



The results indicate that potential on-site receptors (site workers) should not be exposed to contaminated groundwater in the Former Gasworks site for the case where the shallow and deep groundwater systems are not disturbed and altered. This is because the level of the shallow groundwater has been measured to be some 1 to 4m below the present ground surface and the deep aquifer is located below the shallow aquifer. The case where the groundwater system is to be intercepted by deep excavations is addressed in the following section (**Section 11.3.2**).

These results also indicate that potential off-site receptors should not be exposed to contaminated groundwater from the Former Gasworks site for the case where the current groundwater system is not disturbed and altered. This is because the contaminated groundwater flows in south to south-easterly direction and not towards the residential properties located along the eastern side of Burren Street. The data also indicate that the groundwater plumes are contained within railway-owned land and that the down-gradient edge appears not to have migrated into properties on the southern side of Railway Parade. The case where the groundwater system is to be disturbed and altered is addressed in the following section (**Section 11.3.2**).

The available data are considered to support the conclusion that the exposure concentrations for the migration pathway of “*groundwater transport*” from the Former Gasworks site are below the *Investigation Levels* and require no site-specific risk analysis to be undertaken for this migration pathway.

11.3.2 Intercepted or Extracted Groundwater

The available information indicates there are no groundwater wells in the local area that have the potential to affect the groundwater system at the Former Gasworks site. This information includes:

- The search of DIPNR licensed groundwater extraction wells in the local area;
- Site data that indicates no groundwater extraction is currently occurring in the Macdonaldtown Triangle area; and
- The groundwater investigation data indicate the groundwater flows are to the south and south-east and are not being affected by any known underground structure (eg. tar tank, gas holder annulus, sewer main) or extraction well.

However, the present groundwater system at the Former Gasworks site could be disturbed in a number of ways by future developments occurring both at the site and in the local area. These scenarios include:

- Scenario 1 - The installation of a DIPNR licensed groundwater extraction well at either the Former Gasworks site or a nearby off-site area;
- Scenario 2 - The digging of a deep excavation that needs to be temporarily dewatered at either the Former Gasworks site or a nearby off-site area during the construction period; and



- Scenario 3 - Leakage through a basement or other type of underground structure constructed below the water table.

Scenario 1

This study considers Scenario 1 is unlikely because:

- Mains water is the source of all potable water in the area;
- The background quality of water from the Wianamatta Shales in the inner city area is poor due to its naturally high salinity content and the broad-scale impacts caused by the industrial use of the surrounding areas in addition to the Former Gasworks site; and
- The likely low yield of groundwater bores in the area due to the low permeability of the shale and shallow depth to bedrock.

Scenario 2

Scenario 2 could occur during the construction of a deep trench for the installation of buried services or a deep basement. The excavation would need to be deeper than 1.5m, since this is the average depth down to the top of the shallow aquifer.

Scenario 2 has the potential for contaminated groundwater from the Former Gasworks site to be intercepted. Conservative estimates of potential exposure concentrations are considered to be given by the five wells located along the western side of the site, these being MW06S, MW06D, MW07S, MW07D, MW12S, MW12D, MW18S, MW18D and MW20S. The locations of these wells and a summary of exceedances measured by the 2005 investigation were previously shown in **Figures 20 and 21 (Section 10)**.

These 9 wells are considered most relevant for these exposure scenarios since the groundwater investigations have found them to give the highest contaminant concentrations and because they are located near the western boundary of the site and adjacent to the adjacent residential properties. These wells have elevated contaminant levels since they are located in the area where the most likely groundwater contaminant sources are located, these being tarry wastes that may remain in the buried tar tanks and in the gasholder in the north-western corner of the Former Gasworks site.

For most potential contaminants of concern, these 9 wells provide a total of 15 groundwater sample results for this critical area of the site. As previously mentioned in **Section 10**, these contaminant levels vary significantly both between locations, between shallow and deep aquifer, and between sampling events. Due to this variability, the data does not support the development of a sophisticated contaminant groundwater flow model that could be used to provide probabilistic estimates of exposure concentrations to construction workers for this exposure scenario.



In this risk assessment, this issue has been addressed by adopting the maximum concentrations for assessing the risks posed to on-site receptors and the average concentrations for assessing the risks posed to off-site receptors. The maximum values correspond to a mix of groundwater samples collected from the shallow and deep aquifer. This approach is considered to be both practical and conservative for the potential receptors of concern. These concentrations are summarised in **Table 23**, with the contaminants listed corresponding to those found to exceed the *Groundwater Investigation Levels* together with other contaminants that have also been found in the groundwater and need to be included to account for risks posed by chemical mixtures.

■ **Table 23 Exposure Concentrations for Receptors Exposed to Extracted Groundwater (Units µg/L)**

Substances	Threshold Concentrations		Average Values (1)	Maximum Values (1)
	Freshwater Ecology	Health		
HEAVY METALS				
Arsenic (total)	24	7	3.1	23.0
Cadmium	0.2	2	0.2	1.5
Chromium	3.3	55000	3.4	43.0
Copper	1.4	2000	3.6	14.0
Lead	3.4	10	1.9	7.0
Nickel	11	20	7.5	19.0
Zinc	8	---	76.9	362.0
Cyanide	7	80	132.0	479.0
BTEX				
Benzene	950	1	637.9	6370.0
Toluene	180	800	13.8	117.0
Ethylbenzene	50	300	29.3	213.0
Total Xylene	70	600	66.6	417.0
Total Petroleum Hydrocarbons				
Total TPH C10-C36	600	---	2245.6	18220.0
Polycyclic Aromatic Hydrocarbons				
Naphthalene	16	6.2	361.7	3840.0
Phenanthrene	5		1.1	8.0
Total PAHs	3		406.3	4208.0
Ammonia	900		1126.0	3190.0

Note:

(1) Wells in database comprise MW06S, MW06D, MW07S, MW07D, MW12S, MW12D, MW18S, MW18D, MW20S, MW20D



The substances presented in **Table 23** are together considered to define the mixture of contaminants that would need to be considered in assessing health-risks to the potential receptors. Ammonia has also not been included as a risk to human health since the Drinking Water *Investigation Level* is based on aesthetic rather than health considerations and the human gut contains high ammonia concentrations.

Construction workers would be the main potential receptor for this scenario since it is possible that some limited manual work would need to be undertaken in water-filled trenches.

Freshwater ecosystems in the headwaters of Alexandra Canal are not considered to be potential receptors given that groundwater at the Former Gasworks site is contaminated and should not be discharged to the off-site stormwater system. Any groundwater intercepted by construction works would need to be managed on-site. A long-term SMP will need to be placed on the Former Gasworks site in order to ensure that any intercepted groundwater is retained and managed on-site. These recommendations are included in **Section 14.2** of this report.

Scenario 3

Scenario 3 could occur if a deep basement or structure was to be constructed below 1.5m, due to the potential for concrete structures to crack and leak including those that are designed as a tanked structure. The potential receptors for this exposure scenario would be the surrounding residential community and freshwater ecosystems.

An estimate of the exposure concentrations for Scenario 3 has been made by performing a screening assessment that involves comparing the likely flow of water that would seep out from cracks into a deep basement to the total amount of groundwater that would flow from west to east across a residential property located on the eastern side of Burren Street adjacent to the Former Gasworks site. If the amount of seepage water coming out of basement cracks is estimated to be a negligible proportion of the total groundwater flow occurring across the property (say less than 10%), then the exposure concentrations in the groundwater would be the same as the background water quality flowing onto the site along the northern boundary. On the other hand, if the amount of seepage water is found to be a significant proportion of the total groundwater flow across the property (say >10%), then more detailed groundwater modelling would be required in order to determine whether the crack seepage is sufficient to cause contaminated groundwater from the Former gasworks site to reverse direction and flow to the west and into an adjacent residential property.

In this analysis, the crack-to-total area of the basement walls has been taken from the value recommended by the US EPA (February 2005) in their use guidelines for soil vapour analysis, this



being a value of $4.0\text{E-}04$ (dimensionless). The surface area of the basement walls has been taken to be 25m^2 , which corresponds to the entire 10m length of a typical residential property along the western site boundary and a typical 2.5m high basement. This gives a total crack area along this basement wall of 0.01m^2 , which corresponds to a total crack width of 4mm crack extending from the roof to the floor of the basement.

Estimates of the groundwater hydraulic head and flow velocity across the Former Gasworks site have been provided in **Section 10.3**. The hydraulic head was estimated to vary between 1.3×10^{-2} and 3.1×10^{-2} , while the groundwater is estimated to travel at 6.2 to 36.5m/year. Using Darcy's equation, the amount of groundwater that is presently flowing eastwards across the 10m wide property boundary over a 2.5m depth interval (height of submerged basement) is estimated to vary between 17.7 and 104 L/hour.

For the 4mm wide crack, the hydraulic head is conservatively assumed to be 1, which corresponds to a drop of 2.5m over a 2.5m distance into the clay soil or shale bedrock behind the basement wall. Again using Darcy's equation, the amount of groundwater that would seep out from the crack and into the basement is estimated to vary between 0.36 and 1.1 L/hour. This crack seepage rate corresponds to 1 to 2% of the total amount of groundwater that currently flows through a residential property, which is considered to be negligible. The analysis shows that leakage through a basement or other type of underground structure constructed below the water table in the adjoining residential properties should not cause contaminated groundwater to migrate from the Former Gasworks site towards the adjacent residential properties and potentially into tanked basements.

It is considered that this screening assessment supports the conclusion that the exposure concentration for Scenario 3 corresponds to the background water quality, as measured up-gradient of the Former Gasworks site. It is therefore considered that this exposure scenario can be discounted and that the potential receptors (ie. the surrounding residential community and freshwater ecosystems) should not be affected.

11.3.3 Volatilisation & Vapour Transport from Contaminated Groundwater or Soils

From the results of the soil vapour investigation presented in **Section 9**, it was concluded that highly variable field results are to be expected given the highly variable groundwater concentrations that have been measured at the site. The low soil gas levels measured in wells MW30-MW34 in March 2005 are consistent with the low levels of volatile contaminants that were measured in the last groundwater monitoring round undertaken in March 2005. However, the computer analysis showed that much higher soil gas vapours may be present at the Former gasworks site if the higher groundwater concentrations that were measured in earlier monitoring rounds together with the higher concentrations measured in shallow soil samples are more



representative of site conditions. Due to this high degree of variability, the exposure pathway from volatile soil vapours has been included in this risk assessment.

The main risks posed by volatilisation and vapour transport from contaminated groundwater and soils are to human receptors that occupy buildings erected on or close to the contaminant sources due to impacts to indoor air quality. This is because soil vapours can enter buildings through cracks and openings in the floor and basement walls and accumulate within the building spaces. Impacts to ambient air quality outside buildings are less due to the much greater amount of dispersion that occurs in the open air. Consequently, this site-specific risk assessment has examined the potential impacts to indoor air quality from contaminated soils and groundwater at the Former Gasworks site.

The analysis has involved the use of a computer model to estimate the indoor air vapour concentrations that may result from the migration of volatile chemicals from the shallow soils and groundwater at the Former Gasworks site. The computer model is based on the Johnson and Ettinger (1991) one-dimensional analytical solution to convective and diffusive vapour transport into spaces, as previously used in the computer simulations of the field investigations. The analysis performed in this study has used the spreadsheet model developed for the US EPA (February 2004), which is available on their website.

The analysis has adopted one-dimensional steady-state conditions, which are conservative assumptions since the contaminant source is taken to extend across the whole area and does not diminish over time. The US EPA (February 2004) user manual provides the equations that are used to define:

- The mass transfer attenuation coefficient (α);
- The theoretical building ventilation rate (Q_{building});
- The volumetric flow rate of soil gas entering the building (Q_{soil});
- The equivalent radius of the floor-wall seam crack (r_{crack}); and
- The equivalent Peclet number for transport through the building foundation.

The steady-state vapour-phase concentration of the contaminant in the building (C_{building}) is calculated as:

$$C_{\text{building}} = \alpha C_{\text{source}} \dots\dots\dots(4)$$

where:

- C_{building} = Vapour concentration at the contaminant in the building ($\text{g}/\text{cm}^3\text{-v}$)
- C_{source} = Vapour concentration at the source of contamination ($\text{g}/\text{cm}^3\text{-v}$)



The US EPA spreadsheet model has been used to estimate exposure concentrations for two exposure scenarios, these being:

- Scenario 1 – On-site workers; and
- Scenario 2 – Off-site residents on properties bordering the Former Gasworks site along the eastern side of Burren Street.

Scenario 1 – On-site Workers

This exposure scenario examines the impacts of volatilisation and vapour transport from contaminated groundwater and soils to on-site workers who may work in buildings erected at the Former Gasworks site. The analysis has used the average soil profile established for the volatile contaminant plume used in the computer simulations in **Section 9.3**. The stratigraphic input parameters used in the model are:

- Depth below grade to water table = 1.5m
- Soil profile = Clay
- Average soil/groundwater temperature = 15°C
- Depth below grade to bottom of enclosed space floor = 0.15m (program default value)
- Vadose zone soil dry density = 1.5t/m³ (program default value)
- Vadose zone soil total porosity = 0.43 (program default value)
- Vadose zone soil water-filled porosity = 0.215 cm³/cm³ (program default value)

The soil contamination is assumed to be uniformly spread throughout the shallow unsaturated fill layer down to the water table. This means that the soil contamination would extend to the underside of building foundations, which have been assumed to be shallow foundations that are buried to a nominal depth of 0.15m. All other parameters used in the model are calculated using the various theoretical equations.

For the purpose of the analysis, the Former Gasworks site has been divided into two areas. The first area corresponds to the shallow aquifer plume of volatile chemicals that is located towards the centre of the site, as previously shown in **Figure 15**. In this area, the main sources of soil vapours are the volatile chemicals present in the groundwater in the shallow aquifer and in the shallow unsaturated soils.

The second area is the remainder of the Former Gasworks site where the levels of volatile chemicals in the shallow aquifer are low and the main source of volatile contamination is the unsaturated fill and shallow soils located above the water table at an average depth of 1.5m. **Table 23B** provides a summary of all available laboratory results for the target volatile chemicals tested in soil samples taken outside the plume area at a depth of 0 – 1.5m.



For each of these two areas, predicted indoor air concentrations have been calculated using two sets of contaminant concentrations, these being the average and maximum concentrations for the shallow groundwater and shallow unsaturated soils. A summary of the results for the Plume Area and Outside Plume Area are provided in **Tables 23C** and **23D**, respectively.

■ **Table 23B Volatile Chemical Results for Shallow Unsaturated Soils Outside Plume Area**

	CH2M HILL BH01	CH2M HILL SB02	CH2M HILL SB02	CH2M HILL SB07	CH2M HILL SB07	CH2M HILL SB08	CH2M HILL SB08	CH2M HILL BH10	CH2M HILL BH10	CH2M HILL BH11
	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000
	0.00-0.10	0.00-0.10	0.20-0.30	0.00-0.10	1.40-1.50	0.00-0.10	1.00-1.10	0.00-0.10	0.3	1.20-1.30
Benzene	0			0	0		0		0	
Toluene	0			0	0		0		0	
Ethylbenzene	0			0	8		0		0	
Total Xylenes	0			0	32		0		0	
Naphthalene	0	0.6	0	51	650	1.8	7	1.2	0	
Acenaphthene	0	0	0	15	41	0	1.4	0	0	
Fluorene	0	0.6	0.5	78	61	1.2	3.6	1.6	0	
Pyrene	4.4	25	40	290	54	8.4	13	19	4.6	
Chrysene	2	8	10	89	14	3.4	5.2	7.8	2.6	
Benzo[b,k]	3	18	35	270	30	7	9	14	5	

	CH2M HILL BH12	CH2M HILL BH12	CH2M HILL BH13	CH2M HILL BH13	CH2M HILL BH14	CH2M HILL BH14	CH2M HILL BH14	CH2M HILL BH15	CH2M HILL BH15	CH2M HILL BH15
	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000
	0.00-0.10	0.90-1.00	0.00-0.10	0.20-0.30	0.00-0.10	0.20-0.30	0.90-1.00	0.00-0.10	0.20-0.30	0.90-1.00
Benzene				1.6		0	4.6		0	0
Toluene				5		0	0		0	0
Ethylbenzene				0		0	26		0	0
Total Xylenes				9		0	48		0	0
Naphthalene	0.8	0	0.5	5	0	0	3.8	0.7	1.6	0
Acenaphthene	0	0	0	1	0	0	0	0	1.2	0
Fluorene	0	0	0	4.6	0	0	0	0	2.8	0
Pyrene	7	0	6.6	67	5.2	0	0	11	56	2.2
Chrysene	3.6	0	2.6	25	2	0	0	5	29	1
Benzo[b,k]	8	0	6	56	6	0	0	16	60	3

	CH2M HILL BH16	CH2M HILL BH16	CH2M HILL SB18	CH2M HILL TPC	CH2M HILL TPD	CH2M HILL TP99	CH2M HILL TP99	CH2M HILL A25 (5)	CH2M HILL A29 (4)	CH2M HILL A31 (3)
	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	April 2000	Oct 2001	Oct 2001	Oct 2001
	0.00-0.10	0.90-1.00	0.20-0.30	1	0.2	0.0-0.10	0.20-0.30	0.0-0.10	0.0-0.10	0.0-0.10
Benzene	0	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	5	0	0	0	0	0	0
Ethylbenzene	0	0	0	9	0	0	0	0	0	0
Total Xylenes	0	0	0	48	0	0	0	0	0	0
Naphthalene	0.7	0	280	520	0.6	0	0	0	0.6	0
Acenaphthene	0	0	33	21	0	0	0	0	0	0
Fluorene	0.5	0	120	27	0	0	0	0	0.5	0
Pyrene	12	0	600	32	13	0	1.8	0	24.7	9.7
Chrysene	5.4	0	200	9.2	6.2	0	1.2	0	12.7	5.6
Benzo[b,k] fluoranthene	13	0	310	12	11	0	2	0	20	8

	CH2M HILL MW10S	CH2M HILL MW11S	CH2M HILL MW12D	CH2M HILL MW13S	CH2M HILL MW13D	CH2M HILL MW18D	SKM MW31		
	Oct 2001	Oct 2001	Oct 2001	Oct 2001	Oct 2001	Oct 2001	Dec 2004	Maximum	Average
	0.9-1.1	0.6-0.8	1.4-1.5	0.9-1.0	1.4-1.5	1.4-1.5	0.50-0.95		
Benzene	0	0	0	0	0	0	0	4.6	0.2
Toluene	0	0	0	0	0	0	0	5	0.4
Ethylbenzene	0	0	0	0	0	0	0	26	1.6
Total Xylenes	0	0	0	0	0	0	0	48	5.1
Naphthalene	0	0	0	9.7	0	0		650	43.9
Acenaphthene	0	0	0	1	0	0		41	3.3
Fluorene	0	0	0.5	4.2	0	0		120	8.8
Pyrene	12	4.9	9.1	63.3	1.2	0		600	39.9
Chrysene	6.7	2.4	4.2	26.9	0.8	0		200	14.0
Benzo[b,k] fluoranthene	9	3	9	46	2	0		310	28.3