcinogen, with amphibole fibres (crocidolite, tremolite and amosite) considered more dangerous and the primary agents in the increased incidence of mesothelioma. enHealth quotes studies suggesting there is a direct correlation between exposure and risk, with chronic exposure the largest contributor to asbestos related health risks, with significantly increased mortality rates reported in exposed workers with cumulative exposure estimates greater than 25-100 f/mL-years. A further study estimated a 1 per cent increase in the standardised mortality ratio for lung cancer per year of exposure to 1 f/mL

The shape and length of asbestos fibres are also found to alter health risks, with fibres >20 µm <100 µm consider to be most carcinogenic, while in terms of shape, those with fibres >8 µm long and <0.25 µm diameter, with an aspect ratio (length/width) ≥10 appear to be most dangerous.

For non-occupational risk, studies of a crocidolite mining town showed a mesothelioma rate of 260 per 100 million person-years, while the mesothelioma rate for residents living near an asbestos cement factory was 73 (female) and 114 (male) per million person-years, as compared to a background incidence rate of one per million person-years. enHealth quotes guidelines for asbestos exposure as 0.1 f/mL for occupational exposure in Australia, and para-occupational sampling if using a limit of detection of 0.01 f/mL, while there is a proposed standard of 0.033f/mL for ambient air in Tasmania. Further, Australia has set a cut-off of 0.1 per cent by weight asbestos in products for the purpose of carcinogenic classification of the products.

NICNAS

NICNAS has declared chrysotile a Priority Existing Chemical as it is prevalent and a known human carcinogen, causing asbestosis, mesothelioma, and lung cancer. No estimate is given as to a limiting threshold, but lung cancer occurrence estimates for the Australian friction material manufacturing industry are given as 1 to 2 cases from exposure to 1 f/mL, 1 case at 0.5 f/mL and 0.2 case at 0.1 f/mL, per 1000 workers. The PEC also cites the 1999 national exposure standard (TWA) for chrysotile as 1 f/mL, but suggests that monitoring methods do not distinguish between types of asbestos and a limit of 0.1 f/mL would protect against other forms of asbestos.

ATSDR

ATSDR recognizes asbestos as a carcinogen responsible for mesothelioma and lung cancer. They quote the EPA as proposing a concentration limit of 7 million fibres per litre of drinking water for long fibres (lengths greater than or equal to 5 µm), while the Occupational Safety and Health Administration has set a limit of 100,000 f/m^3 with lengths greater than or equal to 5 µm for workplace air for 8-hour shifts and 40-hour work weeks. A number of sources are quoted as given US standards for limits, typically 0.1 – 1.0 f/mL.

NTP

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NTP studies on hamsters and rats show that asbestos is not carcinogenic from ingestion.

US EPA

The EPA established asbestos as a human carcinogen based on consistently higher mortality rates and cancers among occupationally exposed workers. Inhalation was identified as the primary cause, while evidence for carcinogenicity from ingestion remains inconclusive, as studies on white rats resulted in the development of benign polyps. A synergistic interaction between asbestos exposure and cigarette smoking, contributing to the development of lung cancer but not mesothelioma, was identified.

The EPA identifies the Inhalation Unit Risk as 0.23 $(f/mL)^{-1}$. The unit risk is a measure of the incremental lifetime risk of cancer associated with lifetime exposure to a unit concentration $(1\ f/ml)^{-1}$ of asbestos in air. Unit risk factors are derived from the cancer slope factor for the inhalation of carcinogenic chemicals. The US EPA unit risk factor is very similar to the unit risk as derived from WHO reports.

Air Concentrations at Specified Risk Levels as provided by the US EPA are summarised following:

Risk Level	Concentration
E-4 (1 in 10,000)	$4*10^{-4}$ f/mL
E-5 (1 in 100,000)	$4*10^{-5}$ f/mL
E-6 (1 in 1,000,000)	$4*10^{-6}$ f/mL

Different types and fibre sizes of asbestos appear to have different health impacts, with fibre size and processing method appearing to impact relative risk as much as the specific type of asbestos. Evidence remains inconclusive as to the exact nature of these differences.

Level 2 Sources

A range of peer reviewed journals are available describing the potential toxicological effects of asbestos. Noting the extensive data provided with the Level 1 sources for asbestos, these have not been reviewed here. Limited guidance is provided from other regulators as to appropriate levels of asbestos in soils, as discussed in the following section.

Soil Assessment Criteria

Limited soil assessment criteria are available in other jurisdictions globally. As noted in enHealth (2005) 'Management of asbestos in the non-occupational environment' there is currently no reliable method to determine the relationship between soil levels and air levels for asbestos-contaminated soil. As inhalation is the exposure route of concern, this makes exposure assessment from soil concentrations extremely difficult.

EnHealth (2005) notes the work of Addison, J., Davies, L.S.T., Robertson, A., and Willey, R.J. (1988) 'The Release of Dispersed Asbestos Fibres from Soils Technical Memoranda', TM/88/14, Institute of Occupational Medicine: 50, Edinburgh, UK (Addison et al. 1988) in setting an appropriate level of asbestos in soils. Addison et al (1988) have a recommended a level of 0.001% of asbestos in soil as being appropriately protective of construction workers.

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EnHealth (2005) also notes the work of Imray and Neville (1993) which suggested a level of <0.001 f/ml in air and <0.001% in soil would be sufficient to classify a site as uncontaminated, as also based on the work by Addison et al (1988). The amount of allowable asbestos fibres nominated by Addison et al (1988) to premise the setting of soil criteria would not be protective of human receptors where more recent WHO or US EPA toxicological data are used.

The Netherlands have provided an interim standard of 100mg of asbestos per kilogram of soil, for the sum of the concentration of chrysotile asbestos and ten times the concentration of amphibole asbestos. The criterion is based on the derivation of a relationship between levels of asbestos in soil and in airborne concentrations as reported in Swartjes F.A, Tromp P.C, Wezenbeek J.M (2003) 'Assessment of the Risks of Soil Contamination with Asbestos' National Health and Environmental Institute, Netherlands, RIVM Report 711701034/2003 and Swartjes, F.A., Tromp, P.C. (2008) 'A Tiered Approach for the Assessment of Human Health Risks of Asbestos in Soils' Soil and Sediment Contamination, Volume 14, Issue 4, pp. 137 – 149. This has then been compared to the concentration of asbestos in soil as required to generate a level of airborne asbestos that would pose a negligible risk.

Western Australian Department of Health (2009) 'Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia' (WA DoH, 2009) provide assessment levels for asbestos cement products and free asbestos fibres in soils. The assessment criteria are based on the work of Swartjes et al (2003) and Swartjes & Tromp (2008), WHO risk figures for mesothelioma and division by a factor of ten, to account for greater dryness and dust generating potential of WA soils and treating all forms of asbestos as being of equivalent toxicity. The soil investigation criteria as provided by WA DoH (2009) are listed following:

- 0.001% asbestos for all site uses, based on free asbestos and asbestos fibres;
- 0.01% asbestos for residential use, based on ACM;
- 0.04% asbestos for residential use with minimal soil access, based on ACM;
- 0.02% asbestos for parks, public open spaces, playing fields, based on ACM; and
- 0.05% asbestos for commercial / industrial based on ACM.

EnHealth (2005) also provides a summary of other soil asbestos criteria as used globally including:

- Unofficial soil levels of 0.001% have been proposed in the United Kingdom, below which no further action is required;
- Clean up levels between 0.25% and 1% are used by various regions of the United States Environmental Protection Authority; and
- In Manukau City Council, New Zealand, where extensive remediation of asbestos cement fragments has occurred, a semi-quantitative estimate of 0.001% asbestos content has been accepted as a guideline, based on the mass of fibres in handpicked samples and the mass of soil examined.

7.7 Summary and Evaluation of Toxicological Data

The toxicological sources have been reviewed to determine the most appropriate toxicological values to characterise each of the potential exposure pathways for the COPCs. This has been generally undertaken by adopting the order of preference of

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toxicological data instructed by NEPC (1999) and enHealth (2002). It is also noted that assessment of PAHs has considered constituents in addition to benzo(a)pyrene (in contrast to the enHealth / NEPC approach). This is consequent of WHO (2000) reporting that assessment of benzo(a)pyrene solely probably underestimates the carcinogenic potential of PAHs.

US EPA (1989) reports that where dermal toxicity reference values are being derived from oral values it is necessary to adjust the oral toxicity value from an administered to an absorbed dose. Where the oral toxicity is expressed as an absorbed dose, it is not necessary to adjust the toxicity value. Further detail is provided in US EPA (2004) which provides conditions when an adjustment is required for the oral toxicity factor (to account for 'absorbed dose' in the dermal exposure pathway). These include:

- The toxicity value derived from the critical study is based on an administered dose (eg delivery in diet or by gavage) in its study design; and
- A scientifically defensible database demonstrates that the gastrointestinal absorption of the chemical in question, from a medium (e.g. water, feed) similar to the one employed in the critical study, is significantly less than 100%.

Where these conditions are not met, a default of complete oral absorption may be assumed. A review of gastrointestinal tract absorption values (ABS_{GI}), as provided in US EPA (2004), has been undertaken with the finalisation of toxicity values. Dermal toxicity values have been adjusted using an ABS_{GI} as recommended by US EPA (2004), where required.

Toxicological data for non-threshold effects are summarised in **Table 7.19** and threshold effects in **Table 7.20**.

7.8 Odour Thresholds

Potential aesthetic impacts of environmental impact also require consideration. The most likely aesthetic impact will be odours from soils impacted with potentially volatile substances. An assessment is required to ensure that no odours related to environmental impact can be recognised at the redeveloped Headland Park Site surface, or at adjoining off-site locations. This assessment will be undertaken by the comparison of maximum concentrations of each constituent to odour thresholds. Odour thresholds of all potentially malodorous constituents have been summarised in **Table 7.21**.

In reference to odour thresholds, it is noted that coal tar is the likely source of malodorous contaminants on the Barangaroo South and Central sites, and the most likely source of odour within soils bought onto the Headland Park and used as fill material. It is proposed to undertake an odour assessment of coal tar odours in addition to the speciated assessments proposed. Previous odour analysis of coal tar has been undertaken in Egis Consulting (August 2001) 'Notice of Intention for Demolition and Earthworks Former Platypus Site Neutral Bay, North Sydney'. Measurements were the odour strength directly above a coal tar pit. The odour strength was measured at 1,110 odour units (OU). The odour emission rate was further estimated at 290 $OU/m^2.s$.

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Table 7.19: Toxicity Criteria for Carcinogenic / Non-Threshold Endpoints

Constituent	Inhalation Slope Factor $(mg/kg/day)^{-1}$	Oral Slope Factor $(mg/kg/day)^{-1}$	Dermal Slope Factor $(mg/kg/day)^{-1}$	Discussion / Comments
Benzene	$2.1*10^{-2}$	$3.5*10^{-2}$	$3.5*10^{-2}$	Inhalation slope factor based on WHO unit risk of $6.0*10^{-6}$ $(\mu g/m^3)^{-1}$. Oral slope factor based on NHRMC and WHO. No adjustment for dermal slope factor. Benzene reported to be rapidly and efficiently absorbed.
Benzo(a)pyrene	304	0.5	0.5	Inhalation slope factor based on WHO unit risk of $8.7*10^{-2}$ $(\mu g/m^3)^{-1}$. Oral slope factor based on WHO, as adopted in NHRMC/NRMMC (2004). No adjustment for dermal slope factor. PAHs reported to be rapidly and efficiently absorbed.
Benz(a)anthracene	30.4	$5.0*10^{-2}$	$5.0*10^{-2}$	Based on WHO relative potency of 0.1. No adjustment for dermal slope factor. Typically high levels of absorption of PAHs reported by US EPA (2004).
Benzo(b)fluoranthene	30.4	$5.0*10^{-2}$	$5.0*10^{-2}$	Based on WHO relative potency of 0.1. No adjustment for dermal slope factor. Typically high levels of absorption of PAHs reported by US EPA (2004).
Benzo(k)fluoranthene	30.4	$5.0*10^{-2}$	$5.0*10^{-2}$	Based on WHO relative potency of 0.1. No adjustment for dermal slope factor. Typically high levels of absorption of PAHs reported by US EPA (2004).
Dibenz(a,h)anthracene	304	0.5	0.5	Based on WHO relative potency of 1.0. No adjustment for dermal slope factor. Typically high levels of absorption of PAHs reported by US EPA (2004).
Indeno(1,2,3-c,d)pyrene	30.4	$5.0*10^{-2}$	$5.0*10^{-2}$	Based on WHO relative potency of 0.1. No adjustment for dermal slope factor. Typically high levels of absorption of PAHs reported by US EPA (2004).
Chrysene	0.304	$5.0*10^{-3}$	$5.0*10^{-3}$	Based on WHO relative potency of 0.01. No adjustment for dermal slope factor. Typically high levels of absorption of PAHs reported by US EPA (2004).
Nickel	1.4	-	-	Inhalation slope factor based on WHO unit risk of $4.0*10^{-4}$ $(\mu g/m^3)^{-1}$. No oral or dermal slope factor as assessed using threshold endpoints.
Asbestos	Unit Risk – 0.2 $(f/ml)^{-1}$	-	-	Based on WHO increased incidence of mesothelioma and/or lung cancer, which is very similar to US EPA unit risk

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Table 7.20: Toxicity Criteria for Threshold Endpoints

Constituent	Inhalation ADI, mg/kg/day	Oral RfD, mg/kg/day	Dermal RfD, mg/kg/day	Discussion / Comments
Ammonia	$2.0*10^{-2}$	-	-	Assessment based on ATSDR chronic MRL of 0.1ppm. No toxicity values adopted for oral and dermal exposure pathways based on guidance in all Level 1 sources of non likelihood of toxicity.
Arsenic	$4.3 * 10^{-6}$	$2 * 10^{-3}$	$2 * 10^{-3}$	Inhalation ADI based on Californian EPA values. Alternate non-threshold guidelines for arsenic available typically based on industrial; exposure scenarios. Not considered appropriate for recreational / parkland setting Barangaroo and allows consistent assessment of arsenic by threshold approach. Oral RfD based on NHMRC TDI approach. Very similar to level used by enHealth. No adjustment for dermal RfD as US EPA (2004) reports high levels of absorption.
Cadmium	$1.4*10^{-6}$	$7 * 10^{-4}$	$3.5 * 10^{-5}$	Inhalation ADI based on WHO guidance value of $5*10^{-3}$ µg/m^3 1 year guidance value in WHO (2000). Very similar to ATSDR chronic duration acute exposure MRL. More conservative than US EPA unit risk. Oral RfD based on NHMRC TDI derived for critical amount of cadmium. Oral RfD similar to ATSDR chronic duration oral MRL. More conservative than US EPA RfD for exposure to cadmium in water. Adjustment for dermal RfD required as oral TDI is based on human dosing study with consideration of absorption rate. Low rate of absorption noted by WHO (2004). US EPA (2004) recommends adjustment by 0.05. This is the same absorption rate used by WHO (2004).
Chromium	$1.4*10^{-3}$	1.5	$3.75*10^{-2}$	Inhalation ADI based on ATSDR guideline for chronic exposure to Cr(III) particulates. No chronic value available for Cr(VI) particulates. Majority of chromium occurring with particulates would be reasonably considered to consist of the oxidised form of Cr. Oral RfD based on US EPA value for Cr(III). Alertante value noted to have been provided by enHeath Cr(III). However by review this is based on an outdated US EPA value. Majority of chromium occurring in soil horizons where available by oral and dermal pathways is considered to more than likely be oxidised to Cr(III) form. Adjustment for dermal RfD required as oral TDI is based on rat dosing study with water. Low rates of absorption nominated in WHO (2004). US EPA (2004) recommends adjustment by 0.025.
Lead	$1.4*10^{-4}$	$3.5*10^{-3}$	$3.5*10^{-3}$	Inhalation ADI based on WHO. Oral RfD based on NHMRC. No correction for dermal factor for lead. Toxicity data based on lead exposure to children. Lead absorption in children reported in WHO (2004) to be as high as 50%.
Nickel	-	$5 * 10^{-3}$	$2*10^{-4}$	No inhalation ADI as assessment by non-threshold endpoint using WHO unit risk. Oral RfD based on NHMRC TDI. More conservative than more recent WHO study. More conservative than US EPA value. Adjustment for dermal RfD required as NHMRC TDI based on feeding study with rats. US EPA (2004) recommends adjustment by 0.04.
Cyanide (free)	$1.2*10^{-2}$	$1.2*10^{-2}$	$1.2*10^{-2}$	Inhalation ADI set equal to Oral RfD in lieu of available data. Oral RfD based on NHRMC TDI with advised correction factor of 100. Same value as recommended by WHO. More conservative than US EPA value. No adjustment for dermal factor. US EPA (1994) reports free cyanide as having high rates of absorption.
TPH $C_{>6}$-C_8 (aliphatic)	5.26	5	5	TPHCWG (1997). No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).
TPH $C_{>8}$-C_{16} (aliphatic)	0.29	0.1	0.1	TPHCWG (1997). No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).
TPH $C_{>16}$-C_{35} (aliphatic)	0.29	2	2	TPHCWG (1997). Inhalation ADI set equal to $C_{>8}$-C_{16} fraction to allow assessment of inhalation via dust. No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US

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Constituent	Inhalation ADI, mg/kg/day	Oral RfD, mg/kg/day	Dermal RfD, mg/kg/day	Discussion / Comments
				EPA (2004).
TPH $C_{>7}$-C_8 (aromatic)	0.1	0.2	0.2	TPHCWG (1997). No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).
TPH $C_{>8}$-C_{16} (aromatic)	$5.7*10^{-2}$	$4.0*10^{-2}$	$4.0*10^{-2}$	TPHCWG (1997). No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).
TPH $C_{>16}$-C_{35} (aromatic)	$5.7*10^{-2}$	$3*10^{-2}$	$3*10^{-2}$	TPHCWG (1997). Inhalation ADI set equal to $C_{>8}$-C_{16} fraction to allow assessment of inhalation via dust. No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).
Benzene	$2.9*10^{-3}$	$5*10^{-4}$	$5*10^{-4}$	Inhalation ADI based on ATSDR chronic duration inhalation exposure MRL of 10µg/m^3. More conservative than US EPA value. Oral RfD based n ATSDR chronic duration oral exposure MRL. More conservative than US EPA value. No adjustment for dermal RfD. Benzene reported by WHO (2004) to be rapidly and efficiently absorbed.
Toluene	1.4	0.223	0.223	Inhalation ADI based on US EPA RfC of 5mg/m^3. WHO value not used as exposure duration of 1 week less than required averaging times proposed for risk assessment. US EPA value used instead of ATSDR value as more recent, despite ATSDR preferred in hierarchy of sources of toxicological data. Oral RfD based on NHMRC TDI. Same as WHO value. Value is similar, though less conservative than ATSDR intermediate exposure MRL and US EPA RfD. No adjustment for dermal RfD. Toluene reported by WHO (2004) to probably be absorbed completely from the gastrointestinal tract.
Ethylbenzene	0.37	$9.7*10^{-2}$	$9.7*10^{-2}$	Inhalation ADI based on ASTDR chronic duration inhalation exposure MRL of 1.3mg/m^3. This is similar to the US EPA value. Oral RfD based on NHMRC TDI. More conservative than the ATSDR intermediate duration oral toxicity MRL. Value very similar to US EPA value. No adjustment for dermal RfD. Ethylbenzene reported by WHO (2004) to be absorbed easily.
Xylene	$6.2*10^{-2}$	0.179	0.179	Inhalation ADI based on ATSDR chronic MRL of 0.05ppm. Used in preference to NEHF air quality goal as based on more recent data and derived by approach consistent with human health risk assessment. Oral RfD based on NHMRC TDI. More conservative than ASTDR chronic duration oral exposure MRL and US EPA RfD. No adjustment for dermal RfD. Xylene reported by WHO (2004) to well absorbed after inhalation. No data on absorption via ingestion, though anticipated to be sufficiently high base don halation data.
1,2,4-trimethylbenzene	$2.0*10^{-3}$	$2.0*10^{-3}$	$2.0*10^{-3}$	As per US EPA PPRTV RfC. RfC adopted as basis for oral and dermal values.
Dibenzofuran	$6.0*10^{-2}$	$6.0*10^{-2}$	$6.0*10^{-2}$	Inhalation ADI based on RfC of 0.21mg/m^3. RfC as per US EPA PPRTV. Oral RfD based on US EPA PPRTV.
Fluoranthene	$1.25*10^{-2}$	$1.25*10^{-2}$	$1.25*10^{-2}$	Inhalation ADI set equal to Oral RfD in lieu of other data. Oral RfD based on WHO TDI. No adjustment for dermal RfD. Typically high levels of absorption of PAHs reported by US EPA (2004).
Fluorene	$4*10^{-2}$	$4*10^{-2}$	$4*10^{-2}$	Inhalation ADI set equal to Oral RfD in lieu of other data. Oral RfD based on US EPA RfD. No adjustment for dermal RfD. Typically high levels of absorption of PAHs reported by US EPA (2004).
2-methylnaphthalene	$4.0*10^{-2}$	$4.0*10^{-2}$	$4.0*10^{-2}$	Inhalation and oral RfD based on ARSDR MRL.
Naphthalene	$1*10^{-3}$	$2.0*10^{-2}$	$2.0*10^{-2}$	Inhalation ADI based on ATSDR chronic duration inhalation exposure MRL of 3.5µg/m^3. Similar to US EPA value. Oral RfD based on US EPA RfD value. ATSDR noted to not provide chronic duration values (acute / intermediate exposure values only).

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Constituent	Inhalation ADI, mg/kg/day	Oral RfD, mg/kg/day	Dermal RfD, mg/kg/day	Discussion / Comments
				No adjustment for dermal RfD. Typically high levels of absorption of PAHs reported by US EPA (2004).
Pyrene	$3*10^{-2}$	$3*10^{-2}$	$3*10^{-2}$	Inhalation ADI set equal to Oral RfD in lieu of other data. Oral RfD based on US EPA RfD. No adjustment for dermal RfD. Typically high levels of absorption of PAHs reported by US EPA (2004).
Phenol	$5.7*10^{-2}$	0.3	0.3	Inhalation ADI as per Californian EPA RfC in lieu of other data. Oral RfD based on RfD value by US EPA. This is noted to be more recent than the alternate toxicity values presented by enHealth. No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).
Cresols	0.1	$5*10^{-2}$	$5*10^{-2}$	Inhalation ADI based on ASTDR chronic duration inhalation exposure MRL. Oral RfD based on US EPA RfD for 2-and 3-methyphenol. No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).
2,4-dimethylphenol	$2*10^{-2}$	$2*10^{-2}$	$2*10^{-2}$	Inhalation ADI set equal to oral RfD in lieu of other data. Oral RfD based on US EPA RfD. No adjustment for dermal RfD. Typically high levels of absorption of organic compounds reported by US EPA (2004).

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Table 7.21: Summary of Odour Thresholds

Constituent	Odour Threshold	Source / Comments
Acenaphthene	0.5 mg/m^3	ATSDR
Ammonia	18.00 mg/m^3	ATSDR
Benzene	108.61 mg/m^3	ATSDR
Cresol, m-	0.0012 mg/m^3	ATSDR
Cyanide (free, CN^-)	0.64	ATSDR, based on hydrogen cyanide
Dibenzofuran	1.0	US EPA
Ethylbenzene	2.0 mg/m^3	ATSDR
2-methylnaphthalene	0.06 mg/m^3	ATSDR
Naphthalene	0.44 mg/m^3	ATSDR
Phenol	0.15 mg/m^3	ATSDR
Toluene	30.1 mg/m^3	ATSDR
1,2,4-trimethylbenzene	1.96 mg/m^3	US EPA
Xylenes (total)	4.34 mg/m^3	ATSDR

This can be correlated to concentrations of site constituents by observation of maximum levels of malodorous PAHs in samples of coal tar analysed by the investigations completed to date. By review of **Table 7.21**, the most potentially malodorous PAH constituents are found to be naphthalene, 2-methylnaphthalene and acenaphthene. The maximum levels of PAH impact, including the maximum summed level of these constituents, has been reported in Coffey Environments (2008) 'Preliminary Environmental Investigation at Hickson Road' at sample location MW10 at a depth of 8.6 to 8.7m. By review of the borelog at this sample depth, the sample can be observed to consist of tar impacted sandstone. The total concentration of acenaphthene, naphthalene and 2-methylnaphthalene was reported as 18 361 mg/kg. By assuming a porosity of 0.2 for sandstone – and assuming that porosity was filled with tar, it can be assumed that the odour strength of the sandstone sample would have been measured at 20% of the maximum value reported in Egis (2001), equal to 222 OU. This would further infer that a sum concentration of 165mg/kg of naphthalene, 2-methylnaphthalene and acenaphthene would be anticipated to have an odour strength of 2 OU. A level of 2 OU has been used as this is the lowest odour recognition criteria provided in DEC (2006) 'Assessment and management of odour from stationary sources in NSW'.

An assessment of the odour strength of coal tar shall be undertaken by assessing the odour potential at the site surface of soils which have a combined level of acenaphthene, naphthalene and 2-methylnaphthalene of 165 mg/kg. The extent of dilution of vapour from soils above this level of impact (between the source soils and the point of human exposure) will be required to be demonstrated to be above the extent that the sum of the constituents exceeds 165 mg/kg.

7.9 Background Concentrations

Background / environmental contributions of each of the COPCs via oral and dermal pathways has generally been characterised by the review of NHMRC/NRMMC (2004) 'Australian Drinking Water Guidelines', Food Standards Australia and New Zealand (2003) 'The 20th Australian Total Diet Survey' and documents for each of the relevant COPCs. Background levels of the COPCs via an inhalation pathway in an Australian setting, were generally not identified in the toxicological review. Estimates of inhalation exposures to COPCs from background sources have been determined by review of:

- NSW DEC (December 2004) 'Ambient Air Quality Research Project (1996-2001) Internal working paper no. 2 Ambient concentrations of toxic organic compounds in NSW';
- NSW DEC (December 2004) 'Ambient Air Quality Research Project (1996-2001) Internal; working paper no. 3 Ambient Concentrations of Polycyclic Aromatic Hydrocarbon Species in NSW'; and

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- NSW DEC (December 2004) 'Ambient Air Quality Research Project (1996-2001) Internal working paper no. 4 Ambient concentrations of heavy metals in NSW'.

To remain conservative, airborne levels of COPCs recorded in the Sydney CBD, or the wider Sydney area, have been used for each of the COPCs. These are generally the highest levels for each COPC. Background levels of COPCs are summarised in **Table 7.22**.

Table 7.22: Summary of Background Exposures to COPCs

COPC	Background Exposure	
	Oral / Dermal	Inhalation
Arsenic	0.04 mg/day[3] 0.03-0.06mg/day[7]	0.51 ng/m^3 [(1)]
Cadmium	0.03 mg/day[3] 0.005-0.02mg/day[7]	0.28 ng/m^3 [(1)]
Chromium	0.01 mg/day [3,4]	No data
Lead	0.1 mg/day[3] 0.001-0.03mg/day[7]	48 ng/m^3
Nickel	0.2 mg/day[3,5]	No data
Cyanide	0.04 mg/day[3,4]	No data
Total petroleum hydrocarbons	No data	No data
Benzene	Negligible[3]	2.3 ppb[1] (7.7µg/m^3)
Toluene	Negligible[3]	4.2 ppb[1] (15.4µg/m^3)
Ethylbenzene	Negligible[3]	0.5 ppb[1] (2.2µg/m^3)
Xylene	Negligible[3]	3.0 ppb[1] (13.1µg/m^3)
PAHs (total)	1 µg/day[3,4,6]	3.90 ng/m^3 [(2)]
Benzo(a)pyrene	As per PAHs[3]	0.40 ng/m^3 [(2)]
Phenols	No data	No data
Asbestos	Nil	Nil

Note: 1. DECC (December 2004) overall average for Sydney CBD
2. DECC average of mean summer (Sydney) and winter (Sydney CBD) concentrations
3. NHMRC/NRMMC (2004)
4. as derived from reported concentration in drinking water of 0.005mg/l and assumption of adults drinking 2L/day.
5. Average of reported range of values
6. Incorporating estimate of food exposure being an order of magnitude higher then water exposure.
7. Food Standards Australia and New Zealand (2003), range of intake from food consumption for adult males and females

For constituents where no data are available, it has been assumed that background / environmental exposures are negligible. The consideration of background exposures into the derivation of risk based criteria for the development of the Headland Park is detailed further in **Section 9**.

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8 Human Exposure Assessment

8.1 Exposure Scenario(s) Requiring Risk Assessment

A number of potential human exposure scenarios require to be assessed for the proposed Headland Park with the range of identified land-uses associated with the proposed development once completed. These exposure scenarios are summarised in **Table 8.1** following.

Table 8.1: Summary of Required Exposure Scenarios

Source	Exposure Pathway	Location	Receptor
Soil	Inhalation Dermal contact Ingestion (i.e. oral)	Park	Adult Recreational Receptor Child Recreational Receptor Commercial / industrial (Greenskeeper / Gardener)
	Inhalation (dust and vapour) Dermal contact Ingestion	Services Trench (within Park)	Sub-surface Maintenance Worker
	Inhalation of Indoor air	Car Park	Commercial / industrial (car park attendant) Occasional user
	Inhalation of Indoor air	'Cultural Space'	Commercial / industrial Recreational user (Adult / Child)
Groundwater	Inhalation of Indoor air	Car Park	Commercial / industrial (car park attendant) Occasional user (Adult / Child)
	Inhalation of Indoor air	'Cultural Space' (as based on upward migration from car park)	Commercial / industrial Recreational user (Adult / Child)
Seepage water (shallow / leached sub-surface water)	Inhalation (outdoor air)	Park	Adult Recreational Receptor Child Recreational Receptor
	Inhalation Dermal contact	Services Trench	Sub-surface Maintenance Worker
Seepage Water (Sprinkler irrigation)	Inhalation Dermal contact (sprinkler spray) Dermal contact (saturated grass)	Park	Adult Recreational Receptor Child Recreational Receptor Commercial / industrial (Greenskeeper / Gardener)
Seepage water (subsurface irrigation)	Inhalation (shallow seepage water)	Park	Adult Recreational Receptor Child Recreational Receptor

Each of these exposure scenarios are required to be assessed by risk modelling. The characterisation and approximation by modelling of the physical parameters for each potential exposure scenario is summarised following.

8.2 Discussion of Exposure Scenarios

8.2.1 Headland Park

The primary development of the Headland Park consists of an open vegetated area of recreational space. Recreational receptors, potentially consisting of adults and children, would be potentially exposed to:

- Impact present in surface soils by oral and dermal pathways;
- Impact present throughout the soil profile by inhalation of vapours;
- Impact present in shallow seepage water (as may occur subsequent to park development) by inhalation of potential vapours; and
- Impact present in existing groundwater by inhalation of vapours.

Potential inhalation of dusts has not been considered for recreational receptors. The iconic status of the Park within the Sydney area would dictate the maintenance of site

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surfaces to prevent the occurrence of any significant exposed areas that may generate dusts.

It is understood from preliminary remediation planning that a system may be installed within the Headland Park to collect shallow seepage water flows. There is potential that this seepage water (where collected) may be beneficially re-used for irrigation purposes on the park. This may occur by the operation of sprinklers, or by sub-surface 'drip irrigation' systems. On the basis of this grey water re-use within the Park, it is considered that recreational receptors, potentially consisting of adults and children, would be additionally potentially exposed to:

- Irrigation water by dermal pathways, either by wetting under a sprinkler or contact with potential / occasional surface water puddles associated with surfaces in the proximity of sprinkler application. This may also include the scenario where a park user 'rolls around' in saturated soils / grasses subsequent to irrigation; and/or
- Irrigation water by inhalation of volatilised constituents of sprinkler irrigation; and/or
- Sub-surface irrigation water by inhalation of volatile constituents of seepage water present at near surface depths.

It is noted that ingestion of irrigation water is not considered to be a potentially complete exposure pathway for recreational users. It is considered highly unlikely that significant ingestion of irrigated seepage water would occur on the Park.

Sub-surface maintenance workers may be potentially engaged in the area of the Headland Park in the future, for either the installation or repair of sub-surface services. These workers have been assumed to be engaged within trenches with limited ventilation. JBS has been advised by BDA that sub-surface services should not extend below 0.5m below ground surface in the area of the Park, apart from large drainage pits associated with the sub-surface drainage system. Noting the geology of the Park comprising a shallow depth of 'growing medium' overlying compacted relatively impermeable soils it is likely that seepage water may exist in the permeable soil layer.

Groundwater will be shallow at the boundaries of the Park, consistent with the proximity of Sydney Harbour. Groundwater may enter sub-surface maintenance trenches placed in close proximity of the Harbour.

On the basis of trenches potentially extending to the depth of groundwater / seepage water, it is considered that sub-surface maintenance workers would be potentially exposed to:

- Impact present in soils over the depth of the excavation by oral and dermal pathways and inhalation of dusts and vapours;
- Impact present throughout the soil profile (below the depth of the base of the trench / excavation) by inhalation of vapours;
- Impact present in infiltrating groundwater / seepage water by oral, dermal and inhalation pathways; and
- Impact present in potential deeper groundwater / seepage water by inhalation pathways.

Oral ingestion of seepage water within excavations has not been considered to be a significant exposure pathway. It is considered highly unlikely that health and safety

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regulations would permit a sub-surface worker to be engaged within an inundated trench / excavation. Further, it is considered unlikely that a sub-surface maintenance worker would consume infiltrating seepage water within an excavation. However a small amount of incidental ingestion has been assumed in the modelling.

It has also been assumed that no significant seepage occurs through retaining walls as are indicated to be placed throughout the park by the conceptual plan provided in the AgEnviro Water Balance (**Appendix B**). Where seepage does occur it would be localised and generally inaccessible. It is considered that the assessment of sub-surface maintenance worker exposure to shallow infiltrating water within excavations will be sufficiently protective of potential incidental exposures of the potential seepage water discharge at retaining walls.

8.2.2 Car Park

A Car Park is proposed to be constructed within a void underlying Headland Park. Potential receptors within the Car Park have been identified as commercial / industrial workers (employed as 'car park attendants') and occasional users including adults and children. Commercial / industrial workers and users of the Car Park would be potentially exposed to:

- Impact present in existing groundwater and future soils by inhalation of vapours. Levels of contaminants in existing groundwater may be caused to increase by the leaching of impact from soils used as fill material in the void underlying the Car Park; and
- Impact present in potential infiltrating seepage water (through cracks / joins in the concrete walls of the Car Park) by inhalation and potential dermal contact to saturated surfaces.

The paved nature of the Car Park will prevent direct access / contact to soils.

It is considered highly unlikely that a car park attendant would be substantially exposed to seepage water which may accumulate in the Car Park. Consideration of exposure of occasional users of the Car Park to infiltrating seepage water will be appropriately protective of occupational exposures to seepage water.

It is noted that design plans (**Figures 13** to **15**) have nominated the retention of the sandstone face currently to the east of Hickson Rd as part of the design of the Car Park. Seepage water present in the sandstone face has not been considered as it is sourced from off-site and hydrogeologically upgradient of the proposed Headland Park. No off-site source of impact has been identified in the proximity of the proposed Headland Park.

8.2.3 'Cultural Space'

A future 'Cultural Space' is shown above the Car Park on **Figure 13**. The 'Cultural Space' is shown to extend over the entire footprint of the Car Park and further over the general filled area at the east of the proposed Headland Park over the proposed upper levels. The areas above the 'Cultural Space' are proposed to be constructed using 'hollowcore planks'. These can be characterised as honeycombed structural concrete members with voids filled using soils.

Commercial / industrial workers and recreational users of the 'Cultural Space' would be potentially exposed to impact present in existing groundwater and future soils by inhalation of vapours. It is considered highly unlikely that seepage water would be permitted to infiltrate into the 'Cultural Space' structure.

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8.3 Exposure Parameters

Exposure parameters are required for each of the potentially exposed populations listed in **Table 8.1**. The exposure parameters selected for risk modelling are summarised in **Tables 8.2** to **8.9**.

Table 8.2: Global Parameters –Recreational Receptor (Adult & Child) – Headland Park and 'Cultural Space' User

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	365	enHealth (2004)
Exposure Frequency – Sprinkler Water	days/year	26	Assumption that attendance at Park will coincide with sprinkler water application once a fortnight
Exposure Frequency – ground saturated with irrigation water	days/year	26	Assumption of one event per fortnight, based on likelihood of direct contact with wet ground
Exposure Duration	years	6 10 54	Child 0-5 years, enHealth (2004) Child 6-15 years, enHealth (2004) Adult 16+ years, enHealth (2004)
Exposure Time	hours	2	NEPC (1999)
Exposure Time – Sprinkler water	hours	1	NEPC (1999), assumption of 50% of overall exposure time. Only considered for inhalation exposure noting that grass will remain wet subsequent to sprinkler water application
Body Weight	kg kg kg	13.2 34.5 70	Child 0-5 years, enHealth (2004) Child 6-15 years, Langley & Sobardo (1996) as per NEPC (1999) mean body weight for 10 year old child Adult 16+ years, NEPC (1999)
Averaging Time – non Threshold	years	70	NEPC (1999)
Averaging Time – Threshold	years	70	NEPC (1999)

Table 8.3: Global Parameters – Adult Commercial / Industrial Workers – Car Park Attendants, 'Cultural Space' Staff and Greenkeepers

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	240	enHealth (2004)
Exposure Frequency (Greenkeeper) – Sprinkler Water	days/year	120	Assumption of use of sprinklers on 120 days per year (i.e. in excess of irrigation requirements for Park)
Exposure Duration	years	30	enHealth (2004)
Exposure Time	hours	8	enHealth (2004)
Exposure Time (Greenkeeper) – Sprinkler Water	hours	1	Time taken to move sprinklers to position. Potential that sprinklers may be operating during movement. Assuming that sprinklers will not be permanent sub-surface fixtures.
Body Weight	kg	70	NEPC (1999)
Averaging Time – non Threshold	years	70	NEPC (1999)
Averaging Time – Threshold	years	30	NEPC (1999)

Table 8.4: Global Parameters – Adult Maintenance Worker

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	15	Assumption of maximum time spent undertaking maintenance works, three working weeks
Exposure Duration	years	1	Based on single event only
Exposure Time	hours	8	NEPC (1999) as per commercial / industrial worker
Body Weight	kg	70	NEPC (1999)
Averaging Time – non Threshold	years	70	NEPC (1999)
Averaging Time – Threshold	years	1	Based on single event only

Table 8.5: Global Parameters –Occasional User of Car Park (Adult & Child)

Exposure Parameter	Units	Factor	Reference
Exposure Frequency	days/year	240	NEPC (1999) as per exposure commercial / industrial worker. Considered conservative for car park user.
Exposure Frequency – dermal contact with infiltrating seepage water	days/year	6	Likelihood of parking vehicle in location of the Car Park where infiltrating seepage water has accumulated, and likelihood of seepage water puddles

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Exposure Parameter	Units	Factor	Reference
			being present in the Car Park (i.e. not drained away). Used only for dermal exposure calculations
Exposure Duration	years	70	NEPC (1999)
Exposure Time	hours	0.25	Assumption, based on time to move to access parked vehicle.
Body Weight	kg kg kg	13.2 34.5 70	Child 0-5 years, enHealth (2004) Child 6-15 years, Langley & Sobardo (1996) as per NEPC (1999) mean body weight for 10 year old child Adult 16+ years, NEPC (1999)
Averaging Time – non Threshold	years	70	NEPC (1999)
Averaging Time – Threshold	years	70	NEPC (1999)

Table 8.6: Ingestion Parameters (Soil)

Exposure Parameter	Units	Factor	Reference
Sub-Surface Maintenance Worker	mg/day	330	US EPA (1991)
Commercial / Industrial Worker (Gardener)	mg/day	25	NEPC (1999)
Adult Recreational Receptor	mg/day	25	NEPC (1999)
Child Recreational Receptor (6-15 years)	mg/day	50	enHealth (2004)
Child Recreational Receptor (1-5 years)	mg/day	100	NEPC (1999)

Table 8.7: Ingestion Parameters (Groundwater / Seepage Water)

Exposure Parameter	Units	Factor	Reference
Sub-Surface Maintenance Worker	ml/day	5	Assumption of incidental ingestion

Table 8.8: Dermal Contact Parameters

Exposure Parameter	Units	Factor	Reference
Exposed skin surface Sub-Surface Maintenance Worker	cm^2	3 870	US EPA (1997). 50th percentile male surface areas assuming to be wearing short sleeved shirt and long pants.
Exposed skin surface Adult Recreational Receptor	cm^2	4 700	Langley (1993). 24% body area exposed including head, hands, forearms and lower legs.
Exposed skin surface Commercial Industrial (Gardener)	cm^2	4 700	Langley (1993). 24% body area exposed including head, hands, forearms and lower legs.
Exposed skin surface Adult Recreational Receptor – near surface irrigation water / grass wetted with sprinkler water / contact to operating sprinklers	cm^2	4 700	Langley (1993). 24% body area exposed including head, hands, forearms and lower legs.
Exposed skin surface Child Recreational Receptor (6-15 years)	cm^2	3 480	Langley (1993). Older child (9-12 years) with total surface area of 11,600cm^2 with 30% exposed.
Exposed skin surface Child Recreational Receptor (6-15 years) – near surface irrigation water/ grass wetted with sprinkler water / contact to operating sprinklers	cm^2	3 480	Langley (1993). Older child (9-12 years) with total surface area of 11,600cm^2 with 30% exposed.
Exposed skin surface Child Recreational Receptor (0-5 years)	cm^2	2 158	Langley (1993). Young child (3-6 years) with average total surface area of 7,195cm^2 with 30% exposed. Also adopted for park sprinkler irrigation.
Exposed skin surface Child Recreational Receptor (0-5 years) – near surface irrigation water/ grass wetted with sprinkler water / contact to operating sprinklers	cm^2	3 598	US EPA (2004) 2-3 year old entire body apart from torso. Assumed to be 50% of body area
Exposed skin surface Adult Occasional Car Park User – infiltrating seepage water	cm^2	904	Hands only. 50th percentile values, US EPA (2004)
Exposed skin surface Child Occasional Car Park User (6-15 years) – infiltrating seepage water	cm^2	633	Hands only. US EPA (2004) 10-11 year old.
Exposed skin surface Child Occasional Car Park User (0-5 years) – infiltrating seepage water	cm^2	313	Hands only. US EPA (2004) 2-3 year old.
Soil adherence – Sub-Surface	$mg/cm^2/day$	1.5	US EPA (1989)

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Exposure Parameter	Units	Factor	Reference
Maintenance Worker			
Soil adherence – Adult Recreational Receptor	mg/cm^2/day	0.5	enHealth (2004)
Soil adherence – Commercial / Industrial Worker	mg/cm^2/day	0.5	enHealth (2004)
Soil adherence – Child Recreational Receptor (6-15 years)	mg/cm^2/day	0.5	enHealth (2004)
Soil adherence – Child Recreational Receptor (0-5 years)	mg/cm^2/day	0.5	enHealth (2004)
Time of exposure to seepage water – sub-surface maintenance worker	h/day	8	Assumption of maximum time sub-surface maintenance worker may have contact with seepage water in excavation.
Exposed skin surface to infiltrating seepage water Sub Surface Maintenance Worker	cm^2	2 129	Feet and hands only. 50th percentile values, US EPA (2004)

8.4 Estimation of Inhalation Exposure

Inhalation exposures have been estimated by the approach in US EPA (January 2009) 'Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment)'. Equations are provided here for estimating exposure concentrations for assessing cancer risks and for calculating hazard quotients from chronic exposures as per the following:

EC = (CA * ET * EF * ED)/AT (cancer risks)

EC = (CA * ET * EF * ED)/AT (hazard quotients)

Where: EC – exposure concentration (µg/m^3);

CA – contaminant concentration in air (µg/m^3);

ET – exposure time (hours/day)

EF – exposure frequency (days/year)

ED – exposure duration (years)

AT – averaging time, cancer risks (lifetime in years * 365 days/year * 24 hours/day)

AT – averaging time, hazard quotient (ED in years * 365 days/year * 24 hours/day)

Table 8.9 following summarises each of the adjustment factors to be used for each of the receptors assessed by the risk assessment.

Table 8.9: Summary of Factors to Adjust Airborne Concentrations for Inhalation Exposure

Receptor	Media	Location	Cancer Risks (EC)	Hazard Quotients (EC)
Recreational Receptor	Soil	Headland Park	$8.33*10^{-2}$*CA	$8.33*10^{-2}$*CA
	Soil	Cultural Space	$8.33*10^{-2}$*CA	$8.33*10^{-2}$*CA
	Seepage Water	Headland Park	$8.33*10^{-2}$*CA	$8.33*10^{-2}$*CA
	Irrigation Water	Headland Park	$2.97*10^{-3}$*CA	$2.97*10^{-3}$*CA
Commercial / Industrial (Car Park Attendant)	Soil	Car Park	$9.39*10^{-2}$*CA	0.22*CA
	Groundwater	Car Park	$9.39*10^{-2}$*CA	0.22*CA
Commercial / Industrial (Cultural Space)	Soil	Cultural Space	$9.39*10^{-2}$*CA	0.22*CA
Commercial / Industrial (Gardener)	Soil	Headland Park	$9.39*10^{-2}$*CA	0.22*CA
	Seepage Water	Headland Park	$9.39*10^{-2}$*CA	0.22*CA
	Irrigation Water	Headland Park	$5.87*10^{-3}$*CA	$1.37*10^{-2}$*CA
Occasional User	Soil	Car Park	$6.85*10^{-3}$*CA	$6.85*10^{-3}$*CA
	Groundwater	Car Park	$6.85*10^{-3}$*CA	$6.85*10^{-3}$*CA
	Pooled Seepage Water	Car Park	$6.85*10^{-3}$*CA	$6.85*10^{-3}$*CA
Sub-Surface Maintenance Worker	Soil	Headland Park	$1.96*10^{-4}$*CA	$1.37*10^{-2}$*CA
	Seepage Water	Headland Park	$1.96*10^{-4}$*CA	$1.37*10^{-2}$*CA

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Assessment of acute risks is advised to be undertaken by direction comparison to the contaminant concentration in air. It is noted that inhalation toxicity data, summarised in **Section 7**, has been converted to slope factors on the basis of a rate of inhalation of $20m^3$/day and an adult body weight of 70kg.

8.5 Estimation of Oral and Dermal Exposure

Oral and dermal exposures have been adjusted using the exposure parameters in **Section 8.3** as per the relationships provided to the relevant US EPA Risk Assessment Guidance for Superfund guidelines. These calculations have been undertaken using the RISC 4.03 package. Equations used in the RISC v4.03 modelling package are provided as **Appendix C**.

8.6 Estimation of Airborne Concentration

Airborne concentrations have been required to be estimated for constituents as vapour concentrations (by movement of vapours through soils and groundwater to the area of exposure) and as levels contained within particulates for exposure scenarios where dust generation may occur. These calculations have been undertaken using the RISC v4.03 package as described in the following sections.

8.6.1 Vapour

Vapour concentrations have only been estimated for constituents which are considered to be volatile. This has been undertaken by a review of Henry's Law constants for each constituent as summarised in **Table 8.10** following. Constituents which are found to have a Henry's Law constant below $1*10^{-5}$ atm-m^3/mol are considered to be non-volatile and unlikely to pose a significant health risk via the vapour intrusion pathway as per US EPA (2004) 'User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings'.

Table 8.10: Summary of Henry's Law Constants for COPCs

COPC	Henry's Law Constant (atm-m^3/mol)	Reference / Source / Comments
Ammonia	$1.6*10^{-5}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Arsenic	-	Non volatile
Cadmium	-	Non volatile
Chromium	-	Non volatile
Lead	-	Non volatile
Nickel	-	Non volatile
Cyanide	$1.33*10^{-4}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Benzene	$5.54*10^{-3}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Toluene	$6.61*10^{-3}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Ethylbenzene	$7.86*10^{-3}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Xylenes	$5.17*10^{-3}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
1,2,4-trimethylbenzene	$5.04*10^{-3}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
TPH C_6-C_8 (ali)	1.24	TPHCWG (1997), conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
TPH C_8-C_{16} (ali)	3.17	TPHCWG (1997), conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
TPH C_8-C_{16} (aro)	$3.42*10^{-3}$	TPHCWG (1997), conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
TPH $C_{>16}$ (ali)	156	TPHCWG (1997), conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C. Considered to be non-volatile for the purposes of vapour modelling.
TPH $C_{>16}$ (aro)	$3.17*10^{-4}$	TPHCWG (1997), conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C. Considered to be non-volatile for the purposes of vapour modelling.
Benz(a)anthracene	$1.20*10^{-5}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C

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COPC	Henry's Law Constant ($atm\text{-}m^3/mol$)	Reference / Source / Comments
Benzo(a)pyrene	$4.56*10^{-7}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Benzo(b)fluoranthene	$6.56*10^{-7}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Benzo(k)fluoranthene	$5.83*10^{-7}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Chrysene	$5.22*10^{-6}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Dibenz(a,h)anthracene	$1.41*10^{-7}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Dibenzofuran	$2.13*10^{-4}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Fluoranthene	$8.83*10^{-6}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Fluorene	$9.59*10^{-5}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Indeno(1,2,3-c,d)pyrene	$3.46*10^{-7}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
2-methylnaphthalene	$5.17*10^{-5}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Naphthalene	$4.39*10^{-4}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Pyrene	$1.19*10^{-5}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Phenol	$3.32*10^{-5}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
2,4-dimethylphenol	$9.49*10^{-7}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C
Cresols	$1.20*10^{-6}$	Risk Assessment Information System, conversion by US EPA On-line Tools for Site Assessment Calculation at 20°C

On the basis of **Table 8.9**, inhalation of vapours assessment is not required for the heavy metals, TPH $C_{>16}$ fractions, 2,4-dimethylphenol, cresols and heavier PAHs including benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene.

8.6.2 Particulates

Constituent levels in respirable dust have been required to be estimated for sub-surface maintenance workers. This has been undertaken by a particulate emission factor (PEF) method. A PEF of $3.6 * 10^7$ m^3/kg has been adopted for the calculations as based on US EPA (2002) 'Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites' guidance for construction (grazing and dozing) activities. The concentration of a COPC in air consequent of particulates is calculated by:

$CA = CS / PEF$

Where: CA – concentration in air (mg/m^3)

CS – concentration in soil (mg/kg)

PEF – particulate emission factor (m^3/kg)

8.7 Use of RISC Modelling Package

The RISC v4.03 modelling package has been used for modelling to estimate airborne concentrations of constituent vapours.

RISC uses risk equations based on those provided in US EPA Risk Assessment guidance (RAGS Guidelines). These are noted in NEPC (1999) as being appropriate for use in human health risk assessment. Chemical parameters provided to the RISC model have been updated to comply with NEPC (1999) and NSW DECCW guidance where specific guidance is provided (i.e. source of toxicity data). Exposure parameters have likewise also been based on NEPC and enHealth guidance where available. Updated parameters are detailed throughout this risk assessment document. Other parameters as provided

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within the RISC package (i.e. physical properties of modelled constituents) have not been altered in use of the RISC package.

In undertaking modelling of vapour migration into buildings a default value of 5 L/min as advised in US EPA (2004) 'User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings' for all indoor modelling scenarios (i.e. Car Park) has been used to estimate the rate of soil gas flow into a building.

The RISC model uses Johnson & Ettinger relationships in estimating transport of volatile constituents into human breathing zones. US EPA (2003) reports that the use of Johnson & Ettinger relationships is appropriate in undertaking human health risk assessments. The amendments to the RISC model described above ensure that RISC is behaving as closely as possible to the most recent guidance for the use of the Johnson & Ettinger relationships.

8.8 Characterisation of Outdoor Area of Headland Park

Outdoor areas in RISC are characterised by a box model. The default parameters provided to RISC for outdoor air exposures will be used in the modelling here. Of note, an outdoor wind speed of 2m/s has been used in the modelling.

8.9 Characterisation of Sub-Surface Maintenance Trench

Sub-surface maintenance trenches have been assumed to be placed to a maximum depth of 0.5m in accordance with the advice from BDA. A trench of this depth that is excavated in a fashion that is safe for a sub-surface maintenance worker to enter will most likely be subject to normal rates of ambient ventilation. The trench has been modelled as being subject to rates of ventilation consistent with normal outdoor wind speeds.

8.10 Characterisation of Indoor Spaces

8.10.1 Car Park

The Car Park has been assumed to be constructed with a pavement thickness of 150mm. Default crack width and porosity parameters provided to the RISC model have been used to characterise the pavement. Noting the current uncertainty as to the proposed construction of a Car Park Attendant's Office, the standard building dimensions as provided to RISC have been used to characterise the building. These are summarised following:

- Building volume – 400m^3;
- Building cross-sectional area – 150m^2;
- Fraction of foundation present as cracks – 0.001;
- Porosity in foundation cracks – 0.25; and
- Water content in foundation cracks – 0.

The proposed ventilation of the Car Park has been determined in accordance with AS1668.2-2002 'The use of ventilation and air conditioning in buildings Part 2: Ventilation design for indoor air contaminant control (excluding requirements for the health aspects of tobacco smoke exposure)'. It has been assumed that the Car Park will be provided with sufficient ventilation to achieve a fresh / outdoor air flow rate of 3 L/s per m^2. Assuming a typical roof height of 2.8 m within the Car Park, this is equivalent to an overall rate of ventilation of 3.8 volumes changes per hour. It has been assumed that

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Car Park attendant offices will be ventilated at the same rate as the overall Car Park structure.

Car Park users have also been modelled as being potentially exposed to impacted seepage water which may migrate through the walls of the Car Park.

8.10.2 Seepage Water Accumulation in the Car Park

Seepage water may potentially accumulate in localised areas of the Car Park by infiltration through cracks and joins in the Car Park basement walls. Contaminants which are present in seepage water will potentially volatilise into the Car Park atmosphere. US EPA (2004) 'Methods for Estimating Fugitive Air Emissions of Radionuclides from Diffuse Sources at DoE Facilities' provides the following relationship to estimate potential evaporation from pooled water.

$R = (20.73 * P_S * A^{0.9} * U^{0.8} * a) / T^{1.47}$

where: R – emission rate (g/s);

P_S – vapour pressure of water at ambient temperature (assumed to be 20°C, 293 K within the Car Park, equal to 17.5 mmHg)

A – surface area of pooled water (m^2)

U – wind speed at pooled water surface (m/s)

T – Ambient temperature (K), also assumed to be 293 K

a – concentration of constituent in water (g/g)

This relationship is reported by US EPA (2004) to be appropriate for chemicals that volatilise out of water bodies, and non-volatile chemicals.

The wind speed at the surface of the pooled water will be a function of the forced ventilation provided to the Car Park. Using an overall rate of ventilation of 3.8 volumes changes per hour, a typical wind speed within the Car Park is equal to 0.07m/s.

It is anticipated that the actual surface area of puddles of seepage water will be minimal. It has been assumed that a total surface area of 9 000m^2 of Car Park is present as per the Car Park plans. A length of 160m of wall is present on each of the two levels of the Car Park adjoining walls which may potentially be wet (320m total distance over two levels). It has been assumed that 10% of the length of these walls have puddles of infiltrating seepage water present. The width of the puddles has been assumed to be equal to 100mm, typical of the width of the base of a spoon drain. This is equal to an area of 3.2m^2 of pooled water.

To determine an airborne concentration within the Car Park, it has been assumed that perfect mixing occurs of the vapour emissions from the puddles. With a Car Park volume of 25 000m^3, based on the ceiling height of 2.8m, the following equation is determined:

$C_{car\ park} = 0.0011 * a\ (g/m^3)$

where: $C_{car\ park}$ – vapour level in Car Park (g/m^3)

a – concentration of constituent in water (g/g)

As per **Section 8.6.1** it has been assumed that only constituents classified as potentially volatile will be present in vapour from pooled water in the Car Park.

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8.10.3 'Cultural Space'

Little information is available on the proposed design of the 'Cultural Space'. In lieu of this, default building dimensions, crack width and porosity parameters provided to the RISC model have been used to characterise the pavement, as summarised in **Section 8.7.1**. A ventilation rate of 0.00056 volume changes per second as recommended by NZ Ministry for the Environment (1999) for a building has been used to estimate the ventilation for the 'Cultural Space'.

It is considered aesthetically unacceptable for seepage water to be present in an enclosed building used for commercial / industrial or recreational purposes. No direct exposure to infiltrating seepage water has been assumed to occur within the 'Cultural Space'.

8.10.4 Vapour Flow into Buildings

BDA have advised that there will no provision for vapour controls on the proposed Car Park structure or the 'Cultural Space'. Soils which will potentially contain soil contaminant vapours and placed as fill material in the park will be located:

- To the west of the western wall of the Car Park and 'Cultural Space'. The western wall of the Car Park / 'Cultural Space' can be observed in **Figures 13** to **15** to comprise the sandstone retaining wall which is not anticipated to be constructed of contaminated materials;
- Underlying and to the west of the western portion of the proposed 'Cultural Space'; and
- Underlying the Car Park.

Outdoor / naturally ventilated areas are located to the north, west and south of the proposed 'Cultural Space' and Car Park. An assessment has been undertaken of the likelihood of soil vapours present outside of the direct footprint of these structures to move laterally into the structures. Recent three dimensional sub-surface soil vapour migration studies reported in Bozkurt O, Pennell K and Suubery E (2009) 'Simulation of the Vapor Intrusion Process for Nonhomogeneous Soils Using a Three Dimensional Numerical Model' in Ground Water Monitoring & Remediation (Boskurt et al 2009) and Pennell K, Bozkurt and Suuberg E (2009) 'Development and Application of a Three Dimensional Finite Element Vapor Intrusion Model' in Journal of the Waste Management Association (Pennell et al 2009) indicates that significant lateral migration of soil vapours may occur in proximity of buildings.

Vapour migration into buildings is reported to occur by advection where there is a pressure differential between the building interior and the sub-surface. Commercial buildings, such as the 'Cultural Space', are reported to commonly be at negative pressures relative to the surrounding environment. This relative negative pressure draws sub-surface soil vapours into the structures through cracks and joins that occur in the building pavement / slab. Pennell et al (2009) describe this as a chimney effect which results in a flow of soil gas into the building through breaches in the foundation. This causes a concentration gradient-driven upward diffusion of a sub-surface contaminant toward the ground surface in the proximity of the building. A portion of the upward diffusing contaminant is captured by and carried with the advective flow entering the structure. Diffusion of the contaminant through building foundation cracks also occurs.

Soil vapour flow modelling is reported by Bozkurt et al (2009) using a small building at a negative pressure within a large area of contamination (100m * 100m). Soil gas outside the area of the structure was reported to be drawn toward a structure. Where the airflow of soil gas crossed an area of nonzero contaminant vapour concentration, it was reported

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that the contaminant vapour was carried with the soil gas into the structure. This is shown on the following **Diagram 8.1** as taken from Bozkurt et al (2009). The arrows on the right hand side of the diagram show soil gas flow vectors. It can be observed that soil gas is potentially drawn into a building from a substantial distance away from the building. However it must be noted that the paper was not specifically prepared to quantify the lateral influence of soil gas movement underlying structures.

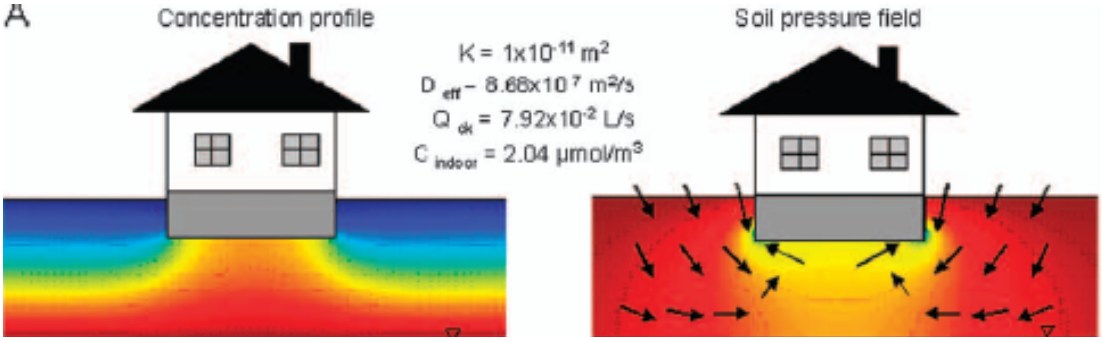


Diagram 8.1: Soil-gas concentration profiles and pressure fields underlying building at Negative Relative Pressure

Lowell P S and Eklund B (April 2004) 'VOC Emission Fluxes as a Function of Lateral Distance from the Source' in Environmmental Progress provide an assessment of the extent of potential lateral movement of soil vapours into buildings. Lowell and Eklund state that emission flux and the soil-gas concentration are insignificant within a relatively short distance from the source. A conservative upper estimate of the potential lateral migration of vapours is nominated as 100 feet within the paper (approximately 30m). This is consistent with guidance provided in several US documents.

On this basis, it is assumed that soils separated in a lateral distance from the 'Cultural Space' and Car Park structures will potentially be a source of vapour inflow into these structures to a distance of 30m as measured laterally from the enclosed part of the northern, southern and western portions of the 'Cultural Space'. This is shown on **Figure 12**.

SESL (*pers comm*. 2010) have advised that 'growing medium' soils will be relatively well oxygenised. This would indicate that vapours as may be present in these soils would preferentially migrate to outdoor air by a 'convective sweep' effect that occurs through the relatively well aerated soils. The convective sweep is caused by wind movement over the near surface penetrating into the permeable soil horizons. These soils (as occurring within 30m of the 'Cultural Space') can be excluded from consideration of potential vapour migration into the 'Cultural Space' and Car Park. Growing medium soils are not proposed to be placed underlying the proposed 'Cultural Space' or Car Park

Preliminary vapour transport modelling has been undertaken of the site conceptual model established here. By observing the most sensitive of the exposure parameters established for the Car Park and 'Cultural Space', the following has been found:

- Higher levels of vapours and associated potential vapour exposure will occur in the Car Park, relative to the 'Cultural Space', from impact present in sub-surface soils directly below the Car Park, as opposed to soils located to the west; and
- Higher levels of vapours and associated potential vapour exposure will occur by vapour transport though the floor of the western portion of the 'Cultural Space', relative to vapour transport through the northern, western and southern walls of the Car Park and 'Cultural Space' from impact present in sub-surface soils to the west of the 'Cultural Space' and Car Park.

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On the basis of these preliminary modelling results and deriving the most conservative soil criteria:

- Potential inhalation exposure to vapours from soils and groundwater underlying the Car Park only requires to consider receptors within the Car Park; and
- Potential inhalation exposures to vapours from soil and seepage water underlying the western portion of the 'Cultural Space' and to the west of the 'Cultural Space' and Car Park to a distance of 30m only requires to consider the exposure of a commercial / industrial receptor within the 'Cultural Space'.

Modelling has been undertaken for all other exposure scenarios.

8.11 Characterisation of Inhalation Exposure from Seepage Water Used for Irrigation

Collected water, including rainfall, near surface flows and potentially deeper seepage water flows in fill materials, are proposed to be re-used on-site for irrigation purposes. JBS has been advised that irrigation will be substantially undertaken using sprinklers.

Volatile constituents may volatilise from sprinklers used during irrigation. NZ Ministry for the Environment (1999) provides a 'shower model' to estimate the extent of volatilisation from sprinklers / showers. This model has been used to determine appropriate levels of groundwater impact in extracted groundwater to ensure safe vapour levels within the sprinkler / shower.

Calculations using the sprinkler model are summarised in **Appendix D**. Parameters used in the application of the shower model are summarised in **Table 8.11** following.

Table 8.11: Summary of Parameters Used for Modelling of Shower Exposure

Parameter	Value	Comments / Reference
Droplet diameter	0.2cm	NZ Ministry for the Environment (1999)
Droplet drop time	10s	NZ Ministry for the Environment (1999)
Shower volume	86 400m^3 (children – recreational) 86 400m^3 (adult – recreational) 10 800m^3 (adult – greenkeeper)	NZ Ministry for the Environment (1999), adjusted for 2 hour exposure duration for recreational receptors and greenkeeper
Shower water temperature	20°C	Assumption
Flow rate through shower	60L/min	Based on assumption of 1L/s discharged at sprinkler
Time of sprinkler operation	2 hours – recreational 15 minutes – greenkeeper	Consistent with longest exposure time of receptors and likely maximum duration of operation

Modelling of inhalation exposure to near surface seepage water associated with sub-surface irrigation has assumed a minimum 0.1m vapour migration length based on the minimum distance for vapour migration recommended in NZ Ministry for the Environment (1999). Only constituents which have been identified in **Section 8.6.1** as potentially volatile have been included in the assessment of vapours from sprinkler water.

It is noted that reduced (dermal) exposure frequencies to near surface / pooled irrigation water have been provided with the exposure parameters. These are consistent with the advised rate of application of sprinkler water to turfed / grassed areas of the site.

The potential for substantial near-surface pooling of irrigation water is considered to be minimal noting that free draining sand based soils are available and proposed to be used as fill materials on the park. Irrigated water would be anticipated to rapidly percolate to the depth of the underlying seepage water / groundwater zone. Further the requirements for the maintenance of the park aesthetics and park usability would prevent regular occurrences of 'puddles' of irrigation water / water logged soils occurring in the proximity to the site surface. This would further prevent the potential for ingestion of these waters.

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8.11.1 Irrigation Water Pre-Treatment

It is assumed that some pre-treatment of collected seepage water / rainwater will occur prior to re-use as sprinkler irrigation. On this basis, risk assessment for the quality of irrigation water has been based on allowable concentrations of contaminants in water only. No assessment has been undertaken of the leaching potential of soils as related to the irrigation water criteria to further derive soil based criteria that may allow irrigation water criteria to be met.

8.12 Characterisation of Site Geology and Hydrogeology

A range of soil and fill types will potentially be used to construct the Headland Park. Based on the extent of information available for the proposed Park design, geological parameters are required for:

- Soils to be present at near surface depths to be used as growing medium;
- Soils to be present in the sandstone retaining wall as shown on **Figure 15**;
- Soils to be present as general fill material throughout the bulk of the Park;
- Soils present as general fill material underlying the Car Park; and
- Current in-situ soils on the Park that will be retained.

8.12.1 Growing Medium

Parameters for sands have been used for soil present as growing medium. It is anticipated that growing soils will be relatively loose and well aerated to facilitate vegetation growth. The occurrence and depth of seepage water in the growing soils layers cannot be accurately predicted. It is highly likely that the occurrence and distribution of seepage water throughout these materials will be variable. Consequently, parameters as based on dry sand have been used as per the values provided to US EPA (2003) to ensure conservatism.

8.12.2 General Fill

General fill materials which will be used to form the Park have been reported to be compared to a '98% density'. The extent of compaction is necessary to achieve and maintain the proposed 'headland' shape of the Park.

To remain conservative, the general fill materials have been characterised as a dry sand similar to that undertaken for the growing soils.

Parameters for sands have been used for soil present as growing medium and general fill. The occurrence and depth of seepage water in the general fill or top soil layers cannot be accurately predicted. It is highly likely that the occurrence and distribution of seepage water throughout these materials will be variable. Consequently, parameters as based on dry sand have been used as per the values provided to US EPA (2003) to ensure conservatism.

8.12.3 Sandstone Retaining Wall

Parameters for capillary zone clay have been used to characterise the sandstone retaining wall. This is in recognition of the hydrated cement between the sandstone boulders controlling vapour migration. It has been assumed that the sandstone retaining wall is a minimum thickness of 1.0m in undertaking modelling. The majority of the sandstone retaining wall is substantially wider than this.

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8.12.4 General Fill Underlying Car Park

General fill underlying the Car Park will be present below a depth of 0.5 to -1 m AHD. ERM (2007 and 2008) groundwater monitoring wells MW02, MW04 and MW07 are present closest to the location of the proposed Car Park. Groundwater has been historically recorded at 0.3 to 0.4 m AHD at these monitoring wells. Groundwater has been reported as being variable over the area of the Barangaroo Site, consistent with tidal fluctuations. The extent of potential tidal fluctuations in the excavation below the Car Park is unknown at this time and is dependent on several final design factors. However, the relative depths of structures and historically recorded depths to water indicate that upper depths of soils underlying the proposed Car Park will potentially be in an unsaturated condition.

Two soil types have been modelled under the Car Park, consisting of unsaturated sands, which would consist of the highest levels of fill emplacement; and capillary zone sands, which would consist of sands present within a potential tidal fluctuation zone that may exist. The actual RL at which these depths would occur on the site have not been determined in this risk assessment. Soils below the depth of groundwater would be anticipated to have a negligible vapour potential and have not been assessed for this pathway. Vapour movement is substantially precluded by the water filled porosity in the saturated zone.

8.12.5 Clay Liner

As discussed in **Section 4** a clay liner is proposed to be placed under the whole of the filled area on the Park to control sub-surface seepage water flows. Potential exposure to this layer would be equivalent to or less than the immediate overlying soils. Risk based criteria for the overlying soils will be able to be applied to these clay soils. No specific assessment has been undertaken to differentiate the 'clay liner' soils from the general fill.

8.12.6 In-situ Soils

In-situ soils as present on the Park will occur either below the clay liner or below the Car Park. These soils as characterised as being sandy soils, as similar to the site sourced soils proposed to be used as general fill. The occurrence of these soils over the majority of the site as being below a clay liner will reduce the potential vapour migration to human receptors on the surface relative to overlying fill based soils. Other potential human exposure scenarios would likewise be considered to be less. On this basis, soil criteria derived for overlying soils will be appropriate to be applied to these soils.

8.12.7 Summary of Geological Properties

Geological properties adopted for modelling are summarised in **Table 8.12**.

Table 8.12: Summary of Soil Properties

Soil Property	Sand – Unsaturated	Sand – Capillary fringe	Clay – Capillary Fringe (Sandstone Retaining Wall)
Total Porosity	0.375	0.375	0.459
Water Porosity	0.053	0.253	0.412
Height of Capillary Zone (cm)	-	17	-
Bulk Density	1.66	1.66	1.43
Organic Carbon Content (%)	0.3 3[1]	0.3	0.5
Vapour Permeability (cm^2)	$1*10^{-9}$	$1*10^{-9}$	$1*10^{-13}$

Note: 1. To be used for upper surface growing medium soils, assumed to be equal to 0.5m based on value for turf soils and assumption that human exposure would predominantly occur over these areas.

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For the purposes of modelling vapours from soils sources, it has been assumed that soils are unsaturated, apart from the approach described for saturated soils underlying the Car Park.

8.12.8 Hydrogeology

The depth to groundwater on Headland Park is currently unknown. It is likely to be highly variable consequent of the steep geology proposed with the site design. For the purposes of potential vapour migration from seepage water, it has been assumed that groundwater / seepage water will typically occur at a depth of 0.5m below ground level for the area of the Park, consistent with seepage water present at the base of the shallowest depth of growing medium. This is a conservative assumption, and the actual depth of any significant seepage water horizon is likely to be substantially deeper.

It has been assumed that groundwater is present at a depth of 0.1 m below the Car Park structure for the purposes of modelling vapours from groundwater underlying this source.

8.12.9 Leaching

Some of the exposure scenarios have required an assessment of potential COPC concentrations in seepage / groundwater horizons consequent of direct leaching from impacted soils. This has included assessment of soils placed into saturated horizons (such as below the car park) and assessment of soils that may potentially generate leachate at near surface depths consistent with growing medium.

Risk based criteria developed as allowable levels of seepage water and groundwater impact will not be able to applied to soils entering the site in lieu of extensive soil leachability testing. Further, risk and hazard estimates for the derivation of based criteria cannot be derived on the basis of risk and hazard estimates foir exposure to multiple media (i.e. sub-surface maintenance worker in Park with inhalation exposure to vapours from soil impact and dermal exposure to leached impact present in seepage water in excavations). Instead, leaching relationships can be used to convert risk based criteria derived on the basis of allowable levels in groundwater and seepage water, to total levels of COPCs in soils that may cause the equivalent levels in seepage water / groundwater.

This has been undertaken using the leaching relationships developed for some of the COPCs in JBS Environmental (14th January 2011) 'Summary of Results of Soil Analysis of Chemical Constituent Leachability Barangaroo'. (JBS 2011) provides leaching relationships on the basis of soils present within the Headland Park and soils present within the Barangaroo Central and South sites.

It is noted that leaching relationships are not available in JBS (2011) for the full extent of COPCs assessed as potentially leaching to seepage water at near surface depths, and groundwater underlying the car park. Theoretical estimates of potential leachability of these constituents have been required.

Heemsbergen D, Warne M, McLaughlin M and Kookana R CSIRO (October 2009) 'The Australian Methodology to Derive Ecological Investigation Levels in Contaminated Soils' (CSIRO, 2009) provides the following to derive soil criteria on the basis of soil leaching and target water concentrations for inorganic constituents:

$EIL = C_w.[K_d + (\theta_W + \theta_a.H') / \rho_b)].DAF$

Where: EIL – ecological investigation level (mg/kg)'

C_w – target leachate concentration, set equal to ANZECC/ARMCANZ 95% protection marine value unless use of 99% advised (mg/l);

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K_d – soil to water partition coefficient (L/kg);

θ_a – air filled porosity;

θ_w – water filled porosity;

H' – Henry's Law Constant (unitless);

ρ_b – soil bulk density (kg/l); and

DAF – dilution attenuation factor including dilution from catchment and tidal dilution at discharge

The following relationship is similarly provided for organic constituents.

$EIL = C_w.[(K_{OC}.f_{OC}) + (\theta_W + \theta_a.H') / \rho_b)].DAF$

Where: EIL – ecological investigation level (mg/kg)'

C_w – target leachate concentration, set equal to ANZECC/ARMCANZ 95% protection marine value unless use of 99% advised (mg/l);

K_{OC} – organic carbon to water partition coefficient (L/kg);

f_{OC} – fraction of organic carbon (g/g)

θ_a – air filled porosity;

θ_w – water filled porosity;

H' – Henry's Law Constant (unitless);

ρ_b – soil bulk density (kg/l); and

DAF – dilution attenuation factor including dilution from catchment and tidal dilution at discharge.

These relationships have been used to derive the equivalent soil criteria to meet the risk based seepage water / groundwater criteria for each COPC where field based estimates are not available in JBS (2011). Geological and chemical data used in the calculations is summarised in **Tables 8.12** and **8.13** respectively. The dilution attenuation factor has been set equal to zero for all calculations.

All risk and hazard results derived on the basis of unit concentration (1 mg/l) seepage water or groundwater exposure have been converted to equivalent risk and hazard estimates as would be caused by the leaching of a unit concentration (1 mg/kg) soil impact. Noting that leaching relationships are available for soils sourced from Headland Park and soils sourced from Barangaroo Central and South, risk and hazard estimates have been prepared separately for each portion of the Barangaroo site.

8.13 Assessment of Total Petroleum Hydrocarbons

Toxicological data for total petroleum hydrocarbons (TPH) are provided for the aliphatic and aromatic fractions of $C_{>6}$-C_8, $C_{>7}$-C_8, $C_{>8}$-C_{16} and $C_{>16}$-C_{35}. However the TPH analytical data available for the site are provided as non speciated TPH fractions of C_6-C_9, C_{10}-C_{14}, C_{15}-C_{28} and C_{29}-C_{36}, as provided by Australian laboratories. Australian laboratories are able to provide speciated TPH data for TPH fractions $C_{>16}$. It is proposed to correlate TPH toxicological data with TPH data able to be readily generated by Australian laboratories in the following manner:

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- Based on the selection of monocyclic aromatic hydrocarbons including benzene, toluene, ethylbenzene and xylenes as COPCs it is not proposed to undertake risk assessment for TPH aromatic fractions $<C_{10}$;
- A TPH C_6-C_9 (aliphatic) criterion shall be derived using data for the TPH $C_{>6}$-C_8 (aliphatic) fraction. This is intended to be compared to the total TPH C_6-C_9 concentration as reported by the laboratory, with the sum of speciated aromatic constituents (determined by BTEX or VOC analysis or similar) subtracted;
- A TPH C_{10}-C_{14} criterion has been derived using the toxicological data for the TPH $C_{>8}$-C_{16} (aliphatic and aromatic) fractions and using fraction specific physical-chemical properties for the TPH $C_{>10}$-C_{12} (aliphatic and aromatic) fractions as provided in Table 8 of TPHCWG (1997) Volume 3. It has been assumed that TPH C_{10}-C_{14} is present as a 50:50 mixture of aliphatic and aromatic fractions; and
- Speciated TPH $C_{>16}$ criteria have been derived using toxicological data for TPH $C_{>16}$-C_{35} (aliphatic and aromatic) fractions and using fraction specific physical-chemical properties for TPH $C_{>16}$-C_{21} (aliphatic) and TPH $C_{>16}$-C_{21} (aromatic) fractions, respectively. It is intended that the sum of the laboratory reported TPH C_{15}-C_{28} and C_{29}-C_{36} levels would be compared to the lowest of these criteria as a screening assessment, with speciated analysis only necessary where direct comparison is required.

8.14 Characterisation of Physical and Chemical Properties of COPCs

A range of physical and chemical properties are required to be identified for each of the COPCs to allow the risk modelling to occur. This have been summarised in **Table 8.13** for physical properties and **Table 8.14** for properties affecting the dermal availability of the COPC. All values have been sourced from the most recent values available to the on-line Risk Assessment Information System. Where values for a particular property are not available within RAIS, the default values provided to the RISC model have been adopted.

Table 8.13: Summary of Physical Properties of COPCs

COPC	Diffusivity in air	Diffusivity in water	Henry's Law constant	Soil-water partition coefficient	Organic carbon partition coefficient	Log of octonal water partition coefficient
	D_a (cm^2/s)	D_w (cm^2/s)	H	K_D (cm^3/g)	K_{OC} (L/kg)	Log K_{OW}
Ammonia	0.1	$1*10^{-5}$	$6.58*10^{-4}$	0.4	-	-
Arsenic	-	-	-	29	-	-
Cadmium	-	-	-	75	-	-
Chromium	-	-	-	19 (VI) $1.8*10^5$ (total)	-	-
Lead	-	-	-	900	-	-
Nickel	-	-	-	65	-	-
Cyanide	0.211	$2.46*10^{-5}$	$5.44*10^{-3}$	9.9	2.84	-0.25
Benzene	$8.95*10^{-2}$	$1.03*10^{-5}$	0.227	-	146	2.13
Toluene	$7.78*10^{-2}$	$9.2*10^{-6}$	0.271	-	234	2.73
Ethylbenzene	$6.85*10^{-2}$	$8.46*10^{-6}$	0.322		446	3.15
Xylenes	$8.74*10^{-2}$	$9.90*10^{-6}$	0.212	-	383	3.12
1,2,4-trimethylbenzene	$6.07*10^{-2}$	$7.92*10^{-6}$	0.252		614	3.63
TPH C_6-C_8 (ali)	0.1	$1*10^{-5}$	51	-	$4*10^3$	4.0
TPH C_8-C_{16} (ali)	0.1	$1*10^{-5}$	130	-	$2.5*10^5$	5.6
TPH C_8-C_{16} (aro)	0.1	$1*10^{-5}$	0.14	-	$2.5*10^3$	3.5
TPH $C_{>16}$ (ali)	0.1	$1*10^{-5}$	$6.4*10^3$	-	$1*10^9$	8.9
TPH $C_{>16}$ (aro)	0.1	$1*10^{-5}$	$1.3*10^{-2}$	-	$1.6*10^4$	4.7
Benz(a)anthracene	$3.2*10^{-2}$	$7.7*10^{-6}$	$4.91*10^{-4}$	-	$1.77*10^5$	5.76

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COPC	Diffusivity in air	Diffusivity in water	Henry's Law constant	Soil-water partition coefficient	Organic carbon partition coefficient	Log of octonal water partition coefficient
	D_a (cm^2/s)	D_w (cm^2/s)	H	K_D (cm^3/g)	K_{OC} (L/kg)	Log K_{OW}
Benzo(a)pyrene	$4.3*10^{-2}$	$9.0*10^{-6}$	$1.87*10^{-5}$	-	$5.87*10^{5}$	6.13
Benzo(b)fluoranthene	$2.3*10^{-2}$	$5.6*10^{-6}$	$2.69*10^{-5}$	-	$5.99*10^{5}$	5.78
Benzo(k)fluoranthene	$2.3*10^{-2}$	$5.6*10^{-6}$	$2.39*10^{-5}$	-	$5.87*10^{5}$	6.11
Chrysene	$2.5*10^{-2}$	$6.2*10^{-6}$	$2.14*10^{-4}$	-	$1.81*10^{5}$	5.81
Dibenz(a,h)anthracene	$2.0*10^{-2}$	$5.2*10^{-6}$	$5.76*10^{-6}$	-	$1.91*10^{6}$	6.75
Dibenzofuran	$4.1*10^{-2}$	$7.38*10^{-6}$	$8.71*10^{-3}$	-	$9.16*10^{3}$	4.12
Fluoranthene	$3.0*10^{-2}$	$6.4*10^{-6}$	$3.62*10^{-4}$	-	$5.55*10^{4}$	5.16
Fluorene	$4.40*10^{-2}$	$7.89*10^{-6}$	$3.93*10^{-3}$	-	$5.55*10^{4}$	5.16
Indeno(1,2,3-c,d)pyrene	$1.9*10^{-2}$	$5.7*10^{-6}$	$1.42*10^{-5}$	-	$1.95*10^{6}$	6.70
2-methylnaphthalene	$5.24*10^{-2}$	$7.78*10^{-6}$	$2.12*10^{-3}$	-	$2.48*10^{3}$	3.86
Naphthalene	$6.05*10^{-2}$	$8.38*10^{-6}$	$1.80*10^{-2}$	-	$1.54*10^{3}$	3.30
Pyrene	$2.87*10^{-2}$	$7.25*10^{-6}$	$4.87*10^{-4}$	-	$5.43*10^{4}$	4.88
Phenol	$8.34*10^{-2}$	$1.03*10^{-5}$	$1.36*10^{-5}$	-	187	1.46
2,4-dimethylphenol	$6.22*10^{-2}$	$8.31*10^{-6}$	$3.89*10^{-5}$	-	492	2.3
Cresols	$8.37*10^{-2}$	$9.78*10^{-6}$	$4.91*10^{-5}$	-	307	1.95

Skin permeability coefficients and dermal absorption factors for each of the COPCs as used in the modelling are summarised in **Table 8.14** following.

Table 8.14: Summary of Skin Adsorption Properties of COPCs

COPC	Skin permeability coefficient	Dermal absorption factor	Source
	K_p (cm/h)	Dermal ABS (-)	
Ammonia	$1 * 10^{-3}$	-	Risk Assessment Information System No RAGS Part E ABS factor.
Arsenic	$1 * 10^{-3}$	0.03	Risk Assessment Information System
Cadmium	$1 * 10^{-3}$	$1 * 10^{-3}$	Risk Assessment Information System
Chromium	$1 * 10^{-3}$	-	Risk Assessment Information System as based on value for 'total chromium'. No RAGS Part E ABS factor.
Lead	$1 * 10^{-4}$	0.1	Risk Assessment Information System. ABS based on RAGS Part E value for 'lead alkyls'.
Nickel	$2 * 10^{-4}$	-	Risk Assessment Information System. No RAGS Part E value available
Cyanide	$7.5*10^{-4}$	-	Risk Assessment Information System
Benzene	$1.49 * 10^{-2}$	-	Risk Assessment Information System. No RAGS Part E value available
Toluene	$4.53 * 10^{-2}$	-	Risk Assessment Information System. No RAGS Part E value available
Ethylbenzene	$7.39 * 10^{-2}$	-	Risk Assessment Information System. No RAGS Part E value available
Xylenes	$7.04 * 10^{-2}$	-	Risk Assessment Information System as based on value for 'xylene, mixture'. No RAGS Part E ABS factor.
1,2,4-trimethylbenzene	$8.57*10^{-2}$	-	Risk Assessment Information System. No RAGS Part E value available
TPH C_6-C_9 (ali)	0.75	-	Value provided in RISC chemical database. No RAGS Part E value available.
TPH C_{10}-C_{14} (ali)	1.9	0.1	RAGS Part E for semivolatile organics
TPH C_{10}-C_{14} (aro)	$8.7 * 10^{-2}$	0.1	RAGS Part E for semivolatile organics
TPH C_{15}-C_{28}	0.3	0.1	RAGS Part E for semivolatile organics
TPH C_{29}-C_{36}	1.5	0.1	RAGS Part E for semivolatile organics
Benz(a)anthracene	0.552	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Benzo(a)pyrene	0.713	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Benzo(b)fluoranthene	0.417	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Benzo(k)fluoranthene	0.691	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Chrysene	0.596	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Dibenz(a,h)anthracene	0.953	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Dibenzofuran	$9.75*10^{-2}$	0.1	Risk Assessment Information System. RAGS Part E for semivolatile organics

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COPC	Skin permeability coefficient	Dermal absorption factor	Source
	K_p (cm/h)	Dermal ABS (-)	
Fluoranthene	0.308	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Fluorene	0.11	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Indeno(1,2,3-c,d)pyrene	1.24	0.13	Risk Assessment Information System. RAGS Part E ABS factor
2-methylnaphthalene	$9.17*10^{-2}$	0.1	Risk Assessment Information System. RAGS Part E for semivolatile organics
Naphthalene	$4.66*10^{-2}$	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Pyrene	0.201	0.13	Risk Assessment Information System. RAGS Part E ABS factor
Phenol	$4.34*10^{-3}$	0.1	Risk Assessment Information System. RAGS Part E ABS factor
2,4-dimethylphenol	$1.09*10^{-2}$	0.1	Risk Assessment Information System. RAGS Part E ABS factor
Cresols	$7.66*10^{-3}$	0.1	Risk Assessment Information System. RAGS Part E ABS factor

8.15 Asbestos Exposure

8.15.1 Characterisation of Potential Occurrence of Asbestos

Limited assessments have been completed on the site for occurrence of asbestos containing materials. Based on previous assessments of historically filled industrial sites completed by JBS, asbestos containing materials (ACM) are commonly present in fill materials. These typically occur as asbestos fibres bound within a cement matrix.

It is noted that within the overall Barangaroo Project Site that asbestos may also occur in insulation / lagging provided to historical gasworks infrastructure. This typically comprises asbestos fibres in a tar matrix. This is considered unlikely for the case of the former gasworks on the Barangaroo Project Site as the development profile of the gasworks was prior to the commercial availability of asbestos products in NSW. Where asbestos products are present in a tar matrix, this would be considered to be substantially more environmentally stable than asbestos fibres present in a cement matrix, consequent of the design and application for a specialised high temperature purpose. The assessment of the matrix in which asbestos occurs is important as it controls the rate at which asbestos fibres are released and may become available to site users.

Assessment of asbestos occurring in a cement matrix for the remainder of the exposure assessment is considered to be sufficiently protective of asbestos that may occur in other matrices on the Barangaroo Project Site.

8.15.2 Identification of Potential Exposure Pathways

The inhalation of asbestos fibres is the primary pathway of concern. By the toxicological review completed in **Section 7.6.17**, there is limited evidence that asbestos fibres are toxic through pathways other than inhalation (i.e. ingestion).

8.15.3 Estimation of Exposure Concentration for Pathways

For asbestos fibres to pose a potential inhalation risk, asbestos fibres need to be released from:

- The fibre cement matrix in which they most likely occur, necessitating a process of asbestos fibre release from the fibre cement matrix, followed by asbestos fibre dispersal to a human breathing zone; or

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- Asbestos fibre release from soils contaminated with free asbestos fibres (i.e. friable asbestos) similarly followed by asbestos fibre dispersal to a human breathing zone.

To estimate an exposure concentration for a human receptor:

1. The quantity of asbestos fibres in the soils is required to be determined. This can include:
    - The extent of free asbestos fibres currently present in soils. This has not been quantified for the site and is not substantially considered further; or
    - Where asbestos containing fibre cement sheet is present on the site (i.e. asbestos containing material – ACM), which is considered likely, the extent of asbestos fibres potentially released from the ACM in the future (**Section 8.15.5**);
2. The rate at which asbestos fibres move out of soils into human breathing zones requires to be quantified. This will include:
    - The rate at which asbestos fibres become airborne from asbestos contaminated soils (**Section 8.15.6** to **8.15.8**); and
    - The extent of dilution of airborne asbestos fibres that will occur between the soil surface and the human breathing zone (**Section 8.15.9**).

Each of the factors has been discussed in turn for the proposed Headland Park. As noted throughout the following sections, there is an absence of site specific data for particularly the second part of the required assessment. In absence of site specific data a literature review has been undertaken.

8.15.4 Occurrence of Free Asbestos Fibres at Barangaroo

On the basis of the limited investigations completed to date, no free asbestos fibres have been identified on the Barangaroo Project Site.

It is considered that asbestos fibres are unable to be readily quantified in soils. No NATA accredited laboratory method is available to reliably report a quantified number / weight of asbestos fibres in a soil sample. enHealth (2005) further states that current asbestos in soil analytical methods should be considered as 'qualitative' only.

On this basis, any soils which are reported to have free asbestos fibres present will be considered to be unsuitable for use on the Headland Park Aite. A quantified level of asbestos fibres in soils, that would be able to be compared to an asbestos criterion derived by risk assessment, is considered unable to be determined.

8.15.5 Occurrence of ACM at Headland Park

As discussed earlier, it is considered most conservative to assume that asbestos potentially occurs in a fibre cement matrix (anticipated as fibre cement fragments) across the Barangaroo Project Site.

Free fibres are typically not identified in the proximity of ACM on contaminated sites. Free fibres have not been identified in the proximity of the limited detections of ACM on the Barangaroo Project Site. In the absence of detection of free asbestos fibres in the proximity of ACM, there is no site specific premise to develop a relationship between the asbestos contained in the ACM, and asbestos that may potentially be released from ACM impacted soils as free asbestos fibres.

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8.15.6 Generation of Asbestos Fibres from Asbestos Cement Materials

Asbestos on the Barangaroo Project Site is anticipated to be most conservatively characterised in the form of bound asbestos fibre cement sheet. Asbestos cement is commonly reported to be a mixture of about 10% asbestos fibres and 90% Portland cement (although enHealth 2005 and WA DoH 2009 recommend that its is assumed asbestos cement materials have a 15% content of asbestos). The product's performance requires that the cement matrix adheres to the outside of the fibres and fibre bundles so that the high tensile strength of the fibres is used to create a stronger product. The asbestos is added to the cement and wet mixed before being formed, compressed and cured to produce the end fibre cement product. This process is intended to prevent the release of asbestos fibres from the ACM. For releases of asbestos fibres to occur, processes require to occur to compromise the ACM properties. These processes would be anticipated to be limited to:

- Weathering of ACM; and/or
- Mechanical damage to the ACM.

Weathering

All materials are subject to weathering when exposed to the atmosphere and moisture. A range of processes takes place as the surface is exposed to electromagnetic waves, moisture, frost fracture, chemicals, gases and biological organisms. Chrysotile is known to have limited resistance to acid attack and both acid rain (sulphuric acid) and organic acids from moulds, mosses and lichen will react with the exposed chrysotile asbestos to remove magnesium hydroxide from the structure (Hodgson 1979 and Favero-Longo 2005).

Cement is also subject to weathering and a number of chemical reactions will occur. The most water soluble component of cement is calcium hydroxide and this is dissolved and washed out by water. Calcium hydroxide also reacts with carbon dioxide to form less soluble calcium carbonate, with further reactions causing calcium carbonate to be turned into more soluble calcium bicarbonate.

Increasing acidity, and the presence of sulphate and carbonate ions, will increase the solubility and removal of all chemical components of cement from the exposed surface layer of fibre cement sheet. The duration of exposure and the acidity of the environment will largely determine the rate of dissolution and wash out of the surface cement matrix, leaving asbestos fibres only loosely attached to the surface and more able to become airborne. The rate of corrosion of the surface of asbestos cement has been estimated at 0.024mm/year in clean environments (Spurney, 1989) and 0.1mm/year in urban environments where higher acidity is expected (UK Health & Safety Laboratory, 2007).

EnHealth (2005) reports that:

- Concentrations of asbestos fibres in air above weathered asbestos cement sheeting have been measured at up to 0.0012 f/ml. The area or extent of the sheeting was not reported;
- Fibre emission factors of 106 – 109 f/m^2/h have been measured from weathered asbestos cement products. Meteorological conditions or other factors which may have affected the generation of the asbestos fibres have not been able to be appropriately reported, presumably as the measurements have been undertaken over an extended sampling period where these factors are variable; and
- Measurements of asbestos fibre concentrations in the vicinity of buildings containing corroded and weathered asbestos cement products have recorded

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airborne asbestos fibre concentrations in the range of 0.0002 – 0.0012 f/ml. The area or extent of the sheeting was not reported.

Mechanical Damage

Any physical breaking and cracking of ACM exerts high mechanical forces to the fracture surface and tends to pull out asbestos fibres and bundles making them more able to become airborne. A proportion of the fibres disturbed during mechanical breakage will be made airborne at the time. Mechanical attrition of the cement will also lead to the release of asbestos fibres and cutting of the cement sheets with saws and angle grinders is particularly able to release fibres from inside the asbestos cement.

It has been demonstrated in UK Health & Safety Laboratory (2007) 'Investigation of the chrysotile fibres in an asbestos cement sample' that individual asbestos fibres are released during the breaking of asbestos cement products with a hammer. A range of other studies have also measured the airborne release of asbestos fibres during agitation of asbestos cement products. These are summarised in **Table 8.15**. It is noted in **Table 8.15** that the reported concentrations have been measured in the proximity of the ACM material, generally as personal levels (i.e. collected by sample inlets on worker clothing in the proximity of breathing zone).

Table 8.15: Published Rates of Asbestos Fibre Generation (Presented as Personal Sample Levels)

Activity	Range	Reference
Roof repair "representative"	<0.01 – 0.3 f/ml	CONSAD, 1990
Roof Removal "representative"	<0.01 – 0.2 f/ml	CONSAD, 1990
Replacing corrugated asbestos cement	<0.01 f/ml	Roberts, 1985
Collecting sheets and cleaning	0.24 f/ml	Roberts, 1985
Removal of corrugated sheets (detachment and sliding to gutter)	0.047 f/ml	Preart, 1993
Throwing sheets into lorry	0.161 f/ml	Preart, 1993
Removal of corrugated sheets (detachment, stacking on elevator, placing in pallets)	0.028, 0.038 f/ml	Preart, 1993
Removal of corrugated sheets (detachment)	0.018 f/ml	Preart, 1993
Stacking of sheets on pallets	0.032 f/ml	Preart, 1993
Removal of slates (detached with hammer)	0.064 f/ml	Preart, 1993
Sliding slates to gutter; throwing to ground	0.195 f/ml	Preart, 1993
Removal of slates (detachment and stacking)	0.037, 0.044 f/ml	Preart, 1993
Removal of slates (detachment and placing in container on roof)	0.050, 0.176 f/ml	Preart, 1993
Removal of slates (pulling off, stacking on elevator, broken slates thrown to ground)	0.100, 0.122 f/ml	Preart, 1993
Removal of slates (detachment with hammer, sliding to gutter)	0.068 f/ml	Preart, 1993
Bringing slates down and throwing into container	0.056 f/ml	Preart, 1993
Dry replacement (severely weathered) – unfastening, removal, stacking, disposal, installation of new roofing	0.03-0.24 f/ml	Brown, 1987
Dry unfastening, removal, disposal, installation of new roofing (no stacking)	0.03 f/ml	Brown, 1987
Dry replacement (severely weathered)	0.04-0.27 f/ml	Brown, 1987
Dry removal (painted)	0.07-0.32 f/ml	Brown, 1987
Wet removal (painted) and replacement (careful handling and wetting as stacked)	<0.01 – 0.07 f/ml	Brown, 1987
Replacement (severely weathered) after lignin sulphonate treatment	0.23 f/ml	Brown, 1987
Replacement (severely weathered) after sealing with acrylic resin	0.03 – 0.08 f/ml	Brown, 1987
Replacement (severely weathered) after sealing with acrylic resin	0.04 – 0.26 f/ml	Brown, 1987
Roof removal by demolition, building collapsed	0.10 – 0.47 f/ml	Brown, 1987
Roof removal by placement onto scissor lift	0.04 – 0.12 f/ml	Brown, 1987
Roof removal with roof sheets stacked in a confined space	0.30 – 0.53 f/ml	Brown, 1987
Roof removal with roof sheets stacked in confined space (accumulated dust under laps and ridges)	0.34 – 1.1 f/ml	Brown, 1987
Wet roof removal	0.05 – 0.06 f/ml	Brown, 1987
Wet roof removal with roof sheets stacked in a confined space	0.10 – 0.13 f/ml	Brown, 1987
Wet roof removal with roof sheets stacked in confined space (accumulated dust under laps and ridges)	0.29 – 0.68 f/ml	Brown, 1987
Roof removal with roof sheets sealed with acrylic resin	0.11 – 0.32 f/ml	Brown, 1987
Roof removal with roof sheets sealed with acrylic resin (sheets stacked in confined space; accumulated dust under laps and ridges)	0.41 – 0.76 f/ml	Brown, 1987

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By review of **Table 8.15**, each of the activities listed are highly unlikely to be replicated in the urban environment of the proposed Headland Park. However the range of positive measurements confirms that fibre release will happen when bound asbestos within fibre cement matrices are agitated and these processes require to be considered when estimating the potential future release of asbestos fibres from ACM.

8.15.7 Estimate of Free Asbestos Fibre Generation Rate from ACM

To allow the quantified risk assessment calculations to be completed, a rate of potential asbestos fibre generation from ACM needs to be determined. For the purposes of this assessment this has been set at 0.024mm/year as per the anticipated rate of weathering of ACM in a clean environment.

This has been further quantified using an 'asbestos powder' bulk density of 0.45 g/cm^3 and assuming that 15% of the weathered ACM is present as asbestos fibres as recommended by enHealth (2005) and WA DoH (2009), this equates to a mass of weathered asbestos fibres of 1.6 mg asbestos fibres / m^2 asbestos sheet / year.

The conservatism of this value can be assessed by comparison to the enHealth (2005) published rate of asbestos fibre generation of 106 – 109 $f/m^2/h$ from weathered ACM. To allow the comparison to be undertaken a conversion factor is required to convert mass of asbestos fibres to actual fibre counts. The correlation between fibre counts and mass measurements of asbestos fibres is reported by US EPA to be very poor. Six data sets are reported to be available in US EPA (1998) which include both fibre and mass measurements which show a conversion between TEM mass and PCM fibre count that ranges from 5-150 $(ug/m^3)/(f/mL)$. The geometric mean of these results is reported to be 30 (ug/m^3) / (f/mL). This indicates that one asbestos fibre weighs $3 * 10^{-11}$g. Using the factor, the adopted rate of weathering (0.024mm/year) is found to be equivalent to a release of $6.2 * 10^7$ $f/m^2/h$ from ACM. This is substantially higher than the enHealth (2005) measured values.

The adoption of this value is further considered highly conservative as it assumes that the complete ACM sheet / fragment to be constantly exposed to weathering. The nature of site surface use as will occur with human occupation would prevent this from ever occurring on a significant scale (i.e. establishment and maintenance of lawn areas and gardens as anticipated with an iconic Sydney parkland etc). This factor is also considered sufficient to account for potential short term fibre releases as may occur by mechanical damage to ACM on the Headland Park Site. Fibre release by mechanical damage would be observed to occur from comparatively very small surface areas, when compared to the assumption of the occurrence of weathering on the largest side of the sheet, by the nature of cracking caused by damage occurring orthogonal to the largest area of the sheet volume.

The minimum thickness of ACM as detected on historically filled sites is typically found to be equal to 4mm, with typical thicknesses of 6mm and thicknesses as great as 12mm where historical asbestos roofing products are encountered. Based on the assumed weathering rate, this would indicate that a maximum of 40% of the mass of the smallest ACM fragment anticipated would be 'broken down' (facilitating the release of fibres) over a 70 year exposure period.

8.15.8 Generation of Asbestos Fibres from Asbestos Fibre Contaminated Soils

As discussed in **Section 8.15.3**, two factors are required to cause exposure to asbestos fibres, the current or potential future presence of asbestos fibres in soils, as discussed in

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Section 8.15.6, and the rate at which asbestos fibres are released from soils into potential human breathing zones.

Two published studies are known to be available which have attempted to quantify the rate of asbestos fibre release from soils. These include:

- Addison, J., Davies, L.S.T., Robertson, A., and Willey, R.J. (1988) 'The Release of Dispersed Asbestos Fibres from Soils Technical Memoranda', TM/88/14, Institute of Occupational Medicine: 50, Edinburgh, UK; and
- Swartjes, F.A., Tromp, P.C. (2008). A Tiered Approach for the Assessment of Human Health Risks of Asbestos in Soils. Soil and Sediment Contamination, Volume 14, Issue 4, pp. 137 – 149 incorporating Swartjes F.A, Tromp P.C, Wezenbeek J.M (2003). Assessment of the Risks of Soil Contamination with Asbestos. National Health and Environmental Institute, Netherlands, RIVM Report 711701034/2003.

Each is discussed following.

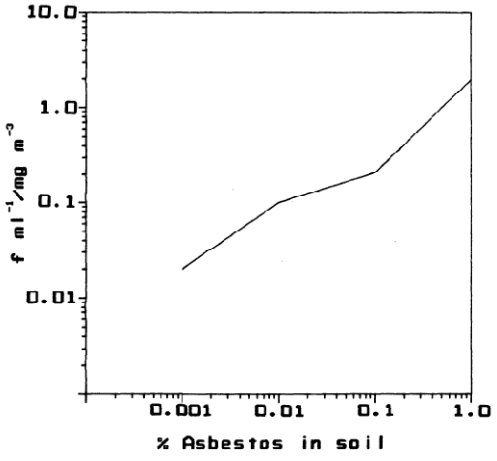
Addison et al (1988)

Assessment of the potential for asbestos generation from asbestos contaminated soils has been undertaken in Addison et al (1988). This study assessed the potential generation of free asbestos fibres from asbestos contaminated soils.

It was found that potentially high concentrations of asbestos fibres could be present in dust generated from contaminated soils. It was found that soils with concentration of free asbestos fibre of 1% by weight could generate airborne fibre concentrations greater than 20 f/ml where dust levels were below 5 mg/m^3. Dry loose soils with 0.001% asbestos fibres reported respirable asbestos concentrations greater than 0.01 f/ml while dust levels were below 5 mg/m^3.

The potential generation of asbestos fibres was found to be reduced for chrysotile forms of asbestos when compared with amphibole forms. Increasing moisture content of soils reduced potential asbestos fibre generation. Clayey soils generated less asbestos fibres than loose sandy soils.

On the basis of the tests completed by Addison et al (1988) a relationship between the normalised airborne fibre concentration (f/ml / mg/m^3) and the proportion of asbestos in soil was produced (**Diagram 8.2**).



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Diagram 8.2: The relationship between the normalised airborne fibre concentration (f/ml / mg/m^3) and the proportion of asbestos in soil; average results from all test runs (Addison et al 1988)

Swartjes et al (2003) and Swartjes & Tromp (2008)

A more recent assessment of the generation of asbestos fibres from soils has been undertaken by Swartjes & Tromp (2008) incorporating the findings of Swartjes et al (2003). An inventory of more than 1 000 measurements of asbestos fibre generation from asbestos impacted soils is reported to have been reviewed. These data resulted from:

- Worse case simulation experiments (wind blower with dry soil and loose asbestos fibres);
- Field experiments consisting of daily practice activities including driving on contaminated roads, digging and dumping and sifting of humid soil on sites contaminated with:
    - Friable asbestos in soils; and
    - Bound asbestos (i.e. ACM) in soils.

Diagram 8.3 following shows the data obtained by Swartjes et al (2003) and Swartjes & Tromp (2008) showing the relationship between soil and air concentrations of asbestos. The graph shows the airborne asbestos concentration during the simulation experiments and field measurements with friable and bound asbestos impact in soils. 95% confidence intervals are also shown.

It is noted by the authors in the preparation of the graph that the worse case simulation experiments give higher airborne asbestos concentrations.

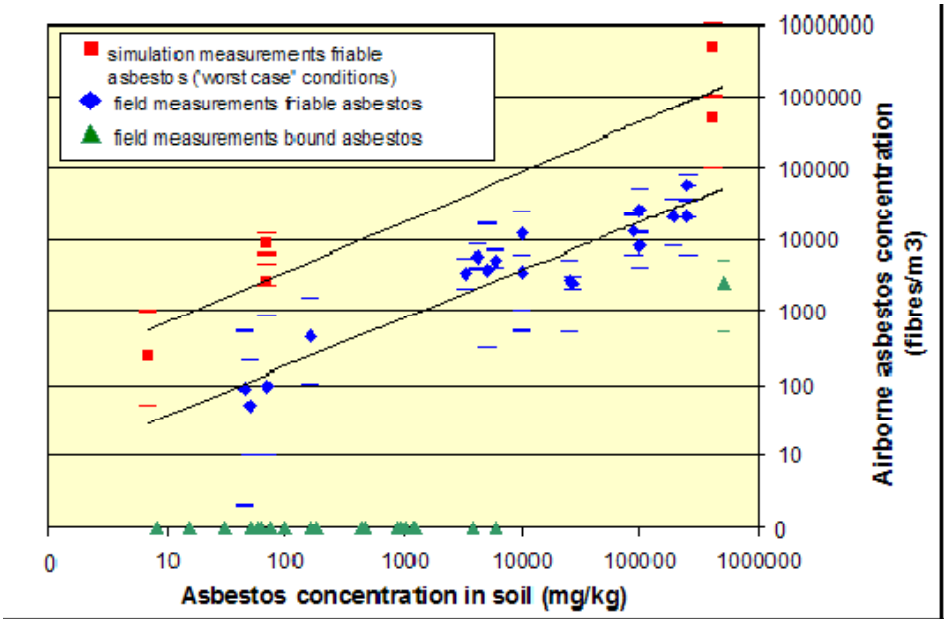


Diagram 8.3: Results showing the relationship developed between soil and air concentrations of asbestos

Estimate of Free Asbestos Fibre Generation Rate from ACM

The Swartjes et al (2003) and Swartjes & Tromp (2008) method for estimating asbestos fibre generation from soils has been preferred for use in this risk assessment on the following basis:

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- Data have been collected from actual contaminated sites and is more representative of what may occur in real-life scenarios as compared to the controlled environment simulations of Addison et al (1988);
- Use of the Addison et al (1988) relationship requires an estimate of future dust emissions from soils on the site. Dust emissions would be anticipated to be highly variable and subject to many factors. It is considered that reliable estimates of future site dust emissions are not possible; and
- The Swartjes et al (2003) and Swartjes & Tromp (2008) data contain a range of levels of friable asbestos as may be reasonably encountered in the field.

The Swartjes et al (2003) and Swartjes & Tromp (2008) data are further noted to have been adopted by other regulators for the derivation of asbestos criteria.

8.15.9 Dispersion of Asbestos Fibres between Soil Surface and Human Exposure

It is reported in Swartjes & Tromp (2008) that measurements of airborne asbestos fibres were undertaken by both personal air samples (in the breathing zone of assessed workers) and stationary air samples near the asbestos fibre generating activities. On this basis, it is considered that the adopted sampling and measurement approach has incorporated the dilution of asbestos fibre concentrations as may occur between the source of asbestos fibres and breathing zones. No further assessment of dispersion of asbestos fibres is required.

8.15.10 Estimation of Contaminant Intakes for Pathways

The contaminant, asbestos fibres, becomes available when released from an asbestos cement matrix. This may occur on the Headland Park by gradual weathering of ACM fragments causing break down of the cement component of bound ACM allowing fibres to be released as fugitive emissions, and by mechanical impact of bound ACM fragments as may occur with future excavation activities.

Fibres released during these scenarios need to be inhaled by human receptors for an exposure pathway to be considered complete. Hence, the estimation of the contaminant intake is a function of:

- The dilution of asbestos currently occurring within the ACM to future levels of airborne asbestos fibres as present within human breathing zones as estimated by the methods assessed in **Sections 8.15.3** to **8.15.9**; and
- The intake of the exposed human receptor (defined following).

8.15.11 Intake Estimation

The intake estimation and associated risk modelling are unable to be undertaken using the RISC package, as it is with the remainder of the COPCs. The approach undertaken to determine the intake of asbestos for each of the potentially exposed populations is summarised following.

The estimated exposure (or intake) of a person is normalised for time and body weight and is generally calculated as:

$$\text{Intake} = \frac{\text{Concentration} \times \text{Contact Rate} \times \text{Exposure Frequency} \times \text{Exposure Duration}}{\text{Body Weight} \times \text{Averaging Time}}$$

Concentration is able to be defined by the procedures detailed in **Sections 8.15.5** to **8.15.9**. Each of the other parameters are characterised by exposure estimation. Exposure estimation has been undertaken by the consideration of a reasonable maximum

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exposure (RME) on a particular site (USEPA, 1989a). The goal of RME is to combine upper bound and average exposure factors in a manner such that the result represents an exposure scenario that is both protective and reasonable. This is not one which is the absolute worst case but that which represents a reasonable maximum exposure.

The approach for exposure assessment used here is based on the procedures developed by the US EPA (1989 and 1991). Exposure parameters have been defined in **Section 8.3**.

8.16 Risk Modelling

As site specific criteria are intended to be derived which can be used to validate the quality of material coming into the proposed Headland Park, and the suitability of current in-situ soils with the proposed site-uses, risk modelling has been required to be based on a number of default exposure parameters. The exposure scenarios and parameters have required that the Park be divided into a number of soil zones. These soil zones are shown on **Figure 16** and are based on exposed populations, distances from proposed park structures, the depth of groundwater / seepage water and the anticipated vapour flows through soils into indoor building spaces. These soil zones are defined in **Table 8.16**.

Table 8.16: Summary of Soil Zones for Setting of Site Specific Criteria

Zone ID	Location / Depth	Description / Comments
Zone 1	0-0.5m below open area of Park	Consist of growing soils to a minimum depth of 0.5m
Zone 2	Below Car Park (Unsaturated) (Saturated)	Unsaturated soils present above highest depth of groundwater, within groundwater tidal fluctuation zone and below depth of groundwater below Car Park. Assessment has considered unsaturated and saturated soils. Requires assessment of exposure of infiltrating seepage water into Car Park building The criteria also require to be used for clay liner and in-situ soils located <30m laterally from the 'Car Park'.
Zone 3	0-1m away from 'Cultural Space'	Requires assessment of exposure of 'Cultural Space' occupants and Car Park occupants to vapours from soils. Requires assessment of exposure of infiltrating seepage water into Car Park building.
Zone 4	>1-10m below / away from 'Cultural Space' and 0-10m away from Car Park	Soils assumed to be unsaturated in close proximity of 'Cultural Space' and Car Park. Excludes soils underlying clay liner Requires assessment of exposure of infiltrating seepage water into Car Park building
Zone 5	>10-30m below / away from 'Cultural Space' and away from Car Park	Soils assumed to be unsaturated in sufficient proximity of 'Cultural Space' and Car Park for lateral migration of impact to occur. Excludes soils underlying clay liner Requires assessment of exposure of infiltrating seepage water into Car Park building
Zone 6	>30m lateral distance from western portion of 'Cultural Space' and >0.5m below Park surface	Soils outside the lateral distance to the 'Cultural Space' and Car Park that would be considered to cause soil vapour to migrate into the 'Cultural Space' / Car Park. The criteria also to be used for clay liner and in-situ soils located >30m laterally from the 'Cultural Space'. Soils underlying the clay liner have been assumed to have a reduced vapour migrations potential to the Cultural Space and Car Park. On this basis, in-situ and fill based soils placed under the clay liner have been assessed as General Fill.

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As per the guidance provided to NZ Ministry for the Environment (1999) for modelling of impact at near surface depths underlying maintenance excavations, a diffusion length of 0.1m has been used for the inhalation exposure modelling for scenarios where impact is potentially present at a near surface depth.

Site specific criteria have been derived for each constituent by back calculation of the risk and hazard results as derived for a unit concentration (1mg/kg or 1mg/l).

Site specific criteria have also been derived for water proposed to be re-used on-site as irrigation water. Unlike criteria for other seepage water scenarios, no assessment has been undertaken of the total levels of contaminants in soils to allow irrigation water to be met. It is assumed that provision will be available on site to treat collected surface water / seepage water prior to re-use as irrigation water

8.17 Models

Each of the potential exposure scenarios for each of the appropriate soil zones has been assessed by modelling. Modelling outputs are provided as **Appendix D**. **Table 8.17** summarises each of the populations, media and exposure pathways assessed by the risk modelling.

Table 8.17: Summary of Risk Modelling

Soil Zone	Population	Media	Exposure Pathways			
			Inhalation - Particulates	Inhalation – Vapour	Oral	Dermal
1	Recreational	Soil		•	•	•
		Seepage Water		•		
	Sub-Surface Maintenance	Soil	•	•	•	•
		Seepage Water		•	•	•
	Commercial / Industrial (Gardener)	Soil		•	•	•
		Seepage Water		•		
2	Occasional User (Car Park)	Soil[1]		•		
		Groundwater		•		
		Pooled Infiltrating Seepage		•		•
	Commercial / Industrial (Car Park Attendant)	Soil[1]		•		
		Groundwater		•		
3	Commercial / Industrial ('Cultural Space')	Soil		•		
	Commercial / Industrial (Car Park Attendant)	Soil		•		
	Recreational ('Cultural Space')	Soil		•		
	Occasional User (Car Park)	Soil		•		
		Pooled Infiltrating Seepage		•		•
4	Commercial / Industrial ('Cultural Space')	Soil		•		
	Commercial / Industrial (Car Park Attendant)	Soil		•		
	Recreational ('Cultural Space')	Soil		•		
	Occasional User (Car Park)	Soil		•		
		Pooled Infiltrating Seepage		•		•
5	Commercial / Industrial ('Cultural Space')	Soil		•		
	Commercial / Industrial (Car Park Attendant)	Soil		•		
	Recreational ('Cultural Space')	Soil		•		
	Occasional User (Car Park)	Soil		•		
		Pooled Infiltrating Seepage		•		•
6	Recreational	Soil		•		
	Commercial / Industrial (Gardener)	Soil		•		
	Sub-Surface Maintenance	Soil		•		

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Soil Zone	Population	Media	Exposure Pathways			
			Inhalation - Particulates	Inhalation – Vapour	Oral	Dermal
-	Recreational	Irrigation Water		•		•
	Commercial / Industrial (Gardener)	Irrigation Water		•		•
Notes: 1 Considered for unsaturated soil horizon only						

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9 Assessment of Human Health Risk

9.1 Risk Measurement

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The slope factor (SF) converts estimated daily intakes averaged over a lifetime of exposure directly to incremental risk of an individual of developing cancer. Because relatively low intakes (compared to those experienced by test animals) occur with exposures on most contaminated sites, it can generally be assumed that the dose response relationship is linear in the low-dose portion of the multistage model dose-response curve. Under this assumption the slope factor is constant and risk is directly related to intake. Thus the following linear based carcinogenic risk equation is used:

Risk = CDI * SF

where: Risk – unitless probability of an individual developing cancer;

CDI – chronic daily intake averaged over 70 years (mg/kg-day); and

SF – slope factor expressed in $(mg/kg\text{-}day)^{-1}$.

The slope factor is often an upper 95% percentile confidence limit of the probability of response based on experimental animal data used in the multistage model. Consequently, the carcinogenic risk estimate will often be an upper bound estimate (US EPA, 1989).

The measure used to describe the potential for non carcinogenic toxicity to occur in an individual is not expressed as the probability of an individual suffering an adverse effect. Instead, the potential for non carcinogenic effects is evaluated by comparing an exposure level over a specific time period with a reference dose derived for a similar exposure period. The ratio of exposure to toxicity is called a hazard quotient and is calculated as:

Noncancer hazard quotient = E / RfD

where: E – exposure level (or intake); and

RfD – reference dose (E and RfD are expressed in the same units (US EPA, 1989).

At most sites the potential health effects of more than one chemical require to be assessed. Potential additive effects of exposure to multiple chemicals requires to be considered in risk assessment. US EPA (1989) recommends that carcinogenic risks are added.

To assess the overall potential for non-carcinogenic effects posed by more than one chemical a hazard index approach is used. This is undertaken by summing of all hazard quotients to determine a hazard index.

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9.2 Adopted Risk Criteria

Acceptable risk guidelines are available from a range of national and international environmental agencies. These include:

- US EPA (1991) states that "Where the cumulative site risk to an individual based on an reasonable maximum exposure for both current and future land use is less than 10^{-4},…. action is generally not warranted unless there are adverse environmental impacts". Where the level of risk exceeds 10^{-4} it is recommended that remediation goals are developed based on a 10^{-6} cancer risk;
- WHO (1996) 'Guidelines for Drinking Water Quality' are based on a risk of 1 in 100 000 (1×10^{-5}); and
- NHMRC/ARMCANZ (1996) 'Australian Drinking Water Guidelines' nominate a negligible level of risk of 1 in 1,000,000 (1×10^{-6}).

No formal policy exists for the acceptable level of cancer risk, however it has been the experience of JBS that NSW, ACT and Victorian Environmental Auditors generally consider risks in the range of 1 in 100 000 (1×10^{-5}) to be acceptable. This level of acceptable risk will be adopted for this site.

For the purposes of this risk assessment an acceptable level of risk is defined as risk less than 1 x 10^{-5} incremental lifetime risk of cancer.

9.3 Assessment of Background Contributions

Background levels of a range of constituents were nominated in **Table 7.19** and are shown in **Table 9.1** following. An additional assessment has been undertaken on the basis of a recreational receptor to determine the level of risk / hazard posed by these constituents at the background concentrations, to determine the potential significance of the background levels. This has been undertaken by a comparison of the background dose of each constituent to the relevant RfD or RfC available for the constituent. It is noted that this comparison has been undertaken for COPCs with threshold toxicological data only. An assessment of background contributions is not strictly needed for non-threshold chemicals, as assessment in based on incremental risk (i.e. risk in addition to existing exposure).

Table 9.1: Estimation of Potential Background Levels of Hazard and Risk

COPC	Background Levels		% of RfD[1]	% of RfC
	Oral / Dermal	Inhalation		
Arsenic	0.04 mg/day	0.51 ng/m^3	30%	3.4%
Cadmium	0.03 mg/day	0.28 ng/m^3	100%	<1%
Chromium	0.01 mg/day	No data	<1%	-
Lead	0.1 mg/day	48 ng/m^3	41%	9.6%
Nickel	0.2 mg/day	No data	60%	-
Cyanide	0.04 mg/day	No data	4.8%	-
Benzene	Negligible	2.3 ppb (7.7µg/m^3)	-	80%
Toluene	Negligible	4.2 ppb (15.4µg/m^3)	-	<1%
Ethylbenzene	Negligible	0.5 ppb (2.2µg/m^3)	-	<1%
Xylene	Negligible	3.0 ppb (13.1µg/m^3)	-	6.0%
Benzo(a)pyrene	As per PAHs (1µg/day)	0.40 ng/m^3	Non threshold criteria only	Non threshold criteria only
Other PAHs	1µg/day	No data	Generally <1%, apart from naphthalene at 1.4%	-

Note: 1. Based on 70 kg receptor

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Based on review of **Table 9.1**, significant background exposures have been identified for arsenic, cadmium, lead, nickel and benzene. Other constituents are generally found to be below 10%. The following adjustments have been made to the risk based criteria to be protective of existing exposures:

- Reduction of risk based arsenic criteria by a factor of 30%;
- Reduction of risk based cadmium criteria by a factor 90% (i.e. one order of magnitude). It is noted that this not account for the complete background exposure to cadmium, but a reduction by an order of magnitude is considered a significant correction to the criteria;
- Reduction of lead criteria by a factor of 60%; and
- Reduction of all benzene criteria as derived by threshold toxicological data by a factor of 80%.

It is noted that background levels are not available for all the COPCs assessed. The COPCs with background data available are found to be the most prevalent in the environment. Other COPCs would be anticipated to be present at substantially reduced levels and more than likely not have significant levels of background exposure.

9.4 Estimation of Risk

The findings of the each of the modelling scenarios using unit concentrations of COPCs for each exposure scenario, potentially exposed population and exposure pathway are provided as **Appendix D**. A summary of all modelling results is provided in **Appendix D**. Results are summarised as per the adopted zones of soil criteria and the irrigation water criteria in **Tables 9.2** to **9.8**.

It is noted that several of the exposure scenarios have considered potential exposures to future seepage water horizons as may occur on the Park. Risk calculations undertaken as water based contaminants have been equated to equivalent total soil concentrations as may cause those contaminant concentrations in water. Consideration of any potential dilution factors has not been included with the leachability factors, as each of the assessed scenarios has potential human exposure to seepage / groundwater occurring in the proximity of the point of generation of the seepage water.

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Table 9.2: Summary of Human Health Based Criteria for 0-0.5m Soil Horizon (Zone 1)

Constituent	Criteria (mg/kg)		Basis of Criteria
	Soils from Headland Park	Soils from Barangaroo Central & South	
Ammonia	5100	5100	Commercial/industrial (gardener)
Arsenic	140	140	Recreational
Cadmium	7.7	7.7	Recreational
Chromium	450	450	Recreational
Lead	130	130	Recreational
Nickel	600[1]	600[1]	Published
Cyanide	220	220	Recreational
Benzene	1.0	1.0	Recreational
Toluene	>MAX	>MAX	
Ethylbenzene	>MAX	>MAX	
Xylenes	1800	1800	Recreational
1,2,4-trimethylbenzene	21	21	Recreational
TPH C_6-C_8 (ali)	5100	5100	Commercial/industrial (gardener)
TPH C_8-C_{16} (ali)	4600	4600	Recreational
TPH C_8-C_{16} (aro)	2400	2400	Recreational
TPH $C_{>16}$ (ali)	130000	130000	Recreational
TPH $C_{>16}$ (aro)	1900	1900	Recreational
Benz(a)anthracene	31	31	Recreational
Benzo(a)pyrene	3.1	3.1	Recreational
Benzo(b)fluoranthene	31	31	Recreational
Benzo(k)fluoranthene	31	31	Recreational
Chrysene	310	310	Recreational
Dibenz(a,h)anthracene	3.1	3.1	Recreational
Dibenzofuran	>MAX	>MAX	
Fluoranthene	670	670	Recreational
Fluorene	>MAX	>MAX	
Indeno(1,2,3-c,d)pyrene	31	31	Recreational
2-methylnaphthalene	2600	2600	Recreational
Naphthalene	880	880	Recreational
Pyrene	1600	1600	Recreational
Phenol	>MAX	>MAX	
2,4-dimethylphenol	>MAX	>MAX	
Cresols	3100	3100	Recreational

Note: 1. Increased to lowest iof published NEPC (1999) criteria. Toxicological data base don occupational exposures considered overly conservative for Parkland exposure.

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Table 9.3: Summary of Human Health Based Criteria for Unsaturated Soil Below Car Park (Zone 2)

Constituent	Criteria (mg/kg)		Basis of Criteria
	Soils from Headland Park	Soils from Barangaroo Central & South	
Ammonia	>MAX	>MAX	
Arsenic	>MAX	>MAX	
Cadmium	>MAX	>MAX	
Chromium	>MAX	>MAX	
Lead	>MAX	>MAX	
Nickel	>MAX	>MAX	
Cyanide	>MAX	>MAX	
Benzene	0.4	0.4	Occasional user of car park[1]
Toluene	460	460	Aesthetic
Ethylbenzene	47	47	Aesthetic
Xylenes	130	130	Aesthetic
1,2,4-trimethylbenzene	44	44	Occasional user of car park
TPH C_6-C_8 (ali)	6000	6000	Occasional user of car park
TPH C_8-C_{16} (ali)	4500	4500	Occasional user of car park
TPH C_8-C_{16} (aro)	6700	6700	Occasional user of car park
TPH $C_{>16}$ (ali)	>MAX	>MAX	
TPH $C_{>16}$ (aro)	50000	50000	Occasional user of car park
Benz(a)anthracene	95	95	Occasional user of car park
Benzo(a)pyrene	810	810	Occasional user of car park
Benzo(b)fluoranthene	>MAX	>MAX	
Benzo(k)fluoranthene	>MAX	>MAX	
Chrysene	>MAX	>MAX	
Dibenz(a,h)anthracene	>MAX	>MAX	
Dibenzofuran	>MAX	>MAX	
Fluoranthene	>MAX	>MAX	
Fluorene	>MAX	>MAX	
Indeno(1,2,3-c,d)pyrene	>MAX	>MAX	
2-methylnaphthalene	1100	1100	Aesthetic
Naphthalene	610	610	Aesthetic
Pyrene	>MAX	>MAX	
Phenol	>MAX	>MAX	
2,4-dimethylphenol	>MAX	>MAX	
Cresols	>MAX	>MAX	

Notes: 1 Saturated soils have criteria of 180 mg/kg for benzene and 810 mg/kg for benzo(a)pyrene only. All other criteria above maximum recorded concentrations

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Table 9.4: Summary of Human Health Based Criteria for Soils to 1m below Cultural Space (Zone 3)

Constituent	Criteria (mg/kg)		Basis of Criteria
	Soils from Headland Park	Soils from Barangaroo Central & South	
Ammonia	580	580	Commercial / industrial (Cultural Space)
Arsenic	>MAX	>MAX	
Cadmium	>MAX	>MAX	
Chromium	>MAX	>MAX	
Lead	>MAX	>MAX	
Nickel	>MAX	>MAX	
Cyanide	950	950	Commercial / industrial (Cultural Space)
Benzene	0.1	0.1	Commercial / industrial (Cultural Space)
Toluene	180	180	Commercial / industrial (Cultural Space)
Ethylbenzene	25	25	Aesthetics
Xylenes	64	64	Commercial / industrial (Cultural Space)
1,2,4-trimethylbenzene	0.8	0.8	Commercial / industrial (Cultural Space)
TPH C_6-C_8 (ali)	100	100	Commercial / industrial (Cultural Space)
TPH C_8-C_{16} (ali)	75	75	Commercial / industrial (Cultural Space)
TPH C_8-C_{16} (aro)	140	140	Commercial / industrial (Cultural Space)
TPH $C_{>16}$ (ali)	>MAX	>MAX	
TPH $C_{>16}$ (aro)	>MAX	>MAX	
Benz(a)anthracene	39	39	Commercial / industrial (Cultural Space)
Benzo(a)pyrene	810	810	Commercial / industrial (Cultural Space)
Benzo(b)fluoranthene	>MAX	>MAX	
Benzo(k)fluoranthene	>MAX	>MAX	
Chrysene	>MAX	>MAX	
Dibenz(a,h)anthracene	>MAX	>MAX	
Dibenzofuran	>MAX	>MAX	
Fluoranthene	>MAX	>MAX	
Fluorene	>MAX	>MAX	
Indeno(1,2,3-c,d)pyrene	>MAX	>MAX	
2-methylnaphthalene	610	610	Aesthetics
Naphthalene	12	12	Commercial / industrial (Cultural Space)
Pyrene	>MAX	>MAX	
Phenol	>MAX	>MAX	
2,4-dimethylphenol	>MAX	>MAX	
Cresols	>MAX	>MAX	

For Zone 3 exposure modelling was undertaken for exposures within both the Cultural Space and Car Park. The highest Risk / HI predicted for the Car Park was found to be at least 4.3 times lower than the Risk / HI adopted for derivation of the risk based criteria. This was found to be much higher for the more volatile constituents (i.e. monocyclic aromatic hydrocarbons). On this basis, the Zone 3 criteria require to only be measured from the Cultural Space. Less sensitive criteria can be used in close proximity to the Car Park, as described in following sections.

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Table 9.5: Summary of Human Health Based Criteria for Soils >1-10m below / away from 'Cultural Space' / Car Park (Zone 4)

Constituent	Criteria (mg/kg)		Basis of Criteria
	Soils from Headland Park	Soils from Barangaroo Central & South	
Ammonia	750	750	Commercial / industrial (Cultural Space)
Arsenic	>MAX	>MAX	
Cadmium	>MAX	>MAX	
Chromium	>MAX	>MAX	
Lead	>MAX	>MAX	
Nickel	>MAX	>MAX	
Cyanide	>MAX	>MAX	
Benzene	0.1[1]	0.1[1]	Commercial / industrial (Cultural Space)
Toluene	260[1]	260[1]	Commercial / industrial (Cultural Space)
Ethylbenzene	36[1]	36[1]	Aesthetics
Xylenes	86[1]	86[1]	Commercial / industrial (Cultural Space)
1,2,4-trimethylbenzene	1.2[1]	1.2[1]	Commercial / industrial (Cultural Space)
TPH C_6-C_8 (ali)	130[1]	130[1]	Commercial / industrial (Cultural Space)
TPH C_8-C_{16} (ali)	98[1]	98[1]	Commercial / industrial (Cultural Space)
TPH C_8-C_{16} (aro)	180[1]	180[1]	Commercial / industrial (Cultural Space)
TPH $C_{>16}$ (ali)	>MAX	>MAX	
TPH $C_{>16}$ (aro)	>MAX	>MAX	
Benz(a)anthracene	73	73	Commercial / industrial (Cultural Space)
Benzo(a)pyrene	810	810	Seepage water leaching into Car Park
Benzo(b)fluoranthene	>MAX	>MAX	
Benzo(k)fluoranthene	>MAX	>MAX	
Chrysene	>MAX	>MAX	
Dibenz(a,h)anthracene	>MAX	>MAX	
Dibenzofuran	>MAX	>MAX	
Fluoranthene	>MAX	>MAX	
Fluorene	>MAX	>MAX	
Indeno(1,2,3-c,d)pyrene	>MAX	>MAX	
2-methylnaphthalene	940	940	Aesthetics
Naphthalene	17[1]	17[1]	Commercial / industrial (Cultural Space)
Pyrene	>MAX	>MAX	
Phenol	>MAX	>MAX	
2,4-dimethylphenol	>MAX	>MAX	
Cresols	>MAX	>MAX	

Note: 1. Zone 6 criteria may be applied for these constituents where soils are >10m from Cultural Space. Based on inhalation modelling for Car Park compared to Cultural Space indicating that these constituents will occur at much lower levels within the Car Park.

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Table 9.6: Summary of Human Health Based Criteria for Soils >10-30m below / away from 'Cultural Space' / Car Park (Zone 5)

Constituent	Criteria (mg/kg)		Basis of Criteria
	Soils from Headland Park	Soils from Barangaroo Central & South	
Ammonia	2500	2500	Commercial / industrial (Cultural Space)
Arsenic	>MAX	>MAX	
Cadmium	>MAX	>MAX	
Chromium	>MAX	>MAX	
Lead	>MAX	>MAX	
Nickel	>MAX	>MAX	
Cyanide	2500	2500	Commercial / industrial (Cultural Space)
Benzene	0.3[1]	0.3[1]	Commercial / industrial (Cultural Space)
Toluene	950[1]	950[1]	Commercial / industrial (Cultural Space)
Ethylbenzene	140[1]	140[1]	Aesthetics
Xylenes	310[1]	310[1]	Commercial / industrial (Cultural Space)
1,2,4-trimethylbenzene	5[1]	5[1]	Commercial / industrial (Cultural Space)
TPH C_6-C_8 (ali)	430[1]	430[1]	Commercial / industrial (Cultural Space)
TPH C_8-C_{16} (ali)	320[1]	320[1]	Commercial / industrial (Cultural Space)
TPH C_8-C_{16} (aro)	590[1]	590[1]	Commercial / industrial (Cultural Space)
TPH $C_{>16}$ (ali)	>MAX	>MAX	
TPH $C_{>16}$ (aro)	>MAX	>MAX	
Benz(a)anthracene	>MAX	>MAX	
Benzo(a)pyrene	810	810	
Benzo(b)fluoranthene	>MAX	>MAX	
Benzo(k)fluoranthene	>MAX	>MAX	
Chrysene	>MAX	>MAX	
Dibenz(a,h)anthracene	>MAX	>MAX	
Dibenzofuran	>MAX	>MAX	
Fluoranthene	>MAX	>MAX	
Fluorene	>MAX	>MAX	
Indeno(1,2,3-c,d)pyrene	>MAX	>MAX	
2-methylnaphthalene	4300	4300	Aesthetics
Naphthalene	73[1]	73[1]	Commercial / industrial (Cultural Space)
Pyrene	>MAX	>MAX	
Phenol	>MAX	>MAX	
2,4-dimethylphenol	>MAX	>MAX	
Cresols	>MAX	>MAX	

Note: 1. Zone 6 criteria may be applied for these constituents where soils are >10m from Cultural Space. Based on inhalation modelling for Car Park compared to Cultural Space indicating that these constituents will occur at much lower levels within the Car Park.

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Table 9.7: Summary of Human Health Based Criteria for Soils >30m Lateral Distance from 'Cultural Space' / Car Park and >0.5m below Park Surface (Zone 6)

Constituent	Criteria (mg/kg)		Basis of Criteria
	Soils from Headland Park	Soils from Barangaroo Central & South	
Ammonia	>MAX	>MAX	
Arsenic	>MAX	>MAX	
Cadmium	>MAX	>MAX	
Chromium	>MAX	>MAX	
Lead	>MAX	>MAX	
Nickel	>MAX	>MAX	
Cyanide	3400	3400	Aesthetics
Benzene	2.3	2.3	Sub-surface maintenance worker
Toluene	690	690	Aesthetics
Ethylbenzene	80	80	Aesthetics
Xylenes	180	180	Aesthetics
1,2,4-trimethylbenzene	46	46	Sub-surface maintenance worker
TPH C_6-C_8 (ali)	3500	3500	Sub-surface maintenance worker
TPH C_8-C_{16} (ali)	2700	2700	Sub-surface maintenance worker
TPH C_8-C_{16} (aro)	4900	4900	Sub-surface maintenance worker
TPH $C_{>16}$ (ali)	>MAX	>MAX	
TPH $C_{>16}$ (aro)	>MAX	>MAX	
Benz(a)anthracene	>MAX	>MAX	
Benzo(a)pyrene	>MAX	>MAX	
Benzo(b)fluoranthene	>MAX	>MAX	
Benzo(k)fluoranthene	>MAX	>MAX	
Chrysene	>MAX	>MAX	
Dibenz(a,h)anthracene	>MAX	>MAX	
Dibenzofuran	>MAX	>MAX	
Fluoranthene	>MAX	>MAX	
Fluorene	>MAX	>MAX	
Indeno(1,2,3-c,d)pyrene	>MAX	>MAX	
2-methylnaphthalene	2500	2500	Aesthetics
Naphthalene	>MAX	>MAX	
Pyrene	>MAX	>MAX	
Phenol	>MAX	>MAX	
2,4-dimethylphenol	>MAX	>MAX	
Cresols	>MAX	>MAX	

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Table 9.8: Summary of Human Health Based Criteria for Irrigation Water

Constituent	Criteria (mg/l)	Basis of Criteria
Ammonia	72	Commercial / industrial (gardener)
Arsenic	45.5	Commercial / industrial (gardener)
Cadmium	0.077	Commercial / industrial (gardener)
Chromium	0.29	Commercial / industrial (gardener)
Lead	460	Commercial / industrial (gardener)
Nickel	23	Commercial / industrial (gardener)
Cyanide	8.8	Aesthetics
Benzene	0.14	Commercial / industrial (gardener)
Toluene	157	Commercial / industrial (gardener)
Ethylbenzene	36	Aesthetics
Xylenes	78	Commercial / industrial (gardener)
1,2,4-trimethylbenzene	0.51	
TPH C_6-C_8 (ali)	150	Commercial / industrial (gardener)
TPH C_8-C_{16} (ali)	1.2	Commercial / industrial (gardener)
TPH C_8-C_{16} (aro)	10	Commercial / industrial (gardener)
TPH $C_{>16}$ (ali)	>SOL	Above solubility limit
TPH $C_{>16}$ (aro)	2.3	Commercial / industrial (gardener)
Benz(a)anthracene	0.0043	Commercial / industrial (gardener)
Benzo(a)pyrene	0.0015	Commercial / industrial (gardener)
Benzo(b)fluoranthene	0.026	Commercial / industrial (gardener)
Benzo(k)fluoranthene	0.015	Commercial / industrial (gardener)
Chrysene	0.18	Commercial / industrial (gardener)
Dibenz(a,h)anthracene	0.0011	Commercial / industrial (gardener)
Dibenzofuran	21	Aesthetics
Fluoranthene	0.91	Commercial / industrial (gardener)
Fluorene	8.0	Commercial / industrial (gardener)
Indeno(1,2,3-c,d)pyrene	0.0083	Commercial / industrial (gardener)
2-methylnaphthalene	9.6	Commercial / industrial (gardener)
Naphthalene	3.3	Commercial / industrial (gardener)
Pyrene	3.3	Commercial / industrial (gardener)
Phenol	32	Aesthetics
2,4-dimethylphenol	42	Commercial / industrial (gardener)
Cresols	150	Commercial / industrial (gardener)

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9.5 Asbestos

A criteria for asbestos of 1% present as fibre cement sheet has been adopted for a sub-surface maintenance worker exposure. This is below the actual level derived for a sub-surface maintenance exposure. No criteria has been derived for surface receptor exposure as it is considered aesthetically unacceptable for asbestos to be present in surface soils on the park.

The criterion of 1% mass of fibre cement sheet fragments will be adopted for soils below 0.8m and soils below buildings across the site. An aesthetic based criteria will be adopted for all accessible surface soils to a depth of 0.8m.

9.6 Assessment of Current Groundwater Impact under Headland Park

Low levels of existing groundwater impact are also found to occur in the area of the Headland Park Site. The modelling results for Zone 2 exposure to seepage water and groundwater have been reviewed. This modelling scenario considered exposure to groundwater / seepage water within existing seepage water / groundwater horizons on the Park.

The highest levels of risk and hazard to each of the exposed receptors have been determined to select the most potentially receptor. Modelling has been repeated for the most sensitive receptor to determine the level of risk and hazard posed by existing groundwater quality to future Park users. Risk and hazard results are summarised in **Table 9.9** following.

Table 9.9: Risk Assessment of Maximum Groundwater Concentrations for Most Potentially Sensitive Potential Exposures

Constituent	Maximum Level in Groundwater (mg/l)	Maximum Calculated Risk / Hazard Index (HI)
Arsenic	0.013	HI-$6.4*10^{-7}$
Benzene	0.003	Risk-$3.9*10^{-8}$ HI-$5.6*10^{-5}$
Cadmium	0.0432	HI-$1.2*10^{-4}$
Chromium	0.0019	HI-$1.5*10^{-5}$
Cyanide (free)	0.0118	HI-$1.6*10^{-6}$
Lead	0.065	HI-$1.8*10^{-7}$
Nickel	0.303	HI-$2.9*10^{-5}$
TPH $C_{>16}$(aliphatic)	0.6	HI-$9*10^{-6}$
TPH $C_{>16}$ (aromatic)	0.6	HI-$5.8*10^{-4}$
Xylene	0.003	HI-$5.7*10^{-7}$
1,2,4-trimethylbenzene	0.0012	HI-$2.9*10^{-5}$
Benz(a)anthracene	0.0022	Risk-$1.2*10^{-7}$
Benzo(a)pyrene	0.0027	Risk-$5.9*10^{-8}$
Benzo(b)fluoranthene	0.0028	Risk-$3.5*10^{-9}$
Benzo(k)fluoranthene	0.0016	Risk-$3.5*10^{-9}$
Chrysene	0.0024	Risk-$4.3*10^{-10}$
Fluoranthene	0.0055	HI-$1.3*10^{-5}$
Indeno(1,2,3,c,d)pyrene	0.0018	Risk-$6.7*10^{-9}$
Naphthalene	0.0077	HI-$2.5*10^{-5}$
Pyrene	0.0065	HI-$4.3*10^{-6}$

The current levels of groundwater impact do not pose a potential level of unacceptable risk or hazard to Park users. It is noted that this assessment has not considered the beneficial use of groundwater as irrigation water. Existing groundwater is typically found to be saline and unsuitable for this purpose. It is also noted that these Risk and HI estimates do not include adjustment for background exposures, as with risk based criteria derived for the site.

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10 Sensitivity Analysis

An assessment has been required to be undertaken of the sensitivity of the risk assessment outcomes. Risk assessment calculations can be observed to have been based on:

- Levels of COPCs as estimated by soil and groundwater sampling programs completed on the site;
- Toxicological parameters used to characterise COPCs;
- Anticipated and assessed current and future land-uses;
- Exposure parameters used to characterise future population behaviours on the site;
- Physical parameters used to characterise site areas and buildings where exposures may occur; and
- Equations and related relationships used to estimate levels of COPCs from reported levels in soils and groundwater to points of exposure.

Each of these is discussed further following.

10.1 Sampling Programs

Soil and groundwater data used for the risk assessment have been obtained from sampling programs previously completed by ERM, AECOM and Douglas Partners. The soil and groundwater data have been used for the selection of constituents of potential concern. Soil and groundwater data are required to be appropriately representative of site conditions. The soil data are considered to more than likely overstate the extent of impact on the site because assessment locations, it has been targeted only to areas of the site where site impact is most likely. This caused the extent of the dara to positively bias the actual extent of impact that may be present on the site. This is magnified by the use of analytical data as collected from the declaration area to assess levels of impact for the Headland Park.

Groundwater monitoring wells have likewise only been installed in areas of the site where the occurrence of impact is considered most likely and likewise groundwater characterisation is considered to have biased the actual distribution of impact across the site.

It is also noted that a potentially limited analytical suite has been undertaken by the previous consultants. This has included analysis for a limited range of monocyclic aromatic hydrocarbons (MAHs). It is noted that other monocyclic aromatic hydrocarbons will most likely also be present with site contamination, potentially including trimethylbenzenes, propyl benzenes etc. However the criteria proposed for the MAHs analysed are considered to appropriately account for other constituents that may be present.

This potential under-representation of the full extent of MAHs is considered to have at least been partially accounted for the inclusion of assessment for TPH fractions. It is also noted that regulators in Australia commonly only provide speciated criteria and advise assessment for the limited range of MAHs as assessed by this risk assessment.

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10.2 Toxicological Parameters

Toxicological data are generally derived by the conversion of dose factors as developed based on animal studies to appropriate levels for human exposure. The conservatism of these values is achieved through the use of uncertainty factors. An uncertainty factor of 100 is commonly applied in converting measured animal toxicity data for use for humans, comprising:

- A factor of 10 to allow for differences that affect the way a chemical behaves in humans rather than the animal species tested; and
- Another factor of 10 adequate to allow for differences in the way the chemical might affect different people, to allow for the most sensitive individuals.

Though the two processes most likely act in two separate ways, indicating a summed factor of 20 should be used, the factors are multiplied to generate an uncertainty factor of 100. It is also noted that most agencies will incorporate an additional factor of 10 where long term toxicity data are not available for a particular constituent, resulting in a total factor of 1,000.

Actual conversion factors used in the derivation of toxicological values has been extensively detailed in **Section 7**. Toxicological data used in the risk assessment has incorporated these uncertainty factors. This is considered an appropriately conservative process for the site.

It is specifically noted that a Level 2 source reported a substantially more conservative toxicological value for dermal exposure to benzo(a)pyrene than what has been adopted by the consideration of the Level 1 sources. The potential sensitivity of the risk based calculations to this toxicological factor, when considered for dermal exposure only, can be assessed by re-calculating the risk criteria for benzo(a)pyrene for surface soils using the alternate toxicological value. A criterion of 3.1mg/kg has been derived in this risk assessment and is presented in **Table 9.1**. This criterion is close to the DEC (2006) recommended assessment criteria for benzo(a)pyrene for open space sites. More conservative criteria have been derived where potential seepage water exposure scenarios are considered for commercial / industrial worker which are substantially below the DEC (2006) open space and commercial / industrial criteria.

Where the alternate toxicological value is used, a risk based criteria of 0.06mg/kg is derived for benzo(a)pyrene. This is substantially below the DEC (2006) published assessment criteria, and below a level able to be achieved by most NATA accredited laboratories in Australia.

In assessing toxicity data for phytotoxicity effects, all overseas based data has been corrected to a conservative EC10 measure. This has resulted in conservative criteria. It is noted that CSIRO (2009) advises that a less conservative EC30 measure of toxicity data has been used to derive phytotoxicity criteria for the proposed revision of NEPC (1997).

10.3 Land-Use

The risk assessment outcomes are only valid for the assumed future land-use of the site. Potentially sensitive land-uses such as the use of the Park for residential purposes have not been considered. The risk assessment would require to be revised where the site was used for a future use other than a recreational use with indoor commercial / industrial exposure limited to the Car Park.

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The ecological assessment has been based on conservative ecological data presumably derived for susceptible ecological species. As discussed throughout **Sections 10** to **12** limited data is available on ecological studies for the majority of the COPCs. Resultant criteria are more than likely significantly overly conservative as a consequence.

10.4 Exposure Parameters

Exposure parameters have been derived for the range of receptors as based on published guidance provided in Australian guidelines. Exposure parameters are based on reasonably maximum exposed persons and are considered to be conservative. For example, for the recreational scenarios, a constant exposure to site impact over a 70 year period has been used for the modelling.

Risk results are generally found to adjust linearly with adjustments in exposure parameters.

10.5 Building Parameters

The most potentially sensitive parameters for characterisation of the Car Park and 'Cultural Space' buildings with the risk assessment is the rate of ventilation of the buildings and the rate of vapour inflow through the pavement.

The minimum required rate of ventilation for a Car Park as recommended by the appropriate Australian Standard has been adopted in the modelling. The ventilation of the Car Park is likely to exceed the Australian Standard, particularly noting that site conceptual designs indicate that the eastern side of the Car Park will be open to ambient ventilation.

A recommended rate of ventilation as provided to NZ Ministry for the Environment (2009) for an enclosed building has been adopted for the 'Cultural Space'. Noting that conceptual designs show the western portion of the 'Cultural Space' to be open this is also considered conservative.

The default US EPA (2003) value for vapour inflow has been adopted in the modelling. This is based on coarse grained soils being present below a building foundation. The use of this default value is found to substantially increase estimates of vapour inflow, and result in substantially more conservative risk based criteria. It is noted that the RISC modelling package contains algorithms to estimate rates of soil vapour inflow based on specific soil and building properties. The risk modelling has been repeated for the modelling scenario of soils >10m below / away from the 'Cultural Space' (Zone 5) using RISC to determine a rate of vapour inflow. A level of benzene of $3.41*10^{-2}mg/m^3$ occurring in the Cultural Space was predicted as based on the default rate of vapour inflow. Modelling has been repeated using the model algorithms to estimate a rate of vapour inflow results into the Cultural Space. A vapour level of $3.48*10^{-3}mg/m^3$ is predicted in the 'Cultural Space' as per this approach. This is an order of magnitude lower than the level used in the risk assessment and confirms the conservatism of this approach.

10.6 Modelling Equations

Modelling for the risk assessment has been undertaken using the RISC modelling package. The modified Johnson and Ettinger model is used by the RISC package. Johnson and Ettinger (1991) developed a model for estimating indoor air concentrations resulting from contaminated soil. The non-depleting (infinite) source model developed by Johnson and Ettinger was used in the RBCA protocol. The Johnson and Ettinger model

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incorporates a simplification of the conceptual model that allows solution of a depleting source model. This model was historically modified to consider slab on ground construction and allow use of the same model to assess transport to outdoor air. The risk results as derived by the modified Johnson and Ettinger model are found to be more conservative than comparative models. For example NZ Ministry for the Environment (1999) notes that results generated by the Johnson and Ettinger model are generally a factor of 2 more conservative than similar results as derived by the Jury (1983) modified behaviour assessment model.

Modifications have been made to the RISC modelling where necessary to ensure that the model undertakes calculations in accordance with the most recent published guidance for the use of Johnson and Ettinger relationships.

10.6.1 Application of Johnson & Ettinger Relationships

The appropriateness of the application of the Johnson & Ettinger relationships for undertaking vapour intrusion modelling, and the associated adopted parameter physical properties, has been assessed by repetition of modelling scenarios using modelling spreadsheets as issued by the US EPA. This has been undertaken for the Zone 2 (vapour intrusion to the Car Park) and Zone 5 (vapour intrusion to the Cultural Space) models using benzene and naphthalene. The results of the comparative modelling are summarised in **Table 10.1** following.

Table 10.1: Summary of Comparison of Johnson & Ettinger Based Model Results (mg/m^3)

Model Scenario	Result using RISC		Result using US EPA Spreadsheets	
	Benzene	Naphthalene	Benzene	Naphthalene
Zone 2	$8.39*10^{-2}$	$7.58*10^{-5}$	$3.52*10^{-3}$	$2.57*10^{-5}$
Zone 5	$4.17*10^{-4}$	$1.52*10^{-5}$	$6.45*10^{-5}$	$1.33*10^{-7}$

The RISC predicted concentrations of each constituent can be observed to be above those provided by the US EPA issued spreadsheets. This confirms that the RISC equations and the adopted physical parameters for each constituents are conservative.

10.6.2 Biodegradation

Importantly, the Johnson and Ettinger model, and the risk assessment calculations, do not take into account potential degradation of hydrocarbon vapours as would occur by oxidation in the sub-surface. Potential vapour generation by contaminated soils and groundwater has been reported in several sources to be controlled by sub-surface oxygen levels, as discussed following.

An assessment of attenuation of hydrocarbon vapours by sub-surface oxygen has been undertaken in Abreu L and Johnson P (2006) 'Simulating the effect of aerobic biodegradation on soil vapor intrusion into buildings: Influence on degradation rate, source concentration and depth' in *Environmental Science and Technology*. It was concluded that significant attenuation of petroleum hydrocarbons with depth can occur beneath and adjacent to foundations provided there is sufficient atmospheric O_2 replenishment to the sub-surface.

An assessment of the occurrence and levels of oxygen below buildings in hydrocarbon impacted sands has been undertaken in Lundegard P, Johnson P and Dahlen P (2008) 'Oxygen Transport From the Atmosphere to Soil Gas Beneath a Slab-on-Grade Foundation Overlying Petroleum Impacted Soil' in *Environmental Science & Technology*. The study site consisted of a slab on grade house constructed over a fine to medium sand with tar like petroleum hydrocarbon impact present at a depth of 1.5 to 1.8m below the slab. It was found that soils between the depths of 0 and 1m below the building had near atmospheric levels of O_2. Below this an aerobic / anaerobic transition zone that occurred

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somewhere between 1.0 and 1.8m, considered to be through the upper region of the hydrocarbon impacted soil zone. It was further demonstrated in the study that oxygen in shallow soils underlying this structure were rapidly replenished on purging of soils. Oxygen was further considered to rapidly move downwards by diffusion.

An assessment of soil-gas distribution beneath and around a slab-on-grade building overlying shallow petroleum hydrocarbon impacted coarse alluvial soils, consisting of fine and medium sands, has been reported in Luo H, Dahlen P, Johnson P, Peargin T and Creamer T (2009) 'Spatial Variability of Soil-Gas Concentrations near and beneath a Building Overlying Shallow Petroleum Hydrocarbon-Impacted Soils' in *Ground Water Monitoring & Remediation*. The study site consisted of a slab on grade warehouse constructed on silty medium to fine sands with petroleum hydrocarbon impact recorded as shallow as 0.15m below the base of the building. It was found in this study that levels of sub-surface petroleum hydrocarbon soil vapour were inversely related to levels of subsurface O_2, with levels of TPH in soil gas generally being at or near the study detection limits where levels of O_2 were above 5%.

Where models were to incorporate sub-surface oxygen levels and associated degradation of hydrocarbon vapours, much lower estimates of vapour migrating to the surface would be anticipated to be predicted. However in lieu of certainty as to the potential level of oxygenation of compacted fill based soils on the site, biodegradation has been omitted.

10.7 Geological Parameters

Geological parameters can substantially influence vapour migration estimates using Johnson & Ettinger based models. This is most prevalent for volatile constituents. A sensitivity analysis on the model results has been undertaken using alternate geological parameters. A dry sand has been assumed for the majority of the modelling undertaken. The sensitivity of the modelling to the assumed geology can be assessed by undertaking additional modelling for the Zone 5 calculations (10m below/away from Cultural Facility). **Table 10.1** following summarises the modelling result for the dry sand as used in the modelling. Additional modelling has been undertaken using alternate geological parameters for gravels, silty sand and silty clay. Default geological parameters provided to RISC have been used for the additional modelling. These additional results are also summarised in **Table 10.2**.

Table 10.2: Additional Modelling of Benzene Levels from Soils 10m Below / Away from Cultural Space (mg/m^3)

Geology	Predicted Airborne Concentration
Sand (as modeled)	$3.41 * 10^{-2}$
Gravels	$1.75 * 10^{-2}$
Silty Sand	$1.19 * 10^{-3}$
Silty Clay	$8.24 * 10^{-5}$

It can be observed from table 10.1 that the geological parameters are conservative. Less conservative results were obtained for all scenarios using recommended default geological parameters provided to the RISC modelling package.

10.8 Potential Synergistic / Additive Effects

The risk based criteria, as based on human health effects, have been derived by correction of unit concentration results to a hazard index of 1.0 or a risk level of $1*10^{-5}$. In a theoretical scenario where several of these constituents occurred together at levels approaching the risk based criteria, the total level of hazard may exceed 1.0, or the level of risk may exceed $1*10^{-5}$.

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This is not considered significant to warrant a revision of the criteria however. The final criteria are noted to have several constituents which have been derived on the basis of ecological end points. Further, the sensitivity analysis and the discussion provided to the risk assessment has demonstrated the conservatism of the assessment approach.

10.9 Conclusion

There are several factors which may have caused the risk and hazard estimates provided in this risk assessment, which have premised the derivation of the risk based criteria for the site, to be underestimated. However, it is more than likely that any underestimation caused by the risk assessment process and limitations of available data and modelling techniques has been overcome by the use of conservative assumptions throughout the assessment. Examples of conservative assumptions provided in this assessment include:

- Consideration of maximum values for contaminant concentrations across the whole of the Barangaroo Site in the selection of constituents of potential concern;
- Conservative assumption of potential substantial leaching of seepage water from the soils used to construct the parkland site and the presence of seepage water at near surface depths;
- Omission of degradation of hydrocarbon vapours in the sub-surface in estimating rates of vapour migration;
- Used of a conservative modelling package and associated physical parameters to characterise COPCs;
- Use of RME (reasonable maximum exposed) based exposure parameters for receptors where locally available data is not present;
- Use of conservative ecological data as corrected to conservative ecological measures; and
- Assumption of all potential pathways.

It is concluded that the risk estimates provided are overestimates of actual risk levels and can be used for future decision making for the site. Considered the degree of conservative assumptions and outcomes of alternative modelling scenarios in **Section 10**, it is considered that the proposed criteria are appropriate for the use in the construction of the Headland Park.

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11 Conclusions and Recommendations

A human health risk assessment has been completed for the proposed Barangaroo Headland Park. The risk assessment has considered a range of human health exposure scenarios for the proposed development of the Headland Park. The key facets of the proposed Headland Park development that have been considered in the risk assessment include:

- Construction of the Park boundary with a sloped foreshore which extends laterally over the high tide and low tide points;
- Incorporation of a Car Park and a ''Cultural Space'' substantially buried within the central and western portions of the Headland Park Site; and
- Sub-surface drainage infrastructure over the area of the Park typically to a maximum depth of 0.5m.

On the basis of these land-use parameters, the conceptual plans for the Headland Park, consideration of human exposure scenarios only, consideration of existing levels of exposure of human receptors to background levels of constituents and the limitations provided in **Section 13**, the following risk based criteria have been derived for use on the site as summarised in **Table 11.1**. **Table 11.1** should be reviewed with **Figure 16**. Risk based criteria have not been presented where the derived criterion has exceeded the historical maximum reported concentration of the constituent as reported in previous environmental assessments completed for the Barangaroo Site.

Irrigation water to be re-used on the site by application via sprinklers are required to meet the criteria as defined in **Table 11.1**.

It has also been found that existing maximum levels of groundwater impact do not pose an unacceptable human health risk.

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Table 11.1: Summary of Risk Based Criteria

Constituent	Zone 1 Risk Based Criteria (mg/kg)	Zone 2 Risk Based Criteria (mg/kg)		Zone 3 Risk Based Criteria (mg/kg)	Zone 4 Risk Based Criteria (mg/kg)	Zone 5 Risk Based Criteria (mg/kg)	Zone 6 Risk Based Criteria (mg/kg)	Irrigation Water Risk Based Criteria (mg/L)
		Unsaturated Soil	Saturated Soil					
Ammonia	5100	>MAX	>MAX	580	750	2500	>MAX	72
Arsenic	140	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	45.5
Cadmium	7.7	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.077
Chromium	450	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.29
Lead	130	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	460
Nickel	600[1]	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	23
Cyanide	220	>MAX	>MAX	950	>MAX	2500	3400	8.8
Benzene	1.0	0.4	810	0.1	0.1[1]	0.3[1]	2.3	0.14
Toluene	>MAX	460	>MAX	180	260[1]	950[1]	690	157
Ethylbenzene	>MAX	47	>MAX	25	36[1]	140[1]	80	36
Xylenes	1800	130	>MAX	64	86[1]	310[1]	180	78
1,2,4-trimethylbenzene	21	44	>MAX	0.8	1.2[1]	5[1]	46	0.51
TPH C_6-C_9	5100	6000	>MAX	100	130[1]	430[1]	3500	150
TPH C_{10}-C_{14}	3500	5600	>MAX	107.5	1391	4551	3800	5.6
TPH C_{15}-C_{28}	65950	25000[2]	>MAX	<MAX	<MAX	<MAX	<MAX	1.15[3]
TPH C_{29}-C_{36}			>MAX					
Benz(a)anthracene	31	95	>MAX	39	73	>MAX	>MAX	0.0043
Benzo(a)pyrene	3.1	810	810	810	>MAX	>MAX	>MAX	0.0015
Benzo(b)fluoranthene	31	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.026
Benzo(k)fluoranthene	31	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.015
Chrysene	310	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.18
Dibenz(a,h)anthracene	3.1	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.0011
Dibenzofuran	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	21
Fluoranthene	670	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.91
Fluorene	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	8.0
Indeno(1,2,3-c,d)pyrene	31	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	0.0083
2-methylnaphthalene	2600	1100	>MAX	610	940	4300	2500	9.6
Naphthalene	880	610	>MAX	12	17[1]	73[1]	>MAX	3.3
Pyrene	1600	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	3.3
Phenol	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	32
2,4-dimethylphenol	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	42
Cresols	3100	>MAX	>MAX	>MAX	>MAX	>MAX	>MAX	150

Note: 1. Criteria based on exposure of Cultural Space Receptors
2. Concentration based on risk based criteria from TPH $C_{>16}$ aromatic concentration only, risk based criterion TPH $C_{>16}$ aliphatic concentration >MAX
3. Concentration based on risk based criteria from TPH $C_{>16}$ aromatic concentration only, risk based criterion TPH $C_{>16}$ aliphatic concentration >MAX
Zone 1 – 0-0.5m below open area of Park
Zone 2 – Below Car Park
Zone 3 – 0-1m away from 'Cultural Space'
Zone 4 – >1-10m below / away from 'Cultural Space' and 0-10m away from Car Park
Zone 5 – >10-30m below / away from 'Cultural Space' and away from Car Park
Zone 6 – >30m lateral distance from western portion of 'Cultural Space' and >0.5m below Park surface
<SOL - Above solubility limit <MAX – risk based criteria exceeds maximum detected concentration on site

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13 Limitations

This report has been prepared for use by the client who commissioned the works in accordance with the project brief only and has been based in part on information obtained from other parties. The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose.

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Sampling and chemical analysis of environmental media is based on appropriate guidance documents made and approved by the relevant regulatory authorities. Conclusions arising from the review and assessment of environmental data are based on the sampling and analysis considered appropriate based on the regulatory requirements and site history, not on sampling and analysis of all media at all locations for all potential contaminants.

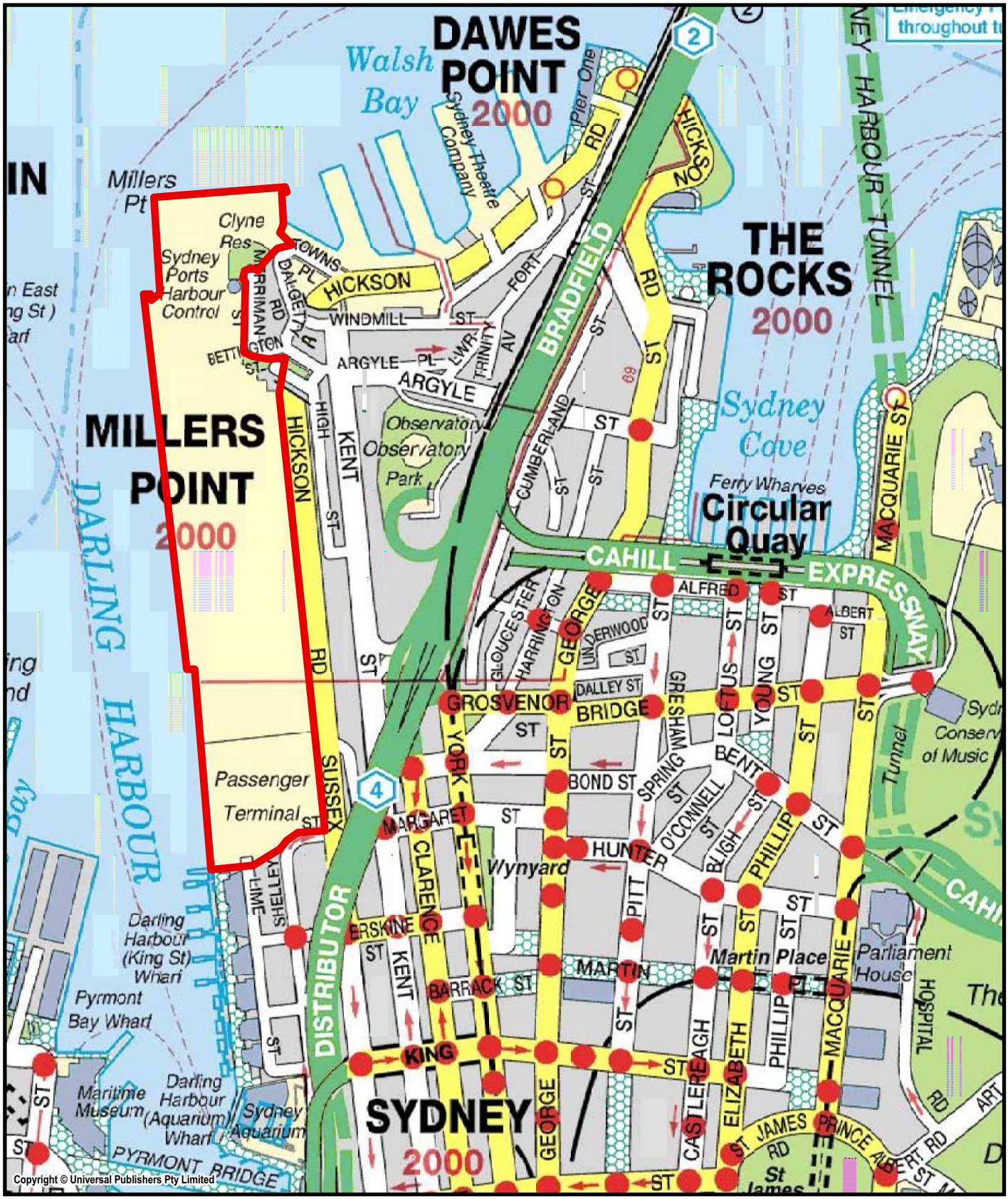
Changes to the subsurface conditions may occur subsequent to the investigations described herein, through natural processes or through the intentional or accidental addition of contaminants. The conclusions and recommendations reached in this report are based on the information obtained at the time of the investigations.

This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown sources of contamination, JBS Environmental Pty Ltd reserves the right to review the report in the context of the additional information.

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Figures

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0 250m

Approximate scale

Figure 1 **Location of Barangaroo Site**

ERM (2008)
Note- All locations shown are approximate only


LIMIT OF WORK
LIMIT OF WORK
LIMIT OF WORK
LIMIT OF WORK
LIMIT OF WORK
-2 Depth
-4 Depth
-4 Depth
-2
Property Boundary
Property Boundary
HIGH STREET
HICKSON ROAD
DALEY ROAD
MERRIMAN STREET
WHARF ROAD
TOWNS PLACE
CAHILL EXPRESSWAY
WHARF ROAD
HICKSON ROAD
HIGH STREET
HIGH STREET
HICKSON ROAD
WHARF ROAD
LORD NELSON HOTEL
PUBLIC TOILETS
PUBLIC TOILETS
PUBLIC TOILETS



Figure 3A

1:1500 @ A3

0 10 20 30 50

BARANGAROO HEADLAND

PWP Landscape Architecture
739 Allston Way, Berkeley, California 94710
Johnson Pilton Walker
Level 10, Plaza Building Australia Square, 95 Pitt Street, Sydney NSW 2000

MAIN WORKS APPLICATION
BARANGAROO HEADLAND PARK
HEADLAND PARK PLAN

MW-PWP-L-S3-1002 REV. 00 22nd September 2010





1:800 @ A3 0 5 10 20 40m

BARANGAROO HEADLAND

PWP Landscape Architecture
739 Allston Way, Berkeley, California 94710
Johnson Pilton Walker
Level 10, Plaza Building Australia Square, 95 Pitt Street, Sydney NSW 2000

MAIN WORKS APPLICATION
BARANGAROO HEADLAND PARK
HEADLAND SECTION 1

MW-PWP-L-S3-2001 REV. 00 22nd September 2010

Figure 3B



Figure 3C

1:500 @ A3

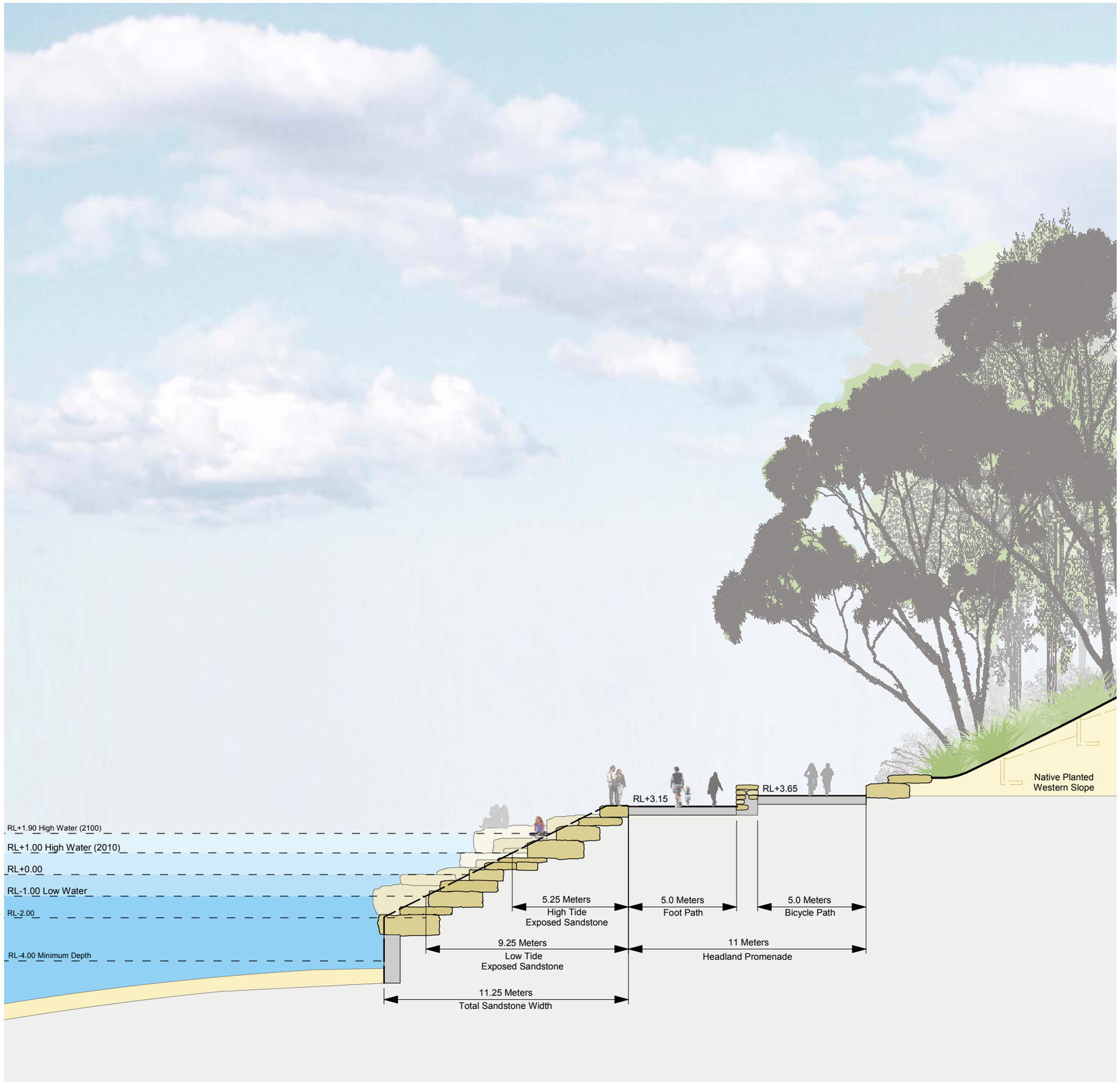
0 5 10 20m

BARANGAROO HEADLAND

PWP Landscape Architecture
739 Allston Way, Berkeley, California 94710
Johnson Pilton Walker
Level 10, Plaza Building Australia Square, 95 Pitt Street, Sydney NSW 2000

MAIN WORKS APPLICATION
BARANGAROO HEADLAND PARK
HEADLAND SECTION 2

MW-PWP-L-S3-2002 REV. 00 22nd September 2010



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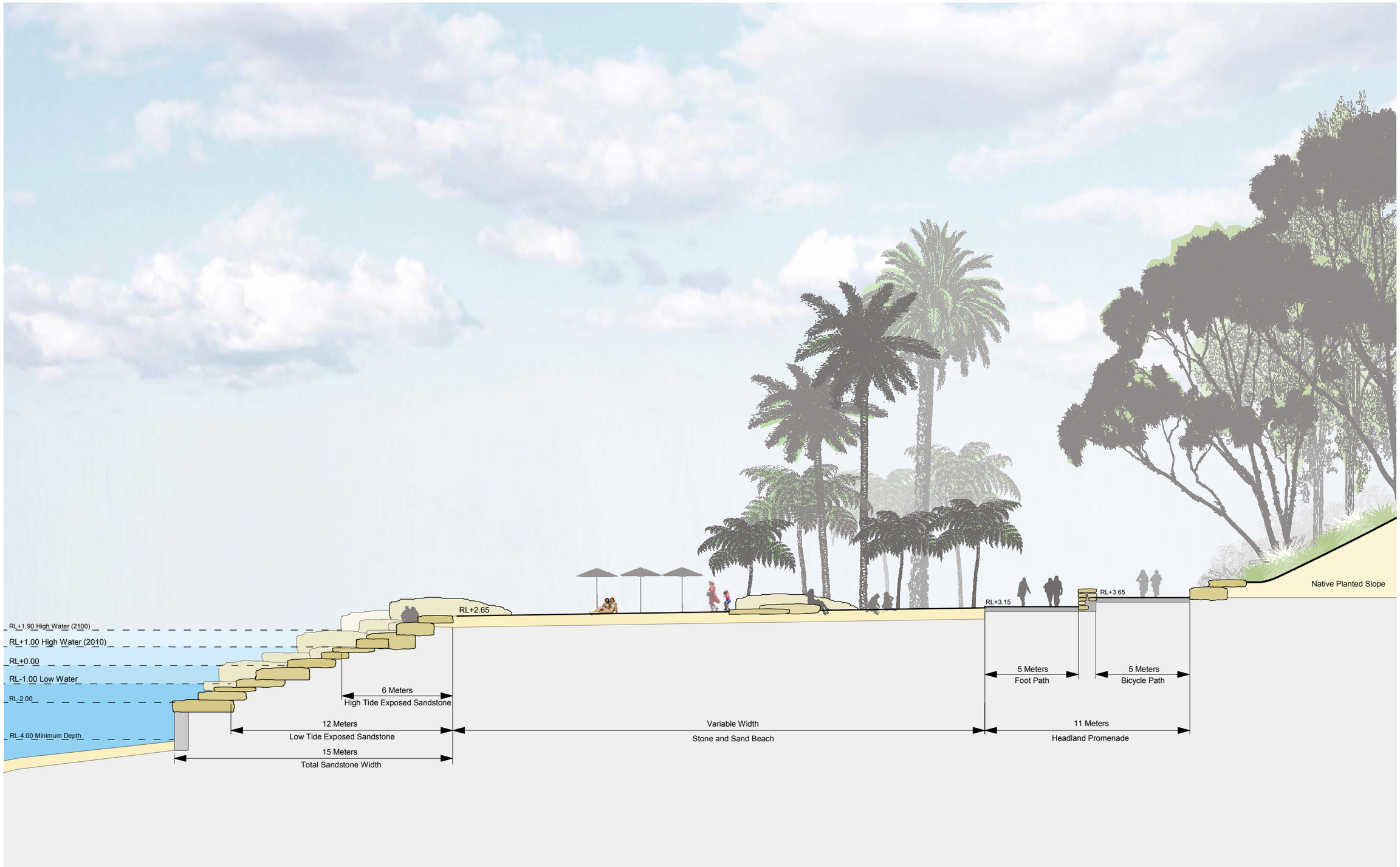
BARANGAROO HEADLAND

PWP Landscape Architecture
739 Allston Way, Berkeley, California 94710
Johnson Pilton Walker
Level 10, Plaza Building Australia Square, 95 Pitt Street, Sydney NSW 2000

MAIN WORKS APPLICATION
BARANGAROO HEADLAND PARK
HEADLAND SECTION 3

MW-PWP-L-S3-2003 REV. 00 22nd September 2010

Figure 3D



1:200 @ A3 0 1 2 3 5 10m

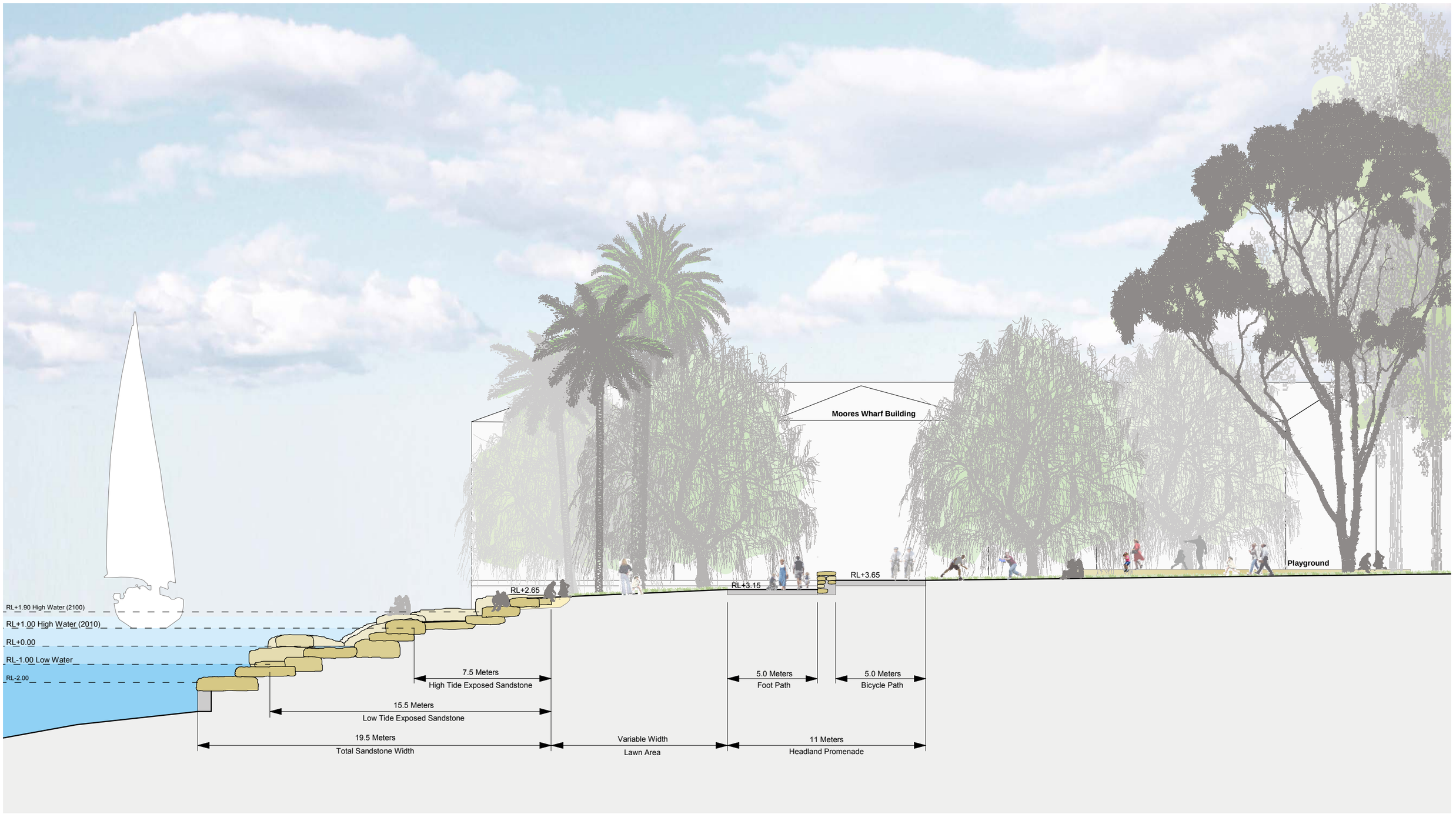
BARANGAROO HEADLAND

PWP Landscape Architecture
739 Allston Way, Berkeley, California 94710
Johnson Pilton Walker
Level 10, Plaza Building Australia Square, 95 Pitt Street, Sydney NSW 2000

MAIN WORKS APPLICATION
BARANGAROO HEADLAND PARK
HEADLAND SECTION 4

MW-PWP-L-S3-2004 REV. 00 22nd September 2010

Figure 3E



1:200 @ A3 0 1 2 3 5 10m

BARANGAROO HEADLAND

PWP Landscape Architecture
739 Allston Way, Berkeley, California 94710
Johnson Pilton Walker
Level 10, Plaza Building Australia Square, 95 Pitt Street, Sydney NSW 2000

MAIN WORKS APPLICATION
BARANGAROO HEADLAND
HEADLAND SECTION 5

MW-PWP-L-S3-2005 REV. 00 22nd September 2010

Figure 3F

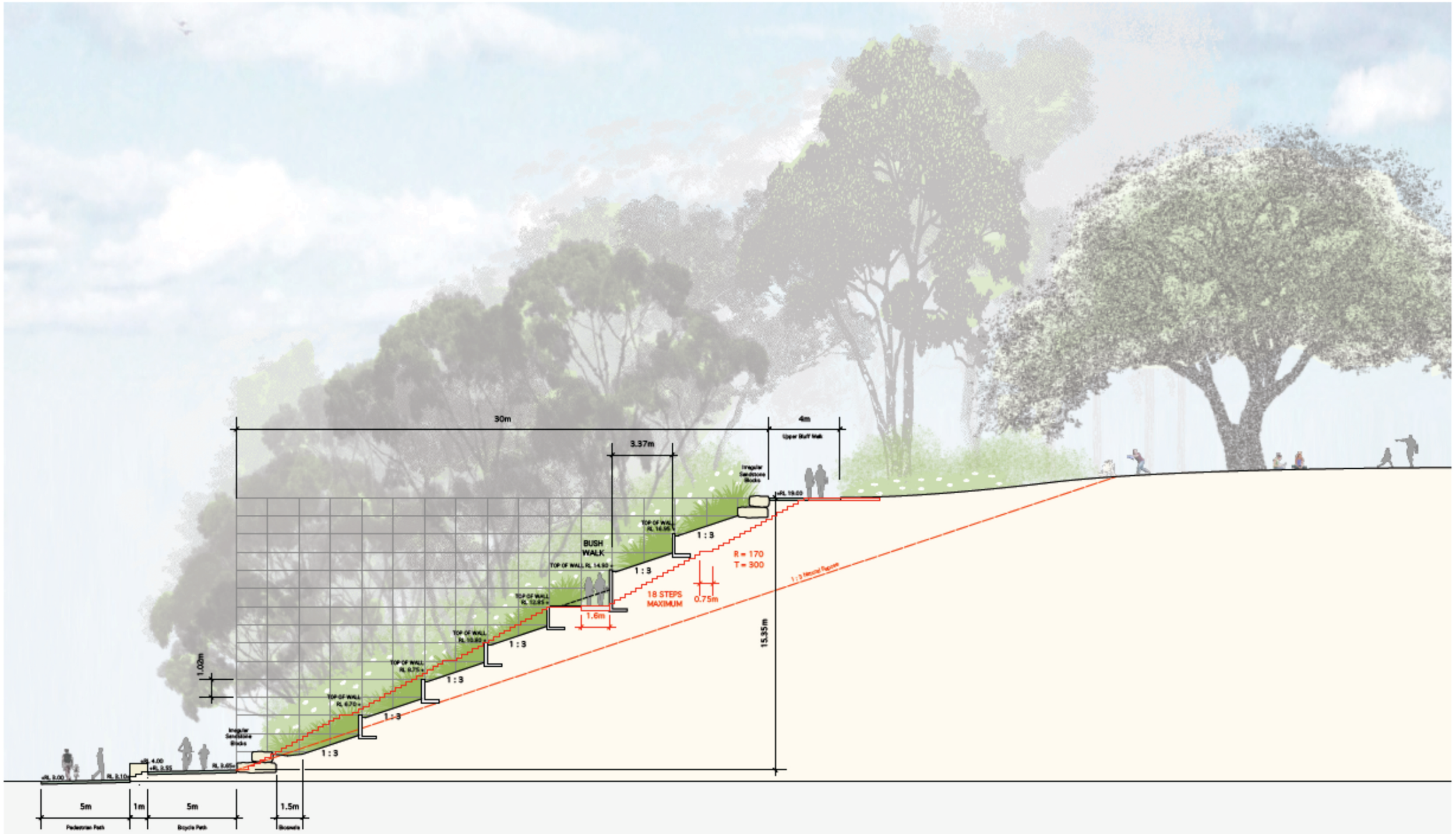
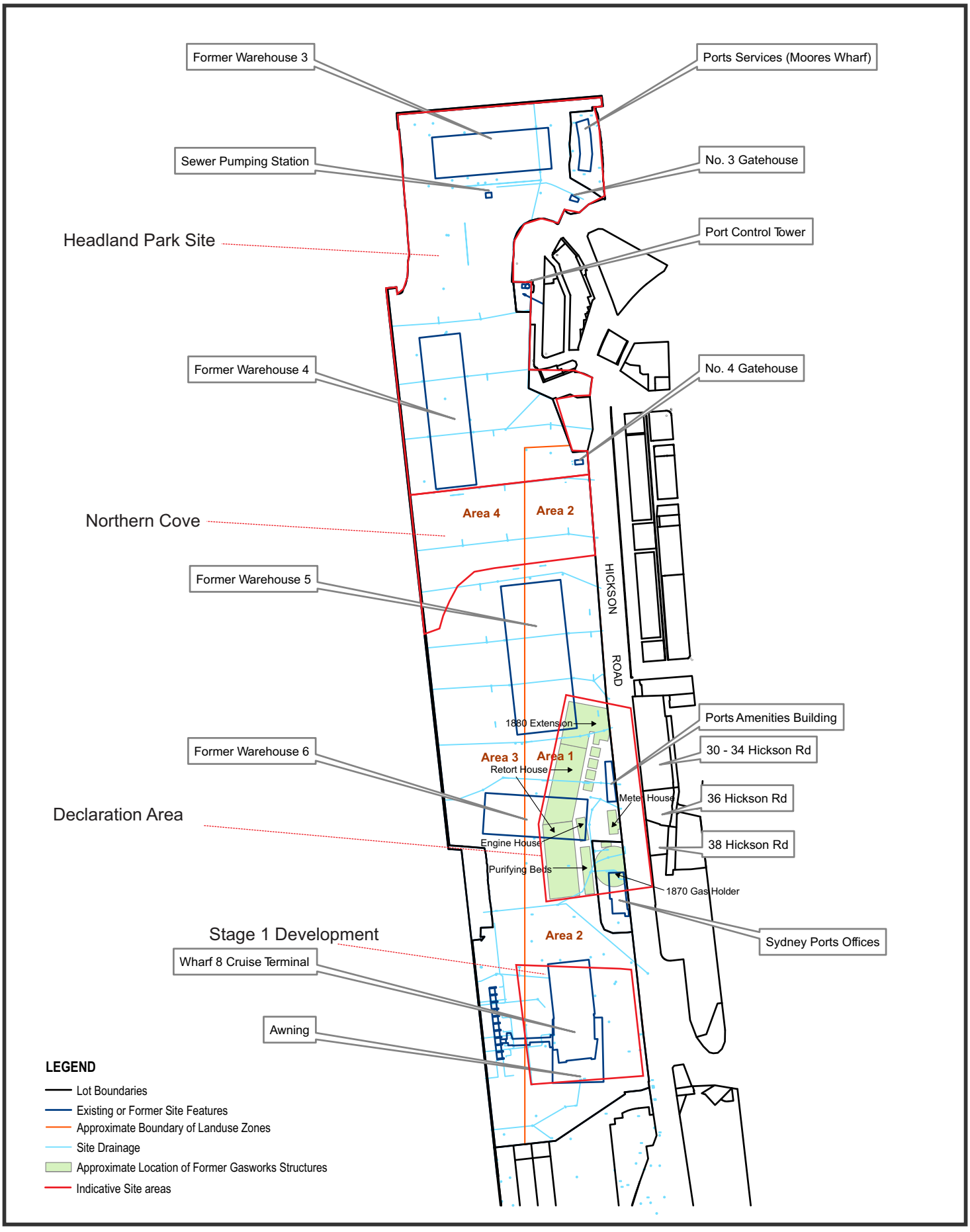


Figure 4

1:100 @ A1 0 2 4 8 10m	BARANGAROO HEADLAND PWP Landscape Architecture 739 Alston Way, Berkeley, California 94710 Johnson Pilton Walker Level 10, Plaza Building Australia Square, 95 Pitt Street, Sydney NSW 2000	DESIGN DEVELOPMENT HEADLAND PARK SLOPE STABILIZATION SECTION A DD-PWP-L-S3-2006 REV. 01 21th September 2010

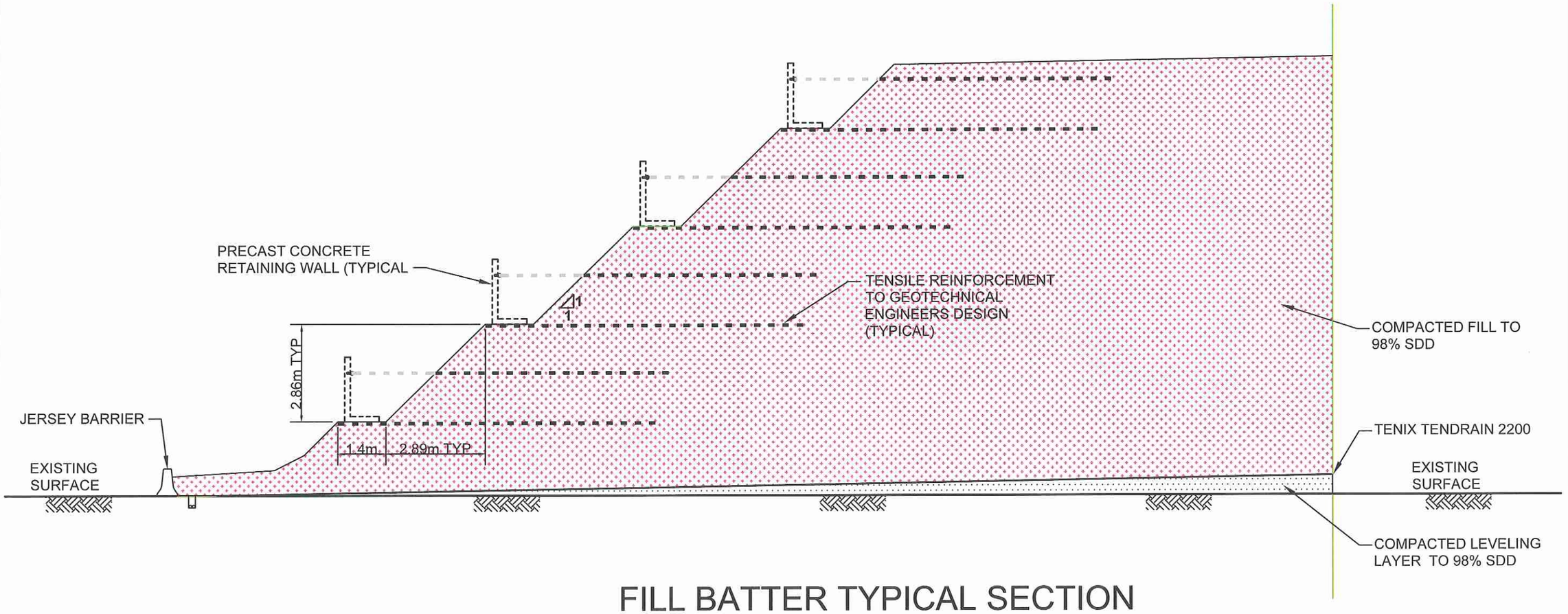


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Figure 5 **Current Site Layout showing Current Site Features**

ERM (2008)
Note- All locations shown are approximate only

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FILL BATTER TYPICAL SECTION

N.T.S.

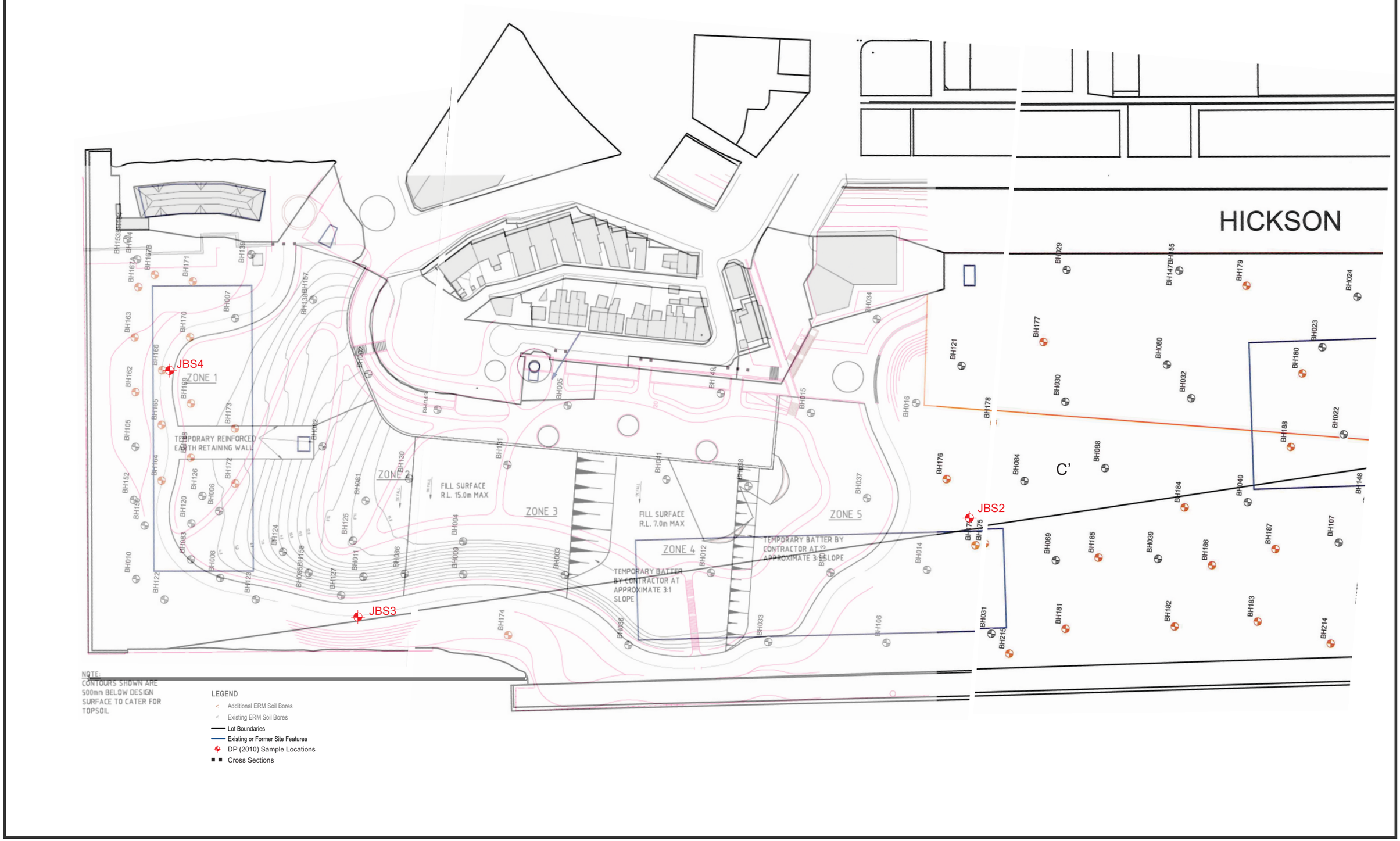
Figure 6

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Rev.	Revision Description	Date
P1	FOR INFORMATION	01.10.10

Client:	BARANGAROO SYDNEY AUSTRALIA	Designed: PD	Date: OCT 2010
Project/Job:	BARANGAROO PUBLIC DOMAIN HEADLAND PARK	Drafted: PD	Scale: AS NOTED
Subject:	FILL BATTER TYPICAL SECTION	Job No: 10400	Dwg No: SK3 Rev: P1



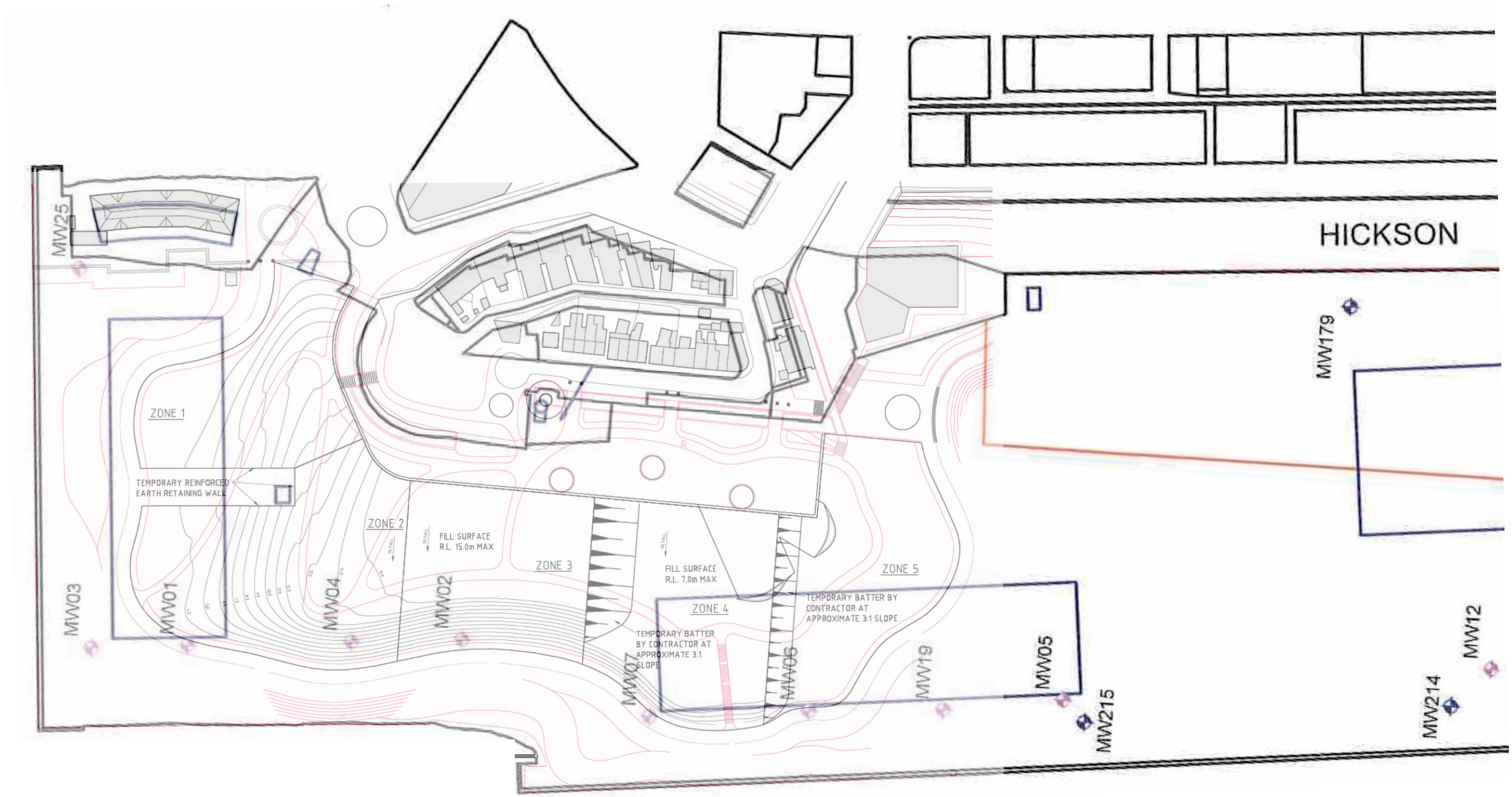
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0 200m

Approximate scale

Figure 7 **Historical Soil Sample Locations as Overlaid on Approximate Proposed Park Dimensions**

ERM (2008) & Robert Bird Group (2010)
Note- All locations shown are approximate only



JBS ENVIRONMENTAL

0 200m

Approximate scale

Figure 8 **Historical Groundwater Monitoring Well Locations as Overlaid on Approximate Proposed Park Dimensions**

ERM (2008) & Robert Bird Group (2010)
Note- All locations shown are approximate only

LEGEND

- Depth to Base of Fill Contour (m AHD)
- Proposed Site Boundary as Based on 2010 High Water Mark (1m AHD)
- Site Boundary as Defined as Limit of Works
- Proposed Excavation -7.6m AHD
- Proposed Excavation -2m AHD
- Likely extent of clay liner
- Shading to Indicate Depth to Natural Soils (Alluvium / Sandstone) / Fill Thickness

HICKSON

JBS4 JBS3 JBS2

-1.9m -2m 0m 1m -2m -8m -12m -10m

333700 333650 333600 333550

6252400 6252350 6252300 6252250 6252200 6252150 6252100 6252050 6252000 6251950 6251900

0 100m

Approximate scale

Figure 9 **Depth to Base of Fill Contours Overlaid on Proposed Site Dimensions and Soil Sample Locations**

Johnson Pilton Walker (2010) and ERM (2008)
Note- All locations shown are approximate only

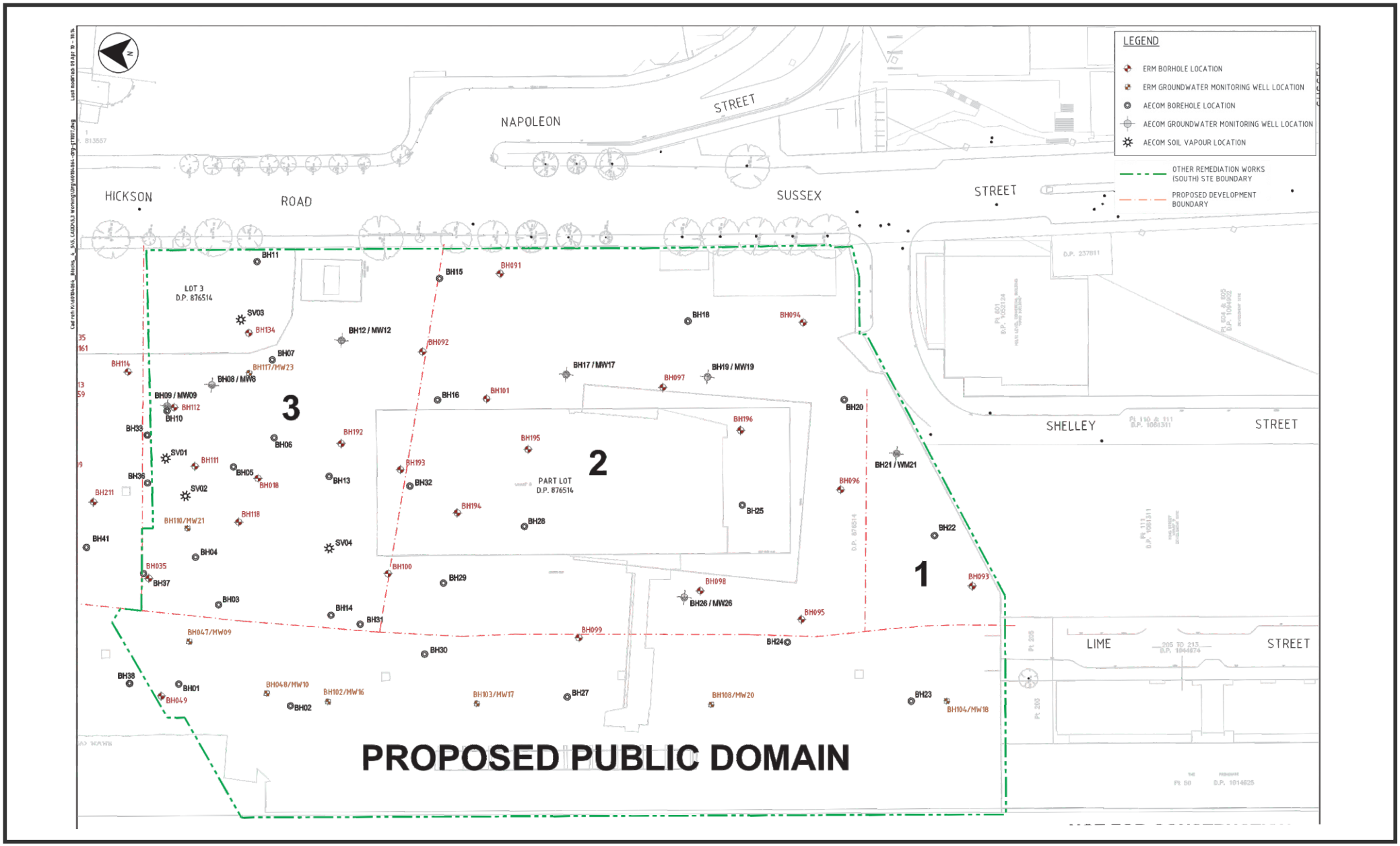


Figure 10 **AECOM Soil Sampling Locations, Southern Portion**

M G Planning (March 2010) and Department of Lands (2010)
Note- All locations shown are approximate only

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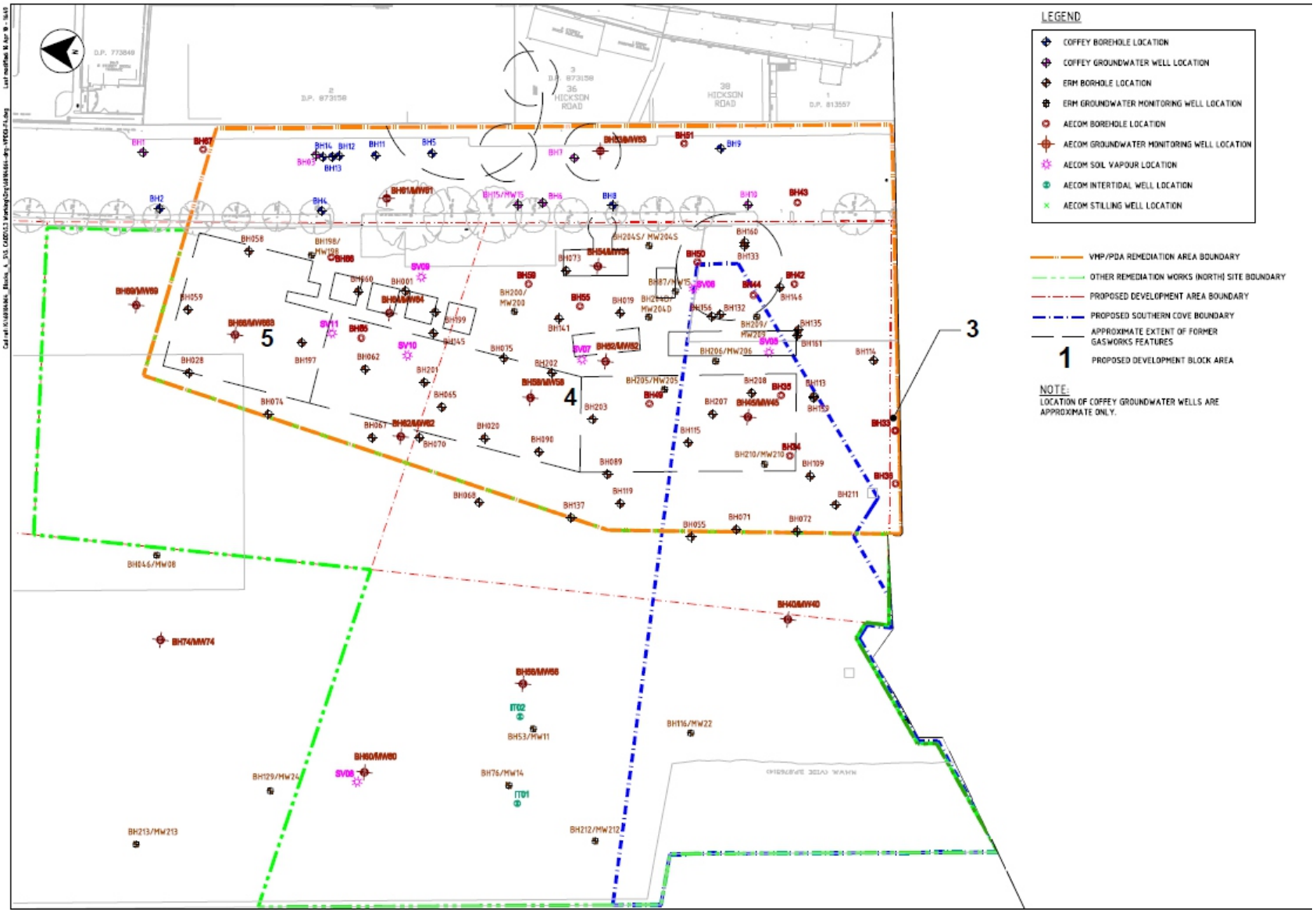
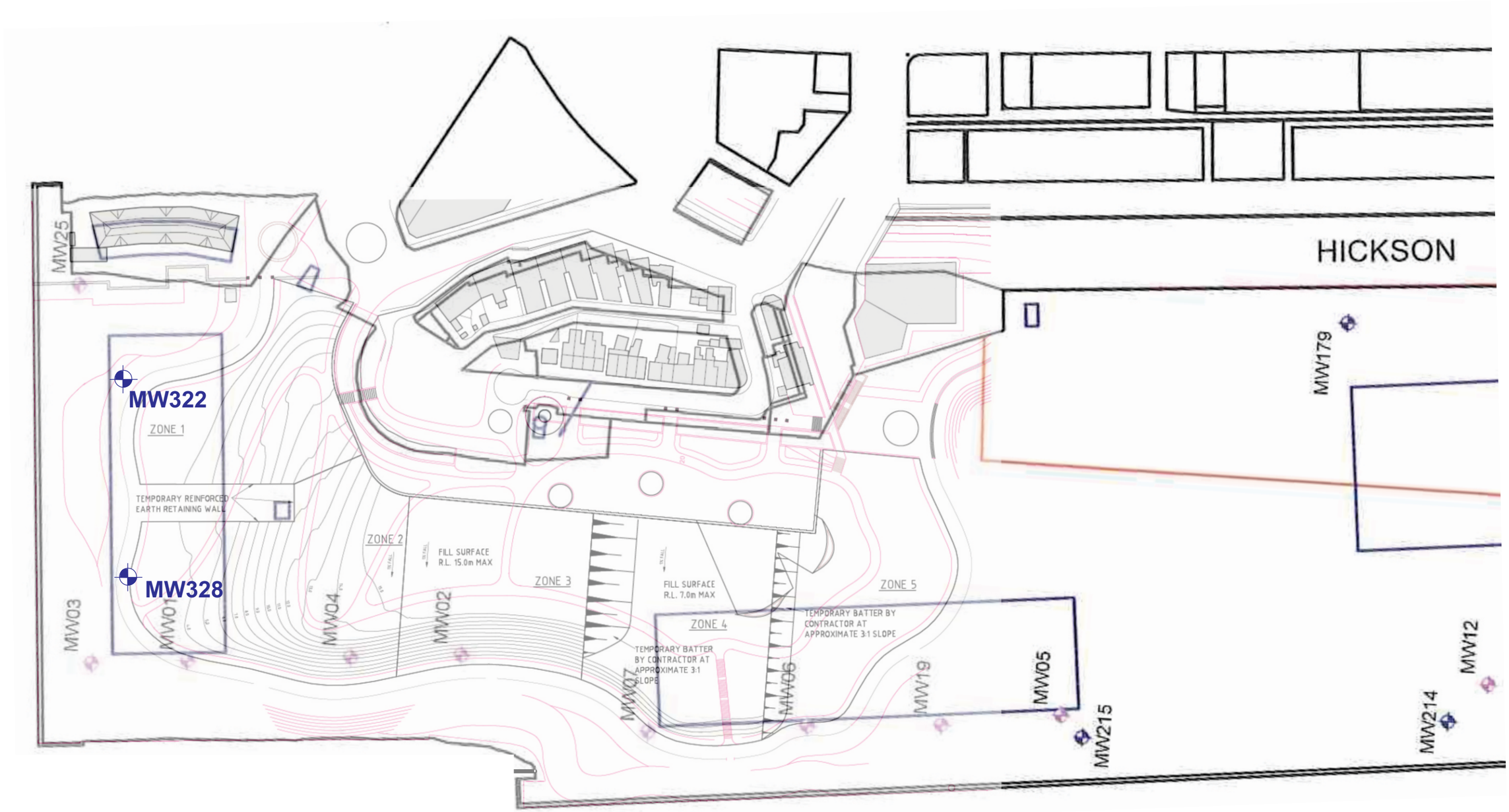


Figure 11 **AECOM Soil Sampling Locations, Declaration Area**

M G Planning (March 2010) and Department of Lands (2010)
Note- All locations shown are approximate only

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JBS ENVIRONMENTAL

0 200m

Approximate scale

Figure 12 **Existing and Proposed Groundwater Monitoring Well Locations**

ERM (2008) & Robert Bird Group (2010)
Note- All locations shown are approximate only

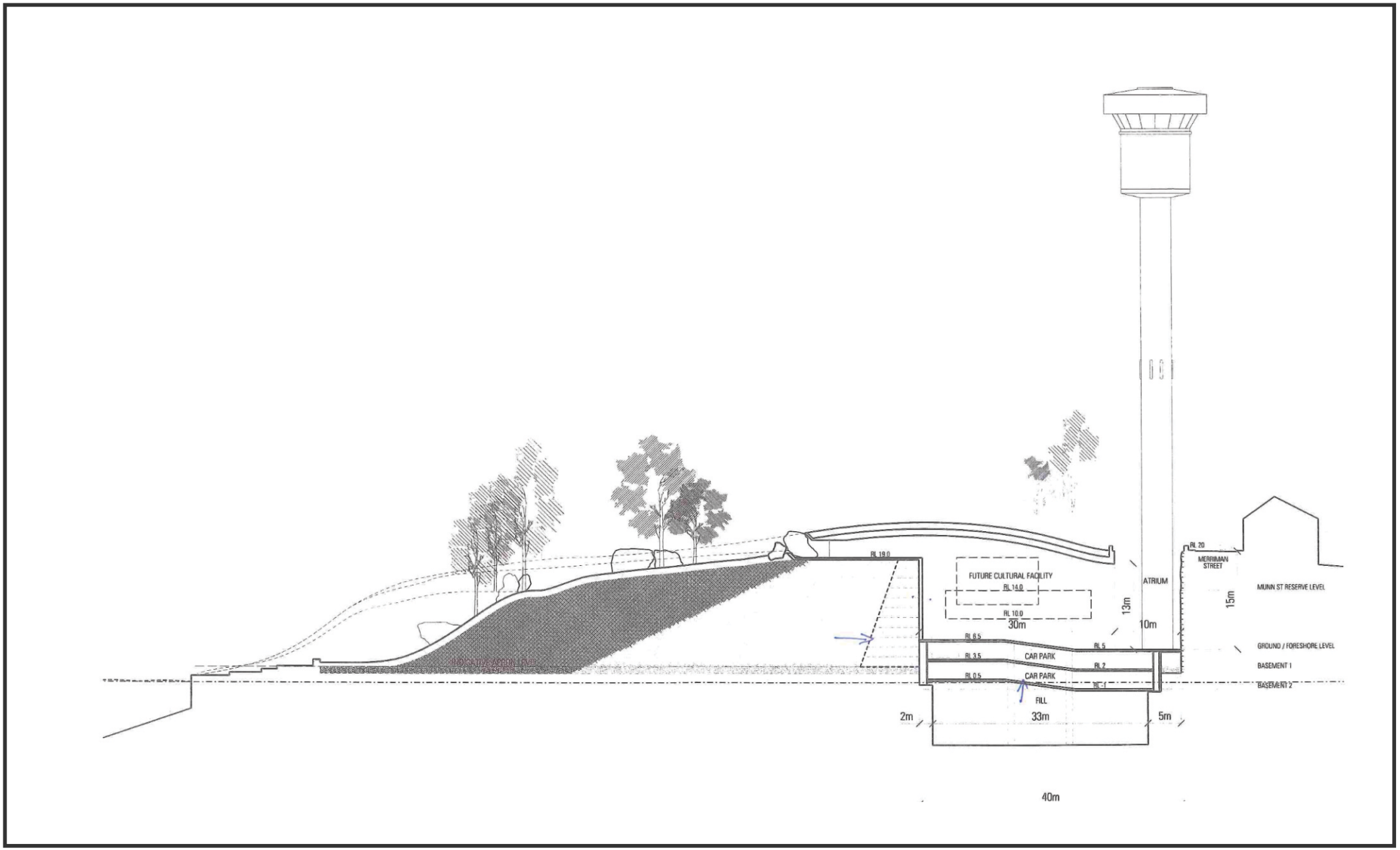
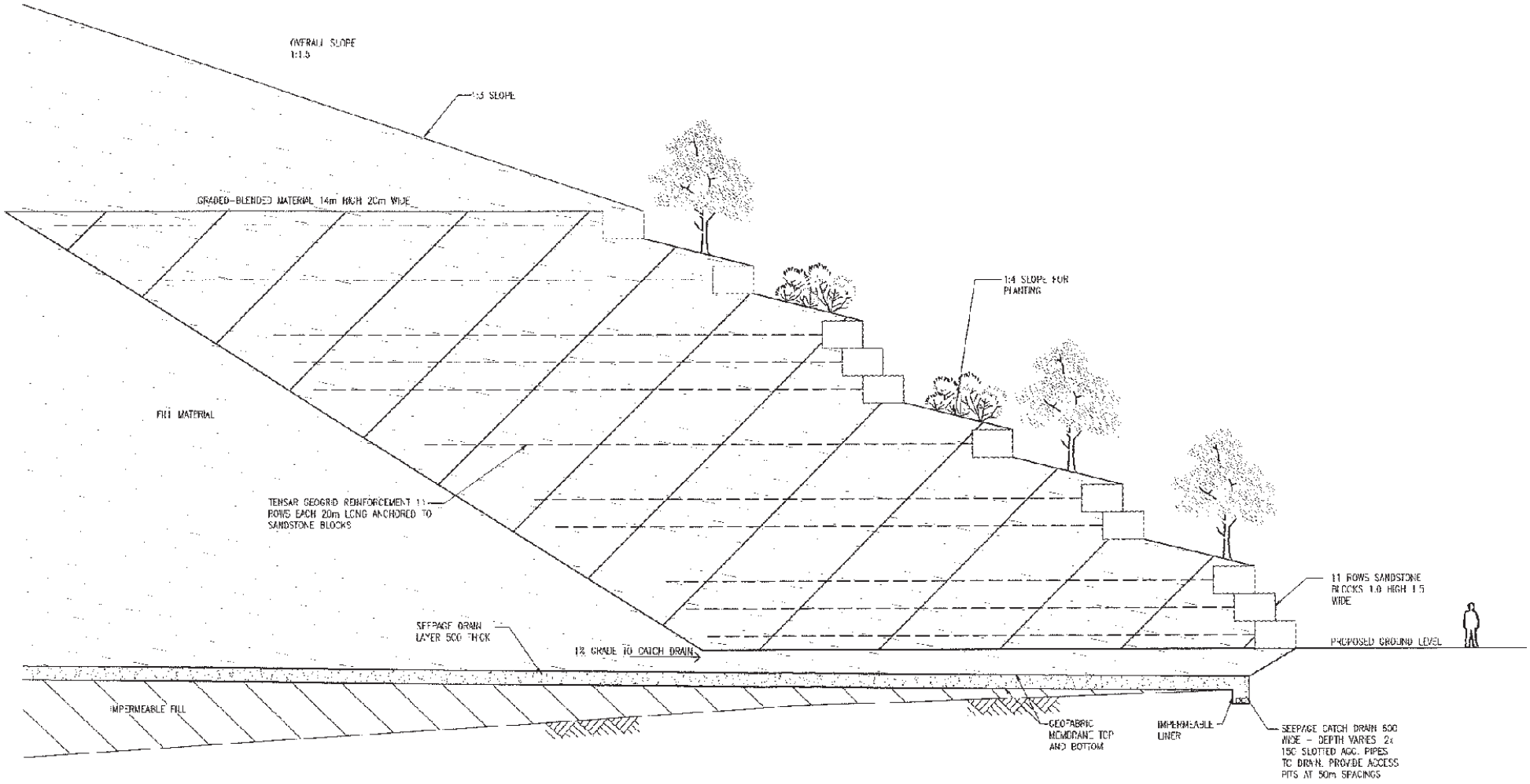


Figure 13 **Proposed Complete Park Section**

0 50m

Approximate scale

Johnson Pilton Walker (2010)
Note- All locations shown are approximate only



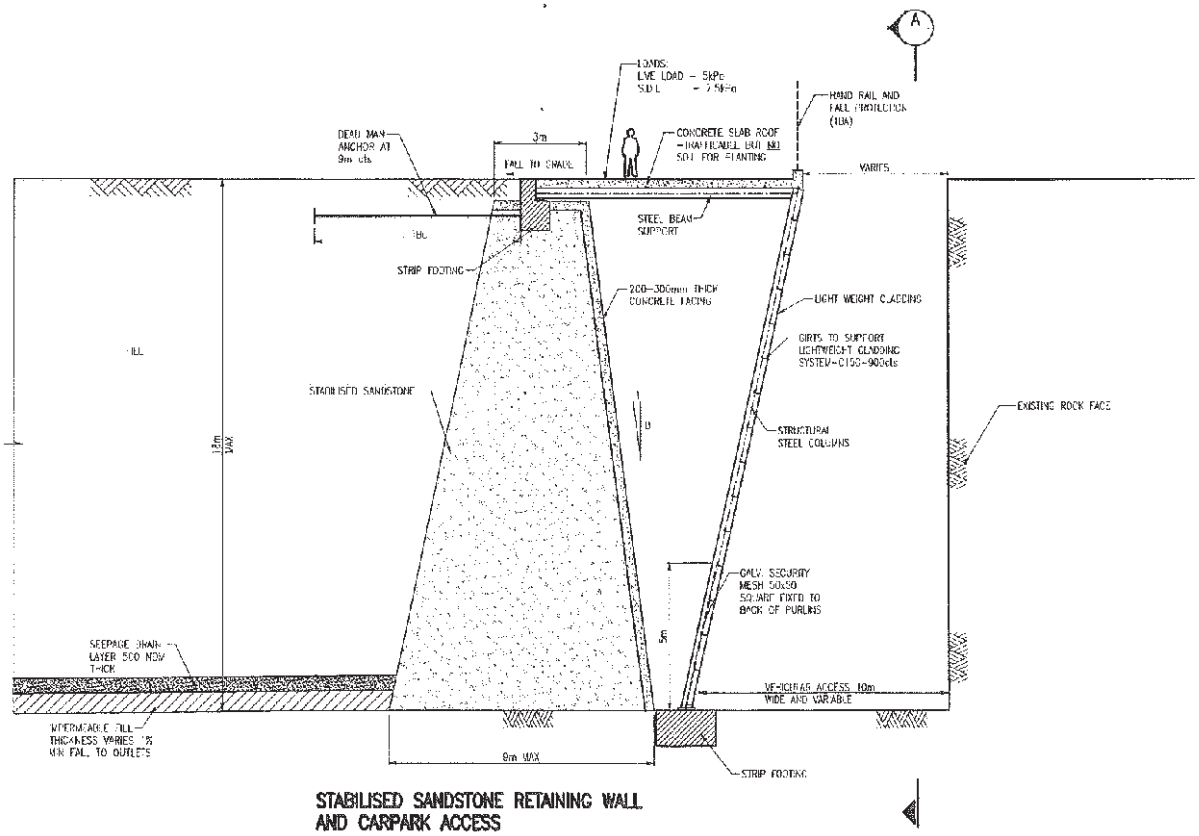
JBS ENVIRONMENTAL

0 10m

Approximate scale

Figure 14 **Proposed Park Cross-Section on Slope**

Department of Lands (2009)
Note- All locations shown are approximate only



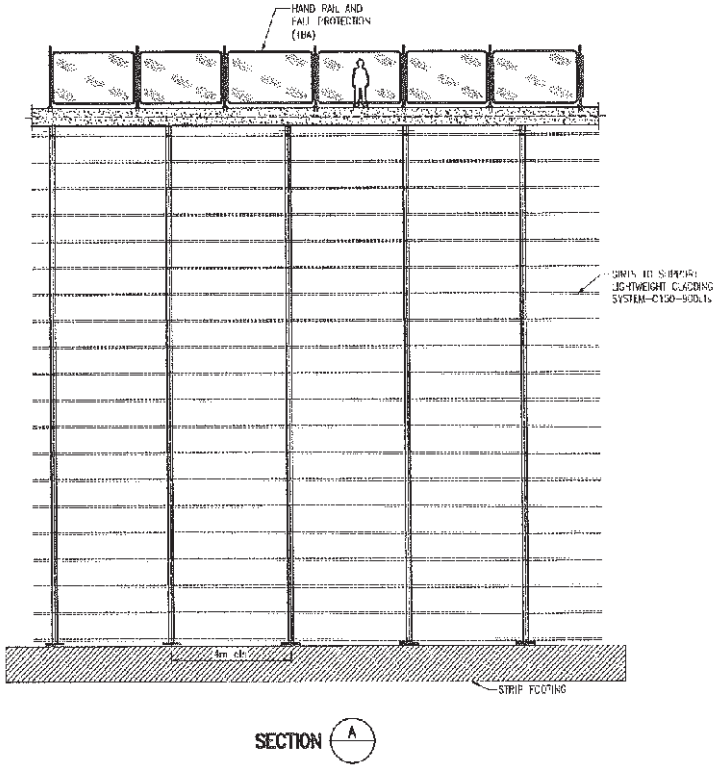


Figure 15 **Proposed Cross Section Adjoining Car Park**

JBS ENVIRONMENTAL

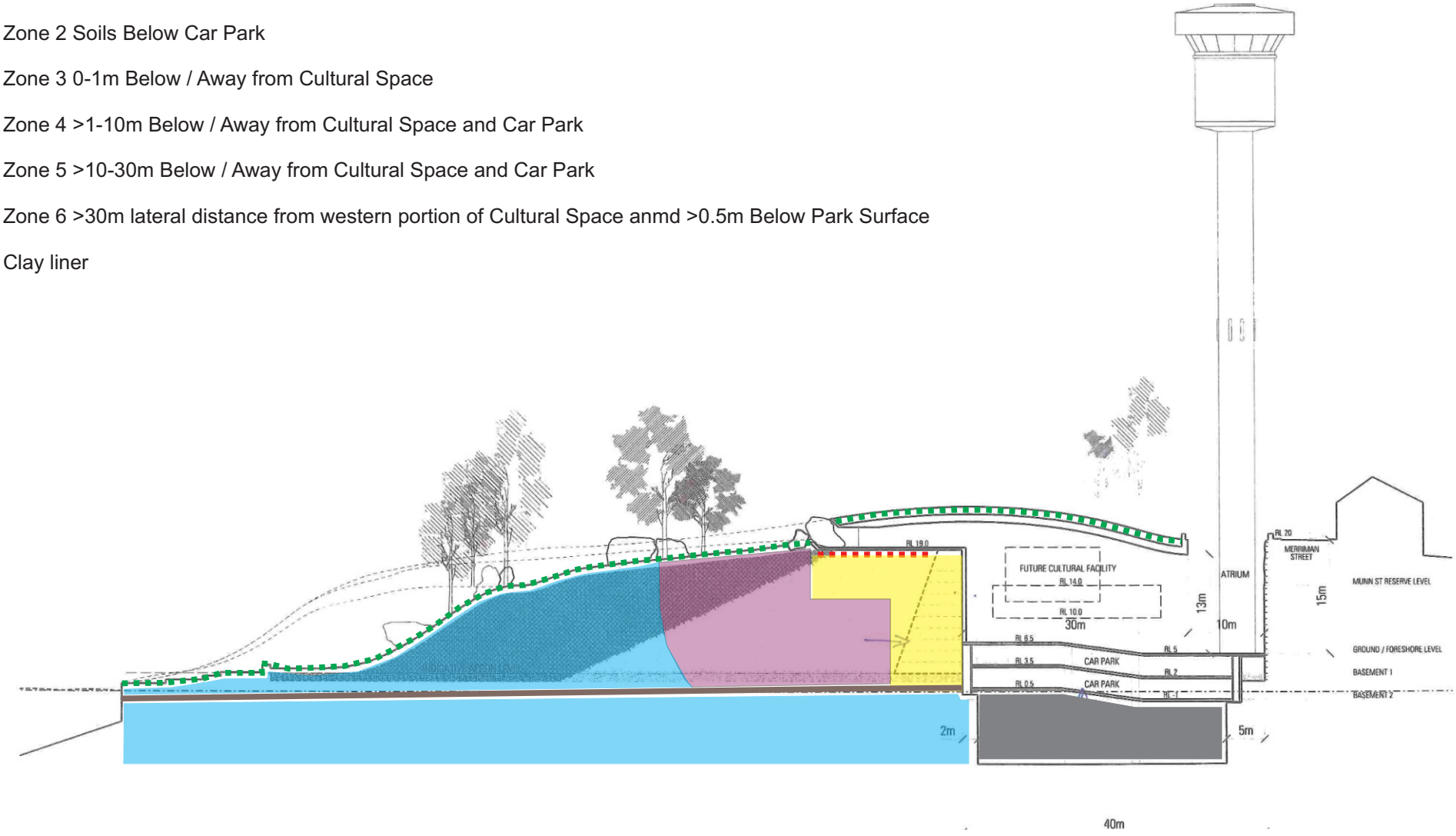
0 10m

Approximate scale

Department of Lands (2009)
Note- All locations shown are approximate only

LEGEND

- Zone 1 <0.5m below Park Surface (Growing Soils)
- Zone 2 Soils Below Car Park
- Zone 3 0-1m Below / Away from Cultural Space
- Zone 4 >1-10m Below / Away from Cultural Space and Car Park
- Zone 5 >10-30m Below / Away from Cultural Space and Car Park
- Zone 6 >30m lateral distance from western portion of Cultural Space anmd >0.5m Below Park Surface
- Clay liner



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0 50m

Approximate scale

Figure 16 **Proposed Complete Park Section and Soil Zones for Derivation of Human Health Risk Based Soil Criteria**

Johnson Pilton Walker (2010)
Note- All locations shown are approximate only

Appendix A

Soil and Groundwater Results Summary Tables

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Table A PAH Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample id	Location	Sampling Depth (m)	Polyc																
			Total PAHs	Acenaphthylene	Acenaphthene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3,cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Assessment criteria [1]								2											
PQL				1	1	1	1	0.5	2	1		1	1	1	1	1	1	1	1
BH003	<2010 High Water	1.05	43.7	<0.5	0.8	1.7	2.6	2.5	2.6	1	1.2	2.5	<0.5	9.8	0.9	0.9	0.7	7.8	8.7
BH006	<2010 High Water	1	5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	2.7	1.1
BH006	<2010 High Water	1.7	11	<0.5	<0.5	<0.5	1.1	1	1.3	0.7	<0.5	1.1	<0.5	2.3	<0.5	<0.5	<0.5	1.4	2.1
BH008	<2010 High Water	0.75	42.7	<0.5	0.7	1.6	2.6	3.1	3.4	2.3	1.1	2.5	<0.5	8.5	0.7	1.8	<0.5	6.5	7.9
BH008	<2010 High Water	1.6	3.2	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	1	<0.5	<0.5	<0.5	0.6	1
BH009	<2010 High Water	1.7	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5
BH011	<2010 High Water	2.9	8.2	<0.5	<0.5	<0.5	1	0.8	0.9	<0.5	<0.5	0.8	<0.5	2	<0.5	<0.5	<0.5	0.7	2
BH011	<2010 High Water	1.7	125	1.5	<0.5	2.6	12.4	10.2	10.5	4.7	4.1	10.1	1.1	26.5	1	3.9	0.6	9.1	26.7
BH083	<2010 High Water	3.2		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH085	<2010 High Water	1.7	1813	4	12.4	46.9	177	82.4	177	39	46.1	144	13.9	377	18.2	41.1	1.9	340	292
BH086	<2010 High Water	3.2		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH086	<2010 High Water	1.7	15.1	<0.5	<0.5	0.8	0.8	0.9	1	0.7	<0.5	0.6	<0.5	3.5	<0.5	<0.5	<0.5	3.6	3.2
BH105	<2010 High Water	1.7	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5
BH106	<2010 High Water	1.7	10.4	<0.5	<0.5	<0.5	0.6	1.4	1	2.4	0.8	0.6	<0.5	1	<0.5	1.5	<0.5	<0.5	1.1
BH106	<2010 High Water	3.2	10.2	<0.5	<0.5	<0.5	0.9	0.6	0.8		1	0.6	0.8	1.4	<0.5	<0.5	<0.5	<0.5	4.1
BH120	<2010 High Water	1.7	9.1	<0.5	<0.5	<0.5	0.9	0.9	1.1	0.6	<0.5	0.9	<0.5	1.9	<0.5	<0.5	<0.5	0.9	1.9
BH123	<2010 High Water	3.2	2.1	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	0.7
BH124	<2010 High Water	1.7	1.8	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	0.6
BH125	<2010 High Water	1.7		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH126	<2010 High Water	5.1	19.6	<0.5	<0.5	0.7	1.6	1.8	2.3	0.8	1	1.6	<0.5	3.8	<0.5	0.7	<0.5	1.9	3.4
BH127	<2010 High Water	3.2		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH162	<2010 High Water	3.5	57.2	1	<0.5	2.2	4	4.1	4.1	2.1	1.8	3.3	<0.5	12.3	1.1	1.8	<0.5	8	11.4
BH162	<2010 High Water	12.3	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5

Table A PAH Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample id	Location	Sampling Depth (m)	Polyc																
			Total PAHs	Acenaphthylene	Acenaphthene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3,cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Assessment criteria [1]								2											
PQL				1	1	1	1	0.5	2	1		1	1	1	1	1	1	1	1
BH162	<2010 High Water	13.5	68.3	5.5	<0.5	3.1	4	3.8	4.9	2.7	1.5	3.6	0.6	11	3.9	2.2	0.8	11.6	9.1
BH164	<2010 High Water	5.5	70.9	<0.5	0.8	1	6	8.5	10	6.1	4.4	5	1.2	9.5	<0.5	4.4	<0.5	1.8	12.2
BH165	<2010 High Water	3.5	16.3	<0.5	<0.5	<0.5	1.4	1.7	2	1	0.6	1.3	<0.5	2.9	<0.5	0.8	<0.5	1.6	3
BH165	<2010 High Water	8	9.3	<0.5	<0.5	<0.5	0.8	1	1.2	0.6	<0.5	0.8	<0.5	1.7	<0.5	0.5	<0.5	1	1.7
BH166	<2010 High Water	1.3	30	<0.5	0.5	0.7	2.5	1.7	3.1	2	1.2	1.9	<0.5	6.1	<0.5	1.4	<0.5	2.5	6.4
BH166	<2010 High Water	4	83.9	3.6	0.7	3.8	4.6	4.6	5.6	4.2	2.2	3.7	<0.5	15.1	2.9	2.7	2.7	12.5	15
BH168	<2010 High Water	0.5	17.7	<0.5	<0.5	<0.5	1.7	1.8	1.9	0.8	0.7	1.3	<0.5	3.7	<0.5	0.7	<0.5	1.4	3.7
BH168	<2010 High Water	5	2.3	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	1
BH168	<2010 High Water	8.8		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH169	<2010 High Water	0.5	28.6	<0.5	<0.5	0.9	2.4	2.5	2.6	1.2	1	2	<0.5	6.1	<0.5	1	<0.5	2.7	6.2
BH169	<2010 High Water	4.4	25.1	<0.5	0.5	0.7	2.1	1.4	2.5	1.6	1	1.7	<0.5	4.9	<0.5	1.1	0.8	2.4	4.4
BH170	<2010 High Water	1.3	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	0.6
BH170	<2010 High Water	3.7	6.1	<0.5	<0.5	<0.5	0.6	0.7	0.7	0.6	<0.5	<0.5	<0.5	1.3	<0.5	<0.5	<0.5	0.8	1.4
BH170	<2010 High Water	6.1	10.9	<0.5	<0.5	<0.5	1	1.1	1.4	0.6	0.7	0.8	<0.5	1.9	<0.5	<0.5	<0.5	0.7	2.7
BH172	<2010 High Water	1.2	29.4	<0.5	0.7	1.2	2.4	2.2	2.2	0.9	0.9	1.9	<0.5	5.8	<0.5	0.8	0.8	4	5.6
BH172	<2010 High Water	1.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH172	<2010 High Water	3.9	5.7	<0.5	<0.5	<0.5	0.6	0.7	<0.5	<0.5	<0.5	0.6	<0.5	1.6	<0.5	<0.5	<0.5	0.6	1.6
BH173	<2010 High Water	1.8	46.9	<0.5	0.6	1.1	5.1	4.4	4.2	2	2.2	4.5	<0.5	8.8	<0.5	1.7	<0.5	3.9	8.4
BH177	<2010 High Water	1.5	6.8	<0.5	<0.5	<0.5	0.8	0.5	0.9	0.6	<0.5	0.9	<0.5	1.5	<0.5	<0.5	<0.5	<0.5	1.6
BH177	<2010 High Water	4	111.4	<0.5	2.6	4	8.7	8.6	10.4	5.5	3.1	7.3	1.2	18.2	<0.5	4.4	0.8	15	21.6
BH182	<2010 High Water	10.6		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
JBS3	<2010 High Water	1.2	22.4	<0.1	0.2	0.5	1.7	2.3	1.5	1	1.5	1.8	0.2	4.4	<0.1	1	0.1	2	4.2
JBS4	<2010 High Water	2	27.6	<0.1	0.5	0.5	2.4	3	1.9	1.1	1.8	2.3	0.2	5.2	<0.1	1.2	0.2	2	5.3

Table A PAH Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample id	Location	Sampling Depth (m)	Polyc																
			Total PAHs	Acenaphthylene	Acenaphthene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3,cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Assessment criteria [1]								2											
PQL				1	1	1	1	0.5	2	1		1	1	1	1	1	1	1	1
BH002	Above GW	0.5	6.4	<0.5	<0.5	<0.5	<0.5	0.6	0.8	<0.5	0.5	0.6	<0.5	1.5	<0.5	<0.5	<0.5	0.9	1.5
BH004	Above GW	1.7		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH138	Above GW	0.4	59.7	<0.5	<0.5	1.8	5.6	5.2	6.1	2.8	2.4	5	0.6	12.3	<0.5	2.2	<0.5	4.6	11.1
BH149	Above GW	0.4	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6
BH005	Excavated	0.55		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH007	Excavated	0.5	4.8	<0.5	<0.5	<0.5	0.6	0.6	0.7	<0.5	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	0.6	1.1
BH007	Excavated	1	8.1	<0.5	<0.5	<0.5	0.9	0.8	1	0.6	<0.5	0.7	<0.5	1.7	<0.5	<0.5	<0.5	0.8	1.6
BH105	Excavated	0.4	40.3	<0.5	<0.5	1.9	3.3	3.3	2.3	1.9	2.4	2.8	0.6	7.2	0.6	1.6	<0.5	5.2	7.2
BH123	Excavated	0.4	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	0.6
BH150	Excavated	1.7	14.3	<0.5	<0.5	<0.5	1.3	1.4	1.7	0.9	0.7	1.1	<0.5	2.7	<0.5	0.8	<0.5	0.9	2.8
BH164	Excavated	0.1		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH182	Excavated	0.4	1.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.9	<0.5	<0.5	<0.5	0.9
JBS3	Excavated	0.7	5.3	<0.1	<0.1	<0.1	0.3	0.7	0.4	0.4	0.4	0.4	<0.1	1	<0.1	0.3	0.1	0.3	1
BH015	Excavated	0.6	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5
BH131	Excavated	0.4	18.2	<0.5	<0.5	0.6	1.5	1.7	2	1.3	0.5	1.3	<0.5	3.3	<0.5	1	<0.5	1.9	3.1
BH010	Off-site	0.4	15.5	<0.5	<0.5	<0.5	1.3	1.7	2.2	1.3	0.9	1.4	<0.5	2.4	<0.5	1.1	<0.5	0.8	2.4
BH010	Off-site	1.7	38.4	0.7	<0.5	0.8	3.6	3.7	4.1	2.1	1.7	3.1	<0.5	7	<0.5	1.8	<0.5	2.8	7
BH029	Off-site	0.4	8	<0.5	<0.5	<0.5	0.9	1	0.8	0.7	0.8	0.9	<0.5	1.5	<0.5	0.6	<0.5	0.8	<0.5
BH030	Off-site	1.7	13.5	<0.5	<0.5	0.8	1	0.8	0.6	<0.5	0.7	0.9	<0.5	2.7	0.6	<0.5	<0.5	3.2	2.2
BH031	Off-site	1.7		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH084	Off-site	0.4	1	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
BH121	Off-site	3.2	39.7	0.9	<0.5	1	3.3	3.2	3.9	2	1.6	3	<0.5	7.3	<0.5	1.5	1	4.1	6.9
BH121	Off-site	0.4	3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	1.3	0.6	<0.5

Table A PAH Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample id	Location	Sampling Depth (m)	Polyc																
			Total PAHs	Acenaphthylene	Acenaphthene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3,cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Assessment criteria [1]								2											
PQL				1	1	1	1	0.5	2	1		1	1	1	1	1	1	1	1
BH121	Off-site	1.7	43.7	1.1	<0.5	1	3.9	4.2	3.2	2.4	2.5	3.4	0.8	7.6	<0.5	2.2	1.2	2.2	8
BH139	Off-site	1.7		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH144	Off-site	3.2	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	0.6
BH163	Off-site	5	16.8	<0.5	<0.5	<0.5	1.1	0.8	1.5	1.4	0.7	0.7	<0.5	4.4	<0.5	0.7	<0.5	1.3	4.2
BH163	Off-site	7	4.6	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.8	<0.5	<0.5	<0.5	0.6	1.6
BH167	Off-site	2.2	9.4	<0.5	<0.5	0.5	1	0.8	0.8	0.5	<0.5	0.7	<0.5	1.7	<0.5	<0.5	<0.5	1.6	1.8
BH167	Off-site	8.6	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5
BH167	Off-site	10.7	16.6	<0.5	<0.5	0.6	1.4	1.4	1.4	0.8	0.5	1.2	<0.5	3.3	<0.5	0.6	<0.5	2.1	3.3
BH171	Off-site	1.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH171	Off-site	2.7	22.6	<0.5	<0.5	0.6	<0.5	3.5	4.4	2.7	1.2	<0.5	0.5	2.6	<0.5	1.8	0.7	1.5	3.1
BH174	Off-site	2.4	15.6	<0.5	<0.5	0.7	1.1	1.2	1	0.8	0.7	0.9	<0.5	3.4	<0.5	0.6	<0.5	1.9	3.3
BH174	Off-site	4.3	10.7	<0.5	<0.5	<0.5	1	1.1	1	0.8	0.6	0.7	<0.5	1.9	<0.5	0.6	<0.5	0.8	2.2
BH175	Off-site	2	6.4	<0.5	<0.5	<0.5	0.8	0.8	0.7	0.6	<0.5	0.6	<0.5	1.1	<0.5	<0.5	<0.5	0.6	1.2
BH175	Off-site	7.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH176	Off-site	2.4	17	<0.5	<0.5	0.6	1.8	1.3	1.6	0.8	0.6	1.2	<0.5	3.4	<0.5	0.6	<0.5	1.7	3.4
BH176	Off-site	3.7	65	<0.5	0.9	1.7	6	6.7	7.7	4.2	3.8	5.1	0.8	9.8	<0.5	3.4	<0.5	4.2	10.7
BH178	Off-site	8.3	3.8	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.9	<0.5	<0.5	<0.5	1.1	1.2
BH181	Off-site	5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH181	Off-site	9.1		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH185	Off-site	4		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH185	Off-site	9.6		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH215	Off-site	2.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH215	Off-site	6.1		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Table A PAH Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample id	Location	Sampling Depth (m)	Polyc																
			Total PAHs	Acenaphthylene	Acenaphthene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3,cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Assessment criteria [1]								2											
PQL				1	1	1	1	0.5	2	1		1	1	1	1	1	1	1	1
JBS2	Off-site	1.8	20.3	0.2	1	0.7	1.1	1.7	1.1	1	1.1	1.1	0.2	2.8	0.6	1	1.1	3.2	2.4
JBS2	Off-site	4	13.8	<0.1	0.2	0.3	1.2	1.6	1	0.7	1	1.2	0.1	2.3	<0.1	0.6	<0.1	1.1	2.5
BH009	Unsaturated	0.4	150.4	<0.5	1.4	4.6	9.2	11.2	11.5	8.2	4	8.2	1.2	32.6	1.5	6.1	0.6	19.8	30.3
BH011	Unsaturated	0.4	4.8	<0.5	<0.5	<0.5	0.5	0.6	<0.5	<0.5	<0.5	0.5	<0.5	1.3	<0.5	<0.5	<0.5	0.6	1.3
BH083	Unsaturated	0.4	4.4	<0.5	<0.5	<0.5	<0.5	0.6	0.7	<0.5	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	0.7	1.2
BH085	Unsaturated	0.4	260.5	1.4	2.4	6.6	16.4	25.7	27.6	25.1	10.3	13.8	3	43.8	2.2	16.6	1.1	17	47.5
BH120	Unsaturated	0.4	4.2	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	0.5	<0.5	<0.5	<0.5	1.2	<0.5	<0.5	<0.5	0.8	1.1
BH125	Unsaturated	0.4	44.3	<0.5	<0.5	1.4	2.8	3.5	4.1	2.7	1.5	2.7	<0.5	8.5	0.6	2.2	0.6	5.5	8.2
BH126	Unsaturated	0.4	26.8	<0.5	<0.5	0.6	2	2.4	2.9	2	1	2	<0.5	5.3	<0.5	1.3	<0.5	2.2	5.1
BH127	Unsaturated	0.4	26	<0.5	<0.5	0.6	1.8	2.5	2.9	2.2	1.1	1.8	<0.5	4.9	<0.5	1.4	<0.5	1.8	5
BH130	Unsaturated	0.4	4.9	<0.5	<0.5	<0.5	<0.5	0.6	0.7	<0.5	<0.5	0.5	<0.5	1.2	<0.5	<0.5	<0.5	0.6	1.3
BH157	Unsaturated	0.3	0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH158	Unsaturated	0.35	0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
JBS3	Unsaturated	0.2	0.4	<0.1	<0.1	<0.1	<0.1	<0.05	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.1
JBS4	Unsaturated	0.5	52.4	0.3	0.3	1	3.7	5.6	3.5	2.9	3.4	3.7	0.4	10	0.2	2.7	0.1	4.7	9.9

Table B Total Petroleum Hydrocarbon Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	TPH				
			C6-C9	C10-C14	C15-C28	C29-C36	ΣC10-C36
Assessment criteria [1]			**65**	**-**			**1000**
PQL			**2**	**50**	**100**	**100**	
BH003	<2010 High Water	1.05	<2	<50	300	<100	300
BH003	<2010 High Water	3.2	<2	<50	<100	<100	-
BH003	<2010 High Water	1.7	<2	<50	<100	<100	-
BH006	<2010 High Water	1	<2	<50	<100	<100	-
BH006	<2010 High Water	1.7	<2	<50	<100	<100	-
BH008	<2010 High Water	0.75	<2	<50	<100	<100	-
BH008	<2010 High Water	1.6	<2	<50	<100	<100	-
BH009	<2010 High Water	1.7	<2	<50	<100	<100	-
BH011	<2010 High Water	2.9	<2	<50	<100	<100	-
BH011	<2010 High Water	1.7	<2	<50	370	260	630
BH013	<2010 High Water	3.2	<2	<50	<100	<100	-
BH013	<2010 High Water	1.7	<2	60	490	270	820
BH036	<2010 High Water	3.2	<2	<50	<100	<100	-
BH036	<2010 High Water	1.7	<2	<50	<100	<100	-
BH083	<2010 High Water	3.2	<2	<50	<100	<100	-
BH085	<2010 High Water	1.7	<2	130	5050	1770	6950
BH086	<2010 High Water	3.2	<2	<50	<100	<100	-
BH086	<2010 High Water	1.7	<2	<50	<100	<100	-
BH106	<2010 High Water	1.7	<2	<50	<100	<100	-
BH106	<2010 High Water	3.2	<2	<50	<100	<100	-
BH123	<2010 High Water	3.2	<2	<50	<100	<100	-
BH124	<2010 High Water	1.7	<2	<50	<100	<100	-
BH125	<2010 High Water	1.7	<2	<50	<100	<100	-
BH126	<2010 High Water	5.1	<2	<50	<100	<100	-
BH127	<2010 High Water	3.2	<2	<50	<100	<100	-

Table B Total Petroleum Hydrocarbon Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	TPH				
			C6-C9	C10-C14	C15-C28	C29-C36	ΣC10-C36
Assessment criteria [1]			**65**	**-**			**1000**
PQL			**2**	**50**	**100**	**100**	
BH162	<2010 High Water	3.5	<2	<50	340	490	830
BH162	<2010 High Water	12.3	<2	<50	<100	<100	-
BH162	<2010 High Water	13.5	<2	<50	<100	<100	-
BH164	<2010 High Water	5.5	<2	<50	630	540	1170
BH165	<2010 High Water	3.5	<2	<50	<100	<100	-
BH165	<2010 High Water	8	<2	<50	<100	<100	-
BH166	<2010 High Water	1.3	<2	<50	<100	<100	-
BH166	<2010 High Water	4	<2	<50	330	320	650
BH168	<2010 High Water	0.5	<2	<50	<100	<100	-
BH168	<2010 High Water	5	<2	<50	<100	<100	-
BH168	<2010 High Water	8.8	<2	<50	<100	<100	-
BH169	<2010 High Water	0.5	<2	<50	130	<100	130
BH169	<2010 High Water	4.4	<2	<50	<100	<100	-
BH170	<2010 High Water	1.3	<2	<50	<100	<100	-
BH170	<2010 High Water	3.7	<2	<50	<100	<100	-
BH170	<2010 High Water	6.1	<2	<50	240	140	380
BH172	<2010 High Water	1.2	<2	<50	110	<100	110
BH172	<2010 High Water	1.5	<2	<50	<100	<100	-
BH172	<2010 High Water	3.9	<2	<50	<100	<100	-
BH173	<2010 High Water	1.8	<2	<50	180	<100	180
BH177	<2010 High Water	1.5	<2	<50	300	160	460
BH177	<2010 High Water	4	<2	<50	400	350	750
BH182	<2010 High Water	10.6	<2	<50	<100	<100	-
JBS3	<2010 High Water	1.2	<25	<50	<100	<100	-
BH002	Above GW	0.5	<2	<50	440	630	1070

Table B Total Petroleum Hydrocarbon Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	TPH				
			C6-C9	C10-C14	C15-C28	C29-C36	ΣC10-C36
Assessment criteria [1]			**65**	**-**			**1000**
PQL			**2**	**50**	**100**	**100**	
BH004	Above GW	1.7	<2	<50	<100	<100	-
BH082	Above GW	0.4	<2	<50	<100	<100	-
BH138	Above GW	0.4	<2	<50	340	230	570
BH149	Above GW	0.4	<2	<50	<100	<100	-
BH005	Excavated	0.55	<2	<50	<100	<100	-
BH007	Excavated	0.5	<2	<50	<100	<100	-
BH007	Excavated	1	<2	<50	<100	<100	-
BH088	Excavated	0.4	<2	<50	<100	<100	-
BH105	Excavated	0.4	<2	<50	<100	<100	-
BH123	Excavated	0.4	<2	<50	<100	<100	-
BH150	Excavated	1.7	<2	<50	<100	<100	-
BH164	Excavated	0.1	<2	<50	<100	<100	-
BH182	Excavated	0.4	<2	<50	<100	<100	-
JBS3	Excavated	0.7	<25	<50	<100	<100	-
BH015	Excavated	0.6	<2	60	370	<100	430
BH038	Excavated	0.4	<2	<50	<100	<100	-
BH041	Excavated	0.4	<2	<50	<100	<100	-
BH131	Excavated	0.4	<2	<50	<100	<100	-
BH010	Off-site	0.4	<2	<50	<100	130	130
BH010	Off-site	1.7	<2	<50	170	110	280
BH029	Off-site	0.4	<2	<50	<100	<100	-
BH030	Off-site	1.7	<2	<50	<100	<100	-
BH031	Off-site	1.7	<2	<50	<100	<100	-
BH069	Off-site	0.4	<2	<50	<100	<100	-
BH084	Off-site	0.4	<2	<50	<100	<100	-

Table B Total Petroleum Hydrocarbon Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	TPH				
			C6-C9	C10-C14	C15-C28	C29-C36	ΣC10-C36
Assessment criteria [1]			**65**		**-**		**1000**
PQL			**2**	**50**	**100**	**100**	
BH121	Off-site	3.2	<2	<50	<100	<100	-
BH121	Off-site	0.4	<2	<50	<100	<100	-
BH139	Off-site	1.7	<2	<50	<100	<100	-
BH144	Off-site	3.2	<2	<50	<100	<100	-
BH163	Off-site	5	<2	<50	<100	<100	-
BH163	Off-site	7	<2	<50	<100	<100	-
BH167	Off-site	2.2	<2	<50	<100	<100	-
BH167	Off-site	8.6	<2	<50	<100	<100	-
BH167	Off-site	10.7	<2	<50	<100	<100	-
BH171	Off-site	1.5	<2	<50	<100	<100	-
BH171	Off-site	2.7	<2	180	2240	910	3330
BH174	Off-site	2.4	<2	<50	<100	<100	-
BH174	Off-site	4.3	<2	<50	<100	<100	-
BH175	Off-site	2	<2	<50	<100	<100	-
BH175	Off-site	7.5	<2	<50	<100	<100	-
BH176	Off-site	2.4	<2	<50	<100	<100	-
BH176	Off-site	3.7	<2	<50	1320	460	1780
BH178	Off-site	8.3	<2	<50	<100	<100	-
BH181	Off-site	5	<2	<50	<100	<100	-
BH181	Off-site	9.1	<2	<50	<100	<100	-
BH185	Off-site	4	<2	<50	<100	<100	-
BH185	Off-site	9.6	<2	<50	<100	<100	-
BH215	Off-site	2.5	<2	<50	<100	<100	-
BH215	Off-site	6.1	<2	<50	<100	<100	-
JBS2	Off-site	1.8	<25	<50	<100	<100	-

Table B Total Petroleum Hydrocarbon Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	TPH				
			C6-C9	C10-C14	C15-C28	C29-C36	ΣC10-C36
Assessment criteria [1]			**65**	**-**			**1000**
PQL			**2**	**50**	**100**	**100**	
JBS2	Off-site	4	<25	<50	130	<100	130
BH009	Unsaturated	0.4	<2	<50	<100	130	130
BH011	Unsaturated	0.4	<2	<50	<100	<100	-
BH033	Unsaturated	0.4	<2	<50	<100	<100	-
BH034	Unsaturated	0.4	<2	<50	250	150	400
BH037	Unsaturated	0.4	<2	<50	<100	<100	-
BH037	Unsaturated	0.7	<2	<50	<100	<100	-
BH039	Unsaturated	0.4	<2	<50	<100	<100	-
BH043	Unsaturated	0.4	<2	<50	<100	<100	-
BH083	Unsaturated	0.4	<2	<50	110	<100	110
BH085	Unsaturated	0.4	<2	<50	700	470	1170
BH120	Unsaturated	0.4	7	<50	<100	<100	-
BH125	Unsaturated	0.4	<2	<50	<100	<100	-
BH126	Unsaturated	0.4	<2	<50	<100	<100	-
BH127	Unsaturated	0.4	<2	<50	<100	<100	-
BH130	Unsaturated	0.4	<2	<50	<100	<100	-
BH157	Unsaturated	0.3	3	<50	400	480	880
BH158	Unsaturated	0.35	<2	<50	130	270	400
JBS3	Unsaturated	0.2	<25	<50	580	1600	2180

Table C Monocyclic Aromatic Hydrocarbons Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Monocyclic Aromatic Hydrocarbons															
			Total MAHs	Benzene	Toluene	Ethylbenzene	meta&para Xylene	ortho Xylene	Styrene	Isopropylbenzene	n-Propylbenzene	1,3,5-Trimethylbenzene	sec-Butylbenzene	1,2,4-Trimethylbenzene	tert-Butylbenzene	p-Isoprpyltoluene	n-Butylbenzene
Assessment criteria				1	1.4	3.1	14		-	-	-	-	-	-	-	-	-
PQL				0.2	0.2	0.2	0.4		1	1	1	1	1	1	1	1	1
BH003	<2010 High Water	1.05		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH003	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH003	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH013	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH013	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH036	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH036	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH083	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH085	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH086	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH086	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH106	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH106	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH123	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH124	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH125	<2010 High Water	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH126	<2010 High Water	5.1		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH127	<2010 High Water	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH162	<2010 High Water	3.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH162	<2010 High Water	12.3		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH162	<2010 High Water	13.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH164	<2010 High Water	5.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH165	<2010 High Water	3.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH165	<2010 High Water	8		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH166	<2010 High Water	1.3		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH166	<2010 High Water	4		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH168	<2010 High Water	0.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH168	<2010 High Water	5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH168	<2010 High Water	8.8		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH169	<2010 High Water	0.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-

Table C Monocyclic Aromatic Hydrocarbons Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Monocyclic Aromatic Hydrocarbons															
			Total MAHs	Benzene	Toluene	Ethylbenzene	meta&para Xylene	ortho Xylene	Styrene	Isopropylbenzene	n-Propylbenzene	1,3,5-Trimethylbenzene	sec-Butylbenzene	1,2,4-Trimethylbenzene	tert-Butylbenzene	p-Isoprpyltoluene	n-Butylbenzene
Assessment criteria				1	1.4	3.1	14		-	-	-	-	-	-	-	-	-
PQL				0.2	0.2	0.2	0.4		1	1	1	1	1	1	1	1	1
BH169	<2010 High Water	4.4		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH170	<2010 High Water	1.3		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH170	<2010 High Water	3.7		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH170	<2010 High Water	6.1		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH172	<2010 High Water	1.2		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH172	<2010 High Water	1.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH172	<2010 High Water	3.9		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH173	<2010 High Water	1.8		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH177	<2010 High Water	1.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH177	<2010 High Water	4		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH182	<2010 High Water	10.6		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH002	Above GW	0.5		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH004	Above GW	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH082	Above GW	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH138	Above GW	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH149	Above GW	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH005	Excavated	0.55		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH038	Excavated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH041	Excavated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH088	Excavated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH105	Excavated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH123	Excavated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH131	Excavated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH150	Excavated	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH164	Excavated	0.1		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH182	Excavated	0.4		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH069	Off-site	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH084	Off-site	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH121	Off-site	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH121	Off-site	0.4		<0.2	<0.2	<0.2	<0.3		-	-	-	-	-	-	-	-	-

Table C Monocyclic Aromatic Hydrocarbons Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Monocyclic Aromatic Hydrocarbons															
			Total MAHs	Benzene	Toluene	Ethylbenzene	meta&para Xylene	ortho Xylene	Styrene	Isopropylbenzene	n-Propylbenzene	1,3,5-Trimethylbenzene	sec-Butylbenzene	1,2,4-Trimethylbenzene	tert-Butylbenzene	p-Isoprpyltoluene	n-Butylbenzene
Assessment criteria				1	1.4	3.1	14		-	-	-	-	-	-	-	-	-
PQL				0.2	0.2	0.2	0.4		1	1	1	1	1	1	1	1	1
BH139	Off-site	1.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH144	Off-site	3.2		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH163	Off-site	5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH163	Off-site	7		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH167	Off-site	2.2		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH167	Off-site	8.6		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH167	Off-site	10.7		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH171	Off-site	1.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH171	Off-site	2.7		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH174	Off-site	2.4		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH174	Off-site	4.3		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH175	Off-site	2		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH175	Off-site	7.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH176	Off-site	2.4		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH176	Off-site	3.7		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH178	Off-site	8.3		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH181	Off-site	5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH181	Off-site	9.1		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH185	Off-site	4		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH185	Off-site	9.6		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH215	Off-site	2.5		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH215	Off-site	6.1		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH033	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH034	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH037	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH037	Unsaturated	0.7		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH039	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH043	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH083	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH085	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-

Table C Monocyclic Aromatic Hydrocarbons Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Monocyclic Aromatic Hydrocarbons														
			Total MAHs	Benzene	Toluene	Ethylbenzene	meta&para Xylene	ortho Xylene	Styrene	Isopropylbenzene	n-Propylbenzene	1,3,5-Trimethylbenzene	sec-Butylbenzene	1,2,4-Trimethylbenzene	tert-Butylbenzene	p-Isoprpyltoluene	n-Butylbenzene
Assessment criteria				1	1.4	3.1	14		-	-	-	-	-	-	-	-	-
PQL				0.2	0.2	0.2	0.4		1	1	1	1	1	1	1	1	1
BH120	Unsaturated	0.4		<0.2	0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH125	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH126	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH127	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH130	Unsaturated	0.4		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH157	Unsaturated	0.3		<0.2	<0.2	<0.2	<0.3		-	-	-	-	-	-	-	-	-
BH158	Unsaturated	0.35		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-

Table D Heavy Metals and Inorganics Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Heavy Metals								Sulphate	Cyanide (total)
			As	Cd	Cr	Cu	Pb	Hg	Ni	Zn		
PQL			**5**	**1**	**1**	**1**	**1**	**0.1**	**2**	**1**	**100**	**1**
Assessment Criteria											**2000**	
BH003	<2010 High Water	1.05	<5	<1	20	123	183	0.2	61	114	-	-
BH003	<2010 High Water	3.2	<5	<1	18	62	124	<0.1	2	39	-	-
BH003	<2010 High Water	1.7	<5	<1	18	42	266	0.3	2	92	-	-
BH006	<2010 High Water	1	<5	<1	18	180	195	2.6	5	155	-	-
BH006	<2010 High Water	1.7	<5	<1	12	59	207	0.5	10	210	-	-
BH008	<2010 High Water	0.75	<5	<1	22	30	111	0.2	20	152	-	-
BH008	<2010 High Water	1.6	<5	<1	12	12	34	<0.1	9	81	-	-
BH009	<2010 High Water	1.7	<5	<1	14	53	301	<0.1	12	49	-	-
BH011	<2010 High Water	2.9	<5	<1	19	20	83	0.1	4	58	-	-
BH011	<2010 High Water	1.7	7	<1	10	74	290	0.7	18	154	-	-
BH012	<2010 High Water	1.7	<5	<1	2	23	70	0.4	<2	126	-	-
BH013	<2010 High Water	3.2	<5	<1	44	82	125	<0.1	10	102	-	-
BH013	<2010 High Water	1.7	<5	<1	6	80	181	0.4	17	348	-	-
BH033	<2010 High Water	3.2	<5	<1	6	61	77	0.1	4	85	-	-
BH033	<2010 High Water	1.7	6	<1	141	31	72	0.1	19	308	-	-
BH034	<2010 High Water	1.7	<5	<1	5	5	5	<0.1	<2	<5	-	-
BH036	<2010 High Water	3.2	<5	<1	10	24	182	0.2	3	28	-	-
BH036	<2010 High Water	1.7	<5	<1	7	28	64	0.1	<2	43	-	-
BH037	<2010 High Water	2.85	<5	<1	14	5	11	<0.1	<2	<5	-	-
BH039	<2010 High Water	2.25	<5	<1	12	18	22	0.1	19	32	-	-
BH083	<2010 High Water	3.2	<5	<1	12	16	45	0.1	8	62	420	<1
BH085	<2010 High Water	1.7	<5	<1	9	293	157	0.2	6	22	500	<1
BH086	<2010 High Water	3.2	<5	<1	8	5	5	<0.1	<2	<5	320	<1
BH086	<2010 High Water	1.7	<5	<1	13	6	21	0.1	<2	8	210	<1
BH088	<2010 High Water	3.2	<5	<1	8	5	12	<0.1	<2	18	-	-
BH105	<2010 High Water	1.7	<5	<1	11	6	21	<0.1	<2	20	-	-
BH106	<2010 High Water	1.7	6	<1	5	5	14	<0.1	<2	19	-	-
BH106	<2010 High Water	3.2	<5	<1	7	9	27	<0.1	3	61	-	-
BH120	<2010 High Water	1.7	12	<1	37	34	168	0.2	21	106	-	-
BH123	<2010 High Water	3.2	<5	<1	9	9	165	<0.1	<2	38	850	<1
BH124	<2010 High Water	1.7	<5	<1	11	36	210	0.4	6	38	510	<1
BH125	<2010 High Water	1.7	<5	1	10	7	24	<0.1	<2	12	-	-
BH126	<2010 High Water	5.1	<5	<1	9	40	101	0.2	8	63	-	-

Table D Heavy Metals and Inorganics Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Heavy Metals								Sulphate	Cyanide (total)
			As	Cd	Cr	Cu	Pb	Hg	Ni	Zn		
PQL			**5**	**1**	**1**	**1**	**1**	**0.1**	**2**	**1**	**100**	**1**
Assessment Criteria											**2000**	
BH126	<2010 High Water	1.7	77	<1	22	79	538	1.7	31	328	-	-
BH127	<2010 High Water	3.2	<5	<1	4	12	19	<0.1	<2	6	-	-
BH150	<2010 High Water	9.7	18	2	41	83	208	1.2	15	369	-	-
BH150	<2010 High Water	3.2	<5	<1	13	30	117	0.3	6	126	-	-
BH162	<2010 High Water	3.5	<5	<1	8	17	69	<0.1	3	59	230	<1
BH162	<2010 High Water	12.3	<5	<1	6	<5	14	<0.1	<2	21	100	<1
BH162	<2010 High Water	13.5	5	<1	9	16	28	<0.1	4	50	1490	<1
BH164	<2010 High Water	5.5	11	<1	16	82	383	2.7	6	291	2290	<1
BH165	<2010 High Water	3.5	<5	<1	33	33	42	<0.1	4	43	600	<1
BH165	<2010 High Water	8	5	<1	13	32	106	0.2	9	94	650	<1
BH166	<2010 High Water	1.3	6	<1	19	47	216	0.3	6	144	490	<1
BH166	<2010 High Water	4	6	<1	21	52	111	0.2	15	189	1530	<1
BH168	<2010 High Water	0.5	<5	<1	18	32	110	0.2	23	450	470	<1
BH168	<2010 High Water	5	6	<1	9	24	149	0.2	4	70	630	<1
BH168	<2010 High Water	8.8	11	<1	14	<5	9	<0.1	10	41	1040	<1
BH169	<2010 High Water	0.5	6	<1	12	58	177	1	12	155	640	<1
BH169	<2010 High Water	4.4	26	<1	20	30	237	0.5	19	116	1320	<1
BH170	<2010 High Water	1.3	6	<1	12	53	304	0.6	6	309	490	2
BH170	<2010 High Water	3.7	7	<1	14	36	433	1.1	5	139	1730	<1
BH170	<2010 High Water	6.1	6	<1	11	51	207	0.4	8	66	1790	<1
BH172	<2010 High Water	1.2	<5	<1	12	27	120	0.7	7	67	450	<1
BH172	<2010 High Water	1.5	<5	<1	7	<5	<5	<0.1	<2	<5	220	<1
BH172	<2010 High Water	3.9	<5	<1	6	9	15	<0.1	<2	13	220	<1
BH173	<2010 High Water	1.8	10	<1	11	157	1250	1	12	163	3640	<1
BH177	<2010 High Water	1.5	36	<1	47	1480	131	8	12	221	11600	<1
BH177	<2010 High Water	4	<5	<1	22	85	58	0.4	19	114	640	<1
BH182	<2010 High Water	10.6	<5	<1	9	8	8	<0.1	6	47	1180	1
JBS3	<2010 High Water	1.2	<4	<0.5	10	150	120	0.7	11	72	-	-
JBS4	<2010 High Water	2	11	<0.5	11	76	170	0.2	3	62	-	-
JBS4	<2010 High Water	7.5	5	<0.5	10	72	230	0.9	9	70	-	-
BH002	Above GW	0.5	<5	<1	67	58	40	0.2	77	66	-	-
BH004	Above GW	1.7	<5	<1	7	5	16	<0.1	<2	5	-	-
BH082	Above GW	0.4	<5	<1	30	19	41	<0.1	30	59	-	-

Table D Heavy Metals and Inorganics Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Heavy Metals								Sulphate	Cyanide (total)
			As	Cd	Cr	Cu	Pb	Hg	Ni	Zn		
PQL			**5**	**1**	**1**	**1**	**1**	**0.1**	**2**	**1**	**100**	**1**
Assessment Criteria											**2000**	
BH138	Above GW	0.4	<5	<1	32	36	54	0.4	33	67	-	-
BH149	Above GW	0.4	<5	<1	8	33	27	<0.1	48	27	-	-
BH005	Excavated	0.55	<5	<1	10	40	39	<0.1	62	63	-	-
BH007	Excavated	0.5	<5	<1	17	36	116	0.2	18	94	-	-
BH007	Excavated	1	<5	<1	20	33	273	0.4	15	130	-	-
BH088	Excavated	0.4	<5	<1	11	18	15	<0.1	41	34	-	-
BH088	Excavated	1.7	<5	<1	8	14	48	<0.1	7	52	-	-
BH105	Excavated	0.4	<5	<1	21	62	129	0.4	38	92	-	-
BH123	Excavated	0.4	<5	<1	16	16	38	<0.1	16	48	520	<1
BH150	Excavated	1.7	<5	<1	15	34	130	0.2	8	126	-	-
BH164	Excavated	0.1	<5	<1	114	35	<5	<0.1	122	59	580	<1
BH182	Excavated	0.4	<5	<1	18	21	38	<0.1	27	54	450	<1
JBS3	Excavated	0.7	-	-	-	-	-	-	-	-	-	-
BH015	Excavated	0.6	<5	<1	7	15	37	<0.1	18	42	-	-
BH038	Excavated	0.4	<5	<1	5	60	9	<0.1	115	42	-	-
BH041	Excavated	0.4	<5	<1	6	55	20	<0.1	90	43	-	-
BH131	Excavated	0.4	<5	<1	8	20	110	<0.1	15	103	-	-
BH010	Off-site	0.4	<5	<1	10	79	108	0.1	15	77	-	-
BH010	Off-site	1.7	<5	<1	8	30	132	0.3	4	84	-	-
BH014	Off-site	6.75	<5	<1	78	16	51	0.1	5	60	-	-
BH014	Off-site	0.4	<5	<1	9	56	25	<0.1	96	50	-	-
BH016	Off-site	0.4	<5	<1	8	42	99	0.3	36	73	-	-
BH016	Off-site	1.7	5	<1	4	14	31	0.1	<2	14	-	-
BH029	Off-site	3.2	5	<1	9	67	215	0.5	<2	43	-	-
BH029	Off-site	0.4	<5	<1	10	43	116	0.2	40	88	-	-
BH030	Off-site	3.2	<5	<1	10	14	64	0.8	7	71	-	-
BH030	Off-site	0.4	<5	<1	7	24	51	<0.1	29	41	-	-
BH030	Off-site	1.7	<5	<1	10	14	38	<0.1	5	23	-	-
BH031	Off-site	1.7	7	<1	7	8	8	<0.1	5	11	-	-
BH069	Off-site	0.4	<5	<1	12	44	54	<0.1	54	61	-	-
BH069	Off-site	1.7	<5	<1	7	6	10	<0.1	<2	<5	-	-
BH084	Off-site	0.4	<5	<1	6	13	15	<0.1	14	14	-	-
BH084	Off-site	1.7	<5	<1	4	5	25	<0.1	<2	12	-	-

Table D Heavy Metals and Inorganics Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Heavy Metals								Sulphate	Cyanide (total)
			As	Cd	Cr	Cu	Pb	Hg	Ni	Zn		
PQL			**5**	**1**	**1**	**1**	**1**	**0.1**	**2**	**1**	**100**	**1**
Assessment Criteria											**2000**	
BH121	Off-site	3.2	<5	<1	42	26	66	0.2	9	48	-	-
BH121	Off-site	0.4	<5	<1	8	19	32	<0.1	10	219	-	-
BH139	Off-site	1.7	<5	<1	8	5	8	<0.1	<2	<5	-	-
BH144	Off-site	3.2	<5	<1	40	13	25	<0.1	22	47	-	-
BH163	Off-site	5	<5	<1	7	6	51	0.2	<2	38	230	<1
BH163	Off-site	7	<5	<1	13	30	101	<0.1	<2	57	210	<1
BH167	Off-site	2.2	<5	<1	7	13	47	<0.1	3	39	260	<1
BH167	Off-site	8.6	<5	<1	7	42	48	<0.1	8	54	220	<1
BH167	Off-site	10.7	<5	<1	7	15	196	0.4	4	104	200	<1
BH171	Off-site	1.5	<5	<1	3	<5	<5	<0.1	<2	<5	150	<1
BH171	Off-site	2.7	<5	<1	6	24	192	0.2	4	101	1650	2
BH174	Off-site	2.4	<5	<1	18	17	74	<0.1	4	46	1460	<1
BH174	Off-site	4.3	-	-	-	-	-	-	-	-	940	<1
BH175	Off-site	2	<5	<1	9	11	11	0.2	3	39	1720	<1
BH175	Off-site	7.5	<5	<1	5	<5	7	<0.1	<2	10	300	<1
BH176	Off-site	2.4	<5	<1	<2	<5	14	<0.1	<2	21	400	<1
BH176	Off-site	3.7	8	<1	8	94	227	5.7	4	152	1550	<1
BH178	Off-site	8.3	<5	<1	18	21	109	0.3	7	284	2360	<1
BH181	Off-site	5	<5	<1	7	<5	18	<0.1	<2	19	120	<1
BH181	Off-site	9.1	<5	<1	6	<5	16	<0.1	2	19	390	1
BH185	Off-site	4	<5	<1	7	7	32	<0.1	5	34	930	<1
BH185	Off-site	9.6	<5	<1	4	<5	12	<0.1	<2	45	520	<1
BH215	Off-site	2.5	<5	<1	7	<5	16	<0.1	<2	9	430	<1
BH215	Off-site	6.1	<5	<1	11	11	483	<0.1	4	311	860	<1
JBS2	Off-site	1.8	<4	<0.5	11	38	210	<0.1	24	290	-	-
JBS2	Off-site	4	-	-	-	-	-	-	-	-	-	-
BH009	Unsaturated	0.4	<5	<1	12	46	280	<0.1	20	97	-	-
BH011	Unsaturated	0.4	6	<1	17	50	78	0.1	49	141	-	-
BH012	Unsaturated	0.4	<5	<1	12	63	41	<0.1	130	63	-	-
BH013	Unsaturated	0.4	<5	<1	8	41	72	<0.1	30	62	-	-
BH033	Unsaturated	0.4	<5	<1	41	50	34	<0.1	69	45	-	-
BH034	Unsaturated	0.4	<5	<1	7	36	93	0.2	25	76	-	-
BH036	Unsaturated	0.4	<5	<1	8	66	5	<0.1	128	38	-	-

Table D Heavy Metals and Inorganics Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Fill Based Soils

all units in mg/kg

Sample ID	Location	Sampling Depth (m)	Heavy Metals								Sulphate	Cyanide (total)
			As	Cd	Cr	Cu	Pb	Hg	Ni	Zn		
PQL			**5**	**1**	**1**	**1**	**1**	**0.1**	**2**	**1**	**100**	**1**
Assessment Criteria											**2000**	
BH037	Unsaturated	0.4	<5	<1	7	42	84	0.2	59	87	-	-
BH037	Unsaturated	0.7	<5	<1	7	5	11	<0.1	<2	<5	-	-
BH039	Unsaturated	0.4	<5	<1	7	26	27	0.1	39	31	-	-
BH043	Unsaturated	0.4	<5	<1	9	32	21	<0.1	56	41	-	-
BH083	Unsaturated	0.4	<5	<1	27	83	57	0.4	52	92	710	<1
BH085	Unsaturated	0.4	<5	<1	9	18	37	<0.1	11	41	260	<1
BH120	Unsaturated	0.4	<5	<1	66	32	42	0.1	70	84	-	-
BH125	Unsaturated	0.4	<5	<1	10	68	210	1.3	32	140	-	-
BH126	Unsaturated	0.4	<5	<1	22	35	108	0.4	20	145	-	-
BH127	Unsaturated	0.4	<5	<1	10	42	71	0.4	30	70	-	-
BH130	Unsaturated	0.4	<5	<1	8	16	46	<0.1	11	51	-	-
BH157	Unsaturated	0.3	-	-	-	-	-	-	-	-	520	1
JBS3	Unsaturated	0.2	-	-	-	-	-	-	-	-	-	-
JBS4	Unsaturated	0.5	<4	<0.5	15	37	110	0.3	15	100	-	-

Table E Polycyclic Aromatic Hydrocarbon Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Natural Soils

all units in mg/kg

Sample id	Sampling Depth (m)	Soil Type / description	Polycyclic Aromatic Hydrocarbons																
			Total PAHs	Acenaphthylene	Acenaphthene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3,cd)pyrene	Naphthalene	Phenanthrene	Pyrene
Assessment criteria [1]			40					2											
PQL				1	1	1	1	0.5	2	1		1	1	1	1	1	1	1	1
BH014	11.7 (1.2)	Sandy clay, orange brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH016	5.8 (2.7)	Silty sand, dark grey		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	0.6
BH029	9.25 (4.25)	Clayey sand, brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH083	7.2 (1.0)	Sandy clay, brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH144	15.2 (1.7)	Sandy clay, orange brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH163	15 (0.5)	Clay, red/orange		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH164	8.3 (1.1)	Sand, grey/brown	25.1	<0.5	<0.5	0.8	2.1	2.2	2.8	1.5	1.1	1.6	<0.5	5.1	<0.5	1.1	<0.5	1.6	5.2
BH165	10.5 (0.5)	Sandstone, orange/yellow		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH166	7 (1.2)	Sand, yellow/brown/grey	1.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	0.9
BH169	7.5 (1.7)	Sandy clay, grey	204.4	2	1.9	8.8	19.1	13.5	18.4	8.1	8.9	14.6	2.3	38.9	3.5	6.3	<0.5	27.4	30.7
BH169	9 (3.2)	Sandy clay, light grey		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH171	4.8 (1.3)	Sandstone, yellow/brown/white		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH173	3.7 (0.1)	Sand, grey/brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH174	8 (0.2)	Clayey sand, yellow/brown/white		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH175	11 (0.25)	Clayey sand, yellow/brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH176	9.2 (1.6)	Clayey sand, yellow/brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH177	12.2 (0)	Clayey sand, yellow/brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH178	12 (0)	Clayey sand, red/brown/grey		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH178	17 (5)	Sandstone, light grey		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH181	22 (8.5)	Sandstone, yellow/brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH182	22.9 (7.9)	Sandy silty clay, brown		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BH185	14.6 (0.1)	Sandy clay, dark grey	2.5	<0.5	<0.5	<0.5	<0.5	0.6	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	0.6
BH215	18 (0)	Sandy clay, dark grey	18.1	<0.5	<0.5	<0.5	1.8	1.8	2.2	1.3	1.1	1.4	<0.5	3	<0.5	1	<0.5	1.2	3.3

Note: value in brackets is depth of sample below fill / natural soil interface

Table F Total Petroleum Hydrocarbon Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Natural Soils

all units in mg/kg

Sample ID	Sampling Depth (m)	Soil Type / Description	TPH				
			C6-C9	C10-C14	C15-C28	C29-C36	ΣC10-C36
Assessment criteria [1]			**65**	**-**			**1000**
PQL			**2**	**50**	**100**	**100**	
BH014	11.7 (1.2)	Sandy clay, orange brown	<2	<50	<100	<100	-
BH016	5.8 (2.7)	Silty sand, dark grey	<2	<50	<100	<100	-
BH029	9.25 (4.25)	Clayey sand, brown	<2	<50	<100	<100	-
BH034	2.7 (0.2)	Clayey sand, dark grey	<2	<50	<100	<100	-
BH083	7.2 (1.0)	Sandy clay, brown	<2	<50	<100	<100	-
BH123	7.7 (5.5)	Sandstone, light grey	<2	<50	<100	<100	-
BH144	15.2 (1.7)	Sandy clay, orange brown	<2	<50	<100	<100	-
BH163	15 (0.5)	Clay, red/orange	<2	<50	<100	<100	-
BH164	8.3 (1.1)	Sand, grey/brown	<2	<50	<100	<100	-
BH165	10.5 (0.5)	Sandstone, orange/yellow	<2	<50	<100	<100	-
BH166	7 (1.2)	Sand, yellow/brown/grey	<2	<50	<100	<100	-
BH169	7.5 (1.7)	Sandy clay, grey	15	<50	820	520	1340
BH169	9 (3.2)	Sandy clay, light grey	<2	<50	<100	<100	-
BH171	4.8 (1.3)	Sandstone, yellow/brown/white	<2	<50	<100	<100	-
BH173	3.7 (0.1)	Sand, grey/brown	<2	<50	<100	<100	-
BH174	8 (0.2)	Clayey sand, yellow/brown/white	<2	<50	<100	<100	-
BH175	11 (0.25)	Clayey sand, yellow/brown	<2	<50	<100	<100	-
BH176	9.2 (1.6)	Clayey sand, yellow/brown	<2	<50	<100	<100	-
BH177	12.2 (0)	Clayey sand, yellow/brown	<2	<50	<100	<100	-
BH178	12 (0)	Clayey sand, red/brown/grey	<2	<50	<100	<100	-
BH178	17 (5)	Sandstone, light grey	<2	<50	<100	<100	-
BH181	22 (8.5)	Sandstone, yellow/brown	<2	<50	<100	<100	-
BH182	22.9 (7.9)	Sandy silty clay, brown	<2	<50	<100	<100	-
BH185	14.6 (0.1)	Sandy clay, dark grey	<2	<50	<100	<100	-
BH215	18 (0)	Sandy clay, dark grey	<2	<50	550	440	990

Note: value in brackets is depth of sample below fill / natural soil interface

Table G Monocyclic Aromatic Hydrocarbons Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Natural Soils

all units in mg/kg

Sample ID	Sampling Depth (m)	Soil Type / Description	Monocyclic Aromatic Hydrocarbons														
			Total MAHs	Benzene	Toluene	Ethylbenzene	meta&para Xylene	ortho Xylene	Styrene	Isopropylbenzene	n-Propylbenzene	1,3,5-Trimethylbenzene	sec-Butylbenzene	1,2,4-Trimethylbenzene	tert-Butylbenzene	p-Isoprpyltoluene	n-Butylbenzene
Assessment criteria				1	1.4	3.1	14		-	-	-	-	-	-	-	-	-
PQL				0.2	0.2	0.2	0.4		1	1	1	1	1	1	1	1	1
BH034	2.7 (0.2)	Clayey sand, dark grey		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH083	7.2 (1.0)	Sandy clay, brown		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH123	7.7 (5.5)	Sandstone, light grey		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH144	15.2 (1.7)	Sandy clay, orange brown		<0.2	<0.2	<0.2	<0.4		-	-	-	-	-	-	-	-	-
BH163	15 (0.5)	Clay, red/orange		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH164	8.3 (1.1)	Sand, grey/brown		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH165	10.5 (0.5)	Sandstone, orange/yellow		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH166	7 (1.2)	Sand, yellow/brown/grey		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH169	7.5 (1.7)	Sandy clay, grey		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH169	9 (3.2)	Sandy clay, light grey		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH171	4.8 (1.3)	Sandstone, yellow/brown/white		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH173	3.7 (0.1)	Sand, grey/brown		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH174	8 (0.2)	Clayey sand, yellow/brown/white		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH175	11 (0.25)	Clayey sand, yellow/brown		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH176	9.2 (1.6)	Clayey sand, yellow/brown		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH177	12.2 (0)	Clayey sand, yellow/brown		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH178	12 (0)	Clayey sand, red/brown/grey		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH178	17 (5)	Sandstone, light grey		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH181	22 (8.5)	Sandstone, yellow/brown		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH182	22.9 (7.9)	Sandy silty clay, brown		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH185	14.6 (0.1)	Sandy clay, dark grey		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-
BH215	18 (0)	Sandy clay, dark grey		<0.2	<0.5	<0.5	<0.5	<0.5	-	-	-	-	-	-	-	-	-

Note: value in brackets is depth of sample below fill / natural soil interface

Table H Heavy Metals and Inorganics Results
Historical Soil Sampling
Barangaroo Headland Park and Northern Cove, Natural Soils

all units in mg/kg

Sample ID	Sampling Depth (m)	Soil Type / Description	Heavy Metals								Sulphate	Cyanide (total)
			As	Cd	Cr	Cu	Pb	Hg	Ni	Zn		
PQL			**5**	**1**	**1**	**1**	**1**	**0.1**	**2**	**1**	**100**	**1**
Assessment Criteria											**2000**	
BH014	11.7 (1.2)	Sandy clay, orange brown	6	<1	18	5	23	0.2	<2	25	-	-
BH016	5.8 (2.7)	Silty sand, dark grey	<5	<1	3	17	57	<0.1	<2	45	-	-
BH029	9.25 (4.25)	Clayey sand, brown	<5	<1	13	8	18	<0.1	3	8	-	-
BH034	2.7 (0.2)	Clayey sand, dark grey	<5	<1	6	186	39	<0.1	<2	12	-	-
BH083	7.2 (1.0)	Sandy clay, brown	<5	<1	17	5	306	<0.1	<2	7	570	<1
BH123	7.7 (5.5)	Sandstone, light grey	<5	<1	56	5	7	<0.1	4	21	-	-
BH144	15.2 (1.7)	Sandy clay, orange brown	<5	<1	14	10	59	0.1	4	37	-	-
BH163	15 (0.5)	Clay, red/orange	3	<1	20	12	77	0.8	<2	25	2090	<1
BH164	8.3 (1.1)	Sand, grey/brown	18	<1	15	19	48	0.4	<2	80	1630	<1
BH165	10.5 (0.5)	Sandstone, orange/yellow	<5	<1	10	<5	11	<0.1	<2	15	650	<1
BH166	7 (1.2)	Sand, yellow/brown/grey	11	<1	12	<5	<5	<0.1	<2	<5	480	<1
BH169	7.5 (1.7)	Sandy clay, grey	7	<1	9	148	247	0.8	4	35	2070	<1
BH169	9 (3.2)	Sandy clay, light grey	5	<1	5	<5	<5	<0.1	<2	<5	2010	<1
BH171	4.8 (1.3)	Sandstone, yellow/brown/white	<5	<1	6	<5	<5	<0.1	<2	<5	410	<1
BH173	3.7 (0.1)	Sand, grey/brown	11	<1	10	<5	7	<0.1	3	13	1430	<1
BH174	8 (0.2)	Clayey sand, yellow/brown/white	<5	<1	8	10	68	<0.1	<2	699	590	<1
BH175	11 (0.25)	Clayey sand, yellow/brown	<5	<1	15	<5	5	<0.1	<2	<5	520	<1
BH176	9.2 (1.6)	Clayey sand, yellow/brown	<5	<1	2	<5	9	1.2	<2	<5	300	<1
BH177	12.2 (0)	Clayey sand, yellow/brown	<5	<1	19	10	<5	0.5	<2	16	160	<1
BH178	12 (0)	Clayey sand, red/brown/grey	7	<1	14	<5	<5	0.7	<2	7	880	<1
BH178	17 (5)	Sandstone, light grey	<5	<1	23	<5	7	<0.1	<2	<5	430	<1
BH181	22 (8.5)	Sandstone, yellow/brown	5	<1	17	<5	11	0.7	<2	13	280	<1
BH182	22.9 (7.9)	Sandy silty clay, brown	<5	<1	8	<5	18	<0.1	<2	<5	480	<1
BH185	14.6 (0.1)	Sandy clay, dark grey	6	<1	14	19	78	0.3	4	101	440	<1
BH215	18 (0)	Sandy clay, dark grey	15	<1	30	104	255	1.5	14	326	850	<1
JBS4	10.5 (6.5)	Sandstone, grey	<4	<0.5	15	14	75	0.2	3	39	-	-

Note: value in brackets is depth of sample below fill / natural soil interface

Table I Groundwater Sample Register
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

Monitoring Well ID	Sample Date	Location	Analytes
MW01	14/07/2006	Adjoiniong proposed north-western site boundary	Heavy metals, PAHs, TPH and PCBs
	5/05/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW02	14/07/2006 & 17/07/2006	Proposed western boundary	Heavy metals, PAHs, TPH and PCBs
	14/08/2007		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
	5/06/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW03	14/07/2006	Adjoining north-west of proposed north-western site boundary	Cu, Pb and Zn
	5/05/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
	14/07/2006		Heavy metals, PAHs, TPH and PCBs

Table I Groundwater Sample Register
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

Monitoring Well ID	Sample Date	Location	Analytes
MW04	13/08/2007	Proposed western boundary	Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
	5/06/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW05	18/07/2006	Within inundated area of proposed Northern Cove (off-site)	Cu, Pb and Zn
	16/08/2007		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
	5/09/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW06	18/07/2006	Proposed south-western boundary	Cu, Pb and Zn
	16/08/2007		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
	5/08/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs

Table I Groundwater Sample Register
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

Monitoring Well ID	Sample Date	Location	Analytes
MW07	17/07/2006	Proposed western boundary	Cu, Pb and Zn
	15/08/2007		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
	5/06/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW19	18/07/2006	Within inundated area of proposed Northern Cove (off-site)	Cu, Pb and Zn
	16/08/2007		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
	5/09/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW25	25/07/2006	Within unundated area to north-east of site (off-site)	Cu, Pb and Zn
	13/08/2007		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs

Table I Groundwater Sample Register
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

Monitoring Well ID	Sample Date	Location	Analytes
	5/12/2008		Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW179	5/06/2008	To east of southern portion of Headland Park site (upgradient / background)	Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs
MW215	5/08/2008	Within inundated area of proposed Northern Cove (off-site)	Heavy metals, anions, cations, cyanide, ammonia (as N), phenols, PAHs, BTEX, TPH and PCBs

Table J Polycyclic Aromatic Hydrocarbons Results
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

all units in ug/l

Sample id	Location	Date sampled	Polycyclic Aromatic Hydrocarbons														
			Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b&k)fluoranthene	Benzo(a)pyrene	Indeno(1,2,3,cd)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene
Assessment criteria [1]			50	-	-	-	2	0.1	1.4	0.24	0.5	0.2	0.05	0.2	0.05	-	0.05
PQL			1	1	1	1	1	1	1	1	1	1	2	0.5	1	1	1
MW01	Boundary	14/07/2006	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW01		5/05/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW02	Boundary	14 & 17/07/2006	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW02		14/08/2007	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW02		5/06/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW03	Boundary	5/05/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW04	Boundary	14/07/2006	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW04		13/08/2007	<1	<1	<1	<1	1.3	<1	**2.2**	**2**	<1	<1	<2	0.9	<1	<1	<1
MW04		5/06/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW06	Boundary	16/08/2007	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW06		5/08/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW07	Boundary	15/08/2007	<1	<1	<1	<1	1.7	<1	**5.4**	**6.1**	**2.2**	**2.1**	**4**	**2.7**	**1.4**	<1	**1.6**
MW07		5/06/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW05	Off-site	16/08/2007	7.7	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW05		5/09/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW19	Off-site	16/08/2007	6.6	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1
MW19		5/09/2008	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.05	<0.1	<0.1	<0.1
MW25	Off-site	13/08/2007	<1	<1	<1	<1	**2.5**	**1.1**	**5.5**	**6.5**	**2.4**	**2.4**	**4.4**	**3**	**1.8**	<1	**2**
MW25		5/12/2008	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2	<0.5	<1	<1	<1

Table J Polycyclic Aromatic Hydrocarbons Results
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

all units in ug/l

Sample id	Location	Date sampled	Polycyclic Aromatic Hydrocarbons														
			Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b&k)fluoranthene	Benzo(a)pyrene	Indeno(1,2,3,cd)pyrene	Dibenz(a,h)anthracene	Benzo(g,h,i)perylene
Assessment criteria [1]			50	-	-	-	2	0.1	1.4	0.24	0.5	0.2	0.05	0.2	0.05	-	0.05
PQL			1	1	1	1	1	1	1	1	1	1	2	0.5	1	1	1
MW215	Off-site	5/08/2008	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.05	<0.1	<0.1	<0.1
MW179	Background	5/06/2008	<1	<1	<1	<1	<1	<1	**1.4**	**1.3**	<1	<1	<2	**0.7**	<1	<1	<1

Table K TPH Results
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

all units in ug/l

Sample ID	Location	Date sampled	TPH				
			C6-C9	C10-C14	C15-C28	C29-C36	ΣC6-C36
Assessment criteria [1]			--	-			**600**
PQL			**20**	**50**	**100**	**50**	
MW01	Boundary	14/07/2006	<20	<50	<100	<50	-
MW01		5/05/2008	<20	<50	<100	<50	-
MW02	Boundary	14 & 17/07/2006	<20	<50	<100	<50	-
MW02		14/08/2007	<20	<50	<100	<50	-
MW02		5/06/2008	<20	<50	<100	<50	-
MW03	Boundary	5/05/2008	<20	<50	<100	<50	-
MW04	Boundary	14/07/2006	<20	<50	<100	<50	-
MW04		13/08/2007	<20	<50	<100	<50	-
MW04		5/06/2008	<20	<50	<100	<50	-
MW06	Boundary	16/08/2007	<20	<50	<100	<50	-
MW06		5/08/2008	<20	<50	<100	<50	-
MW07	Boundary	15/08/2007	<20	<50	300	160	460
MW07		5/06/2008	<20	<50	<100	<50	-
MW05	Off-site	16/08/2007	<20	<50	<100	<50	-
MW05		5/09/2008	<20	<50	<100	<50	-
MW19	Off-site	16/08/2007	<20	<50	<100	<50	-
MW19		5/09/2008	<20	<50	<100	<50	-
MW25	Off-site	13/08/2007	<20	<50	400	200	600
MW25		5/12/2008	<20	<50	100	50	150
MW215	Off-site	5/08/2008	<20	<50	<100	<50	-
MW179	Background	5/06/2008	<20	<50	200	820	**1020**

Table L Monocyclic Aromatic Hydrocarbons Results
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

all units in ug/l

Sample ID	Location	Date sampled	Monocyclic Aromatic Hydrocarbons														
			Total MAHs	Benzene	Toluene	Ethylbenzene	meta&para Xylene	Styrene	ortho Xylene	Isopropylbenzene	n-Propylbenzene	1,3,5-Trimethylbenzene	sec-Butylbenzene	1,2,4-Trimethylbenzene	tert-Butylbenzene	p-Isoprpyltoluene	n-Butylbenzene
Assessment criteria				500	180	5	75	30	75	-	-	-	-	-	-	-	-
PQL				1	1	1	2	1	1	1	1	1	1	1	1	1	1
MW01		14/07/2006		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW01	Boundary	5/05/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW02		14 & 17/07/2006		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW02		14/08/2007		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW02	Boundary	5/06/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW03	Boundary	5/05/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW04		14/07/2006		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW04		13/08/2007		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW04	Boundary	5/06/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW06		16/08/2007		<1	<1	<1	2	-	<1	-	-	-	-	-	-	-	-
MW06	Boundary	5/08/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW07		15/08/2007		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW07	Boundary	5/06/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW05		16/08/2007		1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW05	Off-site	5/09/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW19		16/08/2007		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW19	Off-site	5/09/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW25		13/08/2007		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW25	Off-site	5/12/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW215	Off-site	5/08/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-
MW179	Background	5/06/2008		<1	<1	<1	<2	-	<1	-	-	-	-	-	-	-	-

Table M Phenols Results
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

all units in ug/l

Sample ID	Date sampled	Phenols																	
		Total	Phenol	2-Chlorophenol	2-Methylphenol	3- & 4-Methylphenol	2,4-Dimethylphenol	2-Nitrophenol	2,4-Dichlorphenol	2,4,6-Trichlorophenol	2,4,5-Trichlorophenol	2,4-Dinitrophenol	4-Nitrophenol	4-Chloro-3-methylphenol	2-methyl-4,6-dinitrophenol	Pentachlorophenol	3-methylphenol	2,6-Dichlorophenol	2,3,4,6-Tetrachlorophenol
PQL			1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
MW01	5/05/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW02	14/08/2007		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW02	5/06/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW03	5/05/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW04	13/08/2007		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW04	5/06/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW05	16/08/2007		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW05	5/09/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW06	16/08/2007		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW06	5/08/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW07	15/08/2007		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW07	5/06/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW19	16/08/2007		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW19	5/09/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW25	13/08/2007		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW25	5/12/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW179	5/06/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-
MW215	5/08/2008		-	-	-	-	-	<1	-	<1	-	-	-	<1	-	<2	-	<1	-

Table N Heavy Metals and Inorganics Results
Historical Groundwater Sampling and Analysis
Barangaroo Headland Park and Northern Cove

all units in ug/l

Sample ID	Location	Date sampled	Heavy Metals								Total Dissolved Solids (TDS)	pH	Cyanide (total)	Ammonia (as N)
			As	Cd	Cr	Cu	Pb	Hg	Ni	Zn				
PQL			**1**	**0.1**	**1**	**1**	**1**	**0.1**	**1**	**1**			**4**	**100**
Assessment Criteria			**2.3**	**0.7**	**4.4**	**1.3**	**4.4**	**0.1**	**7**	**15**	**-**	**-**	**4**	**910**
MW01	Boundary	14/07/2006	<10	<1	<10	**2**	0.2	<0.1	<10	**22**	30030	7.34	-	-
MW01		5/05/2008	<0.5	0.6	<0.5	**2**	<0.2	<0.1	**186**	**26**	30095	5.91	<4	204
MW02	Boundary	14 & 17/07/2006	<10	<1	<10	<1	2.5	<0.1	<10	**41**	30160	7.14-7.53	-	-
MW02		14/08/2007	<10	**1.4**	<10	**144**	<10	<0.1	**228**	**156**	-	-	<4	**1000**
MW02		5/06/2008	2.2	0.3	<0.5	<1	0.5	<0.1	**116**	7	31655	7.09	<4	<15
MW03	Boundary	14/07/2006	-	-	-	**3**	0.7	-	-	**17**	30745	7.83	-	-
MW03		5/05/2008	1	**5.5**	<0.5	<1	<0.2	<0.1	**46.3**	12	30420	7.44	<4	130
MW04	Boundary	14/07/2006	<10	<1	<10	1	1.2	<0.1	**10**	**22**	32045	7.24	-	-
MW04		13/08/2007	13	**18.8**	<10	**96**	**65**	<0.1	**241**	**392**	-	-	<4	<100
MW04		5/06/2008	1.3	0.4	<0.5	**11**	1.3	<0.1	**303**	**31**	20280	5.87	<4	119
MW06	Boundary	18/07/2006	-	-	-	**2**	1.6	-	-	**40**	23530	7.73	-	-
MW06		16/08/2007	**11**	**1.1**	<1	**153**	**19**	<0.1	**46**	**127**	-	-	<4	<10
MW06		5/08/2008	1.6	<0.2	<0.5	<1	<0.2	<0.1	<0.5	**12**	31070	7.76	<4	214
MW07	Boundary	17/07/2006	-	-	-	1	**5**	-	-	**95**	30160	7.53	-	-
MW07		15/08/2007	**12**	**4.2**	<10	**25**	<10	<0.1	**29**	**86**	-	-	<4	<100
MW07		5/06/2008	1.6	0.2	<0.5	<1	<0.2	<0.1	**12.2**	10	31135	7.36	<4	581
MW05	Off-site	18/07/2006	-	-	-	1	0.8	-	-	**45**	23855	7.49	-	-
MW05		16/08/2007	<6	**1.7**	<5	**76**	<1	<0.1	**56**	**299**	-	-	<4	<10
MW05		5/09/2008	0.8	0.2	1.9	<1	<0.2	<0.1	0.8	**19**	21775	6.56	<4	<15
MW19	Off-site	18/07/2006	-	-	-	**2**	7	-	-	**45**	20540	7.43	-	-
MW19		16/08/2007	<10	**3.2**	<10	**45**	<10	<0.1	<10	<50	-	-	<4	<100
MW19		5/09/2008	1.4	0.4	1.6	2	3.8	<0.1	0.7	**29**	30615	7.67	<4	<15
MW25	Off-site	25/07/2006	-	-	-	2	**24.8**	-	-	**203**	21190	6.92	-	-
MW25		13/08/2007	<10	**43.2**	<10	**36**	**62**	0.1	**74**	**290**	-	-	<4	**3610**
MW25		5/12/2008	1.4	<0.2	<0.5	<1	<0.2	<0.1	4	6	14625	6.6	11.8	**4320**
MW215	Off-site	5/08/2008	1	0.3	<0.5	1	<0.2	<0.1	1.7	**18**	31005	7.5	<4	78
MW179	Background	5/06/2008	1.1	0.4	<0.5	<1	0.6	<0.1	**86.8**	**36**	31070	7.5	<4	218

Appendix B

Proposed Headland Park Water Balance

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Louis Panagopoulos
Director Civil and Water Engineer
Warren Smith and Partners
Level 1, 123 Clarence St
SYDNEY 2000

29th September 2010

Re: Barangaroo water balance

Dear Louis,

Please find enclosed a summary of the updated water balance modelling for Barangaroo Headland Park.

If we can be of any further assistance please do not hesitate to contact myself on either 0425 363 161 or 46 571 381.

Yours sincerely

Dr Mick Battam
Principal Soil Scientist

1. Background

Barangaroo is located at the northern end of Cockle Bay. The proposed headland park will include a cultural centre and an underground carpark. Warren Smith and Partners commissioned Dr Mick Battam of AgEnviro Solutions to perform a water balance for the site in order to estimate:

- landscape watering requirements;
- effluent top-up; and
- tank storage requirements.

Irrigation requirements

A sandy topsoil is proposed, with a sandy by slightly heavier textured subsoil (Leake, 2010a, b). The topsoil depth will vary from 200 to 400 mm depth, with the subsoil being similar or deeper (Leake, 2010b).

Based on its texture, the growing media soil was assumed to have:

- a saturated hydraulic conductivity of at least 10 to 20 mm hr^{-1} (Leake pers. com.); and
- at least 45 mm m^{-1} of readily available water holding capacity (NSW Agriculture 2001).

Based on the proposed plantings and the exposed microclimate the watering (rain or irrigation) requirements of the site have been estimated (Table 1).

Table 1. Watering requirements.

Description	Summer and spring	Autumn and winter
Turf (kikuyu)–2.64 Ha*	7 mm of water twice a week	7 mm of water once a week
Indigenous plantings–1.26 Ha*	12 mm of water once a fortnight	None

*** Areas based on areas in 10th September quantity estimate report (PWP and JPW 2010a) and draft quantity estimates cost plan 6 (PWP and JPW 2010b).**

Drainage capture

It is proposed that the underlying fill be sufficiently compacted to limit the infiltration of water. For the purposes of this report it is assumed that:

- all drainage and surface water from the upper sections of the park (2.04 Ha of turf, 1.10 Ha indigeneous plantings and 0.5426 Ha of paths) is captured for reuse in either the turf bioswales, the drains proposed behind the retaining walls on each tier of the steep indigenous planted slope and/or in the bio-swale on the bottom tier of the steep planted slope (PWP and JPW, 2010c). To assist in drainage capture a compacted clay layer is assumed to be present under the base of the drains and bio-swales (saturated hydraulic conductivity of 10^{-8} ms^{-1});
- runoff from the foreshore paths (0.8495 Ha) is captured directly in surface drains; and
- based on the meeting discussion (1st September, 2010), drainage water is not captured from the lower sections of the park (0.60 Ha turf and 0.16 Ha indigenous plantings).

The bio-swale locations and slopes on site were estimated based on PWP and JPW (2010c). Beneath the growing media the profile consists of:

- fill that has a saturated hydraulic conductivity of 10^{-7} ms^{-1} (John Braybrooke email, 27th July 2010), an approximate silt and clay content of about 20% (John Braybrooke, pers. com.) and can be aptly described using a Campbell function; overlying
- a drainage layer that is 300 to 500 mm thick with a permeability of 10^{-1} to 10^{-2} ms^{-1} (MoM, 23rd August 2010); overlying
- a clay drainage liner that is about 500 mm thick with a permeability of 10^{-8} (MoM, 23rd August 2010) and has a slope of 1 in 100 as specified in Bruce Gunn's email (26th August, 2010).

It is assumed that the water captured by the deep underlying drainage layer can be reused in the irrigation system (Paul Sancandi, pers. comm.).

2. Methodology

Water balance modelling

In addition to the above assumptions, the water balance was based on:

- 34 years (1975 to 2008) of daily weather data from the Bureau of Meteorology station at Sydney Airport
- daily rainfall data from Observatory Hill; and
- using the proposed irrigation schedule (Table 1) and assuming irrigation events were skipped if significant (>10 mm) rainfall events occurred.

A schematic representation of the model is presented associated with Table 2 (Figure 2). The degree to which the irrigation requirements for the site could be met by effluent was estimated for a range of storage sizes.

Irrigation system performance

A distribution uniformity (DU) of 72% was assumed for the proposed sprinkler irrigation system, which is slightly less than the minimum requirements specified in the Sydney Water Open Space Best Practices Guideline (due for release in late 2010). Of the irrigation water applied, 15% is assumed to be lost as evaporation.

3. Preliminary findings

Water fluxes

A summary of the water fluxes (ML/yr) through the headland park is provided in Table 2. The average annual irrigation requirements are estimated to be 19.6 ML, which is less than the annual drainage/runoff capture in bio-swales, drains associated with the retaining walls (RBG, 18th August, 2010), paths and stone paving areas of about 41.0 ML.

An additional 7.3 ML annually would be captured by the lower clay drainage layer and could be reused in the irrigation system (Paul Sancandi, pers. comm.), but treatment may be required. About 1.6 ML annually will move through the lower clay layer (Table 2).

Despite the net capture of water, effluent top-up is required because significant amounts of drainage capture occurs during periods when little irrigation is required, such as during:

- cooler months; and/or
- following large rainfall events.

Tank sizing

The relationship between tank size and reuse was calculated based on the assumption that at least 250 kL of effluent top-up can occur within a 24 hour period (2.9 L/sec).

The tank should be at least 300 kL in size, with 256 kL representing a single watering event for the turf areas. A tank of 1250 kL would provide storage for two weeks in summer without rain and would enable almost 80% of the site water requirements to be met by drainage capture (Figure 1), but this would vary from year to year.

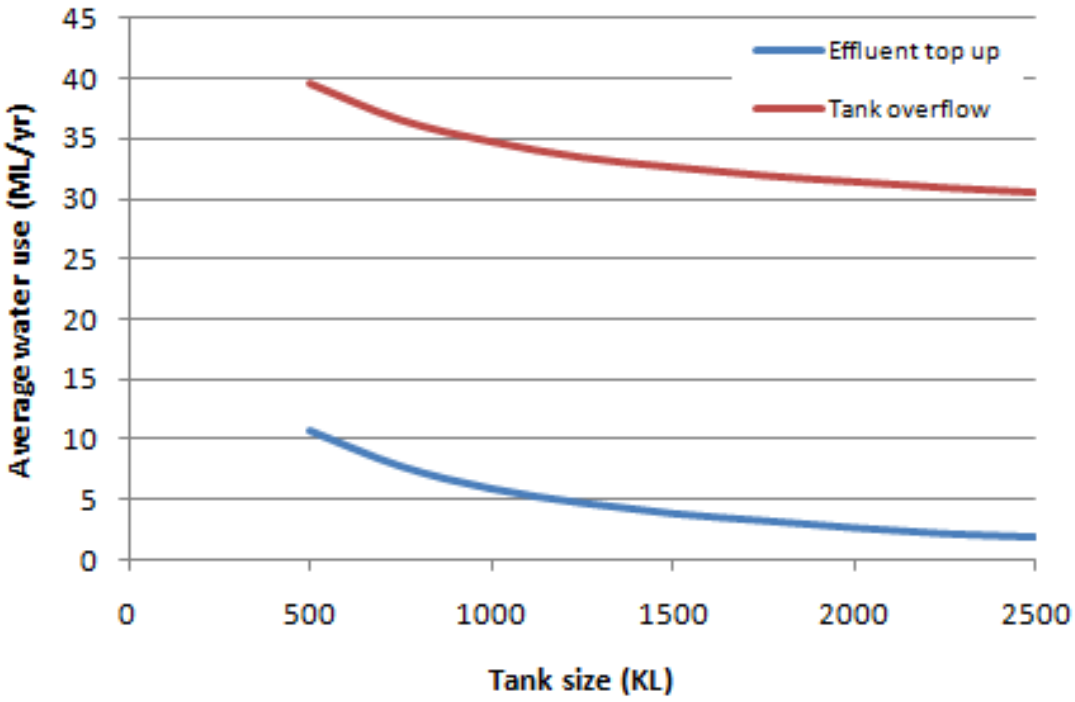


Figure 1. Effect of tank size on the requirements for effluent top-up at Barangaroo headland park (includes drainage capture from the 1 in 100 sloped clay layer)

4. References

Hazelton PA and Murphy BW (1992) What do all the numbers mean? A guide for the interpretation of soil test results. Department of Conservation and Land Management, Sydney.

Leake S (2010a) Soil requirements for Barangaroo report: a preliminary scoping paper. Sydney Environmental and Soil Laboratory.

Leake S (2010b) Technical note: soil volumes. Sydney Environmental and Soil Laboratory.

NSW Agriculture (2001) Irrigation Management: a waterwise farm course.

PWP and JPW (2010a). 10th September Barangaroo cost estimate report (draft) by PWP Landscape Architecture and Johnson Pilton Walker Architecture.

PWP and JPW (2010b). 10th September Barangaroo quantity estimates cost plan (draft) by PWP Landscape Architecture and Johnson Pilton Walker Architecture.

PWP and JPW (2010c) Design development headland park plan, 21st September 2010.

Table 2. Average annual water fluxes (ML) for the headland park.

	Inputs			Outputs				
	Rain	Irrigation	Run-on	Run-off	Evapotranspiration	Irri evap losses	Interface flow	Fill infilt[2]
Paths & stone paving (0.5426 Ha)	6.6	0	0	6	0.6	0	0	0
Turf and plantings (1.8358 Ha)	22.4	12.2	0	3.4	12	1.8	0	5.4
Turf bio-swales[3] (0.2 Ha)	2.4	1.3	7.9	0	1.3	0.2	23.43[1]	0.26
Indigenous slopes (1.0987 Ha)	13.35	1.79	1.5	0	4.5	0.27	8.08[1]	3.19
Foreshore path etc (0.8495 Ha)	10.35	0	0	0	0.96	0	9.4[1]	0
Turf and plantings (0.6042 Ha)	7.36	4.0	0	1.1[4]	4.0	0.6	2.96[4]	2.7
Indigenous plants (0.1643 Ha)	2	0.27	0	0.3[4]	1.1	0.04	0.76[4]	0.5
		Total inputs:	**93.5**				**Total outputs:**	**94.8**

1 interface flow is captured in drainage system

2 indicates movement through the underlying fill based on a saturated hydraulic conductivity function of 10^{-7} ms^{-1}.

3 to assist in drainage capture, a saturated hydraulic conductivity of 10^{-8} ms^{-1} was assumed for the material underlying the bioswales.

4 indicates water movement into the harbour

5 water captured in deep drain that is treated and reused

	Clay seepage	Deep drain capture
Paths & stone paving (0.5426 Ha)	0.0	0.0
Turf and plantings (1.8358 Ha)	0.9	4.5[5]
Turf bio-swales[3] (0.2 Ha)	0.2	0.0
Indigenous slopes (1.0987 Ha)	0.5	2.8[5]
Total:	**1.6**	**7.3**

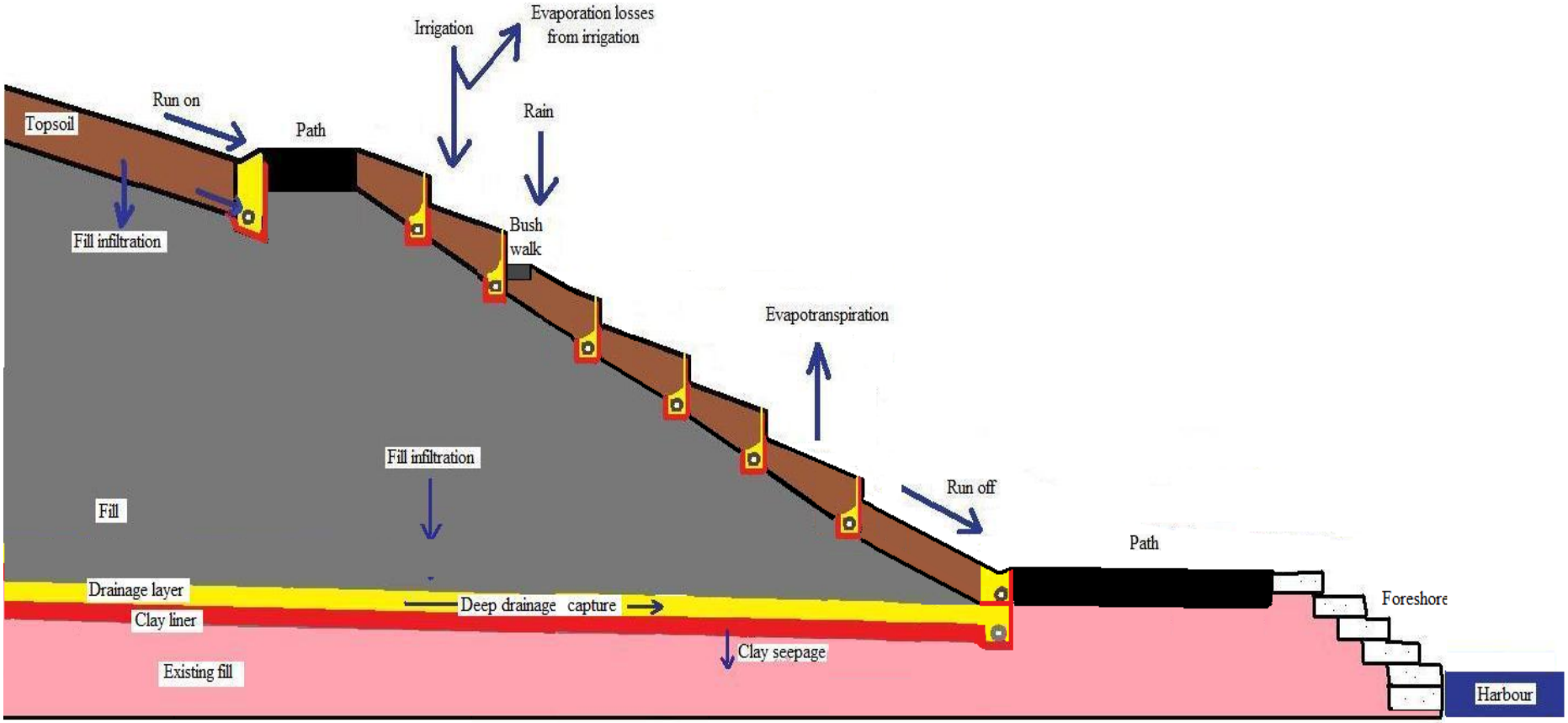


Figure 2. Schematic of water balance model showing various input components. The park is essentially divided into three areas: the upper sections (mostly turf) where runoff and interface flow are captured in bioswales. The steeper sloped areas consisting mainly of indigenous plants, where runoff is captured in drains associated with the retaining walls and a lower bioswale. The lower sections of the site where the path surface runoff is captured.

Underlying the upper and steep slope sections of the site is a clay liner (and overlying drainage layer) that assists in drainage capture, with this water reused in the irrigation system.

Appendix C

RISC Modelling Equations

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Appendix A

Vadose Zone Model

A.1 MODEL DESCRIPTION

The Vadose Zone model in RISC simulates contaminant transport through unsaturated soil. The transport equations are solved using the analytical solutions of the one-dimensional advective-dispersive solute transport equation (van Genuchten and Alves, 1982). The model considers the following fate and transport processes: (i) a well-mixed finite-mass source zone, (ii) pseudo steady-state volatilization and diffusive vapor transport from the source to ground surface, (iii) leaching from the source zone, (iv) advective dissolved-phase transport, (v) dissolved-phase dispersion, (vi) adsorption, and vii) first-order decay in the leachate.

This model is similar to the vadose zone model presented by Unlü et al. (1992) with the exception of several significant differences that are discussed. The most significant change is that the Vadose Zone transport model in RISC allows for the presence of a second soil layer located between the source zone and the ground surface; this layer may have soil properties different from the rest of the vadose zone which can dramatically affect vapor emissions to the surface.

The purpose of the Vadose Zone model is to predict (1) loading to groundwater and (2) volatilization losses. The groundwater loading term may be used as a source input to the saturated zone model (Appendix B). The volatilization losses may be used as a source for the box air model to calculate concentrations in outdoor air (Appendix F). Figure A-1 shows the processes simulated by the Vadose Zone model.

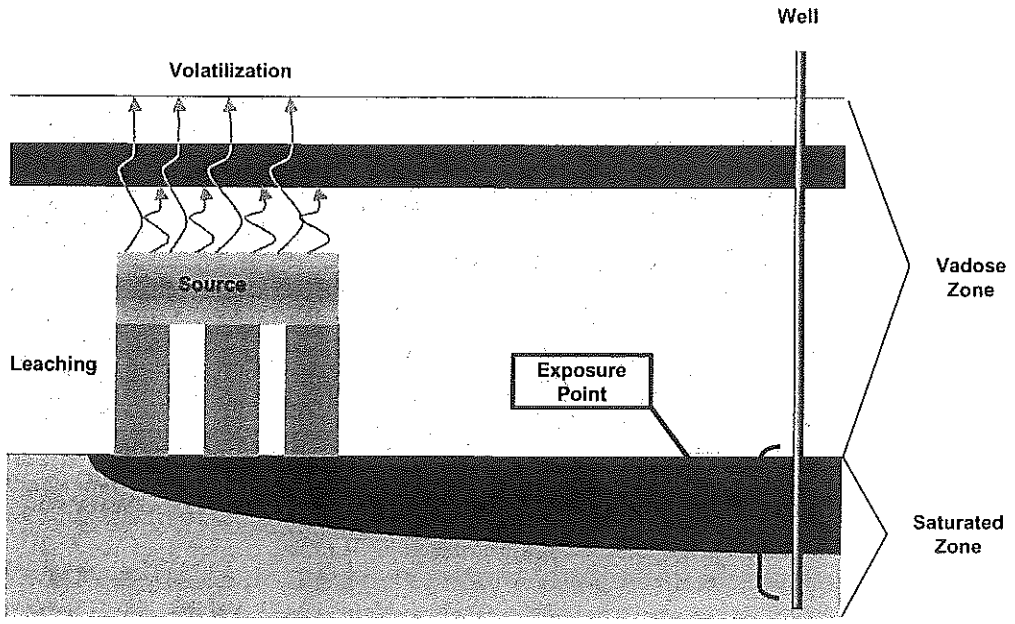


FIGURE A-1. Schematic of the Vadose Zone Model.

This appendix describes the equations used to predict volatile losses from a vadose zone source, leaching/mass loading rates from the source to groundwater and concentration distributions in the vadose zone. Appendix B describes the model used for the saturated zone (including groundwater transport).

A.2 APPLICATIONS OF THIS MODEL

This is a partial list of the main applications and limitations of the model:

- This model estimates the mass loading to groundwater from a vadose zone source. The model accounts for source depletion due to volatilization and leaching. The volatilization flux is only used to estimate losses from the source; it is not linked with an indoor or outdoor air model.
- This model does not simulate the movement of NAPL (free phase product). It is a dissolved phase-only model. Volatilization losses from the source are accounted for, however, the vapor phase concentrations with depth are not estimated. The volatile losses are assumed to be instantaneous and irreversible.

- Degradation is considered in the dissolved phase for the region between the source and the water table.
- The vadose zone model is automatically linked with the dissolved phase model in RISC so that concentrations in groundwater may be estimated.
- The model accounts for the presence of NAPL by limiting the dissolved phase concentration in the source region to the chemicals' effective solubility limit. This is important for two reasons:
    1. Otherwise the leachate and groundwater concentrations may be greatly over-estimated.
    2. Limiting the leachate concentrations to effective solubility limits may cause the source to deplete at a slower rate, thereby increasing the length of time for loading to groundwater. Depending on the problem being simulated, this approach may be more conservative than ignoring solubility limitations because it increases the exposure duration and hence the estimate of long-term cancer risk.

- The source is assumed to be located in the vadose zone. The region in the vadose zone below the source and the groundwater aquifer itself is assumed to be "clean" at the start of the simulation. This means that the vertical extent of the contamination in the vadose zone must be known. If the groundwater is already contaminated there are several ways to model the situation. Here are two ideas:
    1. Assume that the start of the simulation coincides with the date that the spill occurred ("back it up in time"). Run the model through the present day using the current site information to calibrate the model (e.g. make the model predict the current distribution of contaminants in the soil and groundwater).
    2. Skip the vadose zone portion and model the site with one of the groundwater models. If there is still a large amount of contamination in the vadose zone but the system appears to be at steady-state (i.e. the groundwater concentrations are not increasing with time) then use the dissolved phase model with a constant source.

- It is important to choose the source concentration and size of the source carefully. The best approach is to estimate (roughly) the amount of mass thought to be in the vadose zone. The average concentration multiplied by the source size should not exceed the estimated mass. This seems obvious, however, it is very easy to use an unreasonably large source mass especially if maximum concentrations and the maximum extent of detection are used simultaneously.

- The size of the source in the vadose zone is "mapped" onto the water table and becomes the footprint of the groundwater source size. If the receptor well is close to the source region, it may be more conservative to use a smaller source size and a larger source concentration than to average the concentrations across a large source region. More concentrated (but smaller) sources in the groundwater yield higher concentrations along the centerline of the plume when the receptor point is close to the source region.

A.3 FATE AND TRANSPORT PROCESSES

RISC's vadose zone transport model uses a "compartmental" approach; in other words, different models are used to describe the source zone, the vadose zone above the source, and the vadose zone between the source and groundwater.

The source zone is described as being a well-mixed finite source that depletes with time, while the vadose zone above the source is treated as being one-dimensional and at pseudo-steady state.

Beneath the source zone, solute transport of leachate occurs via advection and dispersion, and mass loss may occur through a first-order degradation reaction. The one-dimensional transport equation (including adsorption) in this zone is given by:

$$R\frac{\partial C_w}{\partial t} = D_x\frac{\partial^2 C_w}{\partial x^2} - \bar{v}\frac{\partial C_w}{\partial x} - \mu C_w \qquad \text{(A-1)}$$

where

C_w = dissolved phase concentration of chemical [mg/L]

D_x = dispersion coefficient in the unsaturated zone [cm^2/d]

$\bar{v}$ = seepage velocity (or interstitial velocity) [cm/d]

μ = first-order decay coefficient for chemical [1/d]

x = distance below the source (measured positively downward) [cm]

t = time [d]

R = retardation factor (defined in Equation A-31) [-]

The x-axis is assumed to be aligned with the direction of fluid flow; in the vadose zone that direction is vertically downward. The model considers dispersion in the downward direction only (longitudinal dispersion). The advection-dispersion equation is used to solve for aqueous-phase concentration with depth below the source. This concentration at the water table will be used with the infiltration rate to estimate mass loading to groundwater.

A note on nomenclature: In this appendix the variable, C (C_w, C_v, *or* C_T), will always refer to the concentration of the individual chemical being modeled (not the TPH mixture). If the concentration of TPH is being referenced, the variable C_{TPH} will be used. The same applies to all chemical properties. For example, D_{eff} refers to the chemical-specific diffusion coefficient, MW refers to the chemical-specific molecular weight, and MW_{TPH} refers to the molecular weight of the TPH mixture.

A.3.1 Initial and Boundary Conditions

Below the source it is assumed that concentrations are zero at time = 0:

$$C_w(x, 0) = 0 \qquad \textbf{(A-2)}$$

The leachate concentration leaving the source zone is assumed to decay exponentially with time

$$C_w(0, t) = C_{w_0} e^{-\beta t} \qquad \textbf{(A-3)}$$

where

C_{wo} = dissolved phase concentration of chemical in the source at the beginning of the simulation [mg/L]

β, = source depletion term [-]

The source depletion term, β, is described in equations A-19 and A-23. At a "long distance" below the source the concentration gradient is always zero.

$$\frac{\partial C_w}{\partial x}(\infty, t) = 0 \tag{A-4}$$

The solution for the advection-dispersion equation (A-1) with the above boundary conditions is given by van Genuchten and Alves (1982)

$$C_w(x,t) = C_0 e^{-\beta t} B(x,t) \tag{A-5}$$

where

$$B(x,t) = \frac{1}{2}\exp\left[\frac{(\bar{v} - w)x}{2D_x}\right] erfc\left[\frac{Rx - wt}{2\sqrt{D_x Rt}}\right] + \frac{1}{2}\exp\left[\frac{(\bar{v} + w)x}{2D_x}\right] erfc\left[\frac{Rx + wt}{2\sqrt{D_x Rt}}\right] \tag{A-6}$$

and

$$w = \bar{v}\sqrt{1 + \frac{4D_x}{\bar{v}^2}[\mu - R\beta]} \tag{A-7}$$

where

$C_w(x,t)$ = dissolved phase concentration of chemical at distance x (in cm) below the source and time (in days) [mg/L]

β = source zone depletion coefficient (loss term) defined in equations A-19 and A-23 [-]

In order to solve the above set of equations, the first-order source decay rate must be determined.

A.4 SOURCE TERM

Depletion of the source is assumed to occur due to volatilization and leaching losses. Note that the source is not assumed to undergo microbial decay, or biodegradation, on the assumption that high soil concentrations are toxic to the microorganisms. In terms of a molar balance this can be written as

$$\frac{dm}{dt} = -\frac{J_w}{MW} - \frac{J_v}{MW} \qquad \text{(A-8)}$$

where

m = number of moles of chemical per unit area in the hydrocarbon source [moles/cm^2]

MW = molecular weight of chemical [g/mol]

J_w = rate of mass depletion per area due to percolating water [g/cm^2/d]

J_v = rate of mass depletion per area due to volatilization [g/cm^2/d]

t = time [d]

A.4.1 Aqueous Losses

The leaching loss is assumed to be purely advective (due to water percolating through the source)

$$J_w = qC_{ws}\left(\frac{L}{1000cm^3}\right)\cdot\left(\frac{g}{1000mg}\right) \qquad \text{(A-9)}$$

where

J_w = rate of mass depletion per area due to percolating water [g/cm^2/d]

q = net recharge or infiltration rate [cm/d]

C_{ws} = dissolved phase concentration in the source [mg/L]

In the RISC model, the dissolved phase concentration, C_{ws}, is checked for solubility limitations and therefore is calculated differently depending on whether or not residual phase hydrocarbon (NAPL) is present (see Sections A.4.5 through A.4.7). (Unlü et al., 1992, assumes that the source always contains immiscible phase hydrocarbons.)

A.4.2 Volatilization Losses (Incorporating Lens)

The diffusive vapor loss is estimated using Fick's Law, assuming a linear concentration drop from the source area to the soil surface. Source zone volatilization losses are calculated using a pseudo-steady state vapor flux model based on Fick's Law. In this approach, the steady-state solution for vapor transport is coupled with a source zone concentration that is changing with time. It is assumed that vapor transport reaches steady conditions much faster than the rate at which the source zone concentration changes with time. It is also assumed that vapor concentrations at ground surface are much less than those at the source zone. The mass depletion rate of the source due to volatilization (the volatile losses) is calculated from:

$$J_v = D_{eff} \frac{C_{vs}}{L_d} \left(\frac{86400s}{d} \right) \qquad \textbf{(A-10)}$$

where

J_v = rate of mass depletion per area due to volatilization [g/cm^2/d]

D_{eff} = effective diffusion coefficient in soil [cm^2/s]

C_{vs} = vapor-phase concentration of chemical in the source area [g chemical/cm^3 vapor]

L_d = diffusion path length [cm]

Equation A-10 is Fick's Law applied to the concentration gradient from the source to the ground surface. The concentration of chemical in vapor at the soil surface is assumed to be equal to zero (or very small compared to the source vapor phase concentration). The diffusion path length is assumed to be equal to the distance from the soil surface to the center of the source.

The vapor concentration in the source zone is calculated from Henry's Law:

$$C_{vs} = K_H C_{ws} \left(\frac{L}{1000cm^3} \right) \left(\frac{g}{1000mg} \right) \qquad \textbf{(A-11)}$$

where

K_H = Henry's Law Constant for chemical [(mg/l vapor)/(mg/l water)]

A.4.3 Effective Diffusion Coefficients

The effective diffusion coefficient in vadose zone soil and the lens soil is estimated using the Millington-Quirk relationships:

$$D_{eff\,v} = D_{air} \left(\frac{\theta_{a_v}^{10/3}}{\theta_{T_v}^{2}} \right) + D_{water} \frac{1}{K_H} \left(\frac{\theta_{W_v}^{10/3}}{\theta_{T_v}^{2}} \right) \qquad \textbf{(A-12a)}$$

$$D_{eff\,lens} = D_{air} \left(\frac{\theta_{a\,lens}^{10/3}}{\theta_{T\,lens}^{2}} \right) + D_{water} \frac{1}{K_H} \left(\frac{\theta_{W\,lens}^{10/3}}{\theta_{T\,lens}^{2}} \right) \qquad \textbf{(A-12b)}$$

where

$D_{eff\,v}$ = effective diffusion coefficient for the vadose zone above the source (not including the lens) [cm^2/s]

$D_{eff\,lens}$ = effective diffusion coefficient for the lens [cm^2/s]

D_{air} = molecular diffusion coefficient for chemical in air [cm^2/s]

D_{water} = molecular diffusion coefficient for chemical in water [cm^2/s]

θ_{a_v} = air-filled porosity in the vadose zone [cm^3 air/cm^3 soil]

θ_{w_v} = water-filled porosity in the vadose zone [cm^3 water/cm^3 soil]

θ_{T_v} = total porosity in the vadose zone [cm^3 pores/cm^3 soil]

$\theta_{a\,lens}$ = air-filled porosity in the lens [cm^3 air/cm^3 soil]

$\theta_{w lens}$ = water-filled porosity in the lens [cm^3 water/cm^3 soil]

$\theta_{T lens}$ = total porosity in the lens [cm^3 pores/cm^3 soil]

K_H = Henry's Law Constant for chemical [(mg/l vapor)/(mg/l water)]

Note, the above porosity terms used by the diffusion equations should be total porosity rather than effective porosity. The total effective diffusion coefficient for the vadose zone and lens combined is estimated as the depth-weighted average (Johnson and Ettinger, 1995):

$$D_{eff} = \frac{(h_v + h_{lens})}{\frac{h_{lens}}{D_{eff\ lens}} + \frac{h_v}{D_{eff\ v}}} \quad \textbf{(A-13)}$$

where

D_{eff} = depth-weighted average effective diffusion coefficient for the vadose zone in between the source and the soil surface [cm^2/s]

h_v = thickness of the vadose zone above the source (minus the lens thickness) [cm]

h_{lens} = thickness of the lens [cm]

As a consequence of the modeling assumptions, one can actually account for more than one lens above the source zone, as long as each lens has the same material properties (total porosity, moisture content, etc.). If this is the case, then the user simply sets h_{lens} equal to the combined thickness of all the lenses and h_v is the remaining thickness of the vadose zone.

A.4.4 Overall Source Depletion Rate

Combining equations A-8 through A-11 yields:

$$\frac{dm}{dt} = -\beta m = -\left[\bar{v}\theta_w + \frac{K_H D_{eff}}{L_d}\right] C_w \quad \textbf{(A-14)}$$

where β is a loss term accounting for both dissolution and volatile losses. The loss term is calculated differently depending on whether or not residual phase is present.

A.4.5 Calculating Whether or Not Residual Phase Hydrocarbon is Present

To determine if residual phase hydrocarbon is present, the following condition for multiple chemicals must be met:

$$1 > \sum_{i=1}^{N} \frac{C_{T_i}\rho_b}{S_i\left(\rho_b K_{oc_i} F_{oc} + \theta_w + \theta_a K_{H_i}\right)} \qquad \textbf{(A-15)}$$

where

N	=	total number of chemicals in mixture
$C_{T\,i}$	=	total concentration of chemical i in soil [mg/kg]
S_i	=	liquid phase solubility for chemical i [mg/l or kg/m^3]
ρ_b	=	soil bulk density of the source area [g/cm^3]
F_{oc}	=	fraction organic carbon in soil [g oc/g soil]
$K_{oc\,i}$	=	organic carbon partition coefficient for chemical i [ml/g]
$K_{H\,i}$	=	Henry's Law Constant for chemical i [(mg/l vapor)/(mg/l water)]

This partitioning equation assumes that the total soil concentration for each chemical, $C_{T\,i}$, can be accounted for by summing the mass in the solid, liquid, and vapor phases (i.e. no residual is present). However, equation A-15 requires that all of the chemicals in the mixture are accounted for in the sum. In risk assessments, more often the number of chemicals of concern (and characterized with respect to their concentration) is a small subset of the total number of chemicals present in the mixture. The vadose zone model checks the following equation for each chemical used in the model

$$C_w = \frac{C_T\rho_b}{\rho_b K_{oc} F_{oc} + \theta_w + \theta_a K_H} \qquad \textbf{(A-16)}$$

Again, it is assumed that C_T can be accounted for by summing the mass in the solid, liquid, and vapor phases (i.e. no residual is present). If the liquid phase concentration, C_W, calculated with equation A-15a exceeds the effective solubility of the compound, then it is assumed that residual phase is present (and equation A-15a does not apply).

A.4.6 Source -- When Residual Phase Hydrocarbon is Present

If there is residual phase hydrocarbon present in the source, the aqueous concentration, C_w, will be calculated from

$$C_w = xS \tag{A-17}$$

where

S = aqueous solubility of pure component [mg/l or kg/m^3]

x = mole fraction of component in the hydrocarbon mixture [mol/mol]

The mole fraction is calculated from

$$x = \frac{m}{m_{TPH}} \tag{A-18}$$

$$x = \frac{F_i MW_{TPH}}{MW_i F_{TPH}} \tag{A-19}$$

where

m = total moles of component [mol] $(\frac{\rho_b L_w F_i}{MW_i} A)$

m_{TPH} = total moles of hydrocarbon mixture [mol] $(\frac{\rho_b L_w F_{TPH}}{MW_{TPH}} A)$

L_w = thickness of the source area [cm]

A = area (plan view) of the source [cm^2]

MW_{TPH} = average molecular weight of hydrocarbon [g/mol]

MWi = average molecular weight of component i [g/mol]

F_{TPH} = mass fraction (concentration) of hydrocarbon mixture in the soil source [TPH concentration) [g/g]

F_i = mass fraction (concentration) of component *i* in the soil source [component concentration) [g/g]

As long as there is immiscible phase present, the aqueous phase concentration is given by Equation A-16. Once immiscible phase has been depleted, then the remaining amount of each compound is depleted from the source according with the decay rate given in Equation A-22. In the RISC model, however, it is assumed that if immiscible phase is present initially, then it is present for all time, Thus the approximation developed below is for the case of a more soluble compound leaching from a less soluble mixture, (e.g., benzene from a petroleum fuel mixture).

The source zone depletion coefficient (loss term), β, for the residual case is given by

$$\beta = \frac{qMW_{TPH}S}{\rho_b L_w F_{TPH} MW} + \frac{D_{eff} K_H MW_{TPH} S}{\rho_b L_d L_w F_{TPH} MW} = \beta_w + \beta_v \qquad \textbf{(A-20)}$$

The source zone depletion coefficient is the sum of the leachate losses (β_w) and the vapor losses (β_v). If it is assumed that F_{TPH} is constant (this assumption is only approximate since the source does deplete slowly over time) equation A-8 may be solved analytically to obtain

$$m = m_0 \exp(-\beta t) \qquad \textbf{(A-21)}$$

where

m_0 = initial moles of chemical per area [mol/cm^2]

The aqueous concentration decreases similarly

$$C_w = C_{w0} \exp(-\beta t) \qquad \textbf{(A-22)}$$

where

C_{w0} = initial aqueous concentration of species defined in equation A-16 [mg/l]

Unlü et al. (1992) assumes there is always residual phase hydrocarbon present and uses equation A-19 to estimate losses from the source. This approach is realistic for the types of waste zones that Unlü et al. equations were developed for -- waste sludge pits with high levels of hydrocarbons. However, RISC also allows the user to estimate the behavior of sources for which immiscible phase is not initially present (e.g., equation A-15a is satisfied).

A.4.7 Source -- When Residual Phase Hydrocarbon is Not Present

When an immiscible phase is not present it is assumed that the concentrations of the chemical in each phase are in equilibrium. The equilibrium partitioning equation is:

$$C_{ws} = \frac{C_T \rho_b}{(\rho_b K_{oc} F_{oc} + \theta_w + \theta_a K_H)} \quad \text{(A-23)}$$

which when inserted into Equation A-14 yields:

$$\beta = \frac{q}{(\rho_b K_{oc} F_{oc} + \theta_w + \theta_a K_H) L_w} + \frac{D_{eff} K_H}{(\rho_b K_{oc} F_{oc} + \theta_w + \theta_a K_H) L_d L_w} = \beta_w + \beta_v \quad \text{(A-24)}$$

where all the variables are as defined previously.

A.5 LEACHING AND PERCOLATION RATE

Following Unlü et al. (1992), the RISC Vadose Zone model uses a unit hydraulic gradient approximation, estimating the unsaturated hydraulic conductivity with the Brooks and Corey (1964) model. The unit gradient approach assumes that the pressure (suction) head in the soil profile is constant, as is the moisture content. This is a major simplification of the real processes that control flow in the unsaturated zone. However, the goal in modeling the concentration is to estimate average conditions over long time periods (for purposes of risk assessment: 7 to 30 years). For

this objective, the unit gradient approach has been shown to work reasonably well (Unlü et al., 1992).

A.5.1 Unit Gradient Approach

For more information on this subject the reader is referred to the two papers mentioned above as well as Carsel and Parrish (1988). Briefly, Darcy's equation for the unit gradient case may be written as:

$$q = k_r K_{su} \qquad \text{(A-25)}$$

where

q = infiltration rate or net recharge rate [cm/d]

k_r = relative permeability [unitless]

K_{su} = hydraulic conductivity of the unsaturated zone if it were fully saturated [cm/d]

When using RISC, the user is asked to input the infiltration rate, q, and the unsaturated zone's hydraulic conductivity (K_{su}). This term, K_{su}, is the hydraulic conductivity of the unsaturated zone if it were assumed to be fully saturated, i.e. no air-filled porosity. In many applications of RISC, K_{su} is assumed equal to the hydraulic conductivity of the soil below the water table. If the value entered for the infiltration rate exceeds K_{su}, then q is set to K_{su} assuming that the excess flow will be diverted as runoff.

Having values for q and K_{su}, Equation A-25 is used to solve for the relative permeability, k_r:

$$k_r = \frac{K_{su}}{q} \qquad \text{(A-26)}$$

where the terms are as defined for Equation A-24.

A.5.2 Estimating the Unsaturated Zone Hydraulic Conductivity

In the unsaturated zone, the hydraulic conductivity varies as a function of the moisture content. It is assumed that this relationship can be described by the Brooks and Corey (1964) model

$$k_r = \left[\frac{\theta_w - \theta_r}{\theta_T - \theta_r}\right]^{\gamma} \qquad \text{(A-27)}$$

where

θ_T = total porosity in unsaturated zone [-]

θ_w = volumetric water content or water-filled porosity [cm^3 water/cm^3 soil]

θ_r = irreducible water content [cm^3 water/cm^3 soil]

γ = pore size distribution parameter [-]

The pore size distribution parameter is estimated from the van Genuchten *"n"* parameter using the following relationship (Lenhard et al., 1989)

$$\gamma = 3 + \frac{2}{(n-1)(1-0.5^{\frac{n}{(n-1)}})} \qquad \text{(A-28)}$$

The model requires the user to enter n. Carsel and Parrish (1988) have a large database of van Genuchten's *"n"* for various soil types. This database is also available in the RISC software.

A.5.3 Estimating Moisture Content and Seepage Velocity

The water-filled porosity, θ_w, is calculated using Equation A-26 since values of all the other terms are either specified or previously derived. The calculated water-filled porosity is then used to estimate the seepage velocity, $\bar{v}$:

$$\bar{v} = \frac{q}{\theta_w} \qquad \text{(A-29)}$$

where

$\bar{v}$ = seepage velocity (actual water flowrate through vadose zone) [cm/d]

q = infiltration rate (recharge rate to groundwater) [cm/d]

θ_w = volumetric water content or water-filled porosity [cm^3 water/cm^3 soil]

The seepage velocity, $\bar{v}$, is the average rate of flow that the model uses for the water percolating through the vadose zone.

The water content for the lens may differ from the vadose zone and is also calculated from the same equations as presented above using the lens properties. The values of the estimated moisture contents are presented in the RISC model output. The moisture content is not calculated by the volatilization models (Appendices D, E, J and K) since it is assumed that for soils under a house or building, the infiltration rate is close to zero. In these models the user is requested to specify the average moisture content in the vadose zone. If the vadose zone is subject to infiltration, the above algorithm may be run using the vadose zone model to estimate likely ranges of moisture content. The moisture content can then be entered in the air models.

A.6 UNSATURATED ZONE TRANSPORT

Equations A-5 through A-7 are used to calculate the dissolved phase concentrations in the unsaturated zone from the bottom of the source zone to the groundwater aquifer.

A.6.1 Mass Loading To Groundwater

The mass flux of contaminant at the water table is calculated using Equation A-5 solved at the water table multiplied by the infiltration rate:

$$Q(L_u, t) = q\ C(L_u, t) \cdot \left(\frac{L}{1000cm^2} \right) \qquad \text{(A-30)}$$

where

$Q(L_u,t)$ = mass flux at the water table as a function of time [g/cm^2/d]

$C(L_u,t)$ = dissolved phase concentration of contaminant at the water table as a function of time [mg/L]

L_u = the distance from the source to the water table [cm]

q = net infiltration rate [cm/d]

The mass flux, Q, is used as the time-varying source for the saturated zone model described in Appendix B.

A.6.2 Retardation

The retardation factor for the unsaturated zone, R, is estimated using

$$R = 1 + \frac{\rho_b F_{oc} K_{oc}}{\theta_w} \qquad \text{(A-31)}$$

where

F_{oc} = fraction organic carbon in dry soil [g/g]

K_{oc} = organic carbon normalized partition coefficient [ml/g]

This retardation equation is assumed to be valid when $F_{oc} > 0.001$. [Below values of 0.001 the retardation is estimated to be equal to 1 -- essentially non-retarded.)

A.6.3 Degradation

Degradation is assumed to be a first-order reaction occurring only in the aqueous phase as the leachate is carried from the source to the water table.

A.6.4 Dispersion

The dispersion coefficient is assumed to be a linear function of the seepage velocity, $\bar{v}$, (defined in Equation A-27)

$$D = \alpha_L \left(\bar{v} \cdot \frac{m}{100cm} \right) \qquad \textbf{(A-32)}$$

where

α_L = longitudinal dispersivity [m]

The longitudinal dispersivity is calculated using data from Gelhar et al. (1985) as a function of the vertical distance from the source:

$$\ln \alpha_L = -4.933 + 3.811 \ln x_m \quad x_m \leq 2m \qquad \textbf{(A-33a)}$$

$$\ln \alpha_L = -2.727 + 0.584 \ln x_m \quad x_m \geq 2m \qquad \textbf{(A-33b)}$$

where

x_m = distance from the source to the observation location [m]

A.7 DATA REQUIREMENTS

The data required to run the Vadose Zone model are shown in Table A-1.

Table A-1. Data Requirements for the Vadose Zone Model

		Typical Range of Values	
	Units	**Minimum**	**Maximum**
MEDIA-SPECIFIC PARAMETERS			
Porosity	cm^3/cm^3	0.01	0.5
Irreducible Water Content	cm^3/cm^3	0	porosity
Fraction Organic Carbon	g oc/g soil	0.001	0.05
Hydraulic Conductivity	m/day	1.00E-07	100
Soil Bulk Density	fraction	1.4	2.2
van Genuchten Parameter	dimensionless	~1	~3
Unsaturated Zone Thickness	m	site-specific	site-specific
SOURCE PARAMETERS			
Length of Source (x-direction)	m	site-specific	site-specific
Width of Source (y-direction)	m	site-specific	site-specific
Thickness of Source (z-direction)	m	site-specific	site-specific
TPH DATA			
Molecular Weight of TPH	g/mol	80	120
Concentration of TPH	mg/kg	site-specific	site-specific
CHEMICAL SPECIFIC DATA (individual chemical component)			
Molecular Weight	g/mol	chem-specific	chem-specific
Source Concentration	mg/kg	site-specific	site-specific
Solubility	mg/l	chem-specific	chem-specific
Diffusion Coefficient in Air	cm^2/s	chem-specific	chem-specific
Diffusion Coefficient in Water	cm^2/s	chem-specific	chem-specific
K_{oc}	ml/g	chem-specific	chem-specific
Degradation Rate	1/d	site-specific	site-specific
Henry's Law Constant	(mg/l)/(mg/l)	chem-specific	chem-specific

A.8 ASSUMPTIONS AND LIMITATIONS OF THE VADOSE ZONE MODEL

1. The Vadose Zone model simulates the transport of dissolved phase contaminants downward, and vapor phase contaminants upward. It does not simulate the movement of non-aqueous phase liquids (NAPLs).

2. The Vadose Zone model is a one-dimensional model (from the source to the water table) and accounts for volatile and leachability losses from the source.

3. The vadose zone is considered to be homogeneous and uniform below the source (a lens may be modeled above the source). The hydraulic conductivity is calculated as a function of moisture content, however, this derived moisture content is assumed to be constant for the entire depth of the soil column.

4. The contaminant source has a uniform concentration across the user-specified source volume.

5. Water table fluctuations are not considered. The depth to the aquifer is considered fixed.

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Appendix D

Vapor Transport From Soil Into Buildings Without Biodegradation

D.1 MODEL DESCRIPTION

The vapor transport model for soil estimates emissions into a building from a soil source located either below or laterally adjacent to the building. This model is based on the paper entitled "Heuristic Model for Predicting the Intrusion Rate of Contaminant Vapors into Buildings" by Johnson and Ettinger (1991). This vapor transport model combines a model for both diffusive and advective transport through the soil with a simple model of transport through a building foundation.

Figure D-1 illustrates the problem geometry. Advection is caused by a slightly reduced pressure (versus atmospheric pressure) inside a building due to temperature differences, wind, barometric pressure fluctuations or a slight vacuum created by a basement heating system during operation. The pressure gradient is entered as an input parameter.

This is the basically the same model as the one used in the Tier 1 spreadsheet to calculate risk-based screening levels in soil that are protective of indoor inhalation. The enhancements made by the RISC software are twofold: (1) multiple soil horizons may be considered by using the lens and (2) the model calculates the effective solubility and limits the soil gas concentration at the source if residual levels are exceeded. This second option is an important consideration for chemicals that are part of mixtures such as petroleum hydrocarbons in fuel. The example equations presented in the ASTM RBCA guidance are identical to the Johnson and Ettinger model if the building under-pressurization is equal to zero (no advection).

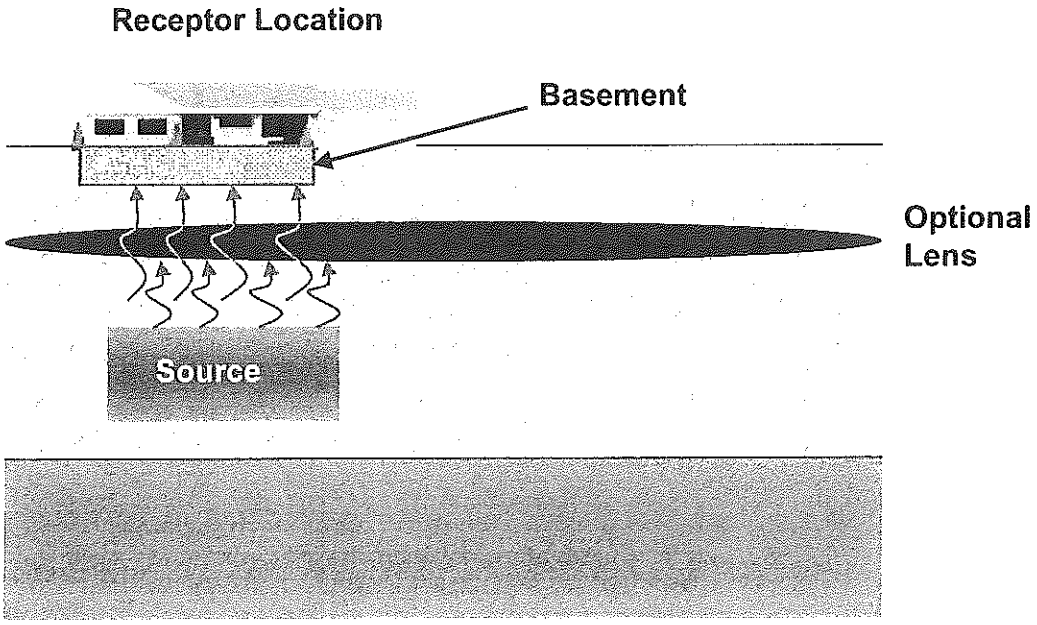


Figure D-1. Schematic of the Vapor Transport Model (from Soil into Buildings).

D.2 APPLICATIONS OF THIS MODEL

This is a partial list of the main applications of the model:

- This is a steady-state model. The source concentration is constant and the size does not deplete with time (i.e. an infinite source). This assumption is valid if the source is large compared to the mass flux rate into the building.
- This model is not linked with any other fate and transport model in RISC. The soil leaching to groundwater model is assumed to have a separate (depleting) source.
- Biodegradation of the chemical vapors is not considered. This is appropriate for chemicals that do not degrade readily, for very short diffusion distances, and/or for screening level calculations. BTEX constituents can have very high degradation rates (higher than in groundwater) under certain conditions. In this case it may be appropriate to use one of the other two vapor transport models in RISC that incorporate degradation.
- The source is located in the vadose zone. For sources located in the saturated zone the volatilization from groundwater model would be more appropriate.
- The likelihood of the building under-pressurization affecting the vapor transport should be evaluated. Often, the reason that advective transport

becomes important is the case where part of the building is sub-grade (e.g. basement) and the path of least resistance from the source is in the direction of the basement. This situation can occur for a laterally offset source if the preferential vapor flow pathways are horizontal (e.g. there are lower permeability units between the source and the ground surface). If the building is not large and does not have a sub-grade basement it is unlikely that the building under-pressurization is affecting the advection processes from an offset soil vapor source. The path of least resistance may be directly out through the ground surface.

- A building on a slab foundation can have advective effects if under-pressurization is present, the source is directly below and close to the foundation, and no partial low permeability lens is available to direct the vapors laterally away from the foundation. But a pier and beam house (where a crawl space is located under the house) would not be subject to advection (and may in fact have only limited diffusion as well if it is vented).

Appendix K.1.2 discusses vertical soil gas profile types and the applicability of the models in RISC to model different soil gas profiles.

D.3 TRANSPORT EQUATIONS AND PROCESSES

The Johnson-Ettinger model assumes that away from the structure, (i.e. out of the influence of pressure-driven flow), the contaminant transport is diffusive only and can be described using Fick's Law:

$$E = \frac{A_B \left(C_{vs} - C_{vf}\right) D_{eff}}{L_T} \qquad \text{(D-1)}$$

where

E = mass transport rate toward the structure [g/s]

D_{eff} = "overall" effective diffusion coefficient [cm^2/s]

C_{vs} = vapor concentration at the source [g/cm^3]

C_{vf} = vapor concentration in the soil just outside the building foundation [g/cm^3]

L_T = distance from source to basement [cm]

A_B = cross-sectional area of foundation available for vapor flux [cm^2]

Note, the effective diffusion coefficient is calculated using the Millington-Quirk relationship (Millington and Quirk, 1961, and described in Appendix A) which accounts for the amount of air vs. water-filled porosity in the soil. Furthermore, a lens can be incorporated in the vapor model so the "overall" effective diffusion coefficient can consider a different soil unit between the source and the house. A clay lens with a high water content can dramatically reduce the overall diffusion coefficient and can result in much lower vapor concentrations inside the house.

Adjacent to the foundation, the transport of contaminants is assumed to occur by a combination of advective and diffusive transport mechanisms through cracks in the foundation slab. The steady-state, one-dimensional solution to the advection-dispersion equation for vapor transport through a crack (just another type of porous media) is given by:

$$E = Q_{soil} C_{vf} - \frac{Q_{soil}\left(C_{vf} - C_{indoor}\right)}{\left[1 - \exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right)\right]} \qquad \text{(D-2)}$$

where

E = entry rate of contaminant into the building [g/s]

Q_{soil} = volumetric flow rate of soil gas into the building [cm^3/s]

C_{indoor} = indoor air concentration in the building [g/cm^3]

C_{vf} = vapor concentration in the soil just outside the building foundation [g/cm^3]

D_{crack} = effective diffusion coefficient in foundation cracks [cm^2/s]

L_{crack} = thickness of the foundation [cm]

A_{crack} = area of cracks or openings through which vapors enter building [cm^2]

The above two equations are assumed to be equal at steady state allowing the contaminant concentration in the soil just outside the foundation to be calculated. Setting Equations D-1 and D-2 equal to each other and rearranging to solve for C_{vf}:

$$C_{vf} = \frac{\left[C_{vs}\left[\frac{D_{eff}A_B}{Q_{soil}L_T}\right]\left[\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)-1\right]+C_{indoor}\right]}{\left[\left[\frac{D_{eff}A_B}{Q_{soil}L_T}\right]\left[\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)-1\right]+\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)\right]} \qquad \textbf{(D-3)}$$

Substituting D-3 into equation D-2 yields:

$$E = \frac{\left[\left[\frac{D_t^{eff}A_BC_{vs}}{L_T}\right]\left[\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)-\left[\frac{C_{indoor}}{C_{vs}}\right]\right]\right]}{\left[\left[\frac{D_T^{eff}A_B}{Q_{soil}L_T}\right]\left[\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)-1\right]+\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)\right]} \qquad \textbf{(D-4)}$$

In equation D-3, the only unknown variable (not entered by the user) is the concentration in the building, C_{indoor}. This concentration can be estimated from a mass balance equation assuming no other contaminant sources or sinks in the building (sorption to walls or furniture). Assuming a well-mixed building this mass balance equation can be written as:

$$Q_B C_{indoor} = E \qquad \textbf{(D-5)}$$

where

Q_B = building ventilation rate (calculated from the number of air exchanges per day and the volume of the building) [m^3/s]

where all the variables have been defined previously. Note, the emission rate, E, is calculated from equation D-4; the building ventilation rate, Q_B, is calculated from user input variables. Substituting Equation D-5 into Equation D-4 yields

$$C_{indoor} = \frac{C^*_{indoor}\left[\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)\right]}{\left[\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)+\left[\frac{D_{eff}A_B}{Q_B L_T}\right]+\left[\frac{D_{eff}A_B}{Q_{soil}L_T}\right]\left[\exp\left(\frac{Q_{soil}L_{crack}}{D_{crack}A_{crack}}\right)-1\right]\right]} \qquad \textbf{(D-6)}$$

where

$$C^*_{indoor} = \frac{D_{eff}A_B C_{vs}}{Q_B L_T} \qquad \textbf{(D-7)}$$

C^*_{indoor} represents the indoor vapor concentration corresponding to the case where vapors diffuse from the source through a bare soil foundation.

The volumetric soil gas flow rate into the basement, Q_{soil}, may be specified by the user or it is calculated from the area of cracks, A_{crack}, soil type and stratigraphy, pressure difference between atmospheric and building pressure, and basement geometry. If Q_{soil} is specified in RISC to be equal to zero, the vapor transport model will calculate it from (Johnson and Ettinger, 1991):

$$Q_{soil} = \frac{2\pi(\Delta P)k_v X_{crack}}{\mu \ln[2Z_{crack}/r_{crack}]} \qquad \frac{r_{crack}}{Z_{crack}} << 1 \qquad \textbf{(D-8)}$$

This equation is based on flow through a cylinder of length X_{crack} and radius r_{crack} located a depth Z_{crack} below ground surface. The rest of the variables used in D-8 are:

ΔP = pressure gradient between building and outside [g/cm-s^2]
Z_{crack} = depth below ground surface to foundation cracks [cm]
k_v = permeability of the soil to vapor flow [cm^2]
μ = viscosity of vapor [g/cm-s]

The crack length, X_{crack} , is an input parameter and can be conservatively assumed to be the total floor/wall seam perimeter distance. r_{crack} is defined as:

$$r_{crack} = \frac{\eta A_B}{X_{crack}} \qquad \textbf{(D-9)}$$

where

η = the ratio: A_{crack}/A_B so that $0 =< \eta =< 1$

For intrinsic permeabilities of vapor flow, k_v, of less than 1E-8 cm^2 (fine sand soils), the soil gas flow rate through the cracks becomes so low that diffusion is the dominant transport mechanism and the solution is independent of k_v. For "larger" values of k_v, (greater than 1E-8 cm^2) the solution is dominated by the advective contribution. In the model output, the contribution from diffusion is estimated by setting k_v to a very low value.

D.4 SOURCE TERM

The source may be specified by entering total soil concentrations or by entering soil vapor concentrations. Using measured soil vapor concentrations has the following advantages:

- It eliminates the uncertainty in the model of estimating the source vapor concentrations from the equilibrium partitioning equation. This can be significant because of the complexities of partitioning when the chemicals are part of a mixture and because the soil properties like soil moisture and porosity are rarely known.
- The soil vapor concentration may be measured in the vadose zone between the source and the building. This approach can directly account for attenuation processes such as degradation and diffusion through different soil horizons (whose soil properties are not known) that the model may under-estimate. This can be very significant and many US State risk-based corrective action programs are developing protocols for starting with soil vapor concentrations rather than total soil concentrations.

Note that if the location of the soil vapor measurement is not close to the source, it is important to evaluate whether or not the soil vapor concentration has yet reached equilibrium. For example, if a recent subsurface chemical spill occurred in a silty clay and the soil vapor measurement point were 3 meters away, the vapor concentrations may not have yet reached their maximum values.

If there is no residual phase hydrocarbon present, the source vapor concentration is calculated from the total soil concentration using the following equation presented by Jury (1983, 1984, and 1990):

$$C_{vs} = \frac{C_T \rho_b K_H}{\theta_a K_H + \theta_w + \rho_b F_{oc} K_{oc}} \left(\frac{kg}{1E6mg} \right) \qquad \textbf{(D-10)}$$

where

C_{vs} = vapor concentration at the source [g/cm^3]

C_T = total soil concentration of chemical *i* [mg/kg]

ρ_b = soil bulk density of the source area [g/cm^3]

F_{oc} = fraction organic carbon in soil [g oc/g soil]

K_{oc} = chemical-specific organic carbon partition coefficient [ml/g m^3/kg]

K_H = Henry's law constant [(mg/l)/(mg/l)]

θ_a = air-filled porosity of vadose zone [cm^3 of air/cm^3 total soil volume]

θ_w = water-filled porosity of vadose zone [cm^3 of water/cm^3 total soil volume]

If residual phase hydrocarbon (NAPL) is present, Raoult's Law is used with the component mole fraction

$$C_{vs} = \frac{x_i P_v^{\,i} MW_i}{RT} \qquad \textbf{(D-11)}$$

where

x_i = mole fraction of component i in the hydrocarbon [mol/mol]

P_i^v = pure component vapor pressure of component i [atm]

MW_i = molecular weight of component i [g/mol]

R = the universal gas constant (82.1) [cm^3-atm/mol-K]

T = absolute temperature [K]

The model checks to see if residual-phase hydrocarbon is present and then calculates the source term accordingly. (The method for determining the residual limit is discussed in more detail in Appendix A, starting with Equation A-15.)

The mole fraction, x_i, is calculated from

$$x_i = \left(\frac{C_T}{C_{TPH}}\right)\left(\frac{MW_{TPH}}{MW}\right) \qquad \textbf{(D-12)}$$

where

C_T = total soil concentration of chemical i [mg/kg]

C_{TPH} = total soil concentration of TPH mixture [mg/kg]

MW_{TPH} = molecular weight of the mixture [g/mol]

MW_i = average molecular weight of component i [g/mol]

If the molecular weights of the component, i, and the mixture are similar, this roughly translates to the concentration of the component, i, over the concentration of total petroleum hydrocarbons (TPH) in the source.

D.5 DATA REQUIREMENTS OF THE SOIL VAPOR MODEL

The input data requirements for this model are presented in Table D-1.

Table D-1. Data Requirements for the Soil Vapor Model for Indoor Air
(Page 1 of 2)

	Units	Typical Range of Values	
		Minimum	Maximum
UNSATURATED ZONE			
Porosity	cm^3/cm^3	0.01	0.5
Water content in diffusion zone	cm^3/cm^3	0	porosity
Hydraulic conductivity of the soil surrounding the foundation (used to estimate soil vapor flow)	m/day	1.0E-07	100
Soil Bulk Density	fraction	1.4	2.2
LENS (Optional)			
Porosity	cm^3/cm^3	0.01	0.5
Water content of lens	cm^3/cm^3	0	porosity
Lens thickness	m	site-specific	site-specific
TPH DATA (Optional)			
Molecular weight of TPH	g/mol	80	120
Concentration of TPH	mg/kg	site-specific	site-specific
FOUNDATION PARAMETERS			
Distance to foundation	m	site-specific	site-specific
Cross-sectional area of foundation perpendicular to vapor flow	m^2	site-specific	site-specific
Volume of house	m^3	site-specific	site-specific
Number of air exchanges per day	d^{-1}	residential: 12 industrial: 20	location/site-specific
Thickness of foundation	m	0	site-specific
Fraction of cracks in foundation	cm^3/cm^3	0	1

Table D-1. Data Requirements for the Soil Vapor Model for Indoor Air
(Page 2 of 2)

	Units	Typical Range of Values	
		Minimum	Maximum
PARAMETERS USED TO CALCULATE PRESSURE-DRIVEN FLOW			
Soil Gas Flow Rate Into Building (Q_{soil}) (**or** next three parameters)	cm^3/s	*>0*	*location/site-specific*
Length of Foundation Perimeter (not needed if Q_{soil} specified)	m	0	site-specific
Depth Below Ground Surface of Foundation (not needed if Q_{soil} specified)	m	0	site-specific
Pressure Difference From Indoors to Outdoors (not needed if Q_{soil} specified)	g/cm^2-s	0	site-specific
CHEMICAL SPECIFIC DATA (individual chemical component)			
Molecular Weight	g/mol	chem-specific	chem-specific
Source Concentration: Soil Vapor Concentration, or Total Soil Concentration	mg/m^3 mg/kg	site-specific	site-specific
Solubility	mg/l	chem-specific	chem-specific
Diffusion Coefficient in Air	cm^2/s	chem-specific	chem-specific
Diffusion Coefficient in Water	cm^2/s	chem-specific	chem-specific
Henry's Law coefficient	(mg/l)/(mg/l)	chem-specific	chem-specific

D.6 LIMITATIONS OF THE SOIL VAPOR MODEL

1. This is a steady-state, constant and one-dimensional model. The source does not deplete due to vapor losses so mass is not conserved. This assumption has only a minor impact on the risk due to non-carcinogens (unless the source is

very small) since the highest seven-year running average intake is compared to the reference dose. It can have a more significant impact however on carcinogens (such as benzene) since the cumulative exposure over a long exposure duration (up to 30 years) forms the basis for the risk calculation.

2. There is no biodegradation of the vapors as they migrate through the soil.

D.7 REFERENCES

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Appendix D

Risk Modelling Spreadsheets and Summary

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Summary of Vapour Modelling Results

Description:	Zone 1 - Surface, outdoor air
Source media:	Soil
Distance:	0.1m
Geology:	sand
Surface Use	Outdoors
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	1.21E-09
Benzene	1.85E-03
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	6.20E-05
Arsenic	
Benzene	1.85E-03
Cadmium	
Chromium	
Cyanide	4.70E-05
Dibenzofuran	5.29E-07
2,4-dimethylphenol	
Ethylbenzene	6.66E-04
Fluoranthene	
Fluorene	2.56E-07
Lead	
Nickel	
2-methylnaphthalene	6.07E-07
Cresols	
Naphthalene	9.58E-06
Phenol	8.36E-08
Pyrene	3.39E-09
Toluene	1.21E-03
TPH C_6-C_8 (ali)	1.60E-02
TPH C_8-C_{16} (ali)	7.03E-04
TPH $C>_{16}$ (ali)	
TPH C_8-C_{16} (aro)	7.59E-05
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	2.88E-04
Xylenes	6.32E-04

Summary of Vapour Modelling Results

Description:	Zone 1 - Surface, outdoor air
Source media:	Seepage water
Distance:	0.5m
Geology:	sand (inc 0.17m capillary fringe)
Surface Use	Outdoors
Input Concentration:	1mg/l

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	6.48E-07
Benzene	1.79E-04
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	1.40E-06
Arsenic	
Benzene	1.79E-04
Cadmium	
Chromium	
Cyanide	1.23E-05
Dibenzofuran	3.80E-06
2,4-dimethylphenol	
Ethylbenzene	1.94E-04
Fluoranthene	
Fluorene	2.22E-06
Lead	
Nickel	
2-methylnaphthalene	1.65E-06
Cresols	
Naphthalene	1.03E-05
Phenol	1.27E-07
Pyrene	5.87E-07
Toluene	1.85E-04
TPH C_6-C_8 (ali)	4.46E-02
TPH C_8-C_{16} (ali)	1.14E-01
TPH $C>_{16}$ (ali)	
TPH C_8-C_{16} (aro)	1.23E-04
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	1.35E-04
Xylenes	1.58E-04

Summary of Vapour Modelling Results

Description:	Zone 1 - Sub-surface maintenance trench, outdoor air
Source media:	Seepage water
Distance:	0.1m
Geology:	sand (capillary)
Surface Use	Outdoors
Input Concentration:	1mg/l

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	6.61E-06
Benzene	1.31E-03
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	1.15E-05
Arsenic	
Benzene	1.31E-03
Cadmium	
Chromium	
Cyanide	9.14E-05
Dibenzofuran	2.82E-05
2,4-dimethylphenol	
Ethylbenzene	1.42E-03
Fluoranthene	
Fluorene	1.68E-05
Lead	
Nickel	
2-methylnaphthalene	1.28E-05
Cresols	
Naphthalene	7.58E-05
Phenol	7.57E-06
Pyrene	6.15E-06
Toluene	1.36E-03
TPH C_6-C_8 (ali)	3.27E-01
TPH C_8-C_{16} (ali)	8.33E-01
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	9.04E-04
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	9.85E-04
Xylenes	1.16E-03

Summary of Vapour Modelling Results

Description:	Zone 2 - soils underlying Car Park
Source media:	Soil
Distance:	0.1m
Geology:	sand
Surface Use	Indoors, car park
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	1.65E-07
Benzene	8.39E-02
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	2.91E-04
Arsenic	
Benzene	8.39E-02
Cadmium	
Chromium	
Cyanide	1.06E-04
Dibenzofuran	5.77E-05
2,4-dimethylphenol	
Ethylbenzene	4.22E-02
Fluoranthene	
Fluorene	2.62E-05
Lead	
Nickel	
2-methylnaphthalene	5.26E-05
Cresols	
Naphthalene	7.22E-04
Phenol	4.35E-06
Pyrene	5.25E-07
Toluene	6.51E-02
TPH C_6-C_8 (ali)	4.44E-01
TPH C_8-C_{16} (ali)	3.20E-02
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	3.53E-03
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	2.11E-02
Xylenes	3.29E-02

Summary of Vapour Modelling Results

Description:	Zone 2 - seepage water / groundwater underlying Car Park
Source media:	Groundwater
Distance:	0.1m
Geology:	sand (capillary)
Surface Use	Indoors (Car Park)
Input Concentration:	1mg/l

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	6.86E-05
Benzene	2.28E-02
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	9.85E-05
Arsenic	
Benzene	2.28E-02
Cadmium	
Chromium	
Cyanide	8.07E-04
Dibenzofuran	6.43E-04
2,4-dimethylphenol	
Ethylbenzene	2.81E-02
Fluoranthene	
Fluorene	3.37E-04
Lead	
Nickel	
2-methylnaphthalene	2.18E-04
Cresols	
Naphthalene	1.53E-03
Phenol	2.66E-06
Pyrene	6.67E-05
Toluene	2.54E-02
TPH C_6-C_8 (ali)	5.39E+00
TPH C_8-C_{16} (ali)	1.37E+01
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	1.48E-02
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	2.05E-02
Xylenes	2.07E-02

Summary of Vapour Modelling Results

Description:	Zone 2/3 - infiltrating seepage water
Source media:	Seepage water
Distance:	N/A
Geology:	N/A
Surface Use	Indoors (Car Park)
Input Concentration:	1mg/l

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	1.10E-06
Benzene	1.10E-06
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	1.10E-06
Arsenic	
Benzene	1.10E-06
Cadmium	
Chromium	
Cyanide	1.10E-06
Dibenzofuran	1.10E-06
2,4-dimethylphenol	
Ethylbenzene	1.10E-06
Fluoranthene	
Fluorene	1.10E-06
Lead	
Nickel	
2-methylnaphthalene	1.10E-06
Cresols	
Naphthalene	1.10E-06
Phenol	1.10E-06
Pyrene	1.10E-06
Toluene	1.10E-06
TPH C_6-C_8 (ali)	1.10E-06
TPH C_8-C_{16} (ali)	1.10E-06
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	1.10E-06
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	1.10E-06
Xylenes	1.10E-06

Summary of Vapour Modelling Results

Description:	Zone 3 - Adjoining Car Park / Cultural Space (0-1m)
Source media:	Soil
Distance:	0.1m
Geology:	sand
Surface Use	Indoor (Cultural Space)
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	3.11E-07
Benzene	1.58E-01
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	5.48E-04
Arsenic	
Benzene	1.58E-01
Cadmium	
Chromium	
Cyanide	2.00E-04
Dibenzofuran	1.09E-04
2,4-dimethylphenol	
Ethylbenzene	7.96E-02
Fluoranthene	
Fluorene	4.93E-05
Lead	
Nickel	
2-methylnaphthalene	9.91E-05
Cresols	
Naphthalene	1.36E-03
Phenol	8.20E-06
Pyrene	9.90E-07
Toluene	1.23E-01
TPH C_6-C_8 (ali)	8.37E-01
TPH C_8-C_{16} (ali)	6.03E-02
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	6.66E-03
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	3.97E-02
Xylenes	6.20E-02

Summary of Vapour Modelling Results

Description:	Zone 3 - Adjoining Car Park / Cultural Space (0-1m)
Source media:	Soil
Distance:	1.1m
Geology:	retaining wall (clay) - 1.0m; sand 0.1m
Surface Use	Indoor (Car Park)
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	7.19E-08
Benzene	4.23E-04
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	1.20E-04
Arsenic	
Benzene	4.23E-04
Cadmium	
Chromium	
Cyanide	1.85E-05
Dibenzofuran	2.34E-06
2,4-dimethylphenol	
Ethylbenzene	1.49E-04
Fluoranthene	
Fluorene	2.33E-06
Lead	
Nickel	
2-methylnaphthalene	7.85E-06
Cresols	
Naphthalene	1.69E-05
Phenol	4.23E-06
Pyrene	2.24E-07
Toluene	2.71E-04
TPH C_6-C_8 (ali)	1.47E-03
TPH C_8-C_{16} (ali)	1.06E-04
TPH $C>_{16}$ (ali)	
TPH C_8-C_{16} (aro)	2.32E-05
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	7.41E-05
Xylenes	1.63E-04

Summary of Vapour Modelling Results

Description:	Zone 4 - Cultural Space / Car Park (Soils 1-10m)
Source media:	Soil
Distance:	1m
Geology:	sand
Surface Use	Indoors (Cultural Space)
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	1.67E-07
Benzene	1.19E-01
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	4.22E-04
Arsenic	
Benzene	1.19E-01
Cadmium	
Chromium	
Cyanide	1.75E-04
Dibenzofuran	6.43E-05
2,4-dimethylphenol	
Ethylbenzene	5.58E-02
Fluoranthene	
Fluorene	2.99E-05
Lead	
Nickel	
2-methylnaphthalene	6.39E-05
Cresols	
Naphthalene	9.19E-04
Phenol	6.09E-06
Pyrene	4.99E-07
Toluene	8.91E-02
TPH C_6-C_8 (ali)	6.45E-01
TPH C_8-C_{16} (ali)	4.65E-02
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	5.14E-03
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	2.69E-02
Xylenes	4.60E-02

Summary of Vapour Modelling Results

Description:	Zone 4 - Cultural Space / Car Park (Soils 1-10m)
Source media:	Soil
Distance:	2m
Geology:	retaining wall (clay) - 1.0m; sand 1.0m
Surface Use	Indoor (Car Park)
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	5.06E-08
Benzene	4.23E-04
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	1.06E-04
Arsenic	
Benzene	4.23E-04
Cadmium	
Chromium	
Cyanide	1.80E-05
Dibenzofuran	2.27E-06
2,4-dimethylphenol	
Ethylbenzene	1.48E-04
Fluoranthene	
Fluorene	2.19E-06
Lead	
Nickel	
2-methylnaphthalene	7.19E-06
Cresols	
Naphthalene	1.67E-05
Phenol	3.08E-06
Pyrene	1.53E-07
Toluene	2.70E-04
TPH C_6-C_8 (ali)	1.47E-03
TPH C_8-C_{16} (ali)	1.06E-04
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	2.31E-05
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	7.40E-05
Xylenes	1.63E-04

Summary of Vapour Modelling Results

Description:	Zone 5 - Cultural Space / Car Park (Soils >10-30m)
Source media:	Soil
Distance:	10m
Geology:	sand
Surface Use	Indoors (Cultural Space)
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	2.95E-08
Benzene	3.41E-02
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	1.28E-04
Arsenic	
Benzene	3.41E-02
Cadmium	
Chromium	
Cyanide	7.78E-05
Dibenzofuran	1.26E-05
2,4-dimethylphenol	
Ethylbenzene	1.40E-02
Fluoranthene	
Fluorene	6.07E-06
Lead	
Nickel	
2-methylnaphthalene	1.40E-05
Cresols	
Naphthalene	2.17E-04
Phenol	1.71E-06
Pyrene	8.38E-08
Toluene	2.38E-02
TPH C_6-C_8 (ali)	1.96E-01
TPH C_8-C_{16} (ali)	1.41E-02
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	1.56E-03
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	6.34E-03
Xylenes	1.28E-02

Summary of Vapour Modelling Results

Description:	Zone 5 - Cultural Space / Car Park (Soils >10-30m)
Source media:	Soil
Distance:	10m
Geology:	retaining wall (clay) - 1.0m; sand 9.0m
Surface Use	Indoor (Car Park)
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	1.52E-08
Benzene	4.17E-04
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	5.42E-05
Arsenic	
Benzene	4.17E-04
Cadmium	
Chromium	
Cyanide	1.49E-05
Dibenzofuran	1.83E-06
2,4-dimethylphenol	
Ethylbenzene	1.46E-04
Fluoranthene	
Fluorene	1.48E-06
Lead	
Nickel	
2-methylnaphthalene	4.33E-06
Cresols	
Naphthalene	1.52E-05
Phenol	9.77E-07
Pyrene	4.35E-08
Toluene	2.67E-04
TPH C_6-C_8 (ali)	1.45E-03
TPH C_8-C_{16} (ali)	1.05E-04
TPH $C>_{16}$ (ali)	
TPH C_8-C_{16} (aro)	2.27E-05
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	7.29E-05
Xylenes	1.60E-04

Summary of Vapour Modelling Results

Description:	Zone 6 - Soils >30m from Cultural Space + Car Park
Source media:	Soil
Distance:	0.5m
Geology:	sand
Surface Use	Outdoors
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	2.41E-09
Benzene	3.22E-03
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	1.24E-05
Arsenic	
Benzene	3.22E-03
Cadmium	
Chromium	
Cyanide	9.40E-06
Dibenzofuran	1.06E-06
2,4-dimethylphenol	
Ethylbenzene	1.25E-03
Fluoranthene	
Fluorene	5.11E-07
Lead	
Nickel	
2-methylnaphthalene	1.21E-06
Cresols	
Naphthalene	1.90E-05
Phenol	1.59E-07
Pyrene	6.77E-09
Toluene	2.18E-03
TPH C_6-C_8 (ali)	1.89E-02
TPH C_8-C_{16} (ali)	1.36E-03
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	1.51E-04
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	5.57E-04
Xylenes	1.20E-03

Summary of Vapour Modelling Results

Description:	Zone 6 - Soils >30m from Cultural Space + Car Park
Source media:	Soil
Distance:	0.1m
Geology:	sand
Surface Use	Outdoors (Sub-surface maintenance trench)
Input Concentration:	1mg/kg

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	4.82E-08
Benzene	6.43E-02
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	2.48E-04
Arsenic	
Benzene	6.43E-02
Cadmium	
Chromium	
Cyanide	1.88E-04
Dibenzofuran	2.11E-05
2,4-dimethylphenol	
Ethylbenzene	2.51E-02
Fluoranthene	
Fluorene	1.02E-05
Lead	
Nickel	
2-methylnaphthalene	2.42E-05
Cresols	
Naphthalene	3.81E-04
Phenol	3.18E-06
Pyrene	1.35E-07
Toluene	4.36E-02
TPH C_6-C_8 (ali)	3.79E-01
TPH C_8-C_{16} (ali)	2.73E-02
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	3.01E-03
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	1.11E-02
Xylenes	2.39E-02

Summary of Vapour Modelling Results

Description:	None, outdoor area of Park
Source media:	Irrigation / sprinkler water
Distance:	N/A
Geology:	N/A
Surface Use	Outdoors
Input Concentration:	1mg/l

Constituent	Air Concentration (mg/m^3)
Benz(a)anthracene	3.52E-02
Benzene	5.94E-02
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h)anthracene	
Indeno(1,2,3-c,d)pyrene	
Nickel	
Ammonia	7.14E-02
Arsenic	
Benzene	5.94E-02
Cadmium	
Chromium	
Cyanide	7.24E-02
Dibenzofuran	4.70E-02
2,4-dimethylphenol	
Ethylbenzene	5.48E-02
Fluoranthene	
Fluorene	4.61E-02
Lead	
Nickel	
2-methylnaphthalene	4.70E-02
Cresols	
Naphthalene	5.15E-02
Phenol	4.75E-03
Pyrene	3.35E-02
Toluene	5.70E-02
TPH C_6-C_8 (ali)	5.57E-02
TPH C_8-C_{16} (ali)	4.86E-02
TPH $C_{>16}$ (ali)	
TPH C_8-C_{16} (aro)	5.17E-02
TPH $C_{>16}$ (aro)	
1,2,4-trimethylbenzene	2.59E-02
Xylenes	5.48E-02

Summary of Oral & Dermal Exposure Modelling

Description: Zone 1
Media: Soil
Input Concentration: 1mg/kg

		Receptor Type			
Constituent	**Measure**	Recreational - Adult	Recreational - Child	C/I - Gardener	Sub-Surface Maintenance Worker
Benz(a)anthracene	Risk	1.80E-07	1.40E-07	6.70E-08	4.50E-10
Benzene	Risk	9.20E-07	5.30E-07	3.30E-07	1.80E-09
Benzo(a)pyrene	Risk	1.80E-06	1.40E-06	6.70E-07	4.50E-09
Benzo(b)fluoranthene	Risk	1.80E-07	1.40E-07	6.70E-08	4.50E-10
Benzo(k)fluoranthene	Risk	1.80E-07	1.40E-07	6.70E-08	4.50E-10
Chrysene	Risk	1.80E-08	1.40E-08	6.70E-09	4.50E-11
Dibenz(a,h)anthracene	Risk	1.80E-06	1.40E-06	6.70E-07	4.50E-09
Indeno(1,2,3-c,d)pyrene	Risk	1.80E-07	1.40E-07	6.70E-08	4.50E-10
Nickel	Risk				
Ammonia	HI				
Arsenic	HI	6.80E-04	5.00E-03	4.50E-04	1.50E-04
Benzene	HI	6.80E-02	1.80E-01	4.50E-02	7.20E-03
Cadmium	HI	1.50E-03	1.30E-02	9.70E-04	3.70E-04
Chromium	HI	9.00E-04	2.20E-03	5.90E-04	9.10E-05
Cyanide	HI	1.70E-03	4.50E-03	1.10E-03	1.80E-04
Dibenzofuran	HI	6.20E-05	2.60E-04	4.10E-05	8.90E-06
2,4-dimethylphenol	HI	1.90E-04	7.90E-04	1.20E-04	2.70E-05
Ethylbenzene	HI	3.50E-04	9.20E-04	2.30E-04	3.70E-05
Fluoranthene	HI	3.80E-04	1.50E-03	2.50E-04	5.10E-05
Fluorene	HI	1.20E-04	4.60E-04	7.80E-05	1.60E-05
Lead	HI	1.10E-03	4.50E-03	7.00E-04	1.50E-04
Nickel	HI	1.70E-01	4.10E-01	1.10E-01	1.70E-02
2-methylnaphthalene	HI	9.30E-05	3.90E-04	6.10E-05	1.30E-05
Cresols	HI	7.40E-05	3.20E-04	4.90E-05	1.10E-05
Naphthalene	HI	2.40E-04	9.10E-04	1.60E-04	3.20E-05
Phenol	HI	1.20E-05	5.20E-05	8.10E-06	1.80E-06
Pyrene	HI	1.60E-04	6.10E-04	1.00E-04	2.10E-05
Toluene	HI	1.50E-04	4.00E-04	1.00E-04	1.60E-05
TPH C_{6}-C_{8} (ali)	HI	6.80E-06	1.80E-05	4.50E-06	7.20E-07
TPH C_{8}-C_{16} (ali)	HI	3.70E-05	1.60E-04	2.40E-05	5.30E-06
TPH $C_{>16}$ (ali)	HI	1.90E-06	7.90E-06	1.20E-06	2.70E-07
TPH C_{8}-C_{16} (aro)	HI	9.30E-05	3.90E-04	6.10E-05	1.30E-05
TPH $C_{>16}$ (aro)	HI	1.20E-04	5.30E-04	8.10E-05	1.80E-05
1,2,4-trimethylbenzene	HI	1.70E-02	4.50E-02	1.10E-02	1.80E-03
Xylenes	HI	1.90E-04	5.00E-04	1.20E-04	2.00E-05

Summary of Oral & Dermal Exposure Modelling

Description: Zone 1
Media: Seepage Water
Input Concentration: 1mg/L

		Receptor Type
Constituent	**Measure**	Sub-Surface Maintenance Worker
Benz(a)anthracene	Risk	3.90E-06
Benzene	Risk	7.60E-08
Benzo(a)pyrene	Risk	5.10E-05
Benzo(b)fluoranthene	Risk	3.00E-06
Benzo(k)fluoranthene	Risk	4.90E-06
Chrysene	Risk	4.30E-07
Dibenz(a,h)anthracene	Risk	6.80E-05
Indeno(1,2,3-c,d)pyrene	Risk	8.90E-06
Nickel	Risk	
Ammonia	HI	
Arsenic	HI	6.50E-03
Benzene	HI	3.00E-01
Cadmium	HI	2.90E-01
Chromium	HI	8.00E-01
Cyanide	HI	5.20E-04
Dibenzofuran	HI	1.70E-03
2,4-dimethylphenol	HI	5.60E-03
Ethylbenzene	HI	5.10E-03
Fluoranthene	HI	2.50E-01
Fluorene	HI	2.80E-02
Lead	HI	1.10E-03
Nickel	HI	1.10E-02
2-methylnaphthalene	HI	2.30E-02
Cresols	HI	1.60E-03
Naphthalene	HI	2.30E-02
Phenol	HI	1.50E-04
Pyrene	HI	6.70E-02
Toluene	HI	1.40E-03
TPH C_6-C_8 (ali)	HI	1.50E-03
TPH C_8-C_{16} (ali)	HI	1.90E-01
TPH $C_{>16}$ (ali)	HI	1.50E-03
TPH C_8-C_{16} (aro)	HI	2.20E-02
TPH $C_{>16}$ (aro)	HI	1.00E-01
1,2,4-trimethylbenzene	HI	4.30E-01
Xylenes	HI	2.60E-03

Summary of Oral & Dermal Exposure Modelling

Description: Zone 2
Media: Pooled Seepage Water
Input Concentration: 1mg/l

		Receptor Type (Dermal only)	
Constituent	**Measure**	Adult Car Park User	Child Car Park User
Benz(a)anthracene	Risk	1.10E-06	5.30E-07
Benzene	Risk	2.10E-08	1.00E-08
Benzo(a)pyrene	Risk	1.50E-05	6.80E-06
Benzo(b)fluoranthene	Risk	8.50E-07	4.00E-07
Benzo(k)fluoranthene	Risk	1.40E-06	6.60E-07
Chrysene	Risk	1.20E-07	5.70E-08
Dibenz(a,h)anthracene	Risk	2.00E-05	9.10E-06
Indeno(1,2,3-c,d)pyrene	Risk	2.50E-06	1.20E-06
Nickel	Risk		
Ammonia	HI		
Arsenic	HI	2.70E-05	4.90E-05
Benzene	HI	1.60E-03	2.90E-03
Cadmium	HI	1.50E-03	2.80E-03
Chromium	HI	4.20E-03	7.80E-03
Cyanide	HI	2.00E-06	3.70E-06
Dibenzofuran	HI	8.60E-06	1.60E-05
2,4-dimethylphenol	HI	2.90E-05	5.30E-05
Ethylbenzene	HI	2.70E-05	5.00E-05
Fluoranthene	HI	1.30E-03	2.40E-03
Fluorene	HI	1.50E-04	2.70E-04
Lead	HI	1.50E-06	2.80E-06
Nickel	HI	5.30E-05	9.70E-05
2-methylnaphthalene	HI	1.20E-04	2.20E-04
Cresols	HI	8.10E-06	1.50E-05
Naphthalene	HI	1.20E-04	2.30E-04
Phenol	HI	7.70E-07	1.40E-06
Pyrene	HI	3.60E-04	6.50E-04
Toluene	HI	7.40E-06	1.40E-05
TPH C_6-C_8 (ali)	HI	8.00E-06	1.50E-05
TPH C_8-C_{16} (ali)	HI	1.00E-03	1.90E-03
TPH $C_{>16}$ (ali)	HI	8.00E-06	1.50E-05
TPH C_8-C_{16} (aro)	HI	1.20E-04	2.10E-04
TPH $C_{>16}$ (aro)	HI	5.30E-04	9.70E-04
1,2,4-trimethylbenzene	HI	2.30E-03	4.20E-03
Xylenes	HI	1.40E-05	2.60E-05

Summary of Oral & Dermal Exposure Modelling

Description: Irrigation / Sprinkler Water
Media: Water
Input Concentration: 1mg/L

		Receptor Type		
Constituent	**Measure**	Recreational - Adult	Recreational - Child	C/I - Gardener
Benz(a)anthracene	Risk	2.00E-04	1.50E-04	5.20E-04
Benzene	Risk	3.80E-06	2.80E-06	9.90E-06
Benzo(a)pyrene	Risk	2.60E-03	1.90E-03	6.70E-03
Benzo(b)fluoranthene	Risk	1.50E-04	1.10E-04	3.90E-04
Benzo(k)fluoranthene	Risk	2.50E-04	1.90E-04	6.50E-04
Chrysene	Risk	2.20E-05	1.60E-05	5.60E-05
Dibenz(a,h)anthracene	Risk	3.50E-03	2.60E-03	9.00E-03
Indeno(1,2,3-c,d)pyrene	Risk	4.60E-04	3.30E-04	1.20E-03
Nickel	Risk			
Ammonia	HI			
Arsenic	HI	4.80E-03	1.90E-02	2.20E-02
Benzene	HI	2.90E-01	1.20E+00	1.30E+00
Cadmium	HI	2.70E-01	1.10E+00	1.30E+00
Chromium	HI	7.70E-01	3.10E+00	3.50E+00
Cyanide	HI	3.60E-04	1.50E-03	1.70E-03
Dibenzofuran	HI	1.60E-03	6.30E-03	7.20E-03
2,4-dimethylphenol	HI	5.20E-03	2.10E-02	2.40E-02
Ethylbenzene	HI	4.90E-03	2.00E-02	2.20E-02
Fluoranthene	HI	2.40E-01	9.60E-01	1.10E+00
Fluorene	HI	2.60E-02	1.10E-01	1.20E-01
Lead	HI	2.70E-04	1.10E-03	1.30E-03
Nickel	HI	9.60E-03	3.90E-02	4.40E-02
2-methylnaphthalene	HI	2.20E-02	8.90E-02	1.00E-01
Cresols	HI	1.50E-03	5.90E-03	6.80E-03
Naphthalene	HI	2.20E-02	9.00E-02	1.00E-01
Phenol	HI	1.40E-04	5.60E-04	6.40E-04
Pyrene	HI	6.40E-02	2.60E-01	3.00E-01
Toluene	HI	1.30E-03	5.40E-03	6.20E-03
TPH C_{6}-C_{8} (ali)	HI	1.40E-03	5.80E-03	6.60E-03
TPH C_{8}-C_{16} (ali)	HI	1.80E-01	7.40E-01	8.40E-01
TPH $C_{>16}$ (ali)	HI	1.40E-03	5.80E-03	6.60E-03
TPH C_{8}-C_{16} (aro)	HI	2.10E-02	8.40E-02	9.60E-02
TPH $C_{>16}$ (aro)	HI	9.60E-02	3.90E-01	4.40E-01
1,2,4-trimethylbenzene	HI	4.10E-01	1.70E+00	1.90E+00
Xylenes	HI	2.50E-03	1.00E-02	1.20E-02

Summary of Leaching Factors used to convert Risk + HI's based on water exposure to equivalent soil concentrations

i.e. Risk + HI estimate based on 1mg/l. Multiplied by factor to determine equivalent Risk + HI for concentration of seepage water caused by leaching of 1mg/kg

Constituent	**Leaching factor - Headland Park Soil - Seepage Water (mg/l / mg/kg)**	**Leaching factor - Central + South Soil - Seepage Water (mg/l / mg/kg)**
Benz(a)anthracene	1.88E-03	1.88E-03
Benzene	1.95E+00	1.95E+00
Benzo(a)pyrene	5.68E-04	5.68E-04
Benzo(b)fluoranthene	5.56E-04	5.56E-04
Benzo(k)fluoranthene	5.68E-04	5.68E-04
Chrysene	1.84E-03	1.84E-03
Dibenz(a,h)anthracene	1.75E-04	1.75E-04
Indeno(1,2,3-c,d)pyrene	1.71E-04	1.71E-04
Nickel	3.30E-04	1.54E-02
Ammonia	2.31E+00	2.31E+00
Arsenic	5.00E-04	4.50E-04
Benzene	1.95E+00	1.95E+00
Cadmium	1.33E-02	5.00E-05
Chromium	2.30E-04	3.00E-04
Cyanide	1.01E-01	1.01E-01
Dibenzofuran	3.63E-02	3.63E-02
2,4-dimethylphenol	6.63E-01	6.63E-01
Ethylbenzene	6.98E-01	6.98E-01
Fluoranthene	2.00E-04	3.10E-04
Fluorene	2.10E-03	1.56E-03
Lead	1.40E-04	2.40E-04
Nickel	3.30E-04	5.00E-04
2-methylnaphthalene	1.34E-01	1.34E-01
Cresols	1.05E+00	1.05E+00
Naphthalene	1.20E-03	9.60E-03
Phenol	1.69E+00	1.69E+00
Pyrene	1.00E-04	2.50E-04
Toluene	1.27E+00	1.27E+00
TPH C_6-C_8 (ali)	4.56E-02	4.56E-02
TPH C_8-C_{16} (ali)	1.29E-03	1.29E-03
TPH $C>_{16}$ (ali)	3.33E-07	3.33E-07
TPH C_8-C_{16} (aro)	1.32E-01	1.32E-01
TPH $C_{>16}$ (aro)	2.08E-02	2.08E-02
1,2,4-trimethylbenzene	5.20E-01	5.20E-01
Xylenes	8.18E-01	8.18E-01

Constituent	Zone 1 Volatile Modelling				Zone 2 Volatile Modelling			Zone 3 Volatile Modelling		Zone 4 Volatile Modelling		Zone 5 Volatile Modelling		Zone 6 Volatile Modelling		Irrigation Water Sprinkler
	Soil	Particulates	Seepage Water (0.5m depth)	Seepage Water (0.1m depth)	Soil	Groundwater	Pooled Seepage	Soil - Car Park	Soil (Cultural Space)	Soil - Car Park	Soil - Cultural Space	Soil - Car Park	Soil - Cultural Space	Soil (Surface)	Soil (Sub-Surface)	
	Ca (1mg/kg)	Ca (1mg/kg)	Ca (1mg/L)	Ca (1mg/L)	Ca (1mg/kg)	Ca (1mg/L)	Ca (1mg/L)	Ca (1mg/kg)	Ca (1mg/kg)	Ca (1mg/kg)	Ca (1mg/kg)	Ca (1mg/kg)	Ca (1mg/kg)	Ca (1mg/kg)		
Benz(a)anthracene	1.21E-09	2.78E-08	6.48E-07	6.61E-06	1.65E-07	6.86E-05	1.10E-06	7.19E-08	3.11E-07	5.06E-08	1.67E-07	1.52E-08	2.95E-08	2.41E-09	4.82E-08	3.52E-02
Benzene	1.85E-03	2.78E-08	1.79E-04	1.31E-03	8.39E-02	2.28E-02	1.10E-06	4.23E-04	1.58E-01	4.23E-04	1.19E-01	4.17E-04	3.41E-02	3.22E-03	6.43E-02	5.94E-02
Benzo(a)pyrene		2.78E-08														
Benzo(b)fluoranthene		2.78E-08														
Benzo(k)fluoranthene		2.78E-08														
Chrysene		2.78E-08														
Dibenz(a,h)anthracene		2.78E-08														
Indeno(1,2,3-c,d)pyrene		2.78E-08														
Nickel		2.78E-08														
Ammonia	6.20E-05	2.78E-08	1.40E-06	1.15E-05	2.91E-04	9.85E-05	1.10E-06	1.20E-04	5.48E-04	1.06E-04	4.22E-04	5.42E-05	1.28E-04	1.24E-05	2.48E-04	7.14E-02
Arsenic		2.78E-08														
Benzene	1.85E-03	2.78E-08	1.79E-04	1.31E-03	8.39E-02	2.28E-02	1.10E-06	4.23E-04	1.58E-01	4.23E-04	1.19E-01	4.17E-04	3.41E-02	3.22E-03	6.43E-02	5.94E-02
Cadmium		2.78E-08														
Chromium		2.78E-08														
Cyanide	4.70E-05	2.78E-08	1.23E-05	9.14E-05	1.06E-04	8.07E-04	1.10E-06	1.85E-05	2.00E-04	1.80E-05	1.75E-04	1.49E-05	7.78E-05	9.40E-06	1.88E-04	7.24E-02
Dibenzofuran	5.29E-07	2.78E-08	3.80E-06	2.82E-05	5.77E-05	6.43E-04	1.10E-06	2.34E-06	1.09E-04	2.27E-06	6.43E-05	1.83E-06	1.26E-05	1.06E-06	2.11E-05	4.70E-02
2,4-dimethylphenol		2.78E-08														
Ethylbenzene	6.66E-04	2.78E-08	1.94E-04	1.42E-03	4.22E-02	2.81E-02	1.10E-06	1.49E-04	7.96E-02	1.48E-04	5.58E-02	1.46E-04	1.40E-02	1.25E-03	2.51E-02	5.48E-02
Fluoranthene		2.78E-08														
Fluorene	2.56E-07	2.78E-08	2.22E-06	1.68E-05	2.62E-05	3.37E-04	1.10E-06	2.33E-06	4.93E-05	2.19E-06	2.99E-05	1.48E-06	6.07E-06	5.11E-07	1.02E-05	4.61E-02
Lead		2.78E-08														
Nickel		2.78E-08														
2-methylnaphthalene	6.07E-07	2.78E-08	1.65E-06	1.28E-05	5.26E-05	2.18E-04	1.10E-06	7.85E-06	9.91E-05	7.19E-06	6.39E-05	4.33E-06	1.40E-05	1.21E-06	2.42E-05	4.70E-02
Cresols		2.78E-08														
Naphthalene	9.58E-06	2.78E-08	1.03E-05	7.58E-05	7.22E-04	1.53E-03	1.10E-06	1.69E-05	1.36E-03	1.67E-05	9.19E-04	1.52E-05	2.17E-04	1.90E-05	3.81E-04	5.15E-02
Phenol	8.36E-08	2.78E-08	1.27E-07	7.57E-06	4.35E-06	2.66E-06	1.10E-06	4.23E-06	8.20E-06	3.08E-06	6.09E-06	9.77E-07	1.71E-06	1.59E-07	3.18E-06	4.75E-03
Pyrene	3.39E-09	2.78E-08	5.87E-07	6.15E-06	5.25E-07	6.67E-05	1.10E-06	2.24E-07	9.90E-07	1.53E-07	4.99E-07	4.35E-08	8.38E-08	6.77E-09	1.35E-07	3.35E-02
Toluene	1.21E-03	2.78E-08	1.85E-04	1.36E-03	6.51E-02	2.54E-02	1.10E-06	2.71E-04	1.23E-01	2.70E-04	8.91E-02	2.67E-04	2.38E-02	2.18E-03	4.36E-02	5.70E-02
TPH C_{6}-C_{9} (ali)	1.60E-02	2.78E-08	4.46E-02	3.27E-01	4.44E-01	5.39E+00	1.10E-06	1.47E-03	8.37E-01	1.47E-03	6.45E-01	1.45E-03	1.96E-01	1.89E-02	3.79E-01	5.57E-02
TPH C_{9}-C_{16} (ali)	7.03E-04	2.78E-08	1.14E-01	8.33E-01	3.20E-02	1.37E+01	1.10E-06	1.06E-04	6.03E-02	1.06E-04	4.65E-02	1.05E-04	1.41E-02	1.36E-03	2.73E-02	4.86E-02
TPH $C_{>16}$ (ali)		2.78E-08														
TPH C_{6}-C_{16} (aro)	7.59E-05	2.78E-08	1.23E-04	9.04E-04	3.53E-03	1.48E-02	1.10E-06	2.32E-05	6.66E-03	2.31E-05	5.14E-03	2.27E-05	1.56E-03	1.51E-04	3.01E-03	5.17E-02
TPH $C_{>16}$ (aro)		2.78E-08														
1,2,4-trimethylbenzene	2.88E-04	2.78E-08	1.35E-04	9.85E-04	2.11E-02	2.05E-02	1.10E-06	7.41E-05	3.97E-02	7.40E-05	2.69E-02	7.29E-05	6.34E-03	5.57E-04	1.11E-02	2.59E-02
Xylenes	6.32E-04	2.78E-08	1.58E-04	1.16E-03	3.29E-02	2.07E-02	1.10E-06	1.63E-04	6.20E-02	1.63E-04	4.60E-02	1.60E-04	1.28E-02	1.20E-03	2.39E-02	5.48E-02

Summary of Inhalation Exposure Adjustment Factors			Zone 1						Zone 2					
			Soil	Soil	Soil	Seepage Water	Seepage Water	Seepage Water	Soil		Groundwater		Pooled Seepage Water	
			Recreational	Commercial / Industrial (Gardener)	Sub-Surface Maintenance	Recreational	Sub-Surface Maintenance	Commercial / Industrial (Gardener)	Occassional User	C/I (Car Park Attendant)	Occassional User	C/I (Car Park Attendant)	Occassional User	
			Inhalation	Inhalation	Inhalation	Inhalation	Inhalation	Inhalation	Inhalation	Inhalation	Inhalation	Inhalation	Inhalation	
		UR (ug/m3)-1 /HI (mg/m3)	All			All			All	Adult	All	Adult	All	
Benz(a)anthracene	Risk	8.70E-03	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Benzene	Risk	6.00E-06	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Benzo(a)pyrene	Risk	8.70E-02	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Benzo(b)fluoranthene	Risk	8.70E-03	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Benzo(k)fluoranthene	Risk	8.70E-03	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Chrysene	Risk	8.70E-05	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Dibenz(a,h)anthracene	Risk	8.70E-02	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Indeno(1,2,3-c,d)pyrene	Risk	8.70E-03	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Nickel	Risk	4.00E-04	0.0833	0.0939	1.96E-04	0.0833	1.96E-04	0.0939	6.85E-03	0.0939	6.85E-03	0.0939	6.85E-03	
Ammonia	HI	7.00E-02	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Arsenic	HI	1.50E-05	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Benzene	HI	1.00E-02	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Cadmium	HI	5.00E-06	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Chromium	HI	5.00E-03	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Cyanide	HI	4.20E-02	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Dibenzofuran	HI	2.10E-01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
2,4-dimethylphenol	HI	7.00E-02	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Ethylbenzene	HI	1.30E+00	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Fluoranthene	HI	4.40E-02	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Fluorene	HI	1.40E-01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Lead	HI	5.00E-04	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Nickel	HI													
2-methylnaphthalene	HI	1.40E-01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Cresols	HI	3.50E-01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Naphthalene	HI	3.50E-03	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Phenol	HI	2.00E-01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Pyrene	HI	1.00E-01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Toluene	HI	5.00E+00	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
TPH C_{6}-C_{8} (ali)	HI	1.84E+01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
TPH C_{8}-C_{16} (ali)	HI	1.00E+00	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
TPH $C_{>16}$ (ali)	HI													
TPH C_{8}-C_{16} (aro)	HI	2.00E-01	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
TPH $C_{>16}$ (aro)	HI													
1,2,4-trimethylbenzene	HI	7.00E-03	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	
Xylenes	HI	0.87	0.0833	0.22	0.0137	0.0833	0.0137	0.22	6.85E-03	0.22	6.85E-03	0.22	6.85E-03	

Summary of Inhalation Exposure Adjustment Factors			Zone 3					Zone 4					Zone 5				
			Soil			Soil		Soil			Soil		Soil				
			Occassional User (Car Park)	C/I (Car Park Attendant)		Recreational User (Cultural Space)	C/I (Cultural Space)	Occassional User (Car Park)	C/I (Car Park Attendant)		Recreational User (Cultural Space)	C/I (Cultural Space)	Occassional User (Car Park)	C/I (Car Park Attendant)			
			Inhalation	Inhalation		Inhalation	Inhalation	Inhalation	Inhalation		Inhalation	Inhalation	Inhalation	Inhalation			
		UR (ug/m3)-1 /HI (mg/m3)	All	Adult		All	Adult	All	Adult		All	Adult	All	Adult			
Benz(a)anthracene	Risk	8.70E-03	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Benzene	Risk	6.00E-06	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Benzo(a)pyrene	Risk	8.70E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Benzo(b)fluoranthene	Risk	8.70E-03	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Benzo(k)fluoranthene	Risk	8.70E-03	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Chrysene	Risk	8.70E-05	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Dibenz(a,h)anthracene	Risk	8.70E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Indeno(1,2,3-c,d)pyrene	Risk	8.70E-03	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Nickel	Risk	4.00E-04	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939		8.33E-02	9.39E-02	6.85E-03	0.0939			
Ammonia	HI	7.00E-02	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Arsenic	HI	1.50E-05	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Benzene	HI	1.00E-02	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Cadmium	HI	5.00E-06	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Chromium	HI	5.00E-03	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Cyanide	HI	4.20E-02	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Dibenzofuran	HI	2.10E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
2,4-dimethylphenol	HI	7.00E-02	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Ethylbenzene	HI	1.30E+00	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Fluoranthene	HI	4.40E-02	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Fluorene	HI	1.40E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Lead	HI	5.00E-04	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Nickel	HI																
2-methylnaphthalene	HI	1.40E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Cresols	HI	3.50E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Naphthalene	HI	3.50E-03	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Phenol	HI	2.00E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Pyrene	HI	1.00E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Toluene	HI	5.00E+00	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
TPH C_{6}-C_{8} (ali)	HI	1.84E+01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
TPH C_{8}-C_{16} (ali)	HI	1.00E+00	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
TPH $C_{>16}$ (ali)	HI																
TPH C_{8}-C_{16} (aro)	HI	2.00E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
TPH $C_{>16}$ (aro)	HI																
1,2,4-trimethylbenzene	HI	7.00E-03	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			
Xylenes	HI	0.87	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22		8.33E-02	2.20E-01	6.85E-03	0.22			

Summary of Inhalation Exposure Adjustment Factors			Soil			Zone 6 Soil			Irrigation Water	
			Recreational User (Cultural Space)	C/I (Cultural Space)		Recreational	C/I (Gardener)	Sub-Surface Maintenance Worker	Recreational	Commercial / Industrial (Gardener)
			Inhalation	Inhalation		Inhalation	Inhalation	Inhalation	Inhalation	Inhalation
		UR (ug/m3)-1 /HI (mg/m3)	All	Adult		All	Adult	All	All	
Benz(a)anthracene	Risk	8.70E-03	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Benzene	Risk	6.00E-06	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Benzo(a)pyrene	Risk	8.70E-02	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Benzo(b)fluoranthene	Risk	8.70E-03	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Benzo(k)fluoranthene	Risk	8.70E-03	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Chrysene	Risk	8.70E-05	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Dibenz(a,h)anthracene	Risk	8.70E-02	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Indeno(1,2,3-c,d)pyrene	Risk	8.70E-03	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Nickel	Risk	4.00E-04	8.33E-02	9.39E-02		8.33E-02	9.39E-02	1.96E-04	2.97E-03	5.87E-03
Ammonia	HI	7.00E-02	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Arsenic	HI	1.50E-05	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Benzene	HI	1.00E-02	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Cadmium	HI	5.00E-06	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Chromium	HI	5.00E-03	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Cyanide	HI	4.20E-02	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Dibenzofuran	HI	2.10E-01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
2,4-dimethylphenol	HI	7.00E-02	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Ethylbenzene	HI	1.30E+00	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Fluoranthene	HI	4.40E-02	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Fluorene	HI	1.40E-01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Lead	HI	5.00E-04	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Nickel	HI									
2-methylnaphthalene	HI	1.40E-01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Cresols	HI	3.50E-01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Naphthalene	HI	3.50E-03	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Phenol	HI	2.00E-01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Pyrene	HI	1.00E-01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Toluene	HI	5.00E+00	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
TPH C_6-C_8 (ali)	HI	1.84E+01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
TPH C_8-C_{16} (ali)	HI	1.00E+00	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
TPH $C_{>16}$ (ali)	HI									
TPH C_8-C_{16} (aro)	HI	2.00E-01	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
TPH $C_{>16}$ (aro)	HI									
1,2,4-trimethylbenzene	HI	7.00E-03	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02
Xylenes	HI	0.87	8.33E-02	2.20E-01		8.33E-02	2.20E-01	1.37E-02	2.97E-03	1.37E-02

Shower Model Calcs	For Shower Model																		
	H	koc	MW	C (GW)	R	T	Kg (H20)	Kl (CO2)	t	d	Q	Time sh	V sh	kg (VOC)	kl (VOC)	K L	Csh	Msh	C (mg/m3)
Ammonia	0.000658		17.03	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	3084.254	32.14763	23.28743	0.054425	770.7465	7.14E-02
Benzene	0.227	146	78.11	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1440.138	15.01077	14.99423	0.153466	642.0217	5.94E-02
Cyanide (free)	5.44E-03	2.84	27	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	2449.49	25.53139	24.40779	0.047313	782.2679	7.24E-02
Ethylbenzene	0.322	446	106.17	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1235.255	12.87524	12.86524	0.200257	591.9409	5.48E-02
Toluene	0.271	234	92.1	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1326.257	13.82377	13.81101	0.177928	615.2882	5.70E-02
TPH C6-C9 (aliphatic)	51	4000	100	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1272.792	13.2665	13.26643	0.190462	602.07	5.57E-02
TPH C10-C14 (alipahtic)	130	2.50E+05	160	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1006.231	10.48809	10.48807	0.269548	524.451	4.86E-02
TPH C10-C14 (aromatic)	0.14	2.50E+03	130	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1116.313	11.63549	11.61471	0.234139	558.1056	5.17E-02
Xylene	0.212	3.83E+02	106.2	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1235.08	12.87342	12.85824	0.200432	591.7611	5.48E-02
1,2,4-trimethylbenzene	0.252	6.14E+02	120	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1161.895	12.1106	12.09858	0.220398	571.6172	5.29E-02
Benz(a)anthracene	4.91E-04	1.77E+05	178.2	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	953.4626	9.93808	6.581363	0.439257	379.9381	3.52E-02
Dibenzofuran	8.71E-03	9.16E+03	168	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	981.9805	10.23533	9.949269	0.288327	507.2045	4.70E-02
Fluorene	3.93E-03	5.55E+04	1.66E+02	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	987.2838	10.2906	9.674149	0.298415	498.095	4.61E-02
2-methylnaphthalene	2.12E-03	2.48E+03	1.42E+02	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1068.103	11.133	9.95684	0.288055	507.4523	4.70E-02
Naphthalene	1.80E-02	1.54E+03	1.28E+02	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1124.122	11.71689	11.55611	0.235861	556.4319	5.15E-02
Phenanthrene	1.73E-03	1.67E+04	1.78E+02	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	953.9981	9.943662	8.686278	0.337637	463.6091	4.29E-02
Phenol	1.36E-05	1.87E+02	9.41E+01	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	1312.087	13.67608	0.704454	0.915709	51.31319	4.75E-03
Pyrene	4.87E-04	5.43E+04	2.02E+02	1	8.20E-05	293	3000	20	10	0.2	60	15	10800	894.8692	9.327353	6.159828	0.463023	361.3448	3.35E-02

Zone 1		Zone 1										
Risk and HI for Unit		Soil			Soil		Soil		Seepage Water			
Concentrations		Recreational			Commercial / Industrial (Gardener)		Sub-Surface Maintenance		Recreational			Sub-Surface M
		Inhalation	Oral & Dermal		Inhalation	Oral & Dermal	Inhalation	Oral & Dermal	Inhalation			Inhalation
	Measure	All	Adult	Child (0-5 & 6-15)					All	Soil HP equiv	Soil C+S equiv	
Benz(a)anthracene	Risk	8.77E-10	1.80E-07	1.40E-07	9.88E-10	6.70E-08	4.94E-11	4.50E-10	4.70E-07	8.84E-11	8.84E-11	1.13E-08
Benzene	Risk	9.25E-07	9.20E-07	5.30E-07	1.04E-06	3.30E-07	2.18E-09	1.80E-09	8.95E-08	2.01E-08	2.01E-08	1.54E-09
Benzo(a)pyrene	Risk	0.00E+00	1.80E-06	1.40E-06	0.00E+00	6.70E-07	4.74E-10	4.50E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(b)fluoranthene	Risk	0.00E+00	1.80E-07	1.40E-07	0.00E+00	6.70E-08	4.74E-11	4.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(k)fluoranthene	Risk	0.00E+00	1.80E-07	1.40E-07	0.00E+00	6.70E-08	4.74E-11	4.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	Risk	0.00E+00	1.80E-08	1.40E-08	0.00E+00	6.70E-09	4.74E-13	4.50E-11	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenz(a,h)anthracene	Risk	0.00E+00	1.80E-06	1.40E-06	0.00E+00	6.70E-07	4.74E-10	4.50E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	1.80E-07	1.40E-07	0.00E+00	6.70E-08	4.74E-11	4.50E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel	Risk	0.00E+00			0.00E+00		2.18E-12		0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ammonia	HI	7.38E-05			1.95E-04		1.21E-05		1.67E-06	3.86E-06	3.86E-06	2.25E-06
Arsenic	HI	0.00E+00	6.80E-04	5.00E-03	0.00E+00	4.50E-04	2.54E-05	1.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	HI	1.54E-02	6.80E-02	1.80E-01	4.07E-02	4.50E-02	2.53E-03	7.20E-03	1.49E-03	3.35E-04	5.26E-05	1.79E-03
Cadmium	HI	0.00E+00	1.50E-03	1.30E-02	0.00E+00	9.70E-04	7.61E-05	3.70E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium	HI	0.00E+00	9.00E-04	2.20E-03	0.00E+00	5.90E-04	7.61E-08	9.10E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cyanide	HI	9.32E-05	1.70E-03	4.50E-03	2.46E-04	1.10E-03	1.53E-05	1.80E-04	2.44E-05	2.46E-06	2.46E-06	2.98E-05
Dibenzofuran	HI	2.10E-07	6.20E-05	2.60E-04	5.54E-07	4.10E-05	3.63E-08	8.90E-06	1.51E-06	5.48E-09	5.48E-09	1.84E-06
2,4-dimethylphenol	HI	0.00E+00	1.90E-04	7.90E-04	0.00E+00	1.20E-04	5.44E-09	2.70E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethylbenzene	HI	4.27E-05	3.50E-04	9.20E-04	1.13E-04	2.30E-04	7.02E-06	3.70E-05	1.24E-05	9.23E-07	9.23E-07	1.50E-05
Fluoranthene	HI	0.00E+00	3.80E-04	1.50E-03	0.00E+00	2.50E-04	8.65E-09	5.10E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fluorene	HI	1.52E-07	1.20E-04	4.60E-04	4.02E-07	7.80E-05	2.78E-08	1.60E-05	1.32E-06	2.77E-09	2.06E-09	1.64E-06
Lead	HI	0.00E+00	1.10E-03	4.50E-03	0.00E+00	7.00E-04	7.61E-07	1.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel	HI		1.70E-01	4.10E-01		1.10E-01		1.70E-02		0.00E+00	0.00E+00	
2-methylnaphthalene	HI	3.61E-07	9.30E-05	3.90E-04	9.54E-07	6.10E-05	6.21E-08	1.30E-05	9.82E-07	1.32E-08	1.32E-08	1.25E-06
Cresols	HI	0.00E+00	7.40E-05	3.20E-04	0.00E+00	4.90E-05	1.09E-09	1.10E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Naphthalene	HI	2.28E-04	2.40E-04	9.10E-04	6.02E-04	1.60E-04	3.76E-05	3.20E-05	2.45E-04	2.94E-07	2.35E-06	2.97E-04
Phenol	HI	3.48E-08	1.20E-05	5.20E-05	9.20E-08	8.10E-06	7.63E-09	1.80E-06	5.29E-08	9.38E-09	9.38E-09	5.19E-07
Pyrene	HI	2.82E-09	1.60E-04	6.10E-04	7.46E-09	1.00E-04	4.27E-09	2.10E-05	4.89E-07	4.89E-11	1.22E-10	8.43E-07
Toluene	HI	2.02E-05	1.50E-04	4.00E-04	5.32E-05	1.00E-04	3.32E-06	1.60E-05	3.08E-06	4.34E-07	4.34E-07	3.73E-06
TPH C_6-C_8 (ali)	HI	7.24E-05	6.80E-06	1.80E-05	1.91E-04	4.50E-06	1.19E-05	7.20E-07	2.02E-04	1.55E-06	1.55E-06	2.43E-04
TPH C_8-C_{16} (ali)	HI	5.86E-05	3.70E-05	1.60E-04	1.55E-04	2.40E-05	9.63E-06	5.30E-06	9.50E-03	1.26E-06	1.26E-06	1.14E-02
TPH $C_{>16}$ (ali)	HI		1.90E-06	7.90E-06		1.20E-06		2.70E-07		0.00E+00	0.00E+00	
TPH C_8-C_{16} (aro)	HI	3.16E-05	9.30E-05	3.90E-04	8.35E-05	6.10E-05	5.20E-06	1.30E-05	5.12E-05	6.83E-07	6.83E-07	6.19E-05
TPH $C_{>16}$ (aro)	HI		1.20E-04	5.30E-04		8.10E-05		1.80E-05		0.00E+00	0.00E+00	
1,2,4-trimethylbenzene	HI	3.43E-03	1.70E-02	4.50E-02	9.05E-03	1.10E-02	5.64E-04	1.80E-03	1.61E-03	8.68E-05	8.68E-05	1.93E-03
Xylenes	HI	6.05E-05	1.90E-04	5.00E-04	1.60E-04	1.20E-04	9.95E-06	2.00E-05	1.51E-05	1.31E-06	1.31E-06	1.83E-05

Zone 1

Risk and HI for Unit Concentrations

		Maintenance			Seepage Water Commercial / Industrial (Gardener)					Physical Properties Estimating Leachate
				Oral & Dermal			Inhalation			
	Measure	Soil HP equiv	Soil C+S equiv		Soil HP equiv	Soil C+S equiv		Soil HP equiv	Soil C+S equiv	H
Benz(a)anthracene	Risk	2.12E-12	2.12E-12	3.90E-06	7.34E-10	7.34E-10	5.29E-07	9.97E-11	9.97E-11	4.91E-04
Benzene	Risk	3.46E-10	3.46E-10	7.60E-08	1.71E-08	1.71E-08	1.01E-07	2.26E-08	2.26E-08	2.27E-01
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	5.10E-05	2.90E-09	2.90E-09	0.00E+00	0.00E+00	0.00E+00	1.87E-05
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	3.00E-06	1.67E-10	1.67E-10	0.00E+00	0.00E+00	0.00E+00	2.69E-05
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	4.90E-06	2.78E-10	2.78E-10	0.00E+00	0.00E+00	0.00E+00	2.39E-05
Chrysene	Risk	0.00E+00	0.00E+00	4.30E-07	7.92E-11	7.92E-11	0.00E+00	0.00E+00	0.00E+00	2.14E-04
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	6.80E-05	1.19E-09	1.19E-09	0.00E+00	0.00E+00	0.00E+00	5.76E-06
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	8.90E-06	1.52E-10	1.52E-10	0.00E+00	0.00E+00	0.00E+00	1.42E-05
Nickel	Risk	0.00E+00	0.00E+00		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ammonia	HI	5.21E-06	5.21E-06		0.00E+00	0.00E+00	4.40E-06	1.02E-05	1.02E-05	6.58E-04
Arsenic	HI	0.00E+00	0.00E+00	6.50E-03	3.25E-06	2.93E-06	0.00E+00	0.00E+00	0.00E+00	
Benzene	HI	4.03E-04	6.33E-05	3.00E-01	6.73E-02	1.06E-02	3.94E-03	8.84E-04	1.39E-04	2.27E-01
Cadmium	HI	0.00E+00	0.00E+00	2.90E-01	3.87E-03	1.45E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium	HI	0.00E+00	0.00E+00	8.00E-01	1.84E-04	2.40E-04	0.00E+00	0.00E+00	0.00E+00	
Cyanide	HI	3.00E-06	3.00E-06	5.20E-04	5.24E-05	5.24E-05	6.44E-05	6.49E-06	6.49E-06	5.44E-03
Dibenzofuran	HI	6.69E-09	6.69E-09	1.70E-03	6.19E-06	6.19E-06	3.98E-06	1.45E-08	1.45E-08	8.71E-03
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	5.60E-03	3.79E-04	3.79E-04	0.00E+00	0.00E+00	0.00E+00	3.89E-05
Ethylbenzene	HI	1.11E-06	1.11E-06	5.10E-03	3.78E-04	3.78E-04	3.28E-05	2.44E-06	2.44E-06	3.22E-01
Fluoranthene	HI	0.00E+00	0.00E+00	2.50E-01	5.00E-05	7.75E-05	0.00E+00	0.00E+00	0.00E+00	
Fluorene	HI	3.45E-09	2.56E-09	2.80E-02	5.88E-05	4.37E-05	3.49E-06	7.33E-09	5.44E-09	
Lead	HI	0.00E+00	0.00E+00	1.10E-03	1.54E-07	2.64E-07	0.00E+00	0.00E+00	0.00E+00	
Nickel	HI	0.00E+00	0.00E+00	1.10E-02	3.63E-06	5.50E-06		0.00E+00	0.00E+00	
2-methylnaphthalene	HI	1.68E-08	1.68E-08	2.30E-02	3.09E-04	3.09E-04	2.59E-06	3.48E-08	3.48E-08	2.12E-03
Cresols	HI	0.00E+00	0.00E+00	1.60E-03	1.73E-04	1.73E-04	0.00E+00	0.00E+00	0.00E+00	4.91E-05
Naphthalene	HI	3.56E-07	2.85E-06	2.30E-02	2.76E-05	2.21E-04	6.47E-04	7.77E-07	6.22E-06	
Phenol	HI	9.19E-08	9.19E-08	1.50E-04	2.66E-05	2.66E-05	1.40E-07	2.48E-08	2.48E-08	1.36E-05
Pyrene	HI	8.43E-11	2.11E-10	6.70E-02	6.70E-06	1.68E-05	1.29E-06	1.29E-10	3.23E-10	
Toluene	HI	5.25E-07	5.25E-07	1.40E-03	1.97E-04	1.97E-04	8.14E-06	1.15E-06	1.15E-06	2.71E-01
TPH C_6-C_8 (ali)	HI	1.87E-06	1.87E-06	1.50E-03	1.15E-05	1.15E-05	5.33E-04	4.10E-06	4.10E-06	5.10E+01
TPH C_8-C_{16} (ali)	HI	1.52E-06	1.52E-06	1.90E-01	2.52E-05	2.52E-05	2.51E-02	3.33E-06	3.33E-06	1.30E+02
TPH $C_{>16}$ (ali)	HI	0.00E+00	0.00E+00	1.50E-03	5.00E-11	5.00E-11		0.00E+00	0.00E+00	6.40E+03
TPH C_8-C_{16} (aro)	HI	8.25E-07	8.25E-07	2.20E-02	2.93E-04	2.93E-04	1.35E-04	1.80E-06	1.80E-06	1.40E-01
TPH $C_{>16}$ (aro)	HI	0.00E+00	0.00E+00	1.00E-01	2.08E-04	2.08E-04		0.00E+00	0.00E+00	1.30E-02
1,2,4-trimethylbenzene	HI	1.04E-04	1.04E-04	4.30E-01	2.32E-02	2.32E-02	4.24E-03	2.29E-04	2.29E-04	2.52E-01
Xylenes	HI	1.58E-06	1.58E-06	2.60E-03	2.25E-04	2.25E-04	4.00E-05	3.46E-06	3.46E-06	2.12E-01

Zone 1
Risk and HI for Unit Concentrations

ɨs of COPCs for
ıbility

	Measure	Koc	Kd	Leaching factor - Headland Park Soil - Seepage Water (mg/l / mg/kg)	Leaching factor - Central + South Soil - Seepage Water (mg/l / mg/kg)	Summations		
						Recreational Head Park	South + Central	C/I (Gardener Head Park
Benz(a)anthracene	Risk	1.77E+05		1.88E-04	1.88E-04	3.21E-07	3.21E-07	6.80E-08
Benzene	Risk	1.46E+02		2.24E-01	2.24E-01	2.37E-06	2.37E-06	1.37E-06
Benzo(a)pyrene	Risk	5.87E+05		5.68E-05	5.68E-05	3.20E-06	3.20E-06	6.70E-07
Benzo(b)fluoranthene	Risk	5.99E+05		5.56E-05	5.56E-05	3.20E-07	3.20E-07	6.70E-08
Benzo(k)fluoranthene	Risk	5.87E+05		5.68E-05	5.68E-05	3.20E-07	3.20E-07	6.70E-08
Chrysene	Risk	1.81E+05		1.84E-04	1.84E-04	3.20E-08	3.20E-08	6.70E-09
Dibenz(a,h)anthracene	Risk	1.91E+06		1.75E-05	1.75E-05	3.20E-06	3.20E-06	6.70E-07
Indeno(1,2,3-c,d)pyrene	Risk	1.95E+06		1.71E-05	1.71E-05	3.20E-07	3.20E-07	6.70E-08
Nickel	Risk		6.50E+01	0.00033	1.54E-02	0.00E+00	0.00E+00	0.00E+00
Ammonia	HI		4.00E-01	2.31E+00	2.31E+00	7.38E-05	7.38E-05	1.95E-04
Arsenic	HI			0.0005	0.00045	5.00E-03	5.00E-03	4.50E-04
Benzene	HI	1.46E+02		2.24E-01	3.53E-02	1.95E-01	1.95E-01	8.57E-02
Cadmium	HI		7.50E+01	1.33E-02	0.00005	1.30E-02	1.30E-02	9.70E-04
Chromium	HI			0.00023	0.0003	2.20E-03	2.20E-03	5.90E-04
Cyanide	HI		9.90E+00	1.01E-01	1.01E-01	4.59E-03	4.59E-03	1.35E-03
Dibenzofuran	HI	9.16E+03		3.64E-03	3.64E-03	2.60E-04	2.60E-04	4.16E-05
2,4-dimethylphenol	HI	4.92E+02		6.76E-02	6.76E-02	7.90E-04	7.90E-04	1.20E-04
Ethylbenzene	HI	4.46E+02		7.42E-02	7.42E-02	9.63E-04	9.63E-04	3.43E-04
Fluoranthene	HI			0.0002	0.00031	1.50E-03	1.50E-03	2.50E-04
Fluorene	HI			0.0021	0.00156	4.60E-04	4.60E-04	7.84E-05
Lead	HI			0.00014	0.00024	4.50E-03	4.50E-03	7.00E-04
Nickel	HI			0.00033	0.0005	4.10E-01	4.10E-01	1.10E-01
2-methylnaphthalene	HI	2.48E+03		1.34E-02	1.34E-02	3.90E-04	3.90E-04	6.20E-05
Cresols	HI	3.07E+02		1.08E-01	1.08E-01	3.20E-04	3.20E-04	4.90E-05
Naphthalene	HI			0.0012	0.0096	1.14E-03	1.14E-03	7.62E-04
Phenol	HI	1.87E+02		1.77E-01	1.77E-01	5.20E-05	5.20E-05	8.19E-06
Pyrene	HI			0.0001	0.00025	6.10E-04	6.10E-04	1.00E-04
Toluene	HI	2.34E+02		1.41E-01	1.41E-01	4.20E-04	4.20E-04	1.53E-04
TPH C_6-C_8 (ali)	HI	4.00E+03		7.70E-03	7.70E-03	9.04E-05	9.04E-05	1.96E-04
TPH C_8-C_{16} (ali)	HI	2.50E+05		1.33E-04	1.33E-04	2.19E-04	2.19E-04	1.79E-04
TPH $C_{>16}$ (ali)	HI	1.00E+09		3.33E-08	3.33E-08	7.90E-06	7.90E-06	1.20E-06
TPH C_8-C_{16} (aro)	HI	2.50E+03		1.33E-02	1.33E-02	4.22E-04	4.22E-04	1.44E-04
TPH $C_{>16}$ (aro)	HI	1.60E+04		2.08E-03	2.08E-03	5.30E-04	5.30E-04	8.10E-05
1,2,4-trimethylbenzene	HI	6.14E+02		5.41E-02	5.41E-02	4.84E-02	4.84E-02	2.01E-02
Xylenes	HI	3.83E+02		8.65E-02	8.65E-02	5.61E-04	5.61E-04	2.80E-04

Zone 1

Risk and HI for Unit Concentrations

		)	Sub-Surf Main		Maximum Risk + HI		Soil Criteria		Potential for Odour
	Measure	South + Central	Head Park	South + Central	Head Park	South + Central	Head Park	South + Central	Odour Threshold
Benz(a)anthracene	Risk	6.80E-08	7.84E-10	7.84E-10	3.21E-07	3.21E-07	31.2	31.2	
Benzene	Risk	1.37E-06	1.92E-08	1.92E-08	2.37E-06	2.37E-06	1.0	1.0	108.6
Benzo(a)pyrene	Risk	6.70E-07	4.97E-09	4.97E-09	3.20E-06	3.20E-06	3.1	3.1	
Benzo(b)fluoranthene	Risk	6.70E-08	4.97E-10	4.97E-10	3.20E-07	3.20E-07	31.3	31.3	
Benzo(k)fluoranthene	Risk	6.70E-08	4.97E-10	4.97E-10	3.20E-07	3.20E-07	31.3	31.3	
Chrysene	Risk	6.70E-09	7.97E-11	7.97E-11	3.20E-08	3.20E-08	312.5	312.5	
Dibenz(a,h)anthracene	Risk	6.70E-07	4.97E-09	4.97E-09	3.20E-06	3.20E-06	3.1	3.1	
Indeno(1,2,3-c,d)pyrene	Risk	6.70E-08	4.97E-10	4.97E-10	3.20E-07	3.20E-07	31.3	31.3	
Nickel	Risk	0.00E+00	2.18E-12	2.18E-12	2.18E-12	2.18E-12	2.4	2.4	
Ammonia	HI	1.95E-04	1.21E-05	1.21E-05	1.95E-04	1.95E-04	5132.0	5132.0	18
Arsenic	HI	4.50E-04	1.75E-04	1.75E-04	5.00E-03	5.00E-03	140.0	140.0	
Benzene	HI	8.57E-02	6.99E-02	1.31E-02	1.95E-01	1.95E-01	1.0	1.0	108.6
Cadmium	HI	9.70E-04	3.94E-03	4.46E-04	1.30E-02	1.30E-02	7.7	7.7	
Chromium	HI	5.90E-04	1.84E-04	2.40E-04	2.20E-03	2.20E-03	454.5	454.5	
Cyanide	HI	1.35E-03	1.95E-04	1.95E-04	4.59E-03	4.59E-03	217.7	217.7	0.64
Dibenzofuran	HI	4.16E-05	8.94E-06	8.94E-06	2.60E-04	2.60E-04	3843.1	3843.1	1
2,4-dimethylphenol	HI	1.20E-04	3.79E-04	3.79E-04	7.90E-04	7.90E-04	1265.8	1265.8	
Ethylbenzene	HI	3.43E-04	3.86E-04	3.86E-04	9.63E-04	9.63E-04	1038.8	1038.8	2
Fluoranthene	HI	2.50E-04	5.10E-05	7.75E-05	1.50E-03	1.50E-03	666.7	666.7	
Fluorene	HI	7.84E-05	5.88E-05	4.37E-05	4.60E-04	4.60E-04	2173.2	2173.2	
Lead	HI	7.00E-04	1.51E-04	1.51E-04	4.50E-03	4.50E-03	133.3	133.3	
Nickel	HI	1.10E-01	1.70E-02	1.70E-02	4.10E-01	4.10E-01	2.4	2.4	
2-methylnaphthalene	HI	6.20E-05	3.09E-04	3.09E-04	3.90E-04	3.90E-04	2561.7	2561.7	0.06
Cresols	HI	4.90E-05	1.73E-04	1.73E-04	3.20E-04	3.20E-04	3125.0	3125.0	0.0012
Naphthalene	HI	7.62E-04	6.96E-05	2.58E-04	1.14E-03	1.14E-03	878.7	878.7	0.44
Phenol	HI	8.19E-06	2.67E-05	2.67E-05	5.20E-05	5.20E-05	19217.9	19217.9	0.15
Pyrene	HI	1.00E-04	2.10E-05	2.10E-05	6.10E-04	6.10E-04	1639.3	1639.3	
Toluene	HI	1.53E-04	2.00E-04	2.00E-04	4.20E-04	4.20E-04	2380.1	2380.1	30
TPH C_6-C_8 (ali)	HI	1.96E-04	2.35E-05	2.35E-05	1.96E-04	1.96E-04	5107.1	5107.1	
TPH C_8-C_{16} (ali)	HI	1.79E-04	3.49E-05	3.49E-05	2.19E-04	2.19E-04	4575.4	4575.4	
TPH $C_{>16}$ (ali)	HI	1.20E-06	2.70E-07	2.70E-07	7.90E-06	7.90E-06	126582.3	126582.3	
TPH C_8-C_{16} (aro)	HI	1.44E-04	2.98E-04	2.98E-04	4.22E-04	4.22E-04	2371.8	2371.8	
TPH $C_{>16}$ (aro)	HI	8.10E-05	2.08E-04	2.08E-04	5.30E-04	5.30E-04	1886.8	1886.8	
1,2,4-trimethylbenzene	HI	2.01E-02	2.38E-02	2.38E-02	4.84E-02	4.84E-02	20.6	20.6	1.96
Xylenes	HI	2.80E-04	2.35E-04	2.35E-04	5.61E-04	5.61E-04	1784.1	1784.1	4.34

Zone 2		Zone 2							
Risk and HI for Unit		Soil		Groundwater					
Concentrations		Occassional User	C/I (Car Park Attendant)	Occassional User			C/I (Car Park Attendant)		
		Inhalation	Inhalation	Inhalation			Inhalation		
	Measure	All	Adult	All	Soil HP equiv	Soil C+S equiv	Adult	Soil HP equiv	Soil C+S equiv
Benz(a)anthracene	Risk	9.83E-09	1.35E-07	4.09E-06	7.70E-09	7.70E-09	5.60E-05	1.06E-07	1.06E-07
Benzene	Risk	3.45E-06	4.73E-05	9.37E-07	1.82E-06	1.82E-06	1.28E-05	2.50E-05	2.50E-05
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chrysene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ammonia	HI	2.85E-05	9.15E-04	9.64E-06	2.23E-05	2.23E-05	9.64E-06	2.23E-05	2.23E-05
Arsenic	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	HI	5.75E-02	1.85E+00	1.56E-02	3.04E-02	3.04E-02	1.56E-02	3.04E-02	3.04E-02
Cadmium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Chromium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cyanide	HI	1.73E-05	5.55E-04	1.32E-04	1.33E-05	1.33E-05	1.32E-04	1.33E-05	1.33E-05
Dibenzofuran	HI	1.88E-06	6.04E-05	2.10E-05	7.62E-07	7.62E-07	2.10E-05	7.62E-07	7.62E-07
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethylbenzene	HI	2.22E-04	7.14E-03	1.48E-04	1.03E-04	1.03E-04	1.48E-04	1.03E-04	1.03E-04
Fluoranthene	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fluorene	HI	1.28E-06	4.12E-05	1.65E-05	3.46E-08	2.57E-08	1.65E-05	3.46E-08	2.57E-08
Lead	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Nickel	HI				0.00E+00	0.00E+00		0.00E+00	0.00E+00
2-methylnaphthalene	HI	2.57E-06	8.27E-05	1.07E-05	1.43E-06	1.43E-06	1.07E-05	1.43E-06	1.43E-06
Cresols	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Naphthalene	HI	1.41E-03	4.54E-02	2.99E-03	3.59E-06	2.87E-05	2.99E-03	3.59E-06	2.87E-05
Phenol	HI	1.49E-07	4.79E-06	9.11E-08	1.54E-07	1.54E-07	9.11E-08	1.54E-07	1.54E-07
Pyrene	HI	3.60E-08	1.16E-06	4.57E-06	4.57E-10	1.14E-09	4.57E-06	4.57E-10	1.14E-09
Toluene	HI	8.92E-05	2.86E-03	3.48E-05	4.42E-05	4.42E-05	3.48E-05	4.42E-05	4.42E-05
TPH C_6-C_8 (ali)	HI	1.65E-04	5.31E-03	2.01E-03	9.15E-05	9.15E-05	2.01E-03	9.15E-05	9.15E-05
TPH C_8-C_{16} (ali)	HI	2.19E-04	7.04E-03	9.38E-02	1.21E-04	1.21E-04	9.38E-02	1.21E-04	1.21E-04
TPH $C_{>16}$ (ali)	HI				0.00E+00	0.00E+00		0.00E+00	0.00E+00
TPH C_8-C_{16} (aro)	HI	1.21E-04	3.88E-03	5.07E-04	6.71E-05	6.71E-05	5.07E-04	6.71E-05	6.71E-05
TPH $C_{>16}$ (aro)	HI				0.00E+00	0.00E+00		0.00E+00	0.00E+00
1,2,4-trimethylbenzene	HI	2.06E-02	6.63E-01	2.01E-02	1.04E-02	1.04E-02	2.01E-02	1.04E-02	1.04E-02
Xylenes	HI	2.59E-04	8.32E-03	1.63E-04	1.33E-04	1.33E-04	1.63E-04	1.33E-04	1.33E-04

Zone 2

Risk and HI for Unit Concentrations — Pooled Seepage Water, Occassional User

		Inhalation			Dermal					
	Measure	All	Soil HP equiv	Soil C+S equiv	Adult	Soil HP equiv	Soil C+S equiv	Child (0-5 & 6-15)	Soil HP equiv	Soil C+S equiv
Benz(a)anthracene	Risk	6.56E-08	1.23E-10	1.23E-10	1.10E-06	2.07E-09	2.07E-09	5.30E-07	9.98E-10	9.98E-10
Benzene	Risk	4.52E-11	8.80E-11	8.80E-11	2.10E-08	4.09E-08	4.09E-08	1.00E-08	1.95E-08	1.95E-08
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	1.50E-05	8.52E-09	8.52E-09	6.80E-06	3.86E-09	3.86E-09
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	8.50E-07	4.73E-10	4.73E-10	4.00E-07	2.23E-10	2.23E-10
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	1.40E-06	7.95E-10	7.95E-10	6.60E-07	3.75E-10	3.75E-10
Chrysene	Risk	0.00E+00	0.00E+00	0.00E+00	1.20E-07	2.21E-10	2.21E-10	5.70E-08	1.05E-10	1.05E-10
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	0.00E+00	2.00E-05	3.49E-09	3.49E-09	9.10E-06	1.59E-09	1.59E-09
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	2.50E-06	4.27E-10	4.27E-10	1.20E-06	2.05E-10	2.05E-10
Nickel	Risk	0.00E+00	0.00E+00	0.00E+00						
Ammonia	HI	1.08E-07	2.49E-07	2.49E-07						
Arsenic	HI	0.00E+00	0.00E+00	0.00E+00	2.70E-05	1.35E-08	1.22E-08	4.90E-05	2.45E-08	2.21E-08
Benzene	HI	7.54E-07	1.47E-06	1.47E-06	1.60E-03	3.11E-03	3.11E-03	2.90E-03	5.64E-03	5.64E-03
Cadmium	HI	0.00E+00	0.00E+00	0.00E+00	1.50E-03	2.00E-05	7.50E-08	2.80E-03	3.73E-05	1.40E-07
Chromium	HI	0.00E+00	0.00E+00	0.00E+00	4.20E-03	9.66E-07	1.26E-06	7.80E-03	1.79E-06	2.34E-06
Cyanide	HI	1.79E-07	1.81E-08	1.81E-08	2.00E-06	2.01E-07	2.01E-07	3.70E-06	3.72E-07	3.72E-07
Dibenzofuran	HI	3.59E-08	1.30E-09	1.30E-09	8.60E-06	3.13E-07	3.13E-07	1.60E-05	5.82E-07	5.82E-07
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	0.00E+00	2.90E-05	1.92E-05	1.92E-05	5.30E-05	3.51E-05	3.51E-05
Ethylbenzene	HI	5.80E-09	4.05E-09	4.05E-09	2.70E-05	1.88E-05	1.88E-05	5.00E-05	3.49E-05	3.49E-05
Fluoranthene	HI	0.00E+00	0.00E+00	0.00E+00	1.30E-03	2.60E-07	4.03E-07	2.40E-03	4.80E-07	7.44E-07
Fluorene	HI	5.38E-08	1.13E-10	8.40E-11	1.50E-04	3.15E-07	2.34E-07	2.70E-04	5.67E-07	4.21E-07
Lead	HI	0.00E+00	0.00E+00	0.00E+00	1.50E-06	2.10E-10	3.60E-10	2.80E-06	3.92E-10	6.72E-10
Nickel	HI		0.00E+00	0.00E+00	5.30E-05	1.75E-08	2.65E-08	9.70E-05	3.20E-08	4.85E-08
2-methylnaphthalene	HI	5.38E-08	7.20E-09	7.20E-09	1.20E-04	1.61E-05	1.61E-05	2.20E-04	2.94E-05	2.94E-05
Cresols	HI	0.00E+00	0.00E+00	0.00E+00	8.10E-06	8.50E-06	8.50E-06	1.50E-05	1.57E-05	1.57E-05
Naphthalene	HI	2.15E-06	2.58E-09	2.07E-08	1.20E-04	1.44E-07	1.15E-06	2.30E-04	2.76E-07	2.21E-06
Phenol	HI	3.77E-08	6.35E-08	6.35E-08	7.70E-07	1.30E-06	1.30E-06	1.40E-06	2.36E-06	2.36E-06
Pyrene	HI	7.54E-08	7.54E-12	1.88E-11	3.60E-04	3.60E-08	9.00E-08	6.50E-04	6.50E-08	1.63E-07
Toluene	HI	1.51E-09	1.92E-09	1.92E-09	7.40E-06	9.41E-06	9.41E-06	1.40E-05	1.78E-05	1.78E-05
TPH C_6-C_8 (ali)	HI	4.10E-10	1.87E-11	1.87E-11	8.00E-06	3.65E-07	3.65E-07	1.50E-05	6.84E-07	6.84E-07
TPH C_8-C_{16} (ali)	HI	7.54E-09	9.72E-12	9.72E-12	1.00E-03	1.29E-06	1.29E-06	1.90E-03	2.45E-06	2.45E-06
TPH $C_{>16}$ (ali)	HI		0.00E+00	0.00E+00	8.00E-06	2.67E-12	2.67E-12	1.50E-05	5.00E-12	5.00E-12
TPH C_8-C_{16} (aro)	HI	3.77E-08	4.98E-09	4.98E-09	1.20E-04	1.59E-05	1.59E-05	2.10E-04	2.78E-05	2.78E-05
TPH $C_{>16}$ (aro)	HI		0.00E+00	0.00E+00	5.30E-04	1.10E-05	1.10E-05	9.70E-04	2.02E-05	2.02E-05
1,2,4-trimethylbenzene	HI	1.08E-06	5.60E-07	5.60E-07	2.30E-03	1.20E-03	1.20E-03	4.20E-03	2.18E-03	2.18E-03
Xylenes	HI	8.66E-09	7.09E-09	7.09E-09	1.40E-05	1.15E-05	1.15E-05	2.60E-05	2.13E-05	2.13E-05

Zone 2

Risk and HI for Unit Concentrations

		C/I (Car Park Attendant) Inhalation						Leaching factor - Headland Park Soil - Seepage Water (mg/l / mg/kg)
	Measure	Adult	Soil HP equiv	Soil C+S equiv	H	Koc	Kd	
Benz(a)anthracene	Risk	8.99E-07	1.69E-09	1.69E-09	4.91E-04	1.77E+05		1.88E-03
Benzene	Risk	6.20E-10	1.21E-09	1.21E-09	2.27E-01	1.46E+02		1.95E+00
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	1.87E-05	5.87E+05		5.68E-04
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	2.69E-05	5.99E+05		5.56E-04
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	2.39E-05	5.87E+05		5.68E-04
Chrysene	Risk	0.00E+00	0.00E+00	0.00E+00	2.14E-04	1.81E+05		1.84E-03
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	0.00E+00	5.76E-06	1.91E+06		1.75E-04
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	1.42E-05	1.95E+06		1.71E-04
Nickel	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00		6.50E+01	0.00033
Ammonia	HI	3.46E-06	8.00E-06	8.00E-06	6.58E-04		4.00E-01	2.31E+00
Arsenic	HI	0.00E+00	0.00E+00	0.00E+00				0.0005
Benzene	HI	2.42E-05	4.71E-05	4.71E-05	2.27E-01	1.46E+02		1.95E+00
Cadmium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00		7.50E+01	1.33E-02
Chromium	HI	0.00E+00	0.00E+00	0.00E+00				0.00023
Cyanide	HI	5.76E-06	5.80E-07	5.80E-07	5.44E-03		9.90E+00	1.01E-01
Dibenzofuran	HI	1.15E-06	4.19E-08	4.19E-08	8.71E-03	9.16E+03		3.63E-02
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	0.00E+00	3.89E-05	4.92E+02		6.63E-01
Ethylbenzene	HI	1.86E-07	1.30E-07	1.30E-07	3.22E-01	4.46E+02		6.98E-01
Fluoranthene	HI	0.00E+00	0.00E+00	0.00E+00				0.0002
Fluorene	HI	1.73E-06	3.63E-09	2.70E-09				0.0021
Lead	HI	0.00E+00	0.00E+00	0.00E+00				0.00014
Nickel	HI		0.00E+00	0.00E+00				0.00033
2-methylnaphthalene	HI	1.73E-06	2.31E-07	2.31E-07	2.12E-03	2.48E+03		1.34E-01
Cresols	HI	0.00E+00	0.00E+00	0.00E+00	4.91E-05	3.07E+02		1.05E+00
Naphthalene	HI	6.91E-05	8.30E-08	6.64E-07				0.0012
Phenol	HI	1.21E-06	2.04E-06	2.04E-06	1.36E-05	1.87E+02		1.69E+00
Pyrene	HI	2.42E-06	2.42E-10	6.05E-10				0.0001
Toluene	HI	4.84E-08	6.15E-08	6.15E-08	2.71E-01	2.34E+02		1.27E+00
TPH C_{6}-C_{8} (ali)	HI	1.32E-08	6.00E-10	6.00E-10	5.10E+01	4.00E+03		4.56E-02
TPH C_{8}-C_{16} (ali)	HI	2.42E-07	3.12E-10	3.12E-10	1.30E+02	2.50E+05		1.29E-03
TPH $C_{>16}$ (ali)	HI		0.00E+00	0.00E+00	6.40E+03	1.00E+09		3.33E-07
TPH C_{8}-C_{16} (aro)	HI	1.21E-06	1.60E-07	1.60E-07	1.40E-01	2.50E+03		1.32E-01
TPH $C_{>16}$ (aro)	HI		0.00E+00	0.00E+00	1.30E-02	1.60E+04		2.08E-02
1,2,4-trimethylbenzene	HI	3.46E-05	1.80E-05	1.80E-05	2.52E-01	6.14E+02		5.20E-01
Xylenes	HI	2.78E-07	2.28E-07	2.28E-07	2.12E-01	3.83E+02		8.18E-01

Zone 2		Leaching factor - Central + South	Maximum Risk + HI				Maximum Ri
Risk and HI for Unit		Soil - Seepage Water	Summations				
Concentrations		(mg/l / mg/kg)					
			Occassional User		Car Park Attendent		
	Measure		Head Park	South + Central	Head Park	South + Central	Head Park
Benz(a)anthracene	Risk	1.88E-03	1.29E-08	1.29E-08	1.06E-07	1.06E-07	1.06E-07
Benzene	Risk	1.95E+00	3.51E-06	3.51E-06	2.50E-05	2.50E-05	2.50E-05
Benzo(a)pyrene	Risk	5.68E-04	1.24E-08	1.24E-08	0.00E+00	0.00E+00	1.24E-08
Benzo(b)fluoranthene	Risk	5.56E-04	6.96E-10	6.96E-10	0.00E+00	0.00E+00	6.96E-10
Benzo(k)fluoranthene	Risk	5.68E-04	1.17E-09	1.17E-09	0.00E+00	0.00E+00	1.17E-09
Chrysene	Risk	1.84E-03	3.26E-10	3.26E-10	0.00E+00	0.00E+00	3.26E-10
Dibenz(a,h)anthracene	Risk	1.75E-04	5.08E-09	5.08E-09	0.00E+00	0.00E+00	5.08E-09
Indeno(1,2,3-c,d)pyrene	Risk	1.71E-04	6.32E-10	6.32E-10	0.00E+00	0.00E+00	6.32E-10
Nickel	Risk	1.54E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Ammonia	HI	2.31E+00	2.85E-05	2.85E-05	2.85E-05	2.85E-05	2.85E-05
Arsenic	HI	0.00045	2.45E-08	2.21E-08	0.00E+00	0.00E+00	2.45E-08
Benzene	HI	1.95E+00	6.31E-02	6.31E-02	5.75E-02	5.75E-02	6.31E-02
Cadmium	HI	0.00005	3.73E-05	1.40E-07	0.00E+00	0.00E+00	3.73E-05
Chromium	HI	0.0003	1.79E-06	2.34E-06	0.00E+00	0.00E+00	1.79E-06
Cyanide	HI	1.01E-01	1.77E-05	1.77E-05	1.73E-05	1.73E-05	1.77E-05
Dibenzofuran	HI	3.63E-02	2.46E-06	2.46E-06	1.88E-06	1.88E-06	2.46E-06
2,4-dimethylphenol	HI	6.63E-01	3.51E-05	3.51E-05	0.00E+00	0.00E+00	3.51E-05
Ethylbenzene	HI	6.98E-01	2.57E-04	2.57E-04	2.22E-04	2.22E-04	2.57E-04
Fluoranthene	HI	0.00031	4.80E-07	7.44E-07	0.00E+00	0.00E+00	4.80E-07
Fluorene	HI	0.00156	1.85E-06	1.70E-06	1.28E-06	1.28E-06	1.85E-06
Lead	HI	0.00024	3.92E-10	6.72E-10	0.00E+00	0.00E+00	3.92E-10
Nickel	HI	0.0005	3.20E-08	4.85E-08	0.00E+00	0.00E+00	3.20E-08
2-methylnaphthalene	HI	1.34E-01	3.20E-05	3.20E-05	2.57E-06	2.57E-06	3.20E-05
Cresols	HI	1.05E+00	1.57E-05	1.57E-05	0.00E+00	0.00E+00	1.57E-05
Naphthalene	HI	0.0096	1.41E-03	1.42E-03	1.41E-03	1.41E-03	1.41E-03
Phenol	HI	1.69E+00	2.51E-06	2.51E-06	2.04E-06	2.04E-06	2.51E-06
Pyrene	HI	0.00025	1.01E-07	1.98E-07	3.60E-08	3.60E-08	1.01E-07
Toluene	HI	1.27E+00	1.07E-04	1.07E-04	8.92E-05	8.92E-05	1.07E-04
TPH C_{6}-C_{8} (ali)	HI	4.56E-02	1.66E-04	1.66E-04	1.65E-04	1.65E-04	1.66E-04
TPH C_{8}-C_{16} (ali)	HI	1.29E-03	2.22E-04	2.22E-04	2.19E-04	2.19E-04	2.22E-04
TPH $C_{>16}$ (ali)	HI	3.33E-07	5.00E-12	5.00E-12	0.00E+00	0.00E+00	5.00E-12
TPH C_{8}-C_{16} (aro)	HI	1.32E-01	1.49E-04	1.49E-04	1.21E-04	1.21E-04	1.49E-04
TPH $C_{>16}$ (aro)	HI	2.08E-02	2.02E-05	2.02E-05	0.00E+00	0.00E+00	2.02E-05
1,2,4-trimethylbenzene	HI	5.20E-01	2.28E-02	2.28E-02	2.06E-02	2.06E-02	2.28E-02
Xylenes	HI	8.18E-01	2.80E-04	2.80E-04	2.59E-04	2.59E-04	2.80E-04

Zone 2 sk + HI Soil Criteria Potential for Odours

Risk and HI for Unit Concentrations

	Measure	South + Central	Head Park	South + Central	Odour Threshold	Odour Level at Criteria	Reduced Criteria Aesthetics
Benz(a)anthracene	Risk	1.06E-07	94.8	94.8			
Benzene	Risk	2.50E-05	0.4	0.4	108.6	3.36E-02	-
Benzo(a)pyrene	Risk	1.24E-08	807.8	807.8			
Benzo(b)fluoranthene	Risk	6.96E-10	14376.3	14376.3			
Benzo(k)fluoranthene	Risk	1.17E-09	8548.7	8548.7			
Chrysene	Risk	3.26E-10	30679.8	30679.8			
Dibenz(a,h)anthracene	Risk	5.08E-09	1969.1	1969.1			
Indeno(1,2,3-c,d)pyrene	Risk	6.32E-10	15810.9	15810.9			
Nickel	Risk						
Ammonia	HI	2.85E-05	35116.8	35116.8	18	1.02E+01	-
Arsenic	HI	2.21E-08	28571428.6	31746031.7			
Benzene	HI	6.31E-02	0.4	0.4	108.6	3.36E-02	-
Cadmium	HI	1.40E-07	2679.7	714285.7			
Chromium	HI	2.34E-06	557413.6	427350.4			
Cyanide	HI	1.77E-05	56623.2	56623.2	0.64	6.00E+00	6037.735849
Dibenzofuran	HI	2.46E-06	405901.9	405901.9	1	2.34E+01	17331.02253
2,4-dimethylphenol	HI	3.51E-05	28451.6	28451.6			
Ethylbenzene	HI	2.57E-04	3887.0	3887.0	2	1.64E+02	47.39336493
Fluoranthene	HI	7.44E-07	2083333.3	1344086.0			
Fluorene	HI	1.70E-06	540853.8	587154.7			
Lead	HI	6.72E-10	##########	595238095.2			
Nickel	HI	4.85E-08	31240237.4	20618556.7			
2-methylnaphthalene	HI	3.20E-05	31234.8	31234.8	0.06	1.64E+00	1140.684411
Cresols	HI	1.57E-05	63529.1	63529.1	0.0012	0.00E+00	-
Naphthalene	HI	1.42E-03	707.5	706.6	0.44	5.11E-01	609.4182825
Phenol	HI	2.51E-06	397644.9	397644.9	0.15	1.73E+00	34482.75862
Pyrene	HI	1.98E-07	9904667.6	5038735.3			
Toluene	HI	1.07E-04	9346.9	9346.9	30	6.08E+02	460.8294931
TPH C_{6}-C_{8} (ali)	HI	1.66E-04	6024.9	6024.9			
TPH C_{8}-C_{16} (ali)	HI	2.22E-04	4511.6	4511.6			
TPH $C_{>16}$ (ali)	HI	5.00E-12	##########	200082765180.7			
TPH C_{8}-C_{16} (aro)	HI	1.49E-04	6725.7	6725.7			
TPH $C_{>16}$ (aro)	HI	2.02E-05	49520.1	49520.1			
1,2,4-trimethylbenzene	HI	2.28E-02	43.8	43.8	1.96	9.24E-01	-
Xylenes	HI	2.80E-04	3567.4	3567.4	4.34	1.17E+02	131.9148936

Zone 3		Zone 3				Soil	Soil Criteria	Potential for Odours		
Risk and HI for Unit Concentrations		Soil Occassional User (Car Park) Inhalation	C/I (Car Park Attendant) Inhalation	Soil Recreational User (Cultural Space) Inhalation	C/I (Cultural Space) Inhalation					
	Measure	All	Adult	All	Adult			Odour Threshold	Odour Level at Criteria	Reduced Criteria Aesthetics
Benz(a)anthracene	Risk	4.28E-09	5.87E-08	2.25E-07	2.54E-07	2.54E-07	39.4			
Benzene	Risk	1.74E-08	2.38E-07	7.90E-05	8.90E-05	8.90E-05	0.1	108.6	9.09E-03	-
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chrysene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ammonia	HI	1.17E-05	3.77E-04	6.52E-04	1.72E-03	1.72E-03	580.6	18	3.18E-01	-
Arsenic	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzene	HI	2.90E-04	9.31E-03	1.32E+00	3.48E+00	3.48E+00	0.1	108.6	9.09E-03	-
Cadmium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chromium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Cyanide	HI	3.02E-06	9.69E-05	3.97E-04	1.05E-03	1.05E-03	954.5	0.64	1.91E-01	-
Dibenzofuran	HI	7.63E-08	2.45E-06	4.32E-05	1.14E-04	1.14E-04	8757.3	1	9.55E-01	-
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ethylbenzene	HI	7.85E-07	2.52E-05	5.10E-03	1.35E-02	1.35E-02	74.2	2	5.91E+00	25.12562814
Fluoranthene	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Fluorene	HI	1.14E-07	3.66E-06	2.93E-05	7.75E-05	7.75E-05	12908.0			
Lead	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	HI					0.00E+00				
2-methylnaphthalene	HI	3.84E-07	1.23E-05	5.90E-05	1.56E-04	1.56E-04	6421.4	0.06	6.36E-01	605.4490414
Cresols	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.0012	0.00E+00	-
Naphthalene	HI	3.31E-05	1.06E-03	3.24E-02	8.55E-02	8.55E-02	11.7	0.44	1.59E-02	-
Phenol	HI	1.45E-07	4.65E-06	3.42E-06	9.02E-06	9.02E-06	110864.7	0.15	9.09E-01	18292.68293
Pyrene	HI	1.53E-08	4.93E-07	8.25E-07	2.18E-06	2.18E-06	459136.8			
Toluene	HI	3.71E-07	1.19E-05	2.05E-03	5.41E-03	5.41E-03	184.8	30	2.27E+01	-
TPH C_{6}-C_{8} (ali)	HI	5.47E-07	1.76E-05	3.79E-03	1.00E-02	1.00E-02	99.9			
TPH C_{8}-C_{16} (ali)	HI	7.26E-07	2.33E-05	5.02E-03	1.33E-02	1.33E-02	75.4			
TPH $C_{>16}$ (ali)	HI					0.00E+00				
TPH C_{8}-C_{16} (aro)	HI	7.95E-07	2.55E-05	2.77E-03	7.33E-03	7.33E-03	136.5			
TPH $C_{>16}$ (aro)	HI					0.00E+00				
1,2,4-trimethylbenzene	HI	7.25E-05	2.33E-03	4.72E-01	1.25E+00	1.25E+00	0.8	1.96	3.18E-02	-
Xylenes	HI	1.28E-06	4.12E-05	5.94E-03	1.57E-02	1.57E-02	63.8	4.34	3.95E+00	-

Zone 4		Zone 4				Soil	Soil Criteria	Potential for Odours		
Risk and HI for Unit Concentrations		Soil Occassional User (Car Park) Inhalation	C/I (Car Park Attendant) Inhalation	Soil Recreational User (Cultural Space) Inhalation	C/I (Cultural Space) Inhalation					Reduced Criteria
	Measure	All	Adult	All	Adult			Odour Threshold	Odour Level at Criteria	Aesthetics
Benz(a)anthracene	Risk	3.02E-09	4.13E-08	1.21E-07	1.36E-07	1.36E-07	73.3			
Benzene	Risk	1.74E-08	2.38E-07	5.95E-05	6.70E-05	6.70E-05	0.1	108.6	9.09E-03	-
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chrysene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ammonia	HI	1.04E-05	3.33E-04	5.02E-04	1.33E-03	1.33E-03	754.0	18	3.18E-01	-
Arsenic	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzene	HI	2.90E-04	9.31E-03	9.91E-01	2.62E+00	2.62E+00	0.1	108.6	9.09E-03	-
Cadmium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chromium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Cyanide	HI	2.94E-06	9.43E-05	3.47E-04	9.17E-04	9.17E-04	1090.9	0.64	1.91E-01	-
Dibenzofuran	HI	7.40E-08	2.38E-06	2.55E-05	6.74E-05	6.74E-05	14845.2	1	9.55E-01	-
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ethylbenzene	HI	7.80E-07	2.50E-05	3.58E-03	9.44E-03	9.44E-03	105.9	2	5.91E+00	35.84229391
Fluoranthene	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Fluorene	HI	1.07E-07	3.44E-06	1.78E-05	4.70E-05	4.70E-05	21283.1			
Lead	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	HI					0.00E+00				
2-methylnaphthalene	HI	3.52E-07	1.13E-05	3.80E-05	1.00E-04	1.00E-04	9958.7	0.06	6.36E-01	938.9671362
Cresols	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.0012	0.00E+00	-
Naphthalene	HI	3.27E-05	1.05E-03	2.19E-02	5.78E-02	5.78E-02	17.3	0.44	1.59E-02	-
Phenol	HI	1.05E-07	3.39E-06	2.54E-06	6.70E-06	6.70E-06	149276.0	0.15	9.09E-01	24630.54187
Pyrene	HI	1.05E-08	3.37E-07	4.16E-07	1.10E-06	1.10E-06	910912.7			
Toluene	HI	3.70E-07	1.19E-05	1.48E-03	3.92E-03	3.92E-03	255.1	30	2.27E+01	-
TPH C_{6}-C_{8} (ali)	HI	5.47E-07	1.76E-05	2.92E-03	7.71E-03	7.71E-03	129.7			
TPH C_{8}-C_{16} (ali)	HI	7.26E-07	2.33E-05	3.87E-03	1.02E-02	1.02E-02	97.8			
TPH $C_{>16}$ (ali)	HI					0.00E+00				
TPH C_{8}-C_{16} (aro)	HI	7.91E-07	2.54E-05	2.14E-03	5.65E-03	5.65E-03	176.9			
TPH $C_{>16}$ (aro)	HI					0.00E+00				
1,2,4-trimethylbenzene	HI	7.24E-05	2.33E-03	3.20E-01	8.45E-01	8.45E-01	1.2	1.96	3.18E-02	-
Xylenes	HI	1.28E-06	4.12E-05	4.40E-03	1.16E-02	1.16E-02	86.0	4.34	3.95E+00	-

Zone 5		Zone 5								
Risk and HI for Unit		Soil		Soil						
Concentrations		Occassional User (Car Park)	C/I (Car Park Attendant)	Recreational User (Cultural Space)	C/I (Cultural Space)					
		Inhalation	Inhalation	Inhalation	Inhalation					
	Measure	All	Adult	All	Adult			Odour Threshold	Odour Level at Criteria	Reduced Criteria Aesthetics
Benz(a)anthracene	Risk	9.06E-10	1.24E-08	2.14E-08	2.41E-08	2.41E-08	414.9			
Benzene	Risk	1.71E-08	2.35E-07	1.70E-05	1.92E-05	1.92E-05	0.3	108.6	9.09E-03	-
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chrysene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ammonia	HI	5.30E-06	1.70E-04	1.52E-04	4.02E-04	4.02E-04	2485.8	18	3.18E-01	-
Arsenic	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzene	HI	2.86E-04	9.17E-03	2.84E-01	7.50E-01	7.50E-01	0.3	108.6	9.09E-03	-
Cadmium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chromium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Cyanide	HI	2.43E-06	7.80E-05	1.54E-04	4.08E-04	4.08E-04	2453.8	0.64	1.91E-01	-
Dibenzofuran	HI	5.97E-08	1.92E-06	5.00E-06	1.32E-05	1.32E-05	75757.6	1	9.55E-01	-
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ethylbenzene	HI	7.69E-07	2.47E-05	8.97E-04	2.37E-03	2.37E-03	422.1	2	5.91E+00	142.8571429
Fluoranthene	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Fluorene	HI	7.24E-08	2.33E-06	3.61E-06	9.54E-06	9.54E-06	104837.5			
Lead	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	HI					0.00E+00				
2-methylnaphthalene	HI	2.12E-07	6.80E-06	8.33E-06	2.20E-05	2.20E-05	45454.5	0.06	6.36E-01	4285.714286
Cresols	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.0012	0.00E+00	-
Naphthalene	HI	2.97E-05	9.55E-04	5.16E-03	1.36E-02	1.36E-02	73.3	0.44	1.59E-02	-
Phenol	HI	3.35E-08	1.07E-06	7.12E-07	1.88E-06	1.88E-06	531632.1	0.15	9.09E-01	87719.29825
Pyrene	HI	2.98E-09	9.57E-08	6.98E-08	1.84E-07	1.84E-07	5424170.1			
Toluene	HI	3.66E-07	1.17E-05	3.97E-04	1.05E-03	1.05E-03	954.9	30	2.27E+01	-
TPH C_{6}-C_{8} (ali)	HI	5.40E-07	1.73E-05	8.87E-04	2.34E-03	2.34E-03	426.7			
TPH C_{8}-C_{16} (ali)	HI	7.19E-07	2.31E-05	1.17E-03	3.10E-03	3.10E-03	322.4			
TPH $C_{>16}$ (ali)	HI					0.00E+00				
TPH C_{8}-C_{16} (aro)	HI	7.77E-07	2.50E-05	6.50E-04	1.72E-03	1.72E-03	582.8			
TPH $C_{>16}$ (aro)	HI					0.00E+00				
1,2,4-trimethylbenzene	HI	7.13E-05	2.29E-03	7.54E-02	1.99E-01	1.99E-01	5.0	1.96	3.18E-02	-
Xylenes	HI	1.26E-06	4.05E-05	1.23E-03	3.24E-03	3.24E-03	308.9	4.34	3.95E+00	-

Zone 6		Zone 6			Soil	Soil Criteria	Potential for Odours		
Risk and HI for Unit		Soil							
Concentrations		Recreational	C/I (Gardener)	Sub-Surface Maintenance Worker					
		Inhalation	Inhalation	Inhalation					Reduced Criteria
	Measure	All	Adult	All			Odour Threshold	Odour Level at Criteria	Aesthetics
Benz(a)anthracene	Risk	1.75E-09	1.97E-09	8.22E-11	1.97E-09	5079.2			
Benzene	Risk	1.61E-06	1.81E-06	7.56E-08	1.81E-06	2.3	108.6	1.46E-01	-
Benzo(a)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(b)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzo(k)fluoranthene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chrysene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Dibenz(a,h)anthracene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	Risk	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ammonia	HI	1.48E-05	3.90E-05	4.85E-05	4.85E-05	20602.8	18	5.11E+00	-
Arsenic	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Benzene	HI	2.68E-02	7.08E-02	8.81E-02	8.81E-02	2.3	108.6	1.46E-01	-
Cadmium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Chromium	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Cyanide	HI	1.86E-05	4.92E-05	6.13E-05	6.13E-05	16306.9	0.64	3.07E+00	3404.255319
Dibenzofuran	HI	4.20E-07	1.11E-06	1.38E-06	1.38E-06	726467.6	1	1.53E+01	47393.36493
2,4-dimethylphenol	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Ethylbenzene	HI	8.01E-05	2.12E-04	2.65E-04	2.65E-04	3780.5	2	9.49E+01	79.6812749
Fluoranthene	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Fluorene	HI	3.04E-07	8.03E-07	9.98E-07	9.98E-07	1001860.6			
Lead	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00				
Nickel	HI				0.00E+00				
2-methylnaphthalene	HI	7.20E-07	1.90E-06	2.37E-06	2.37E-06	422271.8	0.06	1.02E+01	2479.338843
Cresols	HI	0.00E+00	0.00E+00	0.00E+00	0.00E+00		0.0012	0.00E+00	-
Naphthalene	HI	4.52E-04	1.19E-03	1.49E-03	1.49E-03	670.5	0.44	2.55E-01	-
Phenol	HI	6.62E-08	1.75E-07	2.18E-07	2.18E-07	4590735.9	0.15	1.46E+01	47169.81132
Pyrene	HI	5.64E-09	1.49E-08	1.85E-08	1.85E-08	54068667.2			
Toluene	HI	3.63E-05	9.59E-05	1.19E-04	1.19E-04	8370.7	30	3.65E+02	688.0733945
TPH C_{6}-C_{8} (ali)	HI	8.56E-05	2.26E-04	2.82E-04	2.82E-04	3543.7			
TPH C_{8}-C_{16} (ali)	HI	1.13E-04	2.99E-04	3.74E-04	3.74E-04	2673.7			
TPH $C_{>16}$ (ali)	HI				0.00E+00				
TPH C_{8}-C_{16} (aro)	HI	6.29E-05	1.66E-04	2.06E-04	2.06E-04	4850.0			
TPH $C_{>16}$ (aro)	HI				0.00E+00				
1,2,4-trimethylbenzene	HI	6.63E-03	1.75E-02	2.17E-02	2.17E-02	46.0	1.96	5.11E-01	-
Xylenes	HI	1.15E-04	3.03E-04	3.76E-04	3.76E-04	2657.1	4.34	6.35E+01	181.5899582

Irrigation Water		Irrigation Water					Irrigation Water	Irrigation Water Criteria	Potential for Odours		
Risk and HI for Unit		Recreational			Commercial / Industrial (Gardener)						
Concentrations		Inhalation	Dermal		Inhalation	Dermal					Reduced Criteria
	Measure	All	Adult	Child (0-5 & 6-15)					Odour Threshold	Odour Level at Criteria	Aesthetics
Benz(a)anthracene	Risk	9.10E-04	2.00E-04	1.50E-04	1.80E-03	5.20E-04	2.32E-03	4.31E-03			
Benzene	Risk	1.06E-06	3.80E-06	2.80E-06	2.09E-06	9.90E-06	1.20E-05	0.144782963	108.6	8.60E-03	-
Benzo(a)pyrene	Risk	0.00E+00	2.60E-03	1.90E-03	0.00E+00	6.70E-03	6.70E-03	1.49E-03			
Benzo(b)fluoranthene	Risk	0.00E+00	1.50E-04	1.10E-04	0.00E+00	3.90E-04	3.90E-04	2.56E-02			
Benzo(k)fluoranthene	Risk	0.00E+00	2.50E-04	1.90E-04	0.00E+00	6.50E-04	6.50E-04	1.54E-02			
Chrysene	Risk	0.00E+00	2.20E-05	1.60E-05	0.00E+00	5.60E-05	5.60E-05	1.79E-01			
Dibenz(a,h)anthracene	Risk	0.00E+00	3.50E-03	2.60E-03	0.00E+00	9.00E-03	9.00E-03	1.11E-03			
Indeno(1,2,3-c,d)pyrene	Risk	0.00E+00	4.60E-04	3.30E-04	0.00E+00	1.20E-03	1.20E-03	8.33E-03			
Nickel	Risk	0.00E+00			0.00E+00		0.00E+00				
Ammonia	HI	3.03E-03			1.40E-02		1.40E-02	7.16E+01	18	5.11E+00	-
Arsenic	HI	0.00E+00	4.80E-03	1.90E-02	0.00E+00	2.20E-02	2.20E-02	4.55E+01			
Benzene	HI	1.76E-02	2.90E-01	1.20E+00	8.14E-02	1.30E+00	1.38E+00	0.144782963	108.6	8.60E-03	-
Cadmium	HI	0.00E+00	2.70E-01	1.10E+00	0.00E+00	1.30E+00	1.30E+00	7.69E-02			
Chromium	HI	0.00E+00	7.70E-01	3.10E+00	0.00E+00	3.50E+00	3.50E+00	2.86E-01			
Cyanide	HI	5.12E-03	3.60E-04	1.50E-03	2.36E-02	1.70E-03	2.53E-02	3.95E+01	0.64	2.86E+00	8.839779006
Dibenzofuran	HI	6.65E-04	1.60E-03	6.30E-03	3.07E-03	7.20E-03	1.03E-02	9.74E+01	1	4.58E+00	21.27659574
2,4-dimethylphenol	HI	0.00E+00	5.20E-03	2.10E-02	0.00E+00	2.40E-02	2.40E-02	4.17E+01			
Ethylbenzene	HI	1.25E-04	4.90E-03	2.00E-02	5.78E-04	2.20E-02	2.26E-02	4.43E+01	2	2.43E+00	36.49635036
Fluoranthene	HI	0.00E+00	2.40E-01	9.60E-01	0.00E+00	1.10E+00	1.10E+00	9.09E-01			
Fluorene	HI	9.78E-04	2.60E-02	1.10E-01	4.51E-03	1.20E-01	1.25E-01	8.03E+00			
Lead	HI	0.00E+00	2.70E-04	1.10E-03	0.00E+00	1.30E-03	1.30E-03	4.62E+02			
Nickel	HI		9.60E-03	3.90E-02		4.40E-02	4.40E-02	2.27E+01			
2-methylnaphthalene	HI	9.97E-04	2.20E-02	8.90E-02	4.60E-03	1.00E-01	1.05E-01	9.56E+00	0.06	4.49E-01	1.276595745
Cresols	HI	0.00E+00	1.50E-03	5.90E-03	0.00E+00	6.80E-03	6.80E-03	1.47E+02	0.0012	0.00E+00	-
Naphthalene	HI	4.37E-02	2.20E-02	9.00E-02	2.02E-01	1.00E-01	3.02E-01	3.32E+00	0.44	1.71E-01	-
Phenol	HI	7.05E-05	1.40E-04	5.60E-04	3.25E-04	6.40E-04	9.65E-04	1.04E+03	0.15	4.92E+00	31.57894737
Pyrene	HI	9.95E-04	6.40E-02	2.60E-01	4.59E-03	3.00E-01	3.05E-01	3.28E+00			
Toluene	HI	3.39E-05	1.30E-03	5.40E-03	1.56E-04	6.20E-03	6.36E-03	1.57E+02	30	8.97E+00	-
TPH C_{6}-C_{8} (ali)	HI	8.99E-06	1.40E-03	5.80E-03	4.15E-05	6.60E-03	6.64E-03	1.51E+02			
TPH C_{8}-C_{16} (ali)	HI	1.44E-04	1.80E-01	7.40E-01	6.66E-04	8.40E-01	8.41E-01	1.19E+00			
TPH $C_{>16}$ (ali)	HI		1.40E-03	5.80E-03		6.60E-03	6.60E-03	1.52E+02			
TPH C_{8}-C_{16} (aro)	HI	7.68E-04	2.10E-02	8.40E-02	3.54E-03	9.60E-02	9.95E-02	1.00E+01			
TPH $C_{>16}$ (aro)	HI		9.60E-02	3.90E-01		4.40E-01	4.40E-01	2.27E+00			
1,2,4-trimethylbenzene	HI	1.10E-02	4.10E-01	1.70E+00	5.07E-02	1.90E+00	1.95E+00	5.13E-01	1.96	1.33E-02	-
Xylenes	HI	1.87E-04	2.50E-03	1.00E-02	8.63E-04	1.20E-02	1.29E-02	7.77E+01	4.34	4.26E+00	-

Modelling Output Files

Volatilisation Modelling, Zone 1 Soil

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger model for outdoor air
with volatile emissions from soil

Title:
Zone 1 - Soil - Volatilisation Modelling

Simulation time (years).	70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-02
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to surface (m)	0.10

OUTDOOR AIR PARAMETERS

Height of box (breathing zone) (m)	2.0
Length of box (m).	10.
Wind speed (m/s)	2.0

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03

Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32

Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg) 1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg) 1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg) 1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

Model Description:
Johnson and Ettinger model for outdoor air
with volatile emissions from soil gas

Title:
Zone 1 - Seepage Water (0.5m) - Volatilisation Modelling

Simulation time (years).	70

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to surface (m)	0.50

Lens Properties for Vapor Model

Lens thickness (m).	0.17
Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	0.25

OUTDOOR AIR PARAMETERS

Height of box (breathing zone) (m)	2.0
Length of box (m).	10.
Wind speed (m/s)	2.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	0.66

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	0.49

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.27E+02

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	5.4

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	8.7

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	3.22E+02

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06

Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	3.9

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.1

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	18.

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.7

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02

Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.36E-02

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	0.49

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.71E+02

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	5.10E+04

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.30E+05

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.40E+02

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.52E+02

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.12E+02

Volatilisation Modelling, Zone 1 Seepage Water – Sub-Surface Maintenance Worker (0.1m depth)

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger model for outdoor air
with volatile emissions from soil gas

Title:
Zone 1 - Seepage Water (0.1m) - Volatilisation Modelling

Simulation time (years).	70

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	0.25
Distance from source to surface (m)	0.10

OUTDOOR AIR PARAMETERS

Height of box (breathing zone) (m)	0.50
Length of box (m).	10.
Wind speed (m/s)	2.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	0.66

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	0.49

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.27E+02

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05

Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	5.4

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	8.7

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	3.22E+02

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	3.9

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03

Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.1

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	18.

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.7

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.36E-02

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	0.49

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.71E+02

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	5.10E+04

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.30E+05

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	1.40E+02

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.52E+02

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. for outdoor air model (mg/m3)	2.12E+02

Zone 2 – Volatile Modelling – Unsaturated Soil Below Car Park

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil

Title:
Zone 2 - Unsaturated Soil Below Car Park (0.1m) - Volatilisation Modelling

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to building (m)	0.10

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02

Volume of building (m3).	4.00E+02
Number of air changes per day.	91.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02

Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

Zone 2 – Volatile Modelling – Groundwater Below Car Park

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil gas

Title:
Zone 2 - Groundwater Below Car Park (0.1m) - Volatilisation Modelling

Simulation time (years). 70

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	0.25
Distance from source to building (m)	0.10

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02
Volume of building (m3).	4.00E+02
Number of air changes per day.	91.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05

Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. for vapor model (mg/m3)	0.66

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	0.49

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. for vapor model (mg/m3)	2.27E+02

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. for vapor model (mg/m3)	5.4

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03

Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	8.7

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	3.22E+02

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	3.9

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	2.1

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	18.

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	1.7

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. for vapor model (mg/m3)	1.36E-02

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	0.49

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. for vapor model (mg/m3)	2.71E+02

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	5.10E+04

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	1.30E+05

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	1.40E+02

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	2.52E+02

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. for vapor model (mg/m3)	2.12E+02

Zone 3 – Soil 0-1m Underlying Cultural Space

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil

Title:
Zone 3 - Soil >0-1m Away/Underlying Cultural Space - Volatilisation Modelling

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to building (m)	0.10

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02
Volume of building (m3).	4.00E+02
Number of air changes per day.	48.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03

Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

Zone 3 – Soil 0-1m Away from Car Park

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil

Title:
Zone 3 - Soil 0-1m Away from Car Park - Volatilisation Modelling

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to building (m)	1.1

Lens Properties for Vapor Model

Lens thickness (m).	1.0
Total porosity (cm3/cm3)	0.46
Water content(cm3/cm3)	0.41

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02
Volume of building (m3).	4.00E+02
Number of air changes per day.	91.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06

Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03

Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

Zone 4 – Soil >1-10m Underlying / Away from Cultural Space

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil

Title:
Zone 4 - Soil >1-10m Away/Underlying Cultural Space - Volatilisation Modelling

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to building (m)	1.0

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02
Volume of building (m3).	4.00E+02
Number of air changes per day.	48.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1

Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02

Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

Zone 4 – Soil Adjoining Car Park to 10m

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil

Title:
Zone 4 - Soil >1-10m Away from Car Park - Volatilisation Modelling

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to building (m)	2.0

Lens Properties for Vapor Model

Lens thickness (m).	1.0
Total porosity (cm3/cm3)	0.46
Water content(cm3/cm3)	0.41

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02
Volume of building (m3).	4.00E+02
Number of air changes per day.	91.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02

Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.

KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

Zone 5 – Soil >10-30m Underlying / Away from Cultural Space

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil

Title:
Zone 5 - Soil >10-30m Away/Underlying Cultural Space - Volatilisation Modelling

Simulation time (years).	70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to building (m)	10.

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02
Volume of building (m3).	4.00E+02
Number of air changes per day.	48.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.

Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27

Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg) 1.0

Zone 5 – Soil Adjoining Car Park from 10-30m

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger Indoor air model
with volatile emissions from soil

Title:
Zone 5 - Soil >10-30m Away from Car Park - Volatilisation Modelling

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to building (m)	10.

Lens Properties for Vapor Model

Lens thickness (m).	1.0
Total porosity (cm3/cm3)	0.46
Water content(cm3/cm3)	0.41

Building Parameters

Cross-sect. area of basement (m2).	1.50E+02
Volume of building (m3).	4.00E+02
Number of air changes per day.	91.
Foundation thickness (m)	0.15
Flow rate of soil gas into building (cm3/s)	83.

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02

Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1

KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for vapor model (mg/kg)	1.0

Zone 6 – Soil >0.5m below Park Surface and >30m from Cultural Space / Car Park (Surface exposure)

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger model for outdoor air
with volatile emissions from soil

Title:
Zone 6 - Soil >30m Away/Underlying Cultural Space and >0.5m Underlying Park Surf

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to surface (m)	0.50

OUTDOOR AIR PARAMETERS

Height of box (breathing zone) (m)	2.0
Length of box (m).	10.
Wind speed (m/s)	2.0

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02
Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02

Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02
KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.

KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

Zone 6 – Soil >0.5m below Park Surface and >30m from Cultural Space / Car Park (Sub-Surface Maintenance Worker Exposure)

FATE AND TRANSPORT MODEL INPUT SUMMARY FILE

Model Description:
Johnson and Ettinger model for outdoor air
with volatile emissions from soil

Title:
Zone 6 - Soil >30m Away/Underlying Cultural Space and >0.5m Underlying Park Surf

Simulation time (years). 70

Soil Source for Vapor Model

Total porosity in source (cm3/cm3).	0.38
Water content in source (cm3/cm3)	5.30E-02
Fraction organic carbon in source(mg/mg)	3.00E-03
Soil bulk density in source (g/cm3).	1.7

Unsaturated Zone Properties for Vapor Model

Total porosity (cm3/cm3)	0.38
Water content(cm3/cm3)	5.30E-02
Distance from source to surface (m)	0.10

OUTDOOR AIR PARAMETERS

Height of box (breathing zone) (m)	0.50
Length of box (m).	10.
Wind speed (m/s)	2.0

TPH Data for Vapor Model Source

Concentration of TPH (mg/kg)	0.0
Molecular weight of TPH (g/mol).	0.0

CHEMICAL DATA FOR: Ammonia / ammonium

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	4.82E+05
Vapor pressure (mmHg)	7.51E+03
Kd (partition coefficient) (L/kg)	0.40
Henry's Law coefficient (-).	6.58E-04
Molecular weight (g/mol).	17.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Benz(a)anthracene

Diffusion coefficient in air (cm2/s)	3.20E-02
Diffusion coefficient in water (cm2/s)	7.70E-06
Solubility (mg/l)	9.40E-03
Vapor pressure (mmHg)	2.10E-07
KOC (L/kg).	1.77E+05
Henry's Law coefficient (-).	4.91E-04
Molecular weight (g/mol).	2.28E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Benzene

Diffusion coefficient in air (cm2/s)	8.95E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	1.79E+03
Vapor pressure (mmHg)	95.
KOC (L/kg).	1.46E+02
Henry's Law coefficient (-).	0.23
Molecular weight (g/mol).	78.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Cyanide

Diffusion coefficient in air (cm2/s)	0.21
Diffusion coefficient in water (cm2/s)	2.46E-05
Solubility (mg/l)	1.00E+06
Vapor pressure (mmHg)	7.42E+02
Kd (partition coefficient) (L/kg)	9.9
Henry's Law coefficient (-).	5.44E-03
Molecular weight (g/mol).	27.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Dibenzofuran

Diffusion coefficient in air (cm2/s)	4.10E-02

Diffusion coefficient in water (cm2/s)	7.38E-06
Solubility (mg/l)	3.1
Vapor pressure (mmHg)	2.48E-03
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	8.71E-03
Molecular weight (g/mol).	1.68E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Ethylbenzene

Diffusion coefficient in air (cm2/s)	6.85E-02
Diffusion coefficient in water (cm2/s)	8.46E-06
Solubility (mg/l)	1.69E+02
Vapor pressure (mmHg)	9.6
KOC (L/kg).	4.46E+02
Henry's Law coefficient (-).	0.32
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Fluorene

Diffusion coefficient in air (cm2/s)	4.40E-02
Diffusion coefficient in water (cm2/s)	7.89E-06
Solubility (mg/l)	1.7
Vapor pressure (mmHg)	6.00E-04
KOC (L/kg).	9.16E+03
Henry's Law coefficient (-).	3.93E-03
Molecular weight (g/mol).	1.66E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Methyl napthalene (2)

Diffusion coefficient in air (cm2/s)	5.24E-02
Diffusion coefficient in water (cm2/s)	7.78E-06
Solubility (mg/l)	25.
Vapor pressure (mmHg)	8.30E-03
KOC (L/kg).	2.48E+03
Henry's Law coefficient (-).	2.12E-03
Molecular weight (g/mol).	1.42E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Naphthalene

Diffusion coefficient in air (cm2/s)	6.05E-02
Diffusion coefficient in water (cm2/s)	8.38E-06
Solubility (mg/l)	31.
Vapor pressure (mmHg)	8.50E-02

KOC (L/kg).	1.54E+03
Henry's Law coefficient (-).	1.80E-02
Molecular weight (g/mol).	1.28E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenanthrene

Diffusion coefficient in air (cm2/s)	3.45E-02
Diffusion coefficient in water (cm2/s)	6.69E-06
Solubility (mg/l)	1.1
Vapor pressure (mmHg)	1.21E-04
KOC (L/kg).	1.67E+04
Henry's Law coefficient (-).	1.73E-03
Molecular weight (g/mol).	1.78E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Phenol

Diffusion coefficient in air (cm2/s)	8.34E-02
Diffusion coefficient in water (cm2/s)	1.03E-05
Solubility (mg/l)	8.28E+04
Vapor pressure (mmHg)	0.35
KOC (L/kg).	1.87E+02
Henry's Law coefficient (-).	1.36E-05
Molecular weight (g/mol).	94.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Pyrene

Diffusion coefficient in air (cm2/s)	2.78E-02
Diffusion coefficient in water (cm2/s)	7.25E-06
Solubility (mg/l)	0.14
Vapor pressure (mmHg)	4.50E-06
KOC (L/kg).	5.43E+04
Henry's Law coefficient (-).	4.87E-04
Molecular weight (g/mol).	2.02E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: Toluene

Diffusion coefficient in air (cm2/s)	7.78E-02
Diffusion coefficient in water (cm2/s)	9.20E-06
Solubility (mg/l)	5.26E+02
Vapor pressure (mmHg)	28.
KOC (L/kg).	2.34E+02
Henry's Law coefficient (-).	0.27
Molecular weight (g/mol).	92.

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C6-8

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	5.4
Vapor pressure (mmHg)	48.
KOC (L/kg).	4.00E+03
Henry's Law coefficient (-).	51.
Molecular weight (g/mol).	1.00E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aliphatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	3.40E-02
Vapor pressure (mmHg)	0.49
KOC (L/kg).	2.50E+05
Henry's Law coefficient (-).	1.30E+02
Molecular weight (g/mol).	1.60E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: TPH Aromatic C10-12

Diffusion coefficient in air (cm2/s)	0.10
Diffusion coefficient in water (cm2/s)	1.00E-05
Solubility (mg/l)	25.
Vapor pressure (mmHg)	0.48
KOC (L/kg).	2.50E+03
Henry's Law coefficient (-).	0.14
Molecular weight (g/mol).	1.30E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg)	1.0

CHEMICAL DATA FOR: 1,2,4-trimethylbenzene

Diffusion coefficient in air (cm2/s)	6.07E-02
Diffusion coefficient in water (cm2/s)	7.92E-06
Solubility (mg/l)	57.
Vapor pressure (mmHg)	2.1
KOC (L/kg).	7.18E+02
Henry's Law coefficient (-).	0.25
Molecular weight (g/mol).	1.69E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg) 1.0

CHEMICAL DATA FOR: Xylenes

Diffusion coefficient in air (cm2/s)	8.47E-02
Diffusion coefficient in water (cm2/s)	9.90E-06
Solubility (mg/l)	1.06E+02
Vapor pressure (mmHg)	8.0
KOC (L/kg).	3.83E+02
Henry's Law coefficient (-).	0.21
Molecular weight (g/mol).	1.06E+02

Source Concentrations:

Source conc. in soil for outdoor air model (mg/kg) 1.0

Zone 1 – Adult Recreational Receptor – Oral and Dermal - Soil

Title:
Zone 1 - Adult Recreational Receptor - Oral and Dermal Exposure - Soil
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Scenarios:
Adult Resident - RME

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
- Methyl napthalene (2)
- 3- & 4-methylphenol
- Naphthalene
- Phenanthrene
- Phenol
- Pyrene
- Toluene
- TPH Aliphatic C6-8
- TPH Aliphatic C10-12
- TPH Aliphatic C16-35
- TPH Aromatic C10-12
- TPH Aromatic C16-21
- 1,2,4-trimethylbenzene
- Xylenes

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
INGESTION OF SOIL	
Soil Ingestion Rate (mg/day)	25.0
Exp. Frequency Soil (events/year)	365.
Exp. Duration Soil (years)	54.0
Absorption Adjustment Factor for Ingestion of Soil (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0

Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

Soil Bioavailability (-)

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

DERMAL CONTACT WITH SOIL

Total Skin Surface Area (cm^2)	4.700E+03
Fraction Skin Exposed to Soil (-)	1.00
Adherence Factor for Soil (mg/cm^2)	0.500
Exposure Freq. Soil (events/year)	365.
Exposure Duration Soil (years)	54.0

Absorption Adjustment Factor for Dermal Exposure to Soil (-)

Methyl napthalene (2)	0.10
3- & 4-methylphenol	0.10
Naphthalene	0.13
Phenanthrene	0.13
Phenol	0.10
Pyrene	0.13
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	0.10
TPH Aromatic C10-12	0.10
TPH Aromatic C16-21	0.10
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

Soil Bioavailability (-)

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)

- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Ingestion Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

SUMMARY OF RESULTS

INGESTION OF SOIL

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	8.929E-06

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.143E-06

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.786E-05

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.190E-05

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.190E-06

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.190E-05

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.602E-06

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day) 3.57E-07
LADD (mg/kg-day) 2.76E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 7.143E-08

Daily Doses and Risk for : TPH Aliphatic C10-12
CADD (mg/kg-day) 3.57E-07
LADD (mg/kg-day) 2.76E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 3.571E-06

Daily Doses and Risk for : TPH Aliphatic C16-35
CADD (mg/kg-day) 3.57E-07
LADD (mg/kg-day) 2.76E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.786E-07

Daily Doses and Risk for : TPH Aromatic C10-12
CADD (mg/kg-day) 3.57E-07
LADD (mg/kg-day) 2.76E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 8.929E-06

Daily Doses and Risk for : TPH Aromatic C16-21
CADD (mg/kg-day) 3.57E-07
LADD (mg/kg-day) 2.76E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.190E-05

Daily Doses and Risk for : 1,2,4-trimethylbenzene
CADD (mg/kg-day) 3.57E-07
LADD (mg/kg-day) 2.76E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.786E-04

Daily Doses and Risk for : Xylenes
CADD (mg/kg-day) 3.57E-07
LADD (mg/kg-day) 2.76E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.995E-06

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Methyl napthalene (2)
CADD (mg/kg-day) 3.36E-06
LADD (mg/kg-day) 2.59E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 8.393E-05

Daily Doses and Risk for : 3- & 4-methylphenol
CADD (mg/kg-day) 3.36E-06
LADD (mg/kg-day) 2.59E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 6.714E-05

Daily Doses and Risk for : Naphthalene
CADD (mg/kg-day) 4.36E-06
LADD (mg/kg-day) 3.37E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.182E-04

Daily Doses and Risk for : Phenanthrene
CADD (mg/kg-day) 4.36E-06
LADD (mg/kg-day) 3.37E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.455E-04

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	3.36E-06
LADD (mg/kg-day)	2.59E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.119E-05

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	4.36E-06
LADD (mg/kg-day)	3.37E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.455E-04

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	3.36E-05
LADD (mg/kg-day)	2.59E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.505E-04

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day)	3.36E-05
LADD (mg/kg-day)	2.59E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.714E-06

Daily Doses and Risk for : TPH Aliphatic C10-12

CADD (mg/kg-day)	3.36E-06
LADD (mg/kg-day)	2.59E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.357E-05

Daily Doses and Risk for : TPH Aliphatic C16-35

CADD (mg/kg-day)	3.36E-06
LADD (mg/kg-day)	2.59E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.679E-06

Daily Doses and Risk for : TPH Aromatic C10-12

CADD (mg/kg-day)	3.36E-06
LADD (mg/kg-day)	2.59E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	8.393E-05

Daily Doses and Risk for : TPH Aromatic C16-21

CADD (mg/kg-day)	3.36E-06
LADD (mg/kg-day)	2.59E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.119E-04

Daily Doses and Risk for : 1,2,4-trimethylbenzene

CADD (mg/kg-day)	3.36E-05
LADD (mg/kg-day)	2.59E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.679E-02

Daily Doses and Risk for : Xylenes

CADD (mg/kg-day)	3.36E-05
LADD (mg/kg-day)	2.59E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.875E-04

Title:
Zone 1 - Adult Recreational Receptor - Oral and Dermal Exposure - Soil
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Scenarios:
Adult Resident - RME

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
- Ammonia / ammonium
- Arsenic
- Benz(a)anthracene
- Benzene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Cadmium
- Chromium (III)
- Chrysene
- Cyanide
- Dibenz(a,h)anthracene
- Dibenzofuran
- Dimethylphenol (2,4)
- Ethylbenzene
- Fluoranthene
- Fluorene
- Indeno(1,2,3CD)pyrene
- Lead
- Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
INGESTION OF SOIL	
Soil Ingestion Rate (mg/day)	25.0
Exp. Frequency Soil (events/year)	365.
Exp. Duration Soil (years)	54.0
Absorption Adjustment Factor for Ingestion of Soil (-)	
Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0
Soil Bioavailability (-)	
Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0

Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

DERMAL CONTACT WITH SOIL

Total Skin Surface Area (cm^2)	4.700E+03
Fraction Skin Exposed to Soil (-)	1.00
Adherence Factor for Soil (mg/cm^2)	0.500
Exposure Freq. Soil (events/year)	365.
Exposure Duration Soil (years)	54.0
Absorption Adjustment Factor for Dermal Exposure to Soil (-)	
Ammonia / ammonium	1.0
Arsenic	3.00E-02
Benz(a)anthracene	0.13
Benzene	1.0
Benzo(a)pyrene	0.13
Benzo(b)fluoranthene	0.13
Benzo(k)fluoranthene	0.13
Cadmium	1.00E-03
Chromium (III)	1.0
Chrysene	0.13
Cyanide	1.0
Dibenz(a,h)anthracene	0.13
Dibenzofuran	0.10
Dimethylphenol (2,4)	0.10
Ethylbenzene	1.0
Fluoranthene	0.13
Fluorene	0.13
Indeno(1,2,3CD)pyrene	0.13
Lead	0.10
Nickel	1.0

Soil Bioavailability (-)	
Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)
- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (III)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Ingestion Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	7.00E-04
Chromium (III)	1.5
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02

Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	5.00E-03

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (III)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	3.50E-05
Chromium (III)	3.75E-02
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	2.00E-04

SUMMARY OF RESULTS

INGESTION OF SOIL

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00

Hazard Index (-)	1.786E-04

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	1.378E-08
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	9.643E-09
Hazard Index (-)	7.143E-04

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	1.378E-07
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	1.378E-08
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	1.378E-08
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	5.102E-04

Daily Doses and Risk for : Chromium (III)

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.381E-07

Daily Doses and Risk for : Chrysene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	1.378E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cyanide

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.786E-05

Daily Doses and Risk for : Dibenz(a,h)anthracene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	1.378E-07
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Dibenzofuran

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	5.952E-06

Daily Doses and Risk for : Dimethylphenol (2,4)

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.786E-05

Daily Doses and Risk for : Ethylbenzene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.682E-06

Daily Doses and Risk for : Fluoranthene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.857E-05

Daily Doses and Risk for : Fluorene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	8.929E-06

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	1.378E-08
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Lead

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.020E-04

Daily Doses and Risk for : Nickel

CADD (mg/kg-day)	3.57E-07
LADD (mg/kg-day)	2.76E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.143E-05

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	3.36E-05
LADD (mg/kg-day)	2.59E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	1.01E-06
LADD (mg/kg-day)	7.77E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	5.036E-04

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	4.36E-06
LADD (mg/kg-day)	3.37E-06
Cancer Risk (-)	1.683E-07
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	3.36E-05
LADD (mg/kg-day)	2.59E-05

```
  Cancer Risk (-)                9.064E-07
  Hazard Index (-)               6.714E-02

Daily Doses and Risk for : Benzo(a)pyrene
  CADD (mg/kg-day)               4.36E-06
  LADD (mg/kg-day)               3.37E-06
  Cancer Risk (-)                1.683E-06
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene
  CADD (mg/kg-day)               4.36E-06
  LADD (mg/kg-day)               3.37E-06
  Cancer Risk (-)                1.683E-07
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene
  CADD (mg/kg-day)               4.36E-06
  LADD (mg/kg-day)               3.37E-06
  Cancer Risk (-)                1.683E-07
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Cadmium
  CADD (mg/kg-day)               3.36E-08
  LADD (mg/kg-day)               2.59E-08
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               9.592E-04

Daily Doses and Risk for : Chromium (III)
  CADD (mg/kg-day)               3.36E-05
  LADD (mg/kg-day)               2.59E-05
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               8.952E-04

Daily Doses and Risk for : Chrysene
  CADD (mg/kg-day)               4.36E-06
  LADD (mg/kg-day)               3.37E-06
  Cancer Risk (-)                1.683E-08
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Cyanide
  CADD (mg/kg-day)               3.36E-05
  LADD (mg/kg-day)               2.59E-05
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               1.679E-03

Daily Doses and Risk for : Dibenz(a,h)anthracene
  CADD (mg/kg-day)               4.36E-06
  LADD (mg/kg-day)               3.37E-06
  Cancer Risk (-)                1.683E-06
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Dibenzofuran
  CADD (mg/kg-day)               3.36E-06
  LADD (mg/kg-day)               2.59E-06
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               5.595E-05

Daily Doses and Risk for : Dimethylphenol (2,4)
  CADD (mg/kg-day)               3.36E-06
  LADD (mg/kg-day)               2.59E-06
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               1.679E-04

Daily Doses and Risk for : Ethylbenzene
  CADD (mg/kg-day)               3.36E-05
  LADD (mg/kg-day)               2.59E-05
  Cancer Risk (-)                0.000E+00
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Hazard Index (-) 3.461E-04

Daily Doses and Risk for : Fluoranthene
CADD (mg/kg-day) 4.36E-06
LADD (mg/kg-day) 3.37E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 3.491E-04

Daily Doses and Risk for : Fluorene
CADD (mg/kg-day) 4.36E-06
LADD (mg/kg-day) 3.37E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.091E-04

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
CADD (mg/kg-day) 4.36E-06
LADD (mg/kg-day) 3.37E-06
Cancer Risk (-) 1.683E-07
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Lead
CADD (mg/kg-day) 3.36E-06
LADD (mg/kg-day) 2.59E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.592E-04

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 3.36E-05
LADD (mg/kg-day) 2.59E-05
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.679E-01

Zone 1 – Child Recreational Receptor – Oral and Dermal - Soil
Title:
Zone 1 - Child Recreational Receptor - Oral and Dermal Exposure - Soil
File not saved

Scenarios:
Child Resident - RME
Child Resident - Typical

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
Methyl napthalene (2)
3- & 4-methylphenol
Naphthalene
Phenanthrene
Phenol
Pyrene
Toluene
TPH Aliphatic C6-8
TPH Aliphatic C10-12
TPH Aliphatic C16-35
TPH Aromatic C10-12
TPH Aromatic C16-21
1,2,4-trimethylbenzene
Xylenes

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1	2

LIFETIME AND BODY WEIGHT

Body Weight (kg)	13.2	34.5
Lifetime (years)	70.0	70.0
INGESTION OF SOIL		
Soil Ingestion Rate (mg/day)	100.	50.0
Exp. Frequency Soil (events/year)	365.	365.
Exp. Duration Soil (years)	6.00	10.0
Absorption Adjustment Factor for Ingestion of Soil (-)		
Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0
Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0
Soil Bioavailability (-)		
Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0
Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0
DERMAL CONTACT WITH SOIL		
Total Skin Surface Area (cm^2)	2.158E+03	3.480E+03
Fraction Skin Exposed to Soil (-)	1.00	1.00
Adherence Factor for Soil (mg/cm^2)	0.500	0.500
Exposure Freq. Soil (events/year)	365.	365.
Exposure Duration Soil (years)	6.00	10.0
Absorption Adjustment Factor for Dermal Exposure to Soil (-)		
Methyl napthalene (2)	0.10	0.10
3- & 4-methylphenol	0.10	0.10
Naphthalene	0.13	0.13
Phenanthrene	0.13	0.13
Phenol	0.10	0.10
Pyrene	0.13	0.13
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	0.10	0.10
TPH Aliphatic C16-35	0.10	0.10
TPH Aromatic C10-12	0.10	0.10
TPH Aromatic C16-21	0.10	0.10
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0
Soil Bioavailability (-)		
Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0

Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)

- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0
Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND	ND
3- & 4-methylphenol	ND	ND
Naphthalene	ND	ND
Phenanthrene	ND	ND
Phenol	ND	ND
Pyrene	ND	ND
Toluene	ND	ND
TPH Aliphatic C6-8	ND	ND
TPH Aliphatic C10-12	ND	ND
TPH Aliphatic C16-35	ND	ND
TPH Aromatic C10-12	ND	ND
TPH Aromatic C16-21	ND	ND
1,2,4-trimethylbenzene	ND	ND
Xylenes	ND	ND

Ingestion Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02	4.00E-02
3- & 4-methylphenol	5.00E-02	5.00E-02
Naphthalene	2.00E-02	2.00E-02
Phenanthrene	3.00E-02	3.00E-02
Phenol	0.30	0.30
Pyrene	3.00E-02	3.00E-02
Toluene	0.22	0.22
TPH Aliphatic C6-8	5.0	5.0
TPH Aliphatic C10-12	0.10	0.10
TPH Aliphatic C16-35	2.0	2.0
TPH Aromatic C10-12	4.00E-02	4.00E-02
TPH Aromatic C16-21	3.00E-02	3.00E-03
1,2,4-trimethylbenzene	2.00E-03	2.00E-03
Xylenes	0.18	0.18

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND	ND
3- & 4-methylphenol	ND	ND
Naphthalene	ND	ND
Phenanthrene	ND	ND
Phenol	ND	ND
Pyrene	ND	ND
Toluene	ND	ND
TPH Aliphatic C6-8	ND	ND
TPH Aliphatic C10-12	ND	ND
TPH Aliphatic C16-35	ND	ND
TPH Aromatic C10-12	ND	ND
TPH Aromatic C16-21	ND	ND
1,2,4-trimethylbenzene	ND	ND
Xylenes	ND	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02	4.00E-02
3- & 4-methylphenol	5.00E-02	5.00E-02
Naphthalene	2.00E-02	2.00E-02
Phenanthrene	3.00E-02	3.00E-02
Phenol	0.30	0.30
Pyrene	3.00E-02	3.00E-02
Toluene	0.22	0.22
TPH Aliphatic C6-8	5.0	5.0
TPH Aliphatic C10-12	0.10	0.10
TPH Aliphatic C16-35	2.0	2.0
TPH Aromatic C10-12	4.00E-02	4.00E-02
TPH Aromatic C16-21	3.00E-02	3.00E-02
1,2,4-trimethylbenzene	2.00E-03	2.00E-03
Xylenes	0.18	0.18

SUMMARY OF RESULTS — SCENARIO: 1 2 Added

INGESTION OF SOIL

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.894E-04	3.623E-05	

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.515E-04	2.899E-05	

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.788E-04	7.246E-05	

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.525E-04	4.831E-05	

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00

Hazard Index (-) 2.525E-05 4.831E-06

Daily Doses and Risk for : Pyrene
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 2.525E-04 4.831E-05

Daily Doses and Risk for : Toluene
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 3.397E-05 6.499E-06

Daily Doses and Risk for : TPH Aliphatic C6-8
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 1.515E-06 2.899E-07

Daily Doses and Risk for : TPH Aliphatic C10-12
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 7.576E-05 1.449E-05

Daily Doses and Risk for : TPH Aliphatic C16-35
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 3.788E-06 7.246E-07

Daily Doses and Risk for : TPH Aromatic C10-12
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 1.894E-04 3.623E-05

Daily Doses and Risk for : TPH Aromatic C16-21
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 2.525E-04 4.831E-05

Daily Doses and Risk for : 1,2,4-trimethylbenzene
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 3.788E-03 7.246E-04

Daily Doses and Risk for : Xylenes
CADD (mg/kg-day) 7.58E-06 1.45E-06
LADD (mg/kg-day) 6.49E-07 2.07E-07 8.56E-07
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 4.232E-05 8.097E-06

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Methyl napthalene (2)
CADD (mg/kg-day) 8.17E-06 5.04E-06
LADD (mg/kg-day) 7.01E-07 7.20E-07 1.42E-06
Cancer Risk (-) 0.000E+00 0.000E+00 0.000E+00
Hazard Index (-) 2.044E-04 1.261E-04

Daily Doses and Risk for : 3- & 4-methylphenol
CADD (mg/kg-day) 8.17E-06 5.04E-06

LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.635E-04	1.009E-04	

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.313E-04	3.278E-04	

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.542E-04	2.186E-04	

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.725E-05	1.681E-05	

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.542E-04	2.186E-04	

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.666E-04	2.262E-04	

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.635E-05	1.009E-05	

Daily Doses and Risk for : TPH Aliphatic C10-12

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	8.174E-05	5.043E-05	

Daily Doses and Risk for : TPH Aliphatic C16-35

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.087E-06	2.522E-06	

Daily Doses and Risk for : TPH Aromatic C10-12

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.044E-04	1.261E-04	

Daily Doses and Risk for : TPH Aromatic C16-21

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.725E-04	1.681E-04	

Daily Doses and Risk for : 1,2,4-trimethylbenzene

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05

Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.087E-02	2.522E-02	

Daily Doses and Risk for : Xylenes

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.567E-04	2.818E-04	

Title:
Zone 1 - Child Recreational Receptor - Oral and Dermal Exposure - Soil
File not saved

Scenarios:
Child Resident - RME
Child Resident - Typical

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
- Ammonia / ammonium
- Arsenic
- Benz(a)anthracene
- Benzene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Cadmium
- Chromium (III)
- Chrysene
- Cyanide
- Dibenz(a,h)anthracene
- Dibenzofuran
- Dimethylphenol (2,4)
- Ethylbenzene
- Fluoranthene
- Fluorene
- Indeno(1,2,3CD)pyrene
- Lead
- Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1	2
LIFETIME AND BODY WEIGHT		
Body Weight (kg)	13.2	34.5
Lifetime (years)	70.0	70.0
INGESTION OF SOIL		
Soil Ingestion Rate (mg/day)	100.	50.0
Exp. Frequency Soil (events/year)	365.	365.
Exp. Duration Soil (years)	6.00	10.0
Absorption Adjustment Factor for Ingestion of Soil (-)		
Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0
Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (III)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0

Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	1.0	1.0
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0
Soil Bioavailability (-)		
Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0
Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (III)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	1.0	1.0
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0

DERMAL CONTACT WITH SOIL		
Total Skin Surface Area (cm^2)	2.158E+03	3.480E+03
Fraction Skin Exposed to Soil (-)	1.00	1.00
Adherence Factor for Soil (mg/cm^2)	0.500	0.500
Exposure Freq. Soil (events/year)	365.	365.
Exposure Duration Soil (years)	6.00	10.0
Absorption Adjustment Factor for Dermal Exposure to Soil (-)		
Ammonia / ammonium	1.0	1.0
Arsenic	3.00E-02	3.00E-02
Benz(a)anthracene	0.13	0.13
Benzene	1.0	1.0
Benzo(a)pyrene	0.13	0.13
Benzo(b)fluoranthene	0.13	0.13
Benzo(k)fluoranthene	0.13	0.13
Cadmium	1.00E-03	1.00E-03
Chromium (III)	1.0	1.0
Chrysene	0.13	0.13
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	0.13	0.13
Dibenzofuran	0.10	0.10
Dimethylphenol (2,4)	0.10	0.10
Ethylbenzene	1.0	1.0
Fluoranthene	0.13	0.13
Fluorene	0.13	0.13
Indeno(1,2,3CD)pyrene	0.13	0.13
Lead	0.10	0.10
Nickel	1.0	1.0
Soil Bioavailability (-)		
Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0

Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (III)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	1.0	1.0
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)

- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0
Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (III)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	1.0	1.0
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND	ND
Arsenic	ND	ND
Benz(a)anthracene	5.00E-02	5.00E-02
Benzene	3.50E-02	3.50E-02
Benzo(a)pyrene	0.50	0.50
Benzo(b)fluoranthene	5.00E-02	5.00E-02
Benzo(k)fluoranthene	5.00E-02	5.00E-02
Cadmium	ND	ND
Chromium (III)	ND	ND
Chrysene	5.00E-03	5.00E-03
Cyanide	ND	ND
Dibenz(a,h)anthracene	0.50	0.50
Dibenzofuran	ND	ND
Dimethylphenol (2,4)	ND	ND
Ethylbenzene	ND	ND
Fluoranthene	ND	ND
Fluorene	ND	ND
Indeno(1,2,3CD)pyrene	5.00E-02	5.00E-02
Lead	ND	ND
Nickel	ND	ND

Ingestion Reference Dose (mg/kg-day)

Ammonia / ammonium	ND	ND
Arsenic	2.00E-03	2.00E-03
Benz(a)anthracene	ND	ND
Benzene	5.00E-04	5.00E-04
Benzo(a)pyrene	ND	ND
Benzo(b)fluoranthene	ND	ND
Benzo(k)fluoranthene	ND	ND
Cadmium	7.00E-04	7.00E-04
Chromium (III)	1.5	1.5
Chrysene	ND	ND
Cyanide	2.00E-02	2.00E-02
Dibenz(a,h)anthracene	ND	ND
Dibenzofuran	6.00E-02	6.00E-02
Dimethylphenol (2,4)	2.00E-02	2.00E-02
Ethylbenzene	9.70E-02	9.70E-02
Fluoranthene	1.25E-02	1.25E-02
Fluorene	4.00E-02	4.00E-02
Indeno(1,2,3CD)pyrene	ND	ND
Lead	3.50E-03	3.50E-03
Nickel	5.00E-03	5.00E-03

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND	ND
Arsenic	ND	ND
Benz(a)anthracene	5.00E-02	5.00E-02
Benzene	3.50E-02	3.50E-02
Benzo(a)pyrene	0.50	0.50
Benzo(b)fluoranthene	5.00E-02	5.00E-02
Benzo(k)fluoranthene	5.00E-02	5.00E-02
Cadmium	ND	ND
Chromium (III)	ND	ND
Chrysene	5.00E-03	5.00E-03
Cyanide	ND	ND
Dibenz(a,h)anthracene	0.50	0.50
Dibenzofuran	ND	ND
Dimethylphenol (2,4)	ND	ND
Ethylbenzene	ND	ND
Fluoranthene	ND	ND
Fluorene	ND	ND
Indeno(1,2,3CD)pyrene	5.00E-02	5.00E-02
Lead	ND	ND
Nickel	ND	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND	ND
Arsenic	2.00E-03	2.00E-03
Benz(a)anthracene	ND	ND
Benzene	5.00E-04	5.00E-04
Benzo(a)pyrene	ND	ND
Benzo(b)fluoranthene	ND	ND
Benzo(k)fluoranthene	ND	ND
Cadmium	3.50E-05	3.50E-05
Chromium (III)	3.75E-02	3.75E-02
Chrysene	ND	ND
Cyanide	2.00E-02	2.00E-02
Dibenz(a,h)anthracene	ND	ND
Dibenzofuran	6.00E-02	6.00E-02
Dimethylphenol (2,4)	2.00E-02	2.00E-02
Ethylbenzene	9.70E-02	9.70E-02
Fluoranthene	1.25E-02	1.25E-02
Fluorene	4.00E-02	4.00E-02
Indeno(1,2,3CD)pyrene	ND	ND
Lead	3.50E-03	3.50E-03
Nickel	2.00E-04	2.00E-04

SCENARIO:

SUMMARY OF RESULTS 1 2 Added

INGESTION OF SOIL

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.788E-03	7.246E-04	

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	3.247E-08	1.035E-08	4.282E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	2.273E-08	7.246E-09	2.997E-08
Hazard Index (-)	1.515E-02	2.899E-03	

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	3.247E-07	1.035E-07	4.282E-07
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	3.247E-08	1.035E-08	4.282E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	3.247E-08	1.035E-08	4.282E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.082E-02	2.070E-03	

Daily Doses and Risk for : Chromium (III)

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.051E-06	9.662E-07	

Daily Doses and Risk for : Chrysene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	3.247E-09	1.035E-09	4.282E-09
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cyanide

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.788E-04	7.246E-05	

Daily Doses and Risk for : Dibenz(a,h)anthracene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	3.247E-07	1.035E-07	4.282E-07
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Dibenzofuran

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.263E-04	2.415E-05	

Daily Doses and Risk for : Dimethylphenol (2,4)

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.788E-04	7.246E-05	

Daily Doses and Risk for : Ethylbenzene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	7.810E-05	1.494E-05	

Daily Doses and Risk for : Fluoranthene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	6.061E-04	1.159E-04	

Daily Doses and Risk for : Fluorene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.894E-04	3.623E-05	

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	3.247E-08	1.035E-08	4.282E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Lead

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.165E-03	4.141E-04	

Daily Doses and Risk for : Nickel

CADD (mg/kg-day)	7.58E-06	1.45E-06	
LADD (mg/kg-day)	6.49E-07	2.07E-07	8.56E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.515E-03	2.899E-04	

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	2.45E-06	1.51E-06	
LADD (mg/kg-day)	2.10E-07	2.16E-07	4.26E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.226E-03	7.565E-04	

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	4.554E-08	4.683E-08	9.237E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	2.452E-07	2.522E-07	4.974E-07
Hazard Index (-)	1.635E-01	1.009E-01	

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	4.554E-07	4.683E-07	9.237E-07
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	4.554E-08	4.683E-08	9.237E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	4.554E-08	4.683E-08	9.237E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	8.17E-08	5.04E-08	
LADD (mg/kg-day)	7.01E-09	7.20E-09	1.42E-08
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.335E-03	1.441E-03	

Daily Doses and Risk for : Chromium (III)

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.180E-03	1.345E-03	

Daily Doses and Risk for : Chrysene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	4.554E-09	4.683E-09	9.237E-09
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cyanide

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.087E-03	2.522E-03	

Daily Doses and Risk for : Dibenz(a,h)anthracene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	4.554E-07	4.683E-07	9.237E-07
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Dibenzofuran

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.362E-04	8.406E-05	

Daily Doses and Risk for : Dimethylphenol (2,4)

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.087E-04	2.522E-04	

Daily Doses and Risk for : Ethylbenzene

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	8.427E-04	5.199E-04	

Daily Doses and Risk for : Fluoranthene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	8.501E-04	5.245E-04	

Daily Doses and Risk for : Fluorene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.657E-04	1.639E-04	

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene

CADD (mg/kg-day)	1.06E-05	6.56E-06	
LADD (mg/kg-day)	9.11E-07	9.37E-07	1.85E-06
Cancer Risk (-)	4.554E-08	4.683E-08	9.237E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Lead

CADD (mg/kg-day)	8.17E-06	5.04E-06	
LADD (mg/kg-day)	7.01E-07	7.20E-07	1.42E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.335E-03	1.441E-03	

Daily Doses and Risk for : Nickel

CADD (mg/kg-day)	8.17E-05	5.04E-05	
LADD (mg/kg-day)	7.01E-06	7.20E-06	1.42E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.087E-01	2.522E-01	

Zone 1 – Commercial/Industrial (Gardener) – Oral and Dermal – Soil

Title:
Zone 1 - Commercial / Industrial (Gardener) - Oral and Dermal Exposure - Soil
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Scenarios:
Worker - RME

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
- Methyl napthalene (2)
- 3- & 4-methylphenol
- Naphthalene
- Phenanthrene
- Phenol

Pyrene
Toluene
TPH Aliphatic C6-8
TPH Aliphatic C10-12
TPH Aliphatic C16-35
TPH Aromatic C10-12
TPH Aromatic C16-21
1,2,4-trimethylbenzene
Xylenes

SUMMARY OF INPUT PARAMETERS — SCENARIO: 1

LIFETIME AND BODY WEIGHT

Body Weight (kg)	70.0
Lifetime (years)	70.0

INGESTION OF SOIL

Soil Ingestion Rate (mg/day)	25.0
Exp. Frequency Soil (events/year)	240.
Exp. Duration Soil (years)	30.0
Absorption Adjustment Factor for Ingestion of Soil (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0
Soil Bioavailability (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

DERMAL CONTACT WITH SOIL

Total Skin Surface Area (cm^2)	4.700E+03
Fraction Skin Exposed to Soil (-)	1.00
Adherence Factor for Soil (mg/cm^2)	0.500
Exposure Freq. Soil (events/year)	240.
Exposure Duration Soil (years)	30.0
Absorption Adjustment Factor for Dermal Exposure to Soil (-)	
Methyl napthalene (2)	0.10
3- & 4-methylphenol	0.10
Naphthalene	0.13
Phenanthrene	0.13

Phenol	0.10
Pyrene	0.13
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	0.10
TPH Aromatic C10-12	0.10
TPH Aromatic C16-21	0.10
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

Soil Bioavailability (-)

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)
- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Ingestion Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02

3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

SUMMARY OF RESULTS

INGESTION OF SOIL

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	5.871E-06

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.697E-06

Daily Doses and Risk for : Naphthalene

```
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.174E-05

Daily Doses and Risk for : Phenanthrene
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              7.828E-06

Daily Doses and Risk for : Phenol
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              7.828E-07

Daily Doses and Risk for : Pyrene
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              7.828E-06

Daily Doses and Risk for : Toluene
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.053E-06

Daily Doses and Risk for : TPH Aliphatic C6-8
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              4.697E-08

Daily Doses and Risk for : TPH Aliphatic C10-12
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              2.348E-06

Daily Doses and Risk for : TPH Aliphatic C16-35
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.174E-07

Daily Doses and Risk for : TPH Aromatic C10-12
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              5.871E-06

Daily Doses and Risk for : TPH Aromatic C16-21
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              7.828E-06

Daily Doses and Risk for : 1,2,4-trimethylbenzene
  CADD (mg/kg-day)              2.35E-07
  LADD (mg/kg-day)              1.01E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.174E-04

Daily Doses and Risk for : Xylenes
  CADD (mg/kg-day)              2.35E-07
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LADD (mg/kg-day) 1.01E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.312E-06

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Methyl napthalene (2)
CADD (mg/kg-day) 2.21E-06
LADD (mg/kg-day) 9.46E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.519E-05

Daily Doses and Risk for : 3- & 4-methylphenol
CADD (mg/kg-day) 2.21E-06
LADD (mg/kg-day) 9.46E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 4.415E-05

Daily Doses and Risk for : Naphthalene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.435E-04

Daily Doses and Risk for : Phenanthrene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.566E-05

Daily Doses and Risk for : Phenol
CADD (mg/kg-day) 2.21E-06
LADD (mg/kg-day) 9.46E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 7.358E-06

Daily Doses and Risk for : Pyrene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.566E-05

Daily Doses and Risk for : Toluene
CADD (mg/kg-day) 2.21E-05
LADD (mg/kg-day) 9.46E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.899E-05

Daily Doses and Risk for : TPH Aliphatic C6-8
CADD (mg/kg-day) 2.21E-05
LADD (mg/kg-day) 9.46E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 4.415E-06

Daily Doses and Risk for : TPH Aliphatic C10-12
CADD (mg/kg-day) 2.21E-06
LADD (mg/kg-day) 9.46E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.207E-05

Daily Doses and Risk for : TPH Aliphatic C16-35
CADD (mg/kg-day) 2.21E-06
LADD (mg/kg-day) 9.46E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.104E-06

Daily Doses and Risk for : TPH Aromatic C10-12
CADD (mg/kg-day) 2.21E-06
LADD (mg/kg-day) 9.46E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.519E-05

Daily Doses and Risk for : TPH Aromatic C16-21
CADD (mg/kg-day) 2.21E-06
LADD (mg/kg-day) 9.46E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 7.358E-05

Daily Doses and Risk for : 1,2,4-trimethylbenzene
CADD (mg/kg-day) 2.21E-05
LADD (mg/kg-day) 9.46E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.104E-02

Daily Doses and Risk for : Xylenes
CADD (mg/kg-day) 2.21E-05
LADD (mg/kg-day) 9.46E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.233E-04

Title:
Zone 1 - Commercial / Industrial (Gardener) - Oral and Dermal Exposure - Soil
File not saved

Scenarios:
Worker - RME

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
Ammonia / ammonium
Arsenic
Benz(a)anthracene
Benzene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Cadmium
Chromium (III)
Chrysene
Cyanide
Dibenz(a,h)anthracene
Dibenzofuran
Dimethylphenol (2,4)
Ethylbenzene
Fluoranthene
Fluorene
Indeno(1,2,3CD)pyrene
Lead
Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
INGESTION OF SOIL	
Soil Ingestion Rate (mg/day)	25.0
Exp. Frequency Soil (events/year)	240.

Exp. Duration Soil (years)	30.0
Absorption Adjustment Factor for Ingestion of Soil (-)	
Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0
Soil Bioavailability (-)	
Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

DERMAL CONTACT WITH SOIL

Total Skin Surface Area (cm^2)	4.700E+03
Fraction Skin Exposed to Soil (-)	1.00
Adherence Factor for Soil (mg/cm^2)	0.500
Exposure Freq. Soil (events/year)	240.
Exposure Duration Soil (years)	30.0
Absorption Adjustment Factor for Dermal Exposure to Soil (-)	
Ammonia / ammonium	1.0
Arsenic	3.00E-02
Benz(a)anthracene	0.13
Benzene	1.0
Benzo(a)pyrene	0.13
Benzo(b)fluoranthene	0.13
Benzo(k)fluoranthene	0.13
Cadmium	1.00E-03
Chromium (III)	1.0
Chrysene	0.13
Cyanide	1.0
Dibenz(a,h)anthracene	0.13
Dibenzofuran	0.10

Dimethylphenol (2,4)	0.10
Ethylbenzene	1.0
Fluoranthene	0.13
Fluorene	0.13
Indeno(1,2,3CD)pyrene	0.13
Lead	0.10
Nickel	1.0

Soil Bioavailability (-)

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)
- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND

Chromium (III)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Ingestion Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	7.00E-04
Chromium (III)	1.5
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	5.00E-03

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (III)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	3.50E-05
Chromium (III)	3.75E-02

Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	2.00E-04

SUMMARY OF RESULTS

INGESTION OF SOIL

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.174E-04

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	5.032E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	3.523E-09
Hazard Index (-)	4.697E-04

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	5.032E-08
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	5.032E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	5.032E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	2.35E-07
LADD (mg/kg-day)	1.01E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.355E-04

Daily Doses and Risk for : Chromium (III)
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 1.566E-07

Daily Doses and Risk for : Chrysene
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 5.032E-10
  Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Cyanide
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 1.174E-05

Daily Doses and Risk for : Dibenz(a,h)anthracene
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 5.032E-08
  Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Dibenzofuran
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 3.914E-06

Daily Doses and Risk for : Dimethylphenol (2,4)
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 1.174E-05

Daily Doses and Risk for : Ethylbenzene
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 2.421E-06

Daily Doses and Risk for : Fluoranthene
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 1.879E-05

Daily Doses and Risk for : Fluorene
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 5.871E-06

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 5.032E-09
  Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Lead
  CADD (mg/kg-day) 2.35E-07
  LADD (mg/kg-day) 1.01E-07
  Cancer Risk (-) 0.000E+00
  Hazard Index (-) 6.710E-05

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 2.35E-07
LADD (mg/kg-day) 1.01E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 4.697E-05

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Ammonia / ammonium
CADD (mg/kg-day) 2.21E-05
LADD (mg/kg-day) 9.46E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Arsenic
CADD (mg/kg-day) 6.62E-07
LADD (mg/kg-day) 2.84E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 3.311E-04

Daily Doses and Risk for : Benz(a)anthracene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 6.149E-08
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Benzene
CADD (mg/kg-day) 2.21E-05
LADD (mg/kg-day) 9.46E-06
Cancer Risk (-) 3.311E-07
Hazard Index (-) 4.415E-02

Daily Doses and Risk for : Benzo(a)pyrene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 6.149E-07
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 6.149E-08
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 6.149E-08
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Cadmium
CADD (mg/kg-day) 2.21E-08
LADD (mg/kg-day) 9.46E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 6.307E-04

Daily Doses and Risk for : Chromium (III)
CADD (mg/kg-day) 2.21E-05
LADD (mg/kg-day) 9.46E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.886E-04

Daily Doses and Risk for : Chrysene
CADD (mg/kg-day) 2.87E-06
LADD (mg/kg-day) 1.23E-06
Cancer Risk (-) 6.149E-09

Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cyanide

CADD (mg/kg-day)	2.21E-05
LADD (mg/kg-day)	9.46E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.104E-03

Daily Doses and Risk for : Dibenz(a,h)anthracene

CADD (mg/kg-day)	2.87E-06
LADD (mg/kg-day)	1.23E-06
Cancer Risk (-)	6.149E-07
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Dibenzofuran

CADD (mg/kg-day)	2.21E-06
LADD (mg/kg-day)	9.46E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.679E-05

Daily Doses and Risk for : Dimethylphenol (2,4)

CADD (mg/kg-day)	2.21E-06
LADD (mg/kg-day)	9.46E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.104E-04

Daily Doses and Risk for : Ethylbenzene

CADD (mg/kg-day)	2.21E-05
LADD (mg/kg-day)	9.46E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.276E-04

Daily Doses and Risk for : Fluoranthene

CADD (mg/kg-day)	2.87E-06
LADD (mg/kg-day)	1.23E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.296E-04

Daily Doses and Risk for : Fluorene

CADD (mg/kg-day)	2.87E-06
LADD (mg/kg-day)	1.23E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.174E-05

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene

CADD (mg/kg-day)	2.87E-06
LADD (mg/kg-day)	1.23E-06
Cancer Risk (-)	6.149E-08
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Lead

CADD (mg/kg-day)	2.21E-06
LADD (mg/kg-day)	9.46E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.307E-04

Daily Doses and Risk for : Nickel

CADD (mg/kg-day)	2.21E-05
LADD (mg/kg-day)	9.46E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.104E-01

Zone 1 – Sub-Surface Maintenance Worker – Oral and Dermal – Soil

Title:
Zone 1 - Sub-Surface Maintenance Worker - Oral and Dermal Exposure - Soil
File not saved

Scenarios:
Worker - RME

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
   Methyl napthalene (2)
   3- & 4-methylphenol
   Naphthalene
   Phenanthrene
   Phenol
   Pyrene
   Toluene
   TPH Aliphatic C6-8
   TPH Aliphatic C10-12
   TPH Aliphatic C16-35
   TPH Aromatic C10-12
   TPH Aromatic C16-21
   1,2,4-trimethylbenzene
   Xylenes

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
INGESTION OF SOIL	
Soil Ingestion Rate (mg/day)	330.
Exp. Frequency Soil (events/year)	15.0
Exp. Duration Soil (years)	1.00
Absorption Adjustment Factor for Ingestion of Soil (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0
Soil Bioavailability (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0

Xylenes	1.0

DERMAL CONTACT WITH SOIL

Total Skin Surface Area (cm^2)	3.870E+03
Fraction Skin Exposed to Soil (-)	1.00
Adherence Factor for Soil (mg/cm^2)	1.50
Exposure Freq. Soil (events/year)	15.0
Exposure Duration Soil (years)	1.00
Absorption Adjustment Factor for Dermal Exposure to Soil (-)	
Methyl napthalene (2)	0.10
3- & 4-methylphenol	0.10
Naphthalene	0.13
Phenanthrene	0.13
Phenol	0.10
Pyrene	0.13
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	0.10
TPH Aromatic C10-12	0.10
TPH Aromatic C16-21	0.10
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

Soil Bioavailability (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)
- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND

Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Ingestion Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

SUMMARY OF RESULTS

INGESTION OF SOIL

Daily Doses and Risk for : Methyl napthalene (2)
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.843E-06

Daily Doses and Risk for : 3- & 4-methylphenol
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.875E-06

Daily Doses and Risk for : Naphthalene
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	9.687E-06

Daily Doses and Risk for : Phenanthrene
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.458E-06

Daily Doses and Risk for : Phenol
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.458E-07

Daily Doses and Risk for : Pyrene
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.458E-06

Daily Doses and Risk for : Toluene
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	8.688E-07

Daily Doses and Risk for : TPH Aliphatic C6-8
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.875E-08

Daily Doses and Risk for : TPH Aliphatic C10-12
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.937E-06

Daily Doses and Risk for : TPH Aliphatic C16-35
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	9.687E-08

Daily Doses and Risk for : TPH Aromatic C10-12
CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.843E-06

Daily Doses and Risk for : TPH Aromatic C16-21
CADD (mg/kg-day) 1.94E-07
LADD (mg/kg-day) 2.77E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 6.458E-06

Daily Doses and Risk for : 1,2,4-trimethylbenzene
CADD (mg/kg-day) 1.94E-07
LADD (mg/kg-day) 2.77E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.687E-05

Daily Doses and Risk for : Xylenes
CADD (mg/kg-day) 1.94E-07
LADD (mg/kg-day) 2.77E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.082E-06

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Methyl napthalene (2)
CADD (mg/kg-day) 3.41E-07
LADD (mg/kg-day) 4.87E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 8.520E-06

Daily Doses and Risk for : 3- & 4-methylphenol
CADD (mg/kg-day) 3.41E-07
LADD (mg/kg-day) 4.87E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 6.816E-06

Daily Doses and Risk for : Naphthalene
CADD (mg/kg-day) 4.43E-07
LADD (mg/kg-day) 6.33E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.215E-05

Daily Doses and Risk for : Phenanthrene
CADD (mg/kg-day) 4.43E-07
LADD (mg/kg-day) 6.33E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.477E-05

Daily Doses and Risk for : Phenol
CADD (mg/kg-day) 3.41E-07
LADD (mg/kg-day) 4.87E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.136E-06

Daily Doses and Risk for : Pyrene
CADD (mg/kg-day) 4.43E-07
LADD (mg/kg-day) 6.33E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.477E-05

Daily Doses and Risk for : Toluene
CADD (mg/kg-day) 3.41E-06
LADD (mg/kg-day) 4.87E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.528E-05

Daily Doses and Risk for : TPH Aliphatic C6-8
CADD (mg/kg-day) 3.41E-06
LADD (mg/kg-day) 4.87E-08
Cancer Risk (-) 0.000E+00

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      Hazard Index (-)              6.816E-07

   Daily Doses and Risk for : TPH Aliphatic C10-12
      CADD (mg/kg-day)              3.41E-07
      LADD (mg/kg-day)              4.87E-09
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              3.408E-06

   Daily Doses and Risk for : TPH Aliphatic C16-35
      CADD (mg/kg-day)              3.41E-07
      LADD (mg/kg-day)              4.87E-09
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              1.704E-07

   Daily Doses and Risk for : TPH Aromatic C10-12
      CADD (mg/kg-day)              3.41E-07
      LADD (mg/kg-day)              4.87E-09
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              8.520E-06

   Daily Doses and Risk for : TPH Aromatic C16-21
      CADD (mg/kg-day)              3.41E-07
      LADD (mg/kg-day)              4.87E-09
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              1.136E-05

   Daily Doses and Risk for : 1,2,4-trimethylbenzene
      CADD (mg/kg-day)              3.41E-06
      LADD (mg/kg-day)              4.87E-08
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              1.704E-03

   Daily Doses and Risk for : Xylenes
      CADD (mg/kg-day)              3.41E-06
      LADD (mg/kg-day)              4.87E-08
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              1.904E-05
 Title:
Zone 1 - Sub-Surface Maintenance Worker - Oral and Dermal Exposure - Soil
File not saved

Scenarios:
Worker - RME

Routes:
INGESTION OF SOIL
DERMAL CONTACT WITH SOIL

Chemicals:
   Ammonia / ammonium
   Arsenic
   Benz(a)anthracene
   Benzene
   Benzo(a)pyrene
   Benzo(b)fluoranthene
   Benzo(k)fluoranthene
   Cadmium
   Chromium (III)
   Chrysene
   Cyanide
   Dibenz(a,h)anthracene
   Dibenzofuran
   Dimethylphenol (2,4)
   Ethylbenzene
   Fluoranthene
   Fluorene
   Indeno(1,2,3CD)pyrene
```

Lead
Nickel

SUMMARY OF INPUT PARAMETERS — SCENARIO: 1

LIFETIME AND BODY WEIGHT

Body Weight (kg)	70.0
Lifetime (years)	70.0

INGESTION OF SOIL

Soil Ingestion Rate (mg/day)	330.
Exp. Frequency Soil (events/year)	15.0
Exp. Duration Soil (years)	1.00

Absorption Adjustment Factor for Ingestion of Soil (-)

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

Soil Bioavailability (-)

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

DERMAL CONTACT WITH SOIL

Total Skin Surface Area (cm^2)	3.870E+03
Fraction Skin Exposed to Soil (-)	1.00
Adherence Factor for Soil (mg/cm^2)	1.50
Exposure Freq. Soil (events/year)	15.0
Exposure Duration Soil (years)	1.00

Absorption Adjustment Factor for

Dermal Exposure to Soil (-)

Ammonia / ammonium	1.0
Arsenic	3.00E-02
Benz(a)anthracene	0.13
Benzene	1.0
Benzo(a)pyrene	0.13
Benzo(b)fluoranthene	0.13
Benzo(k)fluoranthene	0.13
Cadmium	1.00E-03
Chromium (III)	1.0
Chrysene	0.13
Cyanide	1.0
Dibenz(a,h)anthracene	0.13
Dibenzofuran	0.10
Dimethylphenol (2,4)	0.10
Ethylbenzene	1.0
Fluoranthene	0.13
Fluorene	0.13
Indeno(1,2,3CD)pyrene	0.13
Lead	0.10
Nickel	1.0

Soil Bioavailability (-)

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

MEDIA CONCENTRATIONS

Concentration in Surficial Soil (mg/kg)

- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (III)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0

Nickel	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (III)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Ingestion Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	7.00E-04
Chromium (III)	1.5
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	5.00E-03

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (III)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND

Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	3.50E-05
Chromium (III)	3.75E-02
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	2.00E-04

SUMMARY OF RESULTS

INGESTION OF SOIL

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	0.000E+00
Hazard Index (-)	9.687E-05

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	1.384E-10
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	9.687E-11
Hazard Index (-)	3.875E-04

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09
Cancer Risk (-)	1.384E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	1.94E-07
LADD (mg/kg-day)	2.77E-09

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  Cancer Risk (-)               1.384E-10
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               1.384E-10
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Cadmium
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              2.768E-04

Daily Doses and Risk for : Chromium (III)
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.292E-07

Daily Doses and Risk for : Chrysene
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               1.384E-11
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Cyanide
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              9.687E-06

Daily Doses and Risk for : Dibenz(a,h)anthracene
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               1.384E-09
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Dibenzofuran
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              3.229E-06

Daily Doses and Risk for : Dimethylphenol (2,4)
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              9.687E-06

Daily Doses and Risk for : Ethylbenzene
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.997E-06

Daily Doses and Risk for : Fluoranthene
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.550E-05

Daily Doses and Risk for : Fluorene
  CADD (mg/kg-day)              1.94E-07
  LADD (mg/kg-day)              2.77E-09
  Cancer Risk (-)               0.000E+00
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Hazard Index (-) 4.843E-06

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
CADD (mg/kg-day) 1.94E-07
LADD (mg/kg-day) 2.77E-09
Cancer Risk (-) 1.384E-10
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Lead
CADD (mg/kg-day) 1.94E-07
LADD (mg/kg-day) 2.77E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.535E-05

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 1.94E-07
LADD (mg/kg-day) 2.77E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 3.875E-05

DERMAL CONTACT WITH SOIL

Daily Doses and Risk for : Ammonia / ammonium
CADD (mg/kg-day) 3.41E-06
LADD (mg/kg-day) 4.87E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Arsenic
CADD (mg/kg-day) 1.02E-07
LADD (mg/kg-day) 1.46E-09
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.112E-05

Daily Doses and Risk for : Benz(a)anthracene
CADD (mg/kg-day) 4.43E-07
LADD (mg/kg-day) 6.33E-09
Cancer Risk (-) 3.165E-10
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Benzene
CADD (mg/kg-day) 3.41E-06
LADD (mg/kg-day) 4.87E-08
Cancer Risk (-) 1.704E-09
Hazard Index (-) 6.816E-03

Daily Doses and Risk for : Benzo(a)pyrene
CADD (mg/kg-day) 4.43E-07
LADD (mg/kg-day) 6.33E-09
Cancer Risk (-) 3.165E-09
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene
CADD (mg/kg-day) 4.43E-07
LADD (mg/kg-day) 6.33E-09
Cancer Risk (-) 3.165E-10
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene
CADD (mg/kg-day) 4.43E-07
LADD (mg/kg-day) 6.33E-09
Cancer Risk (-) 3.165E-10
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Cadmium
CADD (mg/kg-day) 3.41E-09

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  LADD (mg/kg-day)              4.87E-11
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              9.737E-05

Daily Doses and Risk for : Chromium (III)
  CADD (mg/kg-day)              3.41E-06
  LADD (mg/kg-day)              4.87E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              9.088E-05

Daily Doses and Risk for : Chrysene
  CADD (mg/kg-day)              4.43E-07
  LADD (mg/kg-day)              6.33E-09
  Cancer Risk (-)               3.165E-11
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Cyanide
  CADD (mg/kg-day)              3.41E-06
  LADD (mg/kg-day)              4.87E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.704E-04

Daily Doses and Risk for : Dibenz(a,h)anthracene
  CADD (mg/kg-day)              4.43E-07
  LADD (mg/kg-day)              6.33E-09
  Cancer Risk (-)               3.165E-09
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Dibenzofuran
  CADD (mg/kg-day)              3.41E-07
  LADD (mg/kg-day)              4.87E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              5.680E-06

Daily Doses and Risk for : Dimethylphenol (2,4)
  CADD (mg/kg-day)              3.41E-07
  LADD (mg/kg-day)              4.87E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.704E-05

Daily Doses and Risk for : Ethylbenzene
  CADD (mg/kg-day)              3.41E-06
  LADD (mg/kg-day)              4.87E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              3.513E-05

Daily Doses and Risk for : Fluoranthene
  CADD (mg/kg-day)              4.43E-07
  LADD (mg/kg-day)              6.33E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              3.544E-05

Daily Doses and Risk for : Fluorene
  CADD (mg/kg-day)              4.43E-07
  LADD (mg/kg-day)              6.33E-09
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.108E-05

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
  CADD (mg/kg-day)              4.43E-07
  LADD (mg/kg-day)              6.33E-09
  Cancer Risk (-)               3.165E-10
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Lead
  CADD (mg/kg-day)              3.41E-07
  LADD (mg/kg-day)              4.87E-09
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Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.737E-05

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 3.41E-06
LADD (mg/kg-day) 4.87E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.704E-02

Zone 1 – Sub-Surface Maintenance Worker – Oral and Dermal – Seepage Water

Title:
Zone 1 - Sub-Surface Maintenance Worker - Oral and Dermal Exposure - Seepage Wat
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Scenarios:
Worker - RME

Routes:
INGESTION WHILE SWIMMING
DERMAL CONTACT WHILE SWIMMING

Chemicals:
Methyl napthalene (2)
3- & 4-methylphenol
Naphthalene
Phenanthrene
Phenol
Pyrene
Toluene
TPH Aliphatic C6-8
TPH Aliphatic C10-12
TPH Aliphatic C16-35
TPH Aromatic C10-12
TPH Aromatic C16-21
1,2,4-trimethylbenzene
Xylenes

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
INGESTION WHILE SWIMMING	
Ingestion rate (ml/hr)	0.625
Exp. Freq Surface Water (events/yr)	15.0
Time in Surface Water (hour/day)	8.00
Exp. Duration Surface Water (years)	1.00
Absorption Adjustment Factor for	
Ingestion of water (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

DERMAL CONTACT WHILE SWIMMING

Total Skin Surface Area (cm^2)	2.129E+03
Time in Surface Water (hour/day)	8.00
Exp. Freq Surface Water (events/yr)	15.0
Exp. Duration Surface Water (years)	1.00
Dermal Permeability Surface Water (cm/hour)	
Methyl napthalene (2)	9.17E-02
3- & 4-methylphenol	7.66E-03
Naphthalene	4.66E-02
Phenanthrene	0.14
Phenol	4.34E-03
Pyrene	0.20
Toluene	3.11E-02
TPH Aliphatic C6-8	0.75
TPH Aliphatic C10-12	1.9
TPH Aliphatic C16-35	0.30
TPH Aromatic C10-12	8.70E-02
TPH Aromatic C16-21	0.30
1,2,4-trimethylbenzene	8.57E-02
Xylenes	4.71E-02
Absorption Adjustment Factor for Dermal Exposure to Water (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)
- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND

Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Ingestion Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

SUMMARY OF RESULTS

INGESTION WHILE SWIMMING

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	2.94E-06

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  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              7.339E-05

Daily Doses and Risk for : 3- & 4-methylphenol
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              5.871E-05

Daily Doses and Risk for : Naphthalene
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.468E-04

Daily Doses and Risk for : Phenanthrene
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              9.785E-05

Daily Doses and Risk for : Phenol
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              9.785E-06

Daily Doses and Risk for : Pyrene
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              9.785E-05

Daily Doses and Risk for : Toluene
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.316E-05

Daily Doses and Risk for : TPH Aliphatic C6-8
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              5.871E-07

Daily Doses and Risk for : TPH Aliphatic C10-12
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              2.935E-05

Daily Doses and Risk for : TPH Aliphatic C16-35
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.468E-06

Daily Doses and Risk for : TPH Aromatic C10-12
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              7.339E-05

Daily Doses and Risk for : TPH Aromatic C16-21
  CADD (mg/kg-day)              2.94E-06
  LADD (mg/kg-day)              4.19E-08
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Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.785E-05

Daily Doses and Risk for : 1,2,4-trimethylbenzene
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.468E-03

Daily Doses and Risk for : Xylenes
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.640E-05

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Methyl napthalene (2)
CADD (mg/kg-day) 9.17E-04
LADD (mg/kg-day) 1.31E-05
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.292E-02

Daily Doses and Risk for : 3- & 4-methylphenol
CADD (mg/kg-day) 7.66E-05
LADD (mg/kg-day) 1.09E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.532E-03

Daily Doses and Risk for : Naphthalene
CADD (mg/kg-day) 4.66E-04
LADD (mg/kg-day) 6.66E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.330E-02

Daily Doses and Risk for : Phenanthrene
CADD (mg/kg-day) 1.44E-03
LADD (mg/kg-day) 2.06E-05
Cancer Risk (-) 0.000E+00
Hazard Index (-) 4.800E-02

Daily Doses and Risk for : Phenol
CADD (mg/kg-day) 4.34E-05
LADD (mg/kg-day) 6.20E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.447E-04

Daily Doses and Risk for : Pyrene
CADD (mg/kg-day) 2.01E-03
LADD (mg/kg-day) 2.87E-05
Cancer Risk (-) 0.000E+00
Hazard Index (-) 6.699E-02

Daily Doses and Risk for : Toluene
CADD (mg/kg-day) 3.11E-04
LADD (mg/kg-day) 4.44E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.395E-03

Daily Doses and Risk for : TPH Aliphatic C6-8
CADD (mg/kg-day) 7.50E-03
LADD (mg/kg-day) 1.07E-04
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.500E-03

Daily Doses and Risk for : TPH Aliphatic C10-12

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      CADD (mg/kg-day)              1.90E-02
      LADD (mg/kg-day)              2.71E-04
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              1.900E-01

   Daily Doses and Risk for : TPH Aliphatic C16-35
      CADD (mg/kg-day)              3.00E-03
      LADD (mg/kg-day)              4.29E-05
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              1.500E-03

   Daily Doses and Risk for : TPH Aromatic C10-12
      CADD (mg/kg-day)              8.70E-04
      LADD (mg/kg-day)              1.24E-05
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              2.175E-02

   Daily Doses and Risk for : TPH Aromatic C16-21
      CADD (mg/kg-day)              3.00E-03
      LADD (mg/kg-day)              4.29E-05
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              9.999E-02

   Daily Doses and Risk for : 1,2,4-trimethylbenzene
      CADD (mg/kg-day)              8.57E-04
      LADD (mg/kg-day)              1.22E-05
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              4.285E-01

   Daily Doses and Risk for : Xylenes
      CADD (mg/kg-day)              4.71E-04
      LADD (mg/kg-day)              6.73E-06
      Cancer Risk (-)               0.000E+00
      Hazard Index (-)              2.631E-03
Title:
Zone 1 - Sub-Surface Maintenance Worker - Oral and Dermal Exposure - Seepage Wat
File not saved

Scenarios:
Worker - RME

Routes:
INGESTION WHILE SWIMMING
DERMAL CONTACT WHILE SWIMMING

Chemicals:
   Ammonia / ammonium
   Arsenic
   Benz(a)anthracene
   Benzene
   Benzo(a)pyrene
   Benzo(b)fluoranthene
   Benzo(k)fluoranthene
   Cadmium
   Chromium (VI)
   Chrysene
   Cyanide
   Dibenz(a,h)anthracene
   Dibenzofuran
   Dimethylphenol (2,4)
   Ethylbenzene
   Fluoranthene
   Fluorene
   Indeno(1,2,3CD)pyrene
   Lead
   Nickel
```

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
INGESTION WHILE SWIMMING	
Ingestion rate (ml/hr)	0.625
Exp. Freq Surface Water (events/yr)	15.0
Time in Surface Water (hour/day)	8.00
Exp. Duration Surface Water (years)	1.00
Absorption Adjustment Factor for Ingestion of water (-)	
Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0
DERMAL CONTACT WHILE SWIMMING	
Total Skin Surface Area (cm^2)	2.129E+03
Time in Surface Water (hour/day)	8.00
Exp. Freq Surface Water (events/yr)	15.0
Exp. Duration Surface Water (years)	1.00
Dermal Permeability Surface Water (cm/hour)	
Ammonia / ammonium	1.00E-03
Arsenic	1.00E-03
Benz(a)anthracene	0.55
Benzene	1.49E-02
Benzo(a)pyrene	0.71
Benzo(b)fluoranthene	0.42
Benzo(k)fluoranthene	0.69
Cadmium	1.00E-03
Chromium (VI)	2.00E-03
Chrysene	0.60
Cyanide	7.50E-04
Dibenz(a,h)anthracene	0.95
Dibenzofuran	9.75E-02
Dimethylphenol (2,4)	1.09E-02
Ethylbenzene	4.93E-02
Fluoranthene	0.31
Fluorene	0.11
Indeno(1,2,3CD)pyrene	1.2
Lead	1.00E-04
Nickel	2.00E-04
Absorption Adjustment Factor for Dermal Exposure to Water (-)	
Ammonia / ammonium	1.0
Arsenic	1.0

Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	0.10
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)

- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

SLOPE FACTORS AND REFERENCE DOSES

Ingestion Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (VI)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND

Nickel	ND

Ingestion Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	7.00E-04
Chromium (VI)	1.00E-03
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	5.00E-03

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (VI)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	3.50E-05
Chromium (VI)	2.50E-05
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	2.00E-04

SUMMARY OF RESULTS

INGESTION WHILE SWIMMING

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.468E-03

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	2.097E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	1.468E-09
Hazard Index (-)	5.871E-03

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	2.097E-08
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	2.097E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	2.097E-09
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.193E-03

Daily Doses and Risk for : Chromium (VI)

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.935E-03

Daily Doses and Risk for : Chrysene

CADD (mg/kg-day)	2.94E-06
LADD (mg/kg-day)	4.19E-08
Cancer Risk (-)	2.097E-10

Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Cyanide
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.468E-04

Daily Doses and Risk for : Dibenz(a,h)anthracene
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 2.097E-08
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Dibenzofuran
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 4.892E-05

Daily Doses and Risk for : Dimethylphenol (2,4)
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.468E-04

Daily Doses and Risk for : Ethylbenzene
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 3.026E-05

Daily Doses and Risk for : Fluoranthene
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.348E-04

Daily Doses and Risk for : Fluorene
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 7.339E-05

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 2.097E-09
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Lead
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 8.387E-04

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 2.94E-06
LADD (mg/kg-day) 4.19E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.871E-04

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Ammonia / ammonium
CADD (mg/kg-day) 1.00E-05

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  LADD (mg/kg-day)              1.43E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Arsenic
  CADD (mg/kg-day)              1.00E-05
  LADD (mg/kg-day)              1.43E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              5.000E-03

Daily Doses and Risk for : Benz(a)anthracene
  CADD (mg/kg-day)              5.52E-03
  LADD (mg/kg-day)              7.89E-05
  Cancer Risk (-)               3.943E-06
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Benzene
  CADD (mg/kg-day)              1.49E-04
  LADD (mg/kg-day)              2.13E-06
  Cancer Risk (-)               7.449E-08
  Hazard Index (-)              2.980E-01

Daily Doses and Risk for : Benzo(a)pyrene
  CADD (mg/kg-day)              7.13E-03
  LADD (mg/kg-day)              1.02E-04
  Cancer Risk (-)               5.092E-05
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene
  CADD (mg/kg-day)              4.17E-03
  LADD (mg/kg-day)              5.96E-05
  Cancer Risk (-)               2.978E-06
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene
  CADD (mg/kg-day)              6.91E-03
  LADD (mg/kg-day)              9.87E-05
  Cancer Risk (-)               4.935E-06
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Cadmium
  CADD (mg/kg-day)              1.00E-05
  LADD (mg/kg-day)              1.43E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              2.857E-01

Daily Doses and Risk for : Chromium (VI)
  CADD (mg/kg-day)              2.00E-05
  LADD (mg/kg-day)              2.86E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              7.999E-01

Daily Doses and Risk for : Chrysene
  CADD (mg/kg-day)              5.96E-03
  LADD (mg/kg-day)              8.51E-05
  Cancer Risk (-)               4.257E-07
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Cyanide
  CADD (mg/kg-day)              7.50E-06
  LADD (mg/kg-day)              1.07E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              3.750E-04

Daily Doses and Risk for : Dibenz(a,h)anthracene
  CADD (mg/kg-day)              9.53E-03
  LADD (mg/kg-day)              1.36E-04
```

Cancer Risk (-) 6.807E-05
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Dibenzofuran
CADD (mg/kg-day) 9.75E-05
LADD (mg/kg-day) 1.39E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.625E-03

Daily Doses and Risk for : Dimethylphenol (2,4)
CADD (mg/kg-day) 1.09E-04
LADD (mg/kg-day) 1.56E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.450E-03

Daily Doses and Risk for : Ethylbenzene
CADD (mg/kg-day) 4.93E-04
LADD (mg/kg-day) 7.04E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.082E-03

Daily Doses and Risk for : Fluoranthene
CADD (mg/kg-day) 3.08E-03
LADD (mg/kg-day) 4.40E-05
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.464E-01

Daily Doses and Risk for : Fluorene
CADD (mg/kg-day) 1.10E-03
LADD (mg/kg-day) 1.57E-05
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.750E-02

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
CADD (mg/kg-day) 1.24E-02
LADD (mg/kg-day) 1.77E-04
Cancer Risk (-) 8.856E-06
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Lead
CADD (mg/kg-day) 1.00E-06
LADD (mg/kg-day) 1.43E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.857E-04

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 2.00E-06
LADD (mg/kg-day) 2.86E-08
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.999E-03

Zone 2 – Occasional Car Park User – Dermal Risk – Seepage Water – Adult
Title:
Zone 2 - Car Park Occassional User - Dermal Exposure - Adult - Infiltrating Seep
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Scenarios:
Adult Resident - RME

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
Ammonia / ammonium
Arsenic
Benz(a)anthracene

Benzene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Cadmium
Chromium (VI)
Chrysene
Cyanide
Dibenz(a,h)anthracene
Dibenzofuran
Dimethylphenol (2,4)
Ethylbenzene
Fluoranthene
Fluorene
Indeno(1,2,3CD)pyrene
Lead
Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
DERMAL CONTACT WHILE SWIMMING	
Total Skin Surface Area (cm^2)	904.
Time in Surface Water (hour/day)	0.250
Exp. Freq Surface Water (events/yr)	6.00
Exp. Duration Surface Water (years)	54.0
Dermal Permeability Surface Water (cm/hour)	
Ammonia / ammonium	1.00E-03
Arsenic	1.00E-03
Benz(a)anthracene	0.55
Benzene	1.49E-02
Benzo(a)pyrene	0.71
Benzo(b)fluoranthene	0.42
Benzo(k)fluoranthene	0.69
Cadmium	1.00E-03
Chromium (VI)	2.00E-03
Chrysene	0.60
Cyanide	7.50E-04
Dibenz(a,h)anthracene	0.95
Dibenzofuran	9.75E-02
Dimethylphenol (2,4)	1.09E-02
Ethylbenzene	4.93E-02
Fluoranthene	0.31
Fluorene	0.11
Indeno(1,2,3CD)pyrene	1.2
Lead	1.00E-04
Nickel	2.00E-04
Absorption Adjustment Factor for Dermal Exposure to Water (-)	
Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0

Dibenzofuran	0.10
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)

- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (VI)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND

Cadmium	3.50E-05
Chromium (VI)	2.50E-05
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	2.00E-04

SUMMARY OF RESULTS

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	5.31E-08
LADD (mg/kg-day)	4.09E-08
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	5.31E-08
LADD (mg/kg-day)	4.09E-08
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.654E-05

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	2.93E-05
LADD (mg/kg-day)	2.26E-05
Cancer Risk (-)	1.130E-06
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	7.91E-07
LADD (mg/kg-day)	6.10E-07
Cancer Risk (-)	2.135E-08
Hazard Index (-)	1.582E-03

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	3.78E-05
LADD (mg/kg-day)	2.92E-05
Cancer Risk (-)	1.460E-05
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	2.21E-05
LADD (mg/kg-day)	1.71E-05
Cancer Risk (-)	8.536E-07
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	3.67E-05
LADD (mg/kg-day)	2.83E-05
Cancer Risk (-)	1.415E-06
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	5.31E-08
LADD (mg/kg-day)	4.09E-08

```
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.516E-03

Daily Doses and Risk for : Chromium (VI)
  CADD (mg/kg-day)              1.06E-07
  LADD (mg/kg-day)              8.19E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              4.246E-03

Daily Doses and Risk for : Chrysene
  CADD (mg/kg-day)              3.16E-05
  LADD (mg/kg-day)              2.44E-05
  Cancer Risk (-)               1.220E-07
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Cyanide
  CADD (mg/kg-day)              3.98E-08
  LADD (mg/kg-day)              3.07E-08
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.990E-06

Daily Doses and Risk for : Dibenz(a,h)anthracene
  CADD (mg/kg-day)              5.06E-05
  LADD (mg/kg-day)              3.90E-05
  Cancer Risk (-)               1.951E-05
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Dibenzofuran
  CADD (mg/kg-day)              5.17E-07
  LADD (mg/kg-day)              3.99E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              8.624E-06

Daily Doses and Risk for : Dimethylphenol (2,4)
  CADD (mg/kg-day)              5.78E-07
  LADD (mg/kg-day)              4.46E-07
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              2.892E-05

Daily Doses and Risk for : Ethylbenzene
  CADD (mg/kg-day)              2.62E-06
  LADD (mg/kg-day)              2.02E-06
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              2.697E-05

Daily Doses and Risk for : Fluoranthene
  CADD (mg/kg-day)              1.63E-05
  LADD (mg/kg-day)              1.26E-05
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.308E-03

Daily Doses and Risk for : Fluorene
  CADD (mg/kg-day)              5.84E-06
  LADD (mg/kg-day)              4.50E-06
  Cancer Risk (-)               0.000E+00
  Hazard Index (-)              1.459E-04

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
  CADD (mg/kg-day)              6.58E-05
  LADD (mg/kg-day)              5.08E-05
  Cancer Risk (-)               2.538E-06
  Hazard Index (-)              0.000E+00

Daily Doses and Risk for : Lead
  CADD (mg/kg-day)              5.31E-09
  LADD (mg/kg-day)              4.09E-09
  Cancer Risk (-)               0.000E+00
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     Hazard Index (-)              1.516E-06

   Daily Doses and Risk for : Nickel
     CADD (mg/kg-day)              1.06E-08
     LADD (mg/kg-day)              8.19E-09
     Cancer Risk (-)               0.000E+00
     Hazard Index (-)              5.307E-05
Title:
Zone 2 - Car Park Occassional User - Dermal Exposure - Adult - Infiltrating Seep
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Scenarios:
Adult Resident - RME

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
   Methyl napthalene (2)
   3- & 4-methylphenol
   Naphthalene
   Phenanthrene
   Phenol
   Pyrene
   Toluene
   TPH Aliphatic C6-8
   TPH Aliphatic C10-12
   TPH Aliphatic C16-35
   TPH Aromatic C10-12
   TPH Aromatic C16-21
   1,2,4-trimethylbenzene
   Xylenes

                                                      SCENARIO:
SUMMARY OF INPUT PARAMETERS                          1
-----------------------------------------------------------------------

LIFETIME AND BODY WEIGHT
   Body Weight (kg)                            70.0
   Lifetime (years)                            70.0

DERMAL CONTACT WHILE SWIMMING
   Total Skin Surface Area (cm^2)              904.
   Time in Surface Water (hour/day)           0.250
   Exp. Freq Surface Water (events/yr)         6.00
   Exp. Duration Surface Water (years)         54.0
   Dermal Permeability Surface Water (cm/hour)
            Methyl napthalene (2)              9.17E-02
            3- & 4-methylphenol                7.66E-03
            Naphthalene                        4.66E-02
            Phenanthrene                       0.14
            Phenol                             4.34E-03
            Pyrene                             0.20
            Toluene                            3.11E-02
            TPH Aliphatic C6-8                 0.75
            TPH Aliphatic C10-12                1.9
            TPH Aliphatic C16-35               0.30
            TPH Aromatic C10-12                8.70E-02
            TPH Aromatic C16-21                0.30
            1,2,4-trimethylbenzene             8.57E-02
            Xylenes                            4.71E-02

   Absorption Adjustment Factor for
      Dermal Exposure to Water (-)
            Methyl napthalene (2)               1.0
            3- & 4-methylphenol                 1.0
            Naphthalene                         1.0
```

Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)

- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

SUMMARY OF RESULTS

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	4.87E-06
LADD (mg/kg-day)	3.75E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.217E-04

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	4.07E-07
LADD (mg/kg-day)	3.14E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	8.131E-06

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	2.47E-06
LADD (mg/kg-day)	1.91E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.237E-04

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	7.64E-06
LADD (mg/kg-day)	5.90E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.547E-04

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	2.30E-07
LADD (mg/kg-day)	1.78E-07
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.678E-07

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	1.07E-05
LADD (mg/kg-day)	8.23E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.556E-04

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	1.65E-06
LADD (mg/kg-day)	1.27E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.402E-06

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day)	3.98E-05
LADD (mg/kg-day)	3.07E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.961E-06

Daily Doses and Risk for : TPH Aliphatic C10-12

CADD (mg/kg-day)	1.01E-04
LADD (mg/kg-day)	7.78E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.008E-03

Daily Doses and Risk for : TPH Aliphatic C16-35

CADD (mg/kg-day)	1.59E-05
LADD (mg/kg-day)	1.23E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.961E-06

Daily Doses and Risk for : TPH Aromatic C10-12
CADD (mg/kg-day) 4.62E-06
LADD (mg/kg-day) 3.56E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.154E-04

Daily Doses and Risk for : TPH Aromatic C16-21
CADD (mg/kg-day) 1.59E-05
LADD (mg/kg-day) 1.23E-05
Cancer Risk (-) 0.000E+00
Hazard Index (-) 5.307E-04

Daily Doses and Risk for : 1,2,4-trimethylbenzene
CADD (mg/kg-day) 4.55E-06
LADD (mg/kg-day) 3.51E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.274E-03

Daily Doses and Risk for : Xylenes
CADD (mg/kg-day) 2.50E-06
LADD (mg/kg-day) 1.93E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.396E-05

Zone 2 – Occasional Car Park User – Dermal Risk – Seepage Water – Child

Title:
Zone 2 - Car Park Occassional User - Dermal Exposure - Child - Infiltrating Seep
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Scenarios:
Child Resident - RME
Child Resident - Typical

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
Methyl napthalene (2)
3- & 4-methylphenol
Naphthalene
Phenanthrene
Phenol
Pyrene
Toluene
TPH Aliphatic C6-8
TPH Aliphatic C10-12
TPH Aliphatic C16-35
TPH Aromatic C10-12
TPH Aromatic C16-21
1,2,4-trimethylbenzene
Xylenes

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1	2
LIFETIME AND BODY WEIGHT		
Body Weight (kg)	13.2	34.5
Lifetime (years)	70.0	70.0
DERMAL CONTACT WHILE SWIMMING		
Total Skin Surface Area (cm^2)	313.	633.
Time in Surface Water (hour/day)	0.250	0.250
Exp. Freq Surface Water (events/yr)	6.00	6.00
Exp. Duration Surface Water (years)	6.00	10.0
Dermal Permeability Surface Water (cm/hour)		

Methyl napthalene (2)	9.17E-02	9.17E-02
3- & 4-methylphenol	7.66E-03	7.66E-03
Naphthalene	4.66E-02	4.66E-02
Phenanthrene	0.14	0.14
Phenol	4.34E-03	4.34E-03
Pyrene	0.20	0.20
Toluene	3.11E-02	3.11E-02
TPH Aliphatic C6-8	0.75	0.75
TPH Aliphatic C10-12	1.9	1.9
TPH Aliphatic C16-35	0.30	0.30
TPH Aromatic C10-12	8.70E-02	8.70E-02
TPH Aromatic C16-21	0.30	0.30
1,2,4-trimethylbenzene	8.57E-02	8.57E-02
Xylenes	4.71E-02	4.71E-02

Absorption Adjustment Factor for
Dermal Exposure to Water (-)

Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0
Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)
- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0
Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND	ND
3- & 4-methylphenol	ND	ND
Naphthalene	ND	ND
Phenanthrene	ND	ND
Phenol	ND	ND
Pyrene	ND	ND
Toluene	ND	ND
TPH Aliphatic C6-8	ND	ND
TPH Aliphatic C10-12	ND	ND
TPH Aliphatic C16-35	ND	ND
TPH Aromatic C10-12	ND	ND
TPH Aromatic C16-21	ND	ND

1,2,4-trimethylbenzene	ND	ND
Xylenes	ND	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02	4.00E-02
3- & 4-methylphenol	5.00E-02	5.00E-02
Naphthalene	2.00E-02	2.00E-02
Phenanthrene	3.00E-02	3.00E-02
Phenol	0.30	0.30
Pyrene	3.00E-02	3.00E-02
Toluene	0.22	0.22
TPH Aliphatic C6-8	5.0	5.0
TPH Aliphatic C10-12	0.10	0.10
TPH Aliphatic C16-35	2.0	2.0
TPH Aromatic C10-12	4.00E-02	4.00E-02
TPH Aromatic C16-21	3.00E-02	3.00E-02
1,2,4-trimethylbenzene	2.00E-03	2.00E-03
Xylenes	0.18	0.18

SUMMARY OF RESULTS — SCENARIO: 1 | 2 | Added

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	8.94E-06	6.91E-06	
LADD (mg/kg-day)	7.66E-07	9.88E-07	1.75E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.234E-04	1.729E-04	

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	7.46E-07	5.78E-07	
LADD (mg/kg-day)	6.40E-08	8.25E-08	1.46E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.493E-05	1.155E-05	

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	4.54E-06	3.51E-06	
LADD (mg/kg-day)	3.89E-07	5.02E-07	8.91E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.271E-04	1.757E-04	

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	1.40E-05	1.09E-05	
LADD (mg/kg-day)	1.20E-06	1.55E-06	2.75E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.677E-04	3.619E-04	

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	4.23E-07	3.27E-07	
LADD (mg/kg-day)	3.63E-08	4.67E-08	8.30E-08
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.410E-06	1.091E-06	

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	1.96E-05	1.52E-05	
LADD (mg/kg-day)	1.68E-06	2.17E-06	3.84E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	6.529E-04	5.052E-04	

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	3.03E-06	2.35E-06	
LADD (mg/kg-day)	2.60E-07	3.35E-07	5.95E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00

Hazard Index (-)	1.359E-05	1.052E-05	

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day)	7.31E-05	5.66E-05	
LADD (mg/kg-day)	6.26E-06	8.08E-06	1.43E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.462E-05	1.131E-05	

Daily Doses and Risk for : TPH Aliphatic C10-12

CADD (mg/kg-day)	1.85E-04	1.43E-04	
LADD (mg/kg-day)	1.59E-05	2.05E-05	3.63E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.851E-03	1.433E-03	

Daily Doses and Risk for : TPH Aliphatic C16-35

CADD (mg/kg-day)	2.92E-05	2.26E-05	
LADD (mg/kg-day)	2.51E-06	3.23E-06	5.74E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.462E-05	1.131E-05	

Daily Doses and Risk for : TPH Aromatic C10-12

CADD (mg/kg-day)	8.48E-06	6.56E-06	
LADD (mg/kg-day)	7.27E-07	9.37E-07	1.66E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.119E-04	1.640E-04	

Daily Doses and Risk for : TPH Aromatic C16-21

CADD (mg/kg-day)	2.92E-05	2.26E-05	
LADD (mg/kg-day)	2.51E-06	3.23E-06	5.74E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	9.745E-04	7.540E-04	

Daily Doses and Risk for : 1,2,4-trimethylbenzene

CADD (mg/kg-day)	8.35E-06	6.46E-06	
LADD (mg/kg-day)	7.16E-07	9.23E-07	1.64E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.176E-03	3.231E-03	

Daily Doses and Risk for : Xylenes

CADD (mg/kg-day)	4.59E-06	3.55E-06	
LADD (mg/kg-day)	3.93E-07	5.07E-07	9.01E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.564E-05	1.984E-05	

Title:
Zone 2 - Car Park Occassional User - Dermal Exposure - Child - Infiltrating Seep
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Scenarios:
Child Resident - RME
Child Resident - Typical

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
- Ammonia / ammonium
- Arsenic
- Benz(a)anthracene
- Benzene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Cadmium
- Chromium (VI)
- Chrysene
- Cyanide

Dibenz(a,h)anthracene
Dibenzofuran
Dimethylphenol (2,4)
Ethylbenzene
Fluoranthene
Fluorene
Indeno(1,2,3CD)pyrene
Lead
Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1	2
LIFETIME AND BODY WEIGHT		
Body Weight (kg)	13.2	34.5
Lifetime (years)	70.0	70.0
DERMAL CONTACT WHILE SWIMMING		
Total Skin Surface Area (cm^2)	313.	633.
Time in Surface Water (hour/day)	0.250	0.250
Exp. Freq Surface Water (events/yr)	6.00	6.00
Exp. Duration Surface Water (years)	6.00	10.0
Dermal Permeability Surface Water (cm/hour)		
Ammonia / ammonium	1.00E-03	1.00E-03
Arsenic	1.00E-03	1.00E-03
Benz(a)anthracene	0.55	0.55
Benzene	1.49E-02	1.49E-02
Benzo(a)pyrene	0.71	0.71
Benzo(b)fluoranthene	0.42	0.42
Benzo(k)fluoranthene	0.69	0.69
Cadmium	1.00E-03	1.00E-03
Chromium (VI)	2.00E-03	2.00E-03
Chrysene	0.60	0.60
Cyanide	7.50E-04	7.50E-04
Dibenz(a,h)anthracene	0.95	0.95
Dibenzofuran	9.75E-02	9.75E-02
Dimethylphenol (2,4)	1.09E-02	1.09E-02
Ethylbenzene	4.93E-02	4.93E-02
Fluoranthene	0.31	0.31
Fluorene	0.11	0.11
Indeno(1,2,3CD)pyrene	1.2	1.2
Lead	1.00E-04	1.00E-04
Nickel	2.00E-04	2.00E-04
Absorption Adjustment Factor for Dermal Exposure to Water (-)		
Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0
Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (VI)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	0.10	0.10
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)
- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0
Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (VI)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	1.0	1.0
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND	ND
Arsenic	ND	ND
Benz(a)anthracene	5.00E-02	5.00E-02
Benzene	3.50E-02	3.50E-02
Benzo(a)pyrene	0.50	0.50
Benzo(b)fluoranthene	5.00E-02	5.00E-02
Benzo(k)fluoranthene	5.00E-02	5.00E-02
Cadmium	ND	ND
Chromium (VI)	ND	ND
Chrysene	5.00E-03	5.00E-03
Cyanide	ND	ND
Dibenz(a,h)anthracene	0.50	0.50
Dibenzofuran	ND	ND
Dimethylphenol (2,4)	ND	ND
Ethylbenzene	ND	ND
Fluoranthene	ND	ND
Fluorene	ND	ND
Indeno(1,2,3CD)pyrene	5.00E-02	5.00E-02
Lead	ND	ND
Nickel	ND	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND	ND
Arsenic	2.00E-03	2.00E-03
Benz(a)anthracene	ND	ND
Benzene	5.00E-04	5.00E-04
Benzo(a)pyrene	ND	ND
Benzo(b)fluoranthene	ND	ND
Benzo(k)fluoranthene	ND	ND
Cadmium	3.50E-05	3.50E-05
Chromium (VI)	2.50E-05	2.50E-05
Chrysene	ND	ND
Cyanide	2.00E-02	2.00E-02
Dibenz(a,h)anthracene	ND	ND
Dibenzofuran	6.00E-02	6.00E-02
Dimethylphenol (2,4)	2.00E-02	2.00E-02
Ethylbenzene	9.70E-02	9.70E-02

Fluoranthene	1.25E-02	1.25E-02
Fluorene	4.00E-02	4.00E-02
Indeno(1,2,3CD)pyrene	ND	ND
Lead	3.50E-03	3.50E-03
Nickel	2.00E-04	2.00E-04

SCENARIO:

SUMMARY OF RESULTS 1 2 Added

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	9.74E-08	7.54E-08	
LADD (mg/kg-day)	8.35E-09	1.08E-08	1.91E-08
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	9.74E-08	7.54E-08	
LADD (mg/kg-day)	8.35E-09	1.08E-08	1.91E-08
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.872E-05	3.770E-05	

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	5.38E-05	4.16E-05	
LADD (mg/kg-day)	4.61E-06	5.95E-06	1.06E-05
Cancer Risk (-)	2.305E-07	2.973E-07	5.278E-07
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	1.45E-06	1.12E-06	
LADD (mg/kg-day)	1.24E-07	1.60E-07	2.85E-07
Cancer Risk (-)	4.356E-09	5.617E-09	9.973E-09
Hazard Index (-)	2.904E-03	2.247E-03	

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	6.95E-05	5.38E-05	
LADD (mg/kg-day)	5.96E-06	7.68E-06	1.36E-05
Cancer Risk (-)	2.978E-06	3.840E-06	6.818E-06
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	4.06E-05	3.14E-05	
LADD (mg/kg-day)	3.48E-06	4.49E-06	7.97E-06
Cancer Risk (-)	1.742E-07	2.246E-07	3.987E-07
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	6.73E-05	5.21E-05	
LADD (mg/kg-day)	5.77E-06	7.44E-06	1.32E-05
Cancer Risk (-)	2.886E-07	3.722E-07	6.607E-07
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	9.74E-08	7.54E-08	
LADD (mg/kg-day)	8.35E-09	1.08E-08	1.91E-08
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.784E-03	2.154E-03	

Daily Doses and Risk for : Chromium (VI)

CADD (mg/kg-day)	1.95E-07	1.51E-07	
LADD (mg/kg-day)	1.67E-08	2.15E-08	3.82E-08
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	7.796E-03	6.032E-03	

Daily Doses and Risk for : Chrysene

CADD (mg/kg-day)	5.81E-05	4.49E-05	
LADD (mg/kg-day)	4.98E-06	6.42E-06	1.14E-05
Cancer Risk (-)	2.489E-08	3.210E-08	5.699E-08
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cyanide

CADD (mg/kg-day)	7.31E-08	5.66E-08	
LADD (mg/kg-day)	6.26E-09	8.08E-09	1.43E-08
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.654E-06	2.828E-06	

Daily Doses and Risk for : Dibenz(a,h)anthracene

CADD (mg/kg-day)	9.29E-05	7.19E-05	
LADD (mg/kg-day)	7.96E-06	1.03E-05	1.82E-05
Cancer Risk (-)	3.980E-06	5.133E-06	9.113E-06
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Dibenzofuran

CADD (mg/kg-day)	9.50E-07	7.35E-07	
LADD (mg/kg-day)	8.14E-08	1.05E-07	1.86E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.584E-05	1.225E-05	

Daily Doses and Risk for : Dimethylphenol (2,4)

CADD (mg/kg-day)	1.06E-06	8.22E-07	
LADD (mg/kg-day)	9.10E-08	1.17E-07	2.08E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.311E-05	4.109E-05	

Daily Doses and Risk for : Ethylbenzene

CADD (mg/kg-day)	4.80E-06	3.72E-06	
LADD (mg/kg-day)	4.12E-07	5.31E-07	9.43E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	4.953E-05	3.832E-05	

Daily Doses and Risk for : Fluoranthene

CADD (mg/kg-day)	3.00E-05	2.32E-05	
LADD (mg/kg-day)	2.57E-06	3.32E-06	5.89E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.401E-03	1.858E-03	

Daily Doses and Risk for : Fluorene

CADD (mg/kg-day)	1.07E-05	8.29E-06	
LADD (mg/kg-day)	9.19E-07	1.18E-06	2.10E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.680E-04	2.074E-04	

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene

CADD (mg/kg-day)	1.21E-04	9.35E-05	
LADD (mg/kg-day)	1.04E-05	1.34E-05	2.37E-05
Cancer Risk (-)	5.179E-07	6.678E-07	1.186E-06
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Lead

CADD (mg/kg-day)	9.74E-09	7.54E-09	
LADD (mg/kg-day)	8.35E-10	1.08E-09	1.91E-09
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.784E-06	2.154E-06	

Daily Doses and Risk for : Nickel

CADD (mg/kg-day)	1.95E-08	1.51E-08	
LADD (mg/kg-day)	1.67E-09	2.15E-09	3.82E-09
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	9.745E-05	7.540E-05	

Irrigation Water – Dermal Exposure – Adult

Title:
Irigation Water - Dermal Exposure - Adult - Grass Saturated with Sprinkler Water
File not saved

Scenarios:
Adult Resident - RME

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
- Ammonia / ammonium
- Arsenic
- Benz(a)anthracene
- Benzene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Cadmium
- Chromium (VI)
- Chrysene
- Cyanide
- Dibenz(a,h)anthracene
- Dibenzofuran
- Dimethylphenol (2,4)
- Ethylbenzene
- Fluoranthene
- Fluorene
- Indeno(1,2,3CD)pyrene
- Lead
- Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
DERMAL CONTACT WHILE SWIMMING	
Total Skin Surface Area (cm^2)	4.700E+03
Time in Surface Water (hour/day)	2.00
Exp. Freq Surface Water (events/yr)	26.0
Exp. Duration Surface Water (years)	54.0
Dermal Permeability Surface Water (cm/hour)	
Ammonia / ammonium	1.00E-03
Arsenic	1.00E-03
Benz(a)anthracene	0.55
Benzene	1.49E-02
Benzo(a)pyrene	0.71
Benzo(b)fluoranthene	0.42
Benzo(k)fluoranthene	0.69
Cadmium	1.00E-03
Chromium (VI)	2.00E-03
Chrysene	0.60
Cyanide	7.50E-04
Dibenz(a,h)anthracene	0.95
Dibenzofuran	9.75E-02
Dimethylphenol (2,4)	1.09E-02
Ethylbenzene	4.93E-02
Fluoranthene	0.31
Fluorene	0.11
Indeno(1,2,3CD)pyrene	1.2
Lead	1.00E-04

Nickel	2.00E-04

Absorption Adjustment Factor for Dermal Exposure to Water (-)

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	0.10
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)
- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (VI)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND

Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	3.50E-05
Chromium (VI)	2.50E-05
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	2.00E-04

SUMMARY OF RESULTS

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	9.57E-06
LADD (mg/kg-day)	7.38E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	9.57E-06
LADD (mg/kg-day)	7.38E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.783E-03

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	5.28E-03
LADD (mg/kg-day)	4.07E-03
Cancer Risk (-)	2.037E-04
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzene

CADD (mg/kg-day)	1.43E-04
LADD (mg/kg-day)	1.10E-04
Cancer Risk (-)	3.848E-06
Hazard Index (-)	2.851E-01

Daily Doses and Risk for : Benzo(a)pyrene

CADD (mg/kg-day)	6.82E-03
LADD (mg/kg-day)	5.26E-03
Cancer Risk (-)	2.631E-03
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene

CADD (mg/kg-day)	3.99E-03
LADD (mg/kg-day)	3.08E-03
Cancer Risk (-)	1.539E-04
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene

CADD (mg/kg-day)	6.61E-03
LADD (mg/kg-day)	5.10E-03
Cancer Risk (-)	2.549E-04
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	9.57E-06
LADD (mg/kg-day)	7.38E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.733E-01

Daily Doses and Risk for : Chromium (VI)

CADD (mg/kg-day)	1.91E-05
LADD (mg/kg-day)	1.48E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	7.652E-01

Daily Doses and Risk for : Chrysene

CADD (mg/kg-day)	5.70E-03
LADD (mg/kg-day)	4.40E-03
Cancer Risk (-)	2.199E-05
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Cyanide

CADD (mg/kg-day)	7.17E-06
LADD (mg/kg-day)	5.53E-06
Cancer Risk (-)	0.000E+00
Hazard Index (-)	3.587E-04

Daily Doses and Risk for : Dibenz(a,h)anthracene

CADD (mg/kg-day)	9.12E-03
LADD (mg/kg-day)	7.03E-03
Cancer Risk (-)	3.516E-03
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Dibenzofuran

CADD (mg/kg-day)	9.33E-05
LADD (mg/kg-day)	7.19E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.554E-03

Daily Doses and Risk for : Dimethylphenol (2,4)

CADD (mg/kg-day)	1.04E-04
LADD (mg/kg-day)	8.04E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	5.213E-03

Daily Doses and Risk for : Ethylbenzene

CADD (mg/kg-day)	4.72E-04
LADD (mg/kg-day)	3.64E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.862E-03

Daily Doses and Risk for : Fluoranthene

CADD (mg/kg-day)	2.95E-03
LADD (mg/kg-day)	2.27E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.357E-01

Daily Doses and Risk for : Fluorene
CADD (mg/kg-day) 1.05E-03
LADD (mg/kg-day) 8.12E-04
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.631E-02

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
CADD (mg/kg-day) 1.19E-02
LADD (mg/kg-day) 9.15E-03
Cancer Risk (-) 4.575E-04
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Lead
CADD (mg/kg-day) 9.57E-07
LADD (mg/kg-day) 7.38E-07
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.733E-04

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 1.91E-06
LADD (mg/kg-day) 1.48E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.566E-03

Title:
Irigation Water - Dermal Exposure - Adult - Grass Saturated with Sprinkler Water
File not saved

Scenarios:
Adult Resident - RME

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
Methyl napthalene (2)
3- & 4-methylphenol
Naphthalene
Phenanthrene
Phenol
Pyrene
Toluene
TPH Aliphatic C6-8
TPH Aliphatic C10-12
TPH Aliphatic C16-35
TPH Aromatic C10-12
TPH Aromatic C16-21
1,2,4-trimethylbenzene
Xylenes

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
DERMAL CONTACT WHILE SWIMMING	
Total Skin Surface Area (cm^2)	4.700E+03
Time in Surface Water (hour/day)	2.00
Exp. Freq Surface Water (events/yr)	26.0
Exp. Duration Surface Water (years)	54.0
Dermal Permeability Surface Water (cm/hour)	
Methyl napthalene (2)	9.17E-02
3- & 4-methylphenol	7.66E-03
Naphthalene	4.66E-02
Phenanthrene	0.14

Phenol	4.34E-03
Pyrene	0.20
Toluene	3.11E-02
TPH Aliphatic C6-8	0.75
TPH Aliphatic C10-12	1.9
TPH Aliphatic C16-35	0.30
TPH Aromatic C10-12	8.70E-02
TPH Aromatic C16-21	0.30
1,2,4-trimethylbenzene	8.57E-02
Xylenes	4.71E-02

Absorption Adjustment Factor for Dermal Exposure to Water (-)

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)
- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND
Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

SUMMARY OF RESULTS

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	8.77E-04
LADD (mg/kg-day)	6.77E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.193E-02

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	7.33E-05
LADD (mg/kg-day)	5.65E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.465E-03

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	4.46E-04
LADD (mg/kg-day)	3.44E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.229E-02

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	1.38E-03
LADD (mg/kg-day)	1.06E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.591E-02

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	4.15E-05
LADD (mg/kg-day)	3.20E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.384E-04

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	1.92E-03
LADD (mg/kg-day)	1.48E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.409E-02

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	2.97E-04
LADD (mg/kg-day)	2.29E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.334E-03

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day)	7.17E-03

LADD (mg/kg-day) 5.53E-03
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.435E-03

Daily Doses and Risk for : TPH Aliphatic C10-12
CADD (mg/kg-day) 1.82E-02
LADD (mg/kg-day) 1.40E-02
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.817E-01

Daily Doses and Risk for : TPH Aliphatic C16-35
CADD (mg/kg-day) 2.87E-03
LADD (mg/kg-day) 2.21E-03
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.435E-03

Daily Doses and Risk for : TPH Aromatic C10-12
CADD (mg/kg-day) 8.32E-04
LADD (mg/kg-day) 6.42E-04
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.081E-02

Daily Doses and Risk for : TPH Aromatic C16-21
CADD (mg/kg-day) 2.87E-03
LADD (mg/kg-day) 2.21E-03
Cancer Risk (-) 0.000E+00
Hazard Index (-) 9.566E-02

Daily Doses and Risk for : 1,2,4-trimethylbenzene
CADD (mg/kg-day) 8.20E-04
LADD (mg/kg-day) 6.32E-04
Cancer Risk (-) 0.000E+00
Hazard Index (-) 4.099E-01

Daily Doses and Risk for : Xylenes
CADD (mg/kg-day) 4.51E-04
LADD (mg/kg-day) 3.48E-04
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.517E-03

Irrigation Water – Dermal Exposure - Child
Title:
Irigation Water - Dermal Exposure - Child - Grass Saturated with Sprinkler Water
File not saved

Scenarios:
Child Resident - RME
Child Resident - Typical

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
Methyl napthalene (2)
3- & 4-methylphenol
Naphthalene
Phenanthrene
Phenol
Pyrene
Toluene
TPH Aliphatic C6-8
TPH Aliphatic C10-12
TPH Aliphatic C16-35
TPH Aromatic C10-12
TPH Aromatic C16-21
1,2,4-trimethylbenzene

Xylenes

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1	2
LIFETIME AND BODY WEIGHT		
Body Weight (kg)	13.2	34.5
Lifetime (years)	70.0	70.0
DERMAL CONTACT WHILE SWIMMING		
Total Skin Surface Area (cm^2)	3.598E+03	3.480E+03
Time in Surface Water (hour/day)	2.00	2.00
Exp. Freq Surface Water (events/yr)	26.0	26.0
Exp. Duration Surface Water (years)	6.00	10.0
Dermal Permeability Surface Water (cm/hour)		
Methyl napthalene (2)	9.17E-02	9.17E-02
3- & 4-methylphenol	7.66E-03	7.66E-03
Naphthalene	4.66E-02	4.66E-02
Phenanthrene	0.14	0.14
Phenol	4.34E-03	4.34E-03
Pyrene	0.20	0.20
Toluene	3.11E-02	3.11E-02
TPH Aliphatic C6-8	0.75	0.75
TPH Aliphatic C10-12	1.9	1.9
TPH Aliphatic C16-35	0.30	0.30
TPH Aromatic C10-12	8.70E-02	8.70E-02
TPH Aromatic C16-21	0.30	0.30
1,2,4-trimethylbenzene	8.57E-02	8.57E-02
Xylenes	4.71E-02	4.71E-02
Absorption Adjustment Factor for Dermal Exposure to Water (-)		
Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0
Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0
MEDIA CONCENTRATIONS		
Concentration in Surface Water (mg/l) - Used to calculate risk and hazard index.		
Methyl napthalene (2)	1.0	1.0
3- & 4-methylphenol	1.0	1.0
Naphthalene	1.0	1.0
Phenanthrene	1.0	1.0
Phenol	1.0	1.0
Pyrene	1.0	1.0
Toluene	1.0	1.0
TPH Aliphatic C6-8	1.0	1.0
TPH Aliphatic C10-12	1.0	1.0
TPH Aliphatic C16-35	1.0	1.0
TPH Aromatic C10-12	1.0	1.0
TPH Aromatic C16-21	1.0	1.0
1,2,4-trimethylbenzene	1.0	1.0
Xylenes	1.0	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND	ND
3- & 4-methylphenol	ND	ND
Naphthalene	ND	ND
Phenanthrene	ND	ND
Phenol	ND	ND
Pyrene	ND	ND
Toluene	ND	ND
TPH Aliphatic C6-8	ND	ND
TPH Aliphatic C10-12	ND	ND
TPH Aliphatic C16-35	ND	ND
TPH Aromatic C10-12	ND	ND
TPH Aromatic C16-21	ND	ND
1,2,4-trimethylbenzene	ND	ND
Xylenes	ND	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02	4.00E-02
3- & 4-methylphenol	5.00E-02	5.00E-02
Naphthalene	2.00E-02	2.00E-02
Phenanthrene	3.00E-02	3.00E-02
Phenol	0.30	0.30
Pyrene	3.00E-02	3.00E-02
Toluene	0.22	0.22
TPH Aliphatic C6-8	5.0	5.0
TPH Aliphatic C10-12	0.10	0.10
TPH Aliphatic C16-35	2.0	2.0
TPH Aromatic C10-12	4.00E-02	4.00E-02
TPH Aromatic C16-21	3.00E-02	3.00E-02
1,2,4-trimethylbenzene	2.00E-03	2.00E-03
Xylenes	0.18	0.18

SUMMARY OF RESULTS	SCENARIO: 1	2	Added

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	3.56E-03	1.32E-03	
LADD (mg/kg-day)	3.05E-04	1.88E-04	4.93E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	8.902E-02	3.294E-02	

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	2.97E-04	1.10E-04	
LADD (mg/kg-day)	2.55E-05	1.57E-05	4.12E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.949E-03	2.202E-03	

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	1.81E-03	6.70E-04	
LADD (mg/kg-day)	1.55E-04	9.57E-05	2.51E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	9.048E-02	3.348E-02	

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	5.59E-03	2.07E-03	
LADD (mg/kg-day)	4.79E-04	2.96E-04	7.75E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.864E-01	6.898E-02	

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	1.69E-04	6.24E-05	
LADD (mg/kg-day)	1.44E-05	8.91E-06	2.34E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.618E-04	2.079E-04	

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	7.81E-03	2.89E-03	
LADD (mg/kg-day)	6.69E-04	4.13E-04	1.08E-03
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.602E-01	9.628E-02	

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	1.21E-03	4.47E-04	
LADD (mg/kg-day)	1.04E-04	6.38E-05	1.67E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.416E-03	2.004E-03	

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day)	2.91E-02	1.08E-02	
LADD (mg/kg-day)	2.50E-03	1.54E-03	4.04E-03
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.825E-03	2.156E-03	

Daily Doses and Risk for : TPH Aliphatic C10-12

CADD (mg/kg-day)	7.38E-02	2.73E-02	
LADD (mg/kg-day)	6.32E-03	3.90E-03	1.02E-02
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	7.378E-01	2.730E-01	

Daily Doses and Risk for : TPH Aliphatic C16-35

CADD (mg/kg-day)	1.16E-02	4.31E-03	
LADD (mg/kg-day)	9.99E-04	6.16E-04	1.61E-03
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	5.825E-03	2.156E-03	

Daily Doses and Risk for : TPH Aromatic C10-12

CADD (mg/kg-day)	3.38E-03	1.25E-03	
LADD (mg/kg-day)	2.90E-04	1.79E-04	4.68E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	8.446E-02	3.126E-02	

Daily Doses and Risk for : TPH Aromatic C16-21

CADD (mg/kg-day)	1.16E-02	4.31E-03	
LADD (mg/kg-day)	9.99E-04	6.16E-04	1.61E-03
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.883E-01	1.437E-01	

Daily Doses and Risk for : 1,2,4-trimethylbenzene

CADD (mg/kg-day)	3.33E-03	1.23E-03	
LADD (mg/kg-day)	2.85E-04	1.76E-04	4.61E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.664E+00	6.158E-01	

Daily Doses and Risk for : Xylenes

CADD (mg/kg-day)	1.83E-03	6.77E-04	
LADD (mg/kg-day)	1.57E-04	9.67E-05	2.53E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.022E-02	3.781E-03	

Title:
Irigation Water - Dermal Exposure - Child - Grass Saturated with Sprinkler Water
File not saved

Scenarios:
Child Resident - RME
Child Resident - Typical

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
- Ammonia / ammonium
- Arsenic
- Benz(a)anthracene
- Benzene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Cadmium
- Chromium (VI)
- Chrysene
- Cyanide
- Dibenz(a,h)anthracene
- Dibenzofuran
- Dimethylphenol (2,4)
- Ethylbenzene
- Fluoranthene
- Fluorene
- Indeno(1,2,3CD)pyrene
- Lead
- Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1	2
LIFETIME AND BODY WEIGHT		
Body Weight (kg)	13.2	34.5
Lifetime (years)	70.0	70.0
DERMAL CONTACT WHILE SWIMMING		
Total Skin Surface Area (cm^2)	3.598E+03	3.480E+03
Time in Surface Water (hour/day)	2.00	2.00
Exp. Freq Surface Water (events/yr)	26.0	26.0
Exp. Duration Surface Water (years)	6.00	10.0
Dermal Permeability Surface Water (cm/hour)		
Ammonia / ammonium	1.00E-03	1.00E-03
Arsenic	1.00E-03	1.00E-03
Benz(a)anthracene	0.55	0.55
Benzene	1.49E-02	1.49E-02
Benzo(a)pyrene	0.71	0.71
Benzo(b)fluoranthene	0.42	0.42
Benzo(k)fluoranthene	0.69	0.69
Cadmium	1.00E-03	1.00E-03
Chromium (VI)	2.00E-03	2.00E-03
Chrysene	0.60	0.60
Cyanide	7.50E-04	7.50E-04
Dibenz(a,h)anthracene	0.95	0.95
Dibenzofuran	9.75E-02	9.75E-02
Dimethylphenol (2,4)	1.09E-02	1.09E-02
Ethylbenzene	4.93E-02	4.93E-02
Fluoranthene	0.31	0.31
Fluorene	0.11	0.11
Indeno(1,2,3CD)pyrene	1.2	1.2
Lead	1.00E-04	1.00E-04
Nickel	2.00E-04	2.00E-04
Absorption Adjustment Factor for Dermal Exposure to Water (-)		
Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0

Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (VI)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	0.10	0.10
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)

- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0	1.0
Arsenic	1.0	1.0
Benz(a)anthracene	1.0	1.0
Benzene	1.0	1.0
Benzo(a)pyrene	1.0	1.0
Benzo(b)fluoranthene	1.0	1.0
Benzo(k)fluoranthene	1.0	1.0
Cadmium	1.0	1.0
Chromium (VI)	1.0	1.0
Chrysene	1.0	1.0
Cyanide	1.0	1.0
Dibenz(a,h)anthracene	1.0	1.0
Dibenzofuran	1.0	1.0
Dimethylphenol (2,4)	1.0	1.0
Ethylbenzene	1.0	1.0
Fluoranthene	1.0	1.0
Fluorene	1.0	1.0
Indeno(1,2,3CD)pyrene	1.0	1.0
Lead	1.0	1.0
Nickel	1.0	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND	ND
Arsenic	ND	ND
Benz(a)anthracene	5.00E-02	5.00E-02
Benzene	3.50E-02	3.50E-02
Benzo(a)pyrene	0.50	0.50
Benzo(b)fluoranthene	5.00E-02	5.00E-02
Benzo(k)fluoranthene	5.00E-02	5.00E-02
Cadmium	ND	ND
Chromium (VI)	ND	ND
Chrysene	5.00E-03	5.00E-03
Cyanide	ND	ND
Dibenz(a,h)anthracene	0.50	0.50
Dibenzofuran	ND	ND
Dimethylphenol (2,4)	ND	ND
Ethylbenzene	ND	ND
Fluoranthene	ND	ND
Fluorene	ND	ND
Indeno(1,2,3CD)pyrene	5.00E-02	5.00E-02
Lead	ND	ND
Nickel	ND	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND	ND
Arsenic	2.00E-03	2.00E-03
Benz(a)anthracene	ND	ND
Benzene	5.00E-04	5.00E-04
Benzo(a)pyrene	ND	ND
Benzo(b)fluoranthene	ND	ND
Benzo(k)fluoranthene	ND	ND
Cadmium	3.50E-05	3.50E-05
Chromium (VI)	2.50E-05	2.50E-05
Chrysene	ND	ND
Cyanide	2.00E-02	2.00E-02
Dibenz(a,h)anthracene	ND	ND
Dibenzofuran	6.00E-02	6.00E-02
Dimethylphenol (2,4)	2.00E-02	2.00E-02
Ethylbenzene	9.70E-02	9.70E-02
Fluoranthene	1.25E-02	1.25E-02
Fluorene	4.00E-02	4.00E-02
Indeno(1,2,3CD)pyrene	ND	ND
Lead	3.50E-03	3.50E-03
Nickel	2.00E-04	2.00E-04

SUMMARY OF RESULTS	SCENARIO: 1	2	Added

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Ammonia / ammonium			
CADD (mg/kg-day)	3.88E-05	1.44E-05	
LADD (mg/kg-day)	3.33E-06	2.05E-06	5.38E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	0.000E+00	0.000E+00	
Daily Doses and Risk for : Arsenic			
CADD (mg/kg-day)	3.88E-05	1.44E-05	
LADD (mg/kg-day)	3.33E-06	2.05E-06	5.38E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.942E-02	7.185E-03	
Daily Doses and Risk for : Benz(a)anthracene			
CADD (mg/kg-day)	2.14E-02	7.93E-03	
LADD (mg/kg-day)	1.84E-03	1.13E-03	2.97E-03
Cancer Risk (-)	9.187E-05	5.666E-05	1.485E-04
Hazard Index (-)	0.000E+00	0.000E+00	
Daily Doses and Risk for : Benzene			
CADD (mg/kg-day)	5.79E-04	2.14E-04	
LADD (mg/kg-day)	4.96E-05	3.06E-05	8.02E-05
Cancer Risk (-)	1.736E-06	1.071E-06	2.806E-06
Hazard Index (-)	1.157E+00	4.282E-01	
Daily Doses and Risk for : Benzo(a)pyrene			
CADD (mg/kg-day)	2.77E-02	1.02E-02	
LADD (mg/kg-day)	2.37E-03	1.46E-03	3.84E-03
Cancer Risk (-)	1.187E-03	7.319E-04	1.918E-03
Hazard Index (-)	0.000E+00	0.000E+00	
Daily Doses and Risk for : Benzo(b)fluoranthene			
CADD (mg/kg-day)	1.62E-02	5.99E-03	
LADD (mg/kg-day)	1.39E-03	8.56E-04	2.24E-03
Cancer Risk (-)	6.940E-05	4.280E-05	1.122E-04
Hazard Index (-)	0.000E+00	0.000E+00	
Daily Doses and Risk for : Benzo(k)fluoranthene			
CADD (mg/kg-day)	2.68E-02	9.93E-03	

LADD (mg/kg-day)	2.30E-03	1.42E-03	3.72E-03
Cancer Risk (-)	1.150E-04	7.093E-05	1.859E-04
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cadmium

CADD (mg/kg-day)	3.88E-05	1.44E-05	
LADD (mg/kg-day)	3.33E-06	2.05E-06	5.38E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.110E+00	4.106E-01	

Daily Doses and Risk for : Chromium (VI)

CADD (mg/kg-day)	7.77E-05	2.87E-05	
LADD (mg/kg-day)	6.66E-06	4.11E-06	1.08E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.107E+00	1.150E+00	

Daily Doses and Risk for : Chrysene

CADD (mg/kg-day)	2.31E-02	8.56E-03	
LADD (mg/kg-day)	1.98E-03	1.22E-03	3.21E-03
Cancer Risk (-)	9.919E-06	6.118E-06	1.604E-05
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Cyanide

CADD (mg/kg-day)	2.91E-05	1.08E-05	
LADD (mg/kg-day)	2.50E-06	1.54E-06	4.04E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.456E-03	5.389E-04	

Daily Doses and Risk for : Dibenz(a,h)anthracene

CADD (mg/kg-day)	3.70E-02	1.37E-02	
LADD (mg/kg-day)	3.17E-03	1.96E-03	5.13E-03
Cancer Risk (-)	1.586E-03	9.782E-04	2.564E-03
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Dibenzofuran

CADD (mg/kg-day)	3.79E-04	1.40E-04	
LADD (mg/kg-day)	3.25E-05	2.00E-05	5.25E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	6.310E-03	2.335E-03	

Daily Doses and Risk for : Dimethylphenol (2,4)

CADD (mg/kg-day)	4.23E-04	1.57E-04	
LADD (mg/kg-day)	3.63E-05	2.24E-05	5.87E-05
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	2.116E-02	7.832E-03	

Daily Doses and Risk for : Ethylbenzene

CADD (mg/kg-day)	1.91E-03	7.08E-04	
LADD (mg/kg-day)	1.64E-04	1.01E-04	2.65E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.974E-02	7.304E-03	

Daily Doses and Risk for : Fluoranthene

CADD (mg/kg-day)	1.20E-02	4.43E-03	
LADD (mg/kg-day)	1.03E-03	6.32E-04	1.66E-03
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	9.568E-01	3.541E-01	

Daily Doses and Risk for : Fluorene

CADD (mg/kg-day)	4.27E-03	1.58E-03	
LADD (mg/kg-day)	3.66E-04	2.26E-04	5.92E-04
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.068E-01	3.952E-02	

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene

CADD (mg/kg-day)	4.82E-02	1.78E-02	
LADD (mg/kg-day)	4.13E-03	2.55E-03	6.67E-03

Cancer Risk (-)	2.064E-04	1.273E-04	3.336E-04
Hazard Index (-)	0.000E+00	0.000E+00	

Daily Doses and Risk for : Lead

CADD (mg/kg-day)	3.88E-06	1.44E-06	
LADD (mg/kg-day)	3.33E-07	2.05E-07	5.38E-07
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	1.110E-03	4.106E-04	

Daily Doses and Risk for : Nickel

CADD (mg/kg-day)	7.77E-06	2.87E-06	
LADD (mg/kg-day)	6.66E-07	4.11E-07	1.08E-06
Cancer Risk (-)	0.000E+00	0.000E+00	0.000E+00
Hazard Index (-)	3.883E-02	1.437E-02	

Irrigation Water – Dermal Exposure – Commercial / Industrial Worker (Gardener)

Title:
Irigation Water - Dermal Exposure - Gardener - Grass Saturated with Sprinkler Wa
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Scenarios:
Worker - RME

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
- Ammonia / ammonium
- Arsenic
- Benz(a)anthracene
- Benzene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Cadmium
- Chromium (VI)
- Chrysene
- Cyanide
- Dibenz(a,h)anthracene
- Dibenzofuran
- Dimethylphenol (2,4)
- Ethylbenzene
- Fluoranthene
- Fluorene
- Indeno(1,2,3CD)pyrene
- Lead
- Nickel

SUMMARY OF INPUT PARAMETERS	SCENARIO: 1
LIFETIME AND BODY WEIGHT	
Body Weight (kg)	70.0
Lifetime (years)	70.0
DERMAL CONTACT WHILE SWIMMING	
Total Skin Surface Area (cm^2)	4.700E+03
Time in Surface Water (hour/day)	2.00
Exp. Freq Surface Water (events/yr)	120.
Exp. Duration Surface Water (years)	30.0
Dermal Permeability Surface Water (cm/hour)	
Ammonia / ammonium	1.00E-03
Arsenic	1.00E-03
Benz(a)anthracene	0.55
Benzene	1.49E-02
Benzo(a)pyrene	0.71

Benzo(b)fluoranthene	0.42
Benzo(k)fluoranthene	0.69
Cadmium	1.00E-03
Chromium (VI)	2.00E-03
Chrysene	0.60
Cyanide	7.50E-04
Dibenz(a,h)anthracene	0.95
Dibenzofuran	9.75E-02
Dimethylphenol (2,4)	1.09E-02
Ethylbenzene	4.93E-02
Fluoranthene	0.31
Fluorene	0.11
Indeno(1,2,3CD)pyrene	1.2
Lead	1.00E-04
Nickel	2.00E-04

Absorption Adjustment Factor for
Dermal Exposure to Water (-)

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	0.10
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)
- Used to calculate risk and hazard index.

Ammonia / ammonium	1.0
Arsenic	1.0
Benz(a)anthracene	1.0
Benzene	1.0
Benzo(a)pyrene	1.0
Benzo(b)fluoranthene	1.0
Benzo(k)fluoranthene	1.0
Cadmium	1.0
Chromium (VI)	1.0
Chrysene	1.0
Cyanide	1.0
Dibenz(a,h)anthracene	1.0
Dibenzofuran	1.0
Dimethylphenol (2,4)	1.0
Ethylbenzene	1.0
Fluoranthene	1.0
Fluorene	1.0
Indeno(1,2,3CD)pyrene	1.0
Lead	1.0
Nickel	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Ammonia / ammonium	ND
Arsenic	ND
Benz(a)anthracene	5.00E-02
Benzene	3.50E-02
Benzo(a)pyrene	0.50
Benzo(b)fluoranthene	5.00E-02
Benzo(k)fluoranthene	5.00E-02
Cadmium	ND
Chromium (VI)	ND
Chrysene	5.00E-03
Cyanide	ND
Dibenz(a,h)anthracene	0.50
Dibenzofuran	ND
Dimethylphenol (2,4)	ND
Ethylbenzene	ND
Fluoranthene	ND
Fluorene	ND
Indeno(1,2,3CD)pyrene	5.00E-02
Lead	ND
Nickel	ND

Dermal Reference Dose (mg/kg-day)

Ammonia / ammonium	ND
Arsenic	2.00E-03
Benz(a)anthracene	ND
Benzene	5.00E-04
Benzo(a)pyrene	ND
Benzo(b)fluoranthene	ND
Benzo(k)fluoranthene	ND
Cadmium	3.50E-05
Chromium (VI)	2.50E-05
Chrysene	ND
Cyanide	2.00E-02
Dibenz(a,h)anthracene	ND
Dibenzofuran	6.00E-02
Dimethylphenol (2,4)	2.00E-02
Ethylbenzene	9.70E-02
Fluoranthene	1.25E-02
Fluorene	4.00E-02
Indeno(1,2,3CD)pyrene	ND
Lead	3.50E-03
Nickel	2.00E-04

SUMMARY OF RESULTS

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Ammonia / ammonium

CADD (mg/kg-day)	4.41E-05
LADD (mg/kg-day)	1.89E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	0.000E+00

Daily Doses and Risk for : Arsenic

CADD (mg/kg-day)	4.41E-05
LADD (mg/kg-day)	1.89E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.207E-02

Daily Doses and Risk for : Benz(a)anthracene

CADD (mg/kg-day)	2.44E-02
LADD (mg/kg-day)	1.04E-02

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  Cancer Risk (-)                5.222E-04
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Benzene
  CADD (mg/kg-day)               6.58E-04
  LADD (mg/kg-day)               2.82E-04
  Cancer Risk (-)                9.867E-06
  Hazard Index (-)               1.316E+00

Daily Doses and Risk for : Benzo(a)pyrene
  CADD (mg/kg-day)               3.15E-02
  LADD (mg/kg-day)               1.35E-02
  Cancer Risk (-)                6.745E-03
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Benzo(b)fluoranthene
  CADD (mg/kg-day)               1.84E-02
  LADD (mg/kg-day)               7.89E-03
  Cancer Risk (-)                3.945E-04
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Benzo(k)fluoranthene
  CADD (mg/kg-day)               3.05E-02
  LADD (mg/kg-day)               1.31E-02
  Cancer Risk (-)                6.537E-04
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Cadmium
  CADD (mg/kg-day)               4.41E-05
  LADD (mg/kg-day)               1.89E-05
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               1.261E+00

Daily Doses and Risk for : Chromium (VI)
  CADD (mg/kg-day)               8.83E-05
  LADD (mg/kg-day)               3.78E-05
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               3.532E+00

Daily Doses and Risk for : Chrysene
  CADD (mg/kg-day)               2.63E-02
  LADD (mg/kg-day)               1.13E-02
  Cancer Risk (-)                5.638E-05
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Cyanide
  CADD (mg/kg-day)               3.31E-05
  LADD (mg/kg-day)               1.42E-05
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               1.656E-03

Daily Doses and Risk for : Dibenz(a,h)anthracene
  CADD (mg/kg-day)               4.21E-02
  LADD (mg/kg-day)               1.80E-02
  Cancer Risk (-)                9.016E-03
  Hazard Index (-)               0.000E+00

Daily Doses and Risk for : Dibenzofuran
  CADD (mg/kg-day)               4.30E-04
  LADD (mg/kg-day)               1.84E-04
  Cancer Risk (-)                0.000E+00
  Hazard Index (-)               7.174E-03

Daily Doses and Risk for : Dimethylphenol (2,4)
  CADD (mg/kg-day)               4.81E-04
  LADD (mg/kg-day)               2.06E-04
  Cancer Risk (-)                0.000E+00
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Hazard Index (-) 2.406E-02

Daily Doses and Risk for : Ethylbenzene
CADD (mg/kg-day) 2.18E-03
LADD (mg/kg-day) 9.33E-04
Cancer Risk (-) 0.000E+00
Hazard Index (-) 2.244E-02

Daily Doses and Risk for : Fluoranthene
CADD (mg/kg-day) 1.36E-02
LADD (mg/kg-day) 5.83E-03
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.088E+00

Daily Doses and Risk for : Fluorene
CADD (mg/kg-day) 4.86E-03
LADD (mg/kg-day) 2.08E-03
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.214E-01

Daily Doses and Risk for : Indeno(1,2,3CD)pyrene
CADD (mg/kg-day) 5.47E-02
LADD (mg/kg-day) 2.35E-02
Cancer Risk (-) 1.173E-03
Hazard Index (-) 0.000E+00

Daily Doses and Risk for : Lead
CADD (mg/kg-day) 4.41E-06
LADD (mg/kg-day) 1.89E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 1.261E-03

Daily Doses and Risk for : Nickel
CADD (mg/kg-day) 8.83E-06
LADD (mg/kg-day) 3.78E-06
Cancer Risk (-) 0.000E+00
Hazard Index (-) 4.415E-02

Title:
Irigation Water - Dermal Exposure - Gardener - Grass Saturated with Sprinkler Wa
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Scenarios:
Worker - RME

Routes:
DERMAL CONTACT WHILE SWIMMING

Chemicals:
Methyl napthalene (2)
3- & 4-methylphenol
Naphthalene
Phenanthrene
Phenol
Pyrene
Toluene
TPH Aliphatic C6-8
TPH Aliphatic C10-12
TPH Aliphatic C16-35
TPH Aromatic C10-12
TPH Aromatic C16-21
1,2,4-trimethylbenzene
Xylenes

SUMMARY OF INPUT PARAMETERS SCENARIO: 1

LIFETIME AND BODY WEIGHT

Body Weight (kg)	70.0
Lifetime (years)	70.0

DERMAL CONTACT WHILE SWIMMING

Total Skin Surface Area (cm^2)	4.700E+03
Time in Surface Water (hour/day)	2.00
Exp. Freq Surface Water (events/yr)	120.
Exp. Duration Surface Water (years)	30.0
Dermal Permeability Surface Water (cm/hour)	
Methyl napthalene (2)	9.17E-02
3- & 4-methylphenol	7.66E-03
Naphthalene	4.66E-02
Phenanthrene	0.14
Phenol	4.34E-03
Pyrene	0.20
Toluene	3.11E-02
TPH Aliphatic C6-8	0.75
TPH Aliphatic C10-12	1.9
TPH Aliphatic C16-35	0.30
TPH Aromatic C10-12	8.70E-02
TPH Aromatic C16-21	0.30
1,2,4-trimethylbenzene	8.57E-02
Xylenes	4.71E-02
Absorption Adjustment Factor for Dermal Exposure to Water (-)	
Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

MEDIA CONCENTRATIONS

Concentration in Surface Water (mg/l)
- Used to calculate risk and hazard index.

Methyl napthalene (2)	1.0
3- & 4-methylphenol	1.0
Naphthalene	1.0
Phenanthrene	1.0
Phenol	1.0
Pyrene	1.0
Toluene	1.0
TPH Aliphatic C6-8	1.0
TPH Aliphatic C10-12	1.0
TPH Aliphatic C16-35	1.0
TPH Aromatic C10-12	1.0
TPH Aromatic C16-21	1.0
1,2,4-trimethylbenzene	1.0
Xylenes	1.0

SLOPE FACTORS AND REFERENCE DOSES

Dermal Slope Factor [1/(mg/kg-day)]

Methyl napthalene (2)	ND
3- & 4-methylphenol	ND

Naphthalene	ND
Phenanthrene	ND
Phenol	ND
Pyrene	ND
Toluene	ND
TPH Aliphatic C6-8	ND
TPH Aliphatic C10-12	ND
TPH Aliphatic C16-35	ND
TPH Aromatic C10-12	ND
TPH Aromatic C16-21	ND
1,2,4-trimethylbenzene	ND
Xylenes	ND

Dermal Reference Dose (mg/kg-day)

Methyl napthalene (2)	4.00E-02
3- & 4-methylphenol	5.00E-02
Naphthalene	2.00E-02
Phenanthrene	3.00E-02
Phenol	0.30
Pyrene	3.00E-02
Toluene	0.22
TPH Aliphatic C6-8	5.0
TPH Aliphatic C10-12	0.10
TPH Aliphatic C16-35	2.0
TPH Aromatic C10-12	4.00E-02
TPH Aromatic C16-21	3.00E-02
1,2,4-trimethylbenzene	2.00E-03
Xylenes	0.18

SUMMARY OF RESULTS

DERMAL CONTACT WHILE SWIMMING

Daily Doses and Risk for : Methyl napthalene (2)

CADD (mg/kg-day)	4.05E-03
LADD (mg/kg-day)	1.74E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.012E-01

Daily Doses and Risk for : 3- & 4-methylphenol

CADD (mg/kg-day)	3.38E-04
LADD (mg/kg-day)	1.45E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.764E-03

Daily Doses and Risk for : Naphthalene

CADD (mg/kg-day)	2.06E-03
LADD (mg/kg-day)	8.82E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.029E-01

Daily Doses and Risk for : Phenanthrene

CADD (mg/kg-day)	6.36E-03
LADD (mg/kg-day)	2.72E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.119E-01

Daily Doses and Risk for : Phenol

CADD (mg/kg-day)	1.92E-04
LADD (mg/kg-day)	8.21E-05
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.387E-04

Daily Doses and Risk for : Pyrene

CADD (mg/kg-day)	8.87E-03
LADD (mg/kg-day)	3.80E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	2.958E-01

Daily Doses and Risk for : Toluene

CADD (mg/kg-day)	1.37E-03
LADD (mg/kg-day)	5.88E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.157E-03

Daily Doses and Risk for : TPH Aliphatic C6-8

CADD (mg/kg-day)	3.31E-02
LADD (mg/kg-day)	1.42E-02
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.622E-03

Daily Doses and Risk for : TPH Aliphatic C10-12

CADD (mg/kg-day)	8.39E-02
LADD (mg/kg-day)	3.59E-02
Cancer Risk (-)	0.000E+00
Hazard Index (-)	8.388E-01

Daily Doses and Risk for : TPH Aliphatic C16-35

CADD (mg/kg-day)	1.32E-02
LADD (mg/kg-day)	5.68E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	6.622E-03

Daily Doses and Risk for : TPH Aromatic C10-12

CADD (mg/kg-day)	3.84E-03
LADD (mg/kg-day)	1.65E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	9.602E-02

Daily Doses and Risk for : TPH Aromatic C16-21

CADD (mg/kg-day)	1.32E-02
LADD (mg/kg-day)	5.68E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	4.415E-01

Daily Doses and Risk for : 1,2,4-trimethylbenzene

CADD (mg/kg-day)	3.78E-03
LADD (mg/kg-day)	1.62E-03
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.892E+00

Daily Doses and Risk for : Xylenes

CADD (mg/kg-day)	2.08E-03
LADD (mg/kg-day)	8.91E-04
Cancer Risk (-)	0.000E+00
Hazard Index (-)	1.162E-02

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