



■ Table 15 Occupational Exposure Standards for Atmospheric Contaminants

Contaminant	TWA	
	Ppm	ug/m <sup>3</sup>
Benzene	5	16,000
Toluene	100	377,000
Ethyl Benzene	100	434,000
Xylene	80	350,000
Petroleum Hydrocarbons*	240	900,000
Naphthalene	10	52,000
Coal tar pitch volatiles (as benzene soluble)	---	200

Notes: \* the substance requires further review by the Exposure Standards Expert Working Group.

Conversion Factors (from ATSDR)

Benzene: 1ppm = 3.24 mg/m<sup>3</sup> @ 20°C

Toluene: 1ppm = 3.75 mg/m<sup>3</sup> @ 20°C

Xylenes (mixed): 1ppm = 4.34 mg/m<sup>3</sup> @ 20°C

#### 8.4 Aesthetic Criteria

The 1999 NEPM 'Schedule B(1) Guideline on the Investigation Levels for Soil and Groundwater' advises that:

*'There are no numeric Aesthetic Guidelines but the fundamental principle is that the soils should not be discoloured, malodorous (including when dug over or wet) nor of abnormal consistency. The natural state of the soil should be considered.'*

NSW DEC guidelines also specify the following requirements for sites:

- Any contaminant odours emanating from Site soils have been adequately addressed - refer NSW EPA (1998) Site Auditor Guidelines; and
- No floating product remains on the groundwater – refer NSW EPA (1994) Service Station Guidelines.

Discoloured soils are not considered by the NSW DEC as a quality of the environment that needs to be protected on a commercial/industrial site. Given these NEPM and NSW DEC requirements, the aesthetic criteria of relevance to the Macdonaldtown Triangle area and the Former Gasworks site in its present and future condition are considered to be:

- No malodorous materials exposed at the final ground surface;
- No malodorous gases emanating from the ground at the final ground surface into any buildings or structures to be accessed by people; and
- No floating product to remain on groundwater at or near the Site.



## 9 Soil Vapour Analysis

*This section of the report presents the results of a soil vapour investigation and assessment conducted at the Former Gasworks site. The purpose of these investigations was to address data gaps that existed in previous investigations, as previously discussed in Section 5.8. The results of a screening assessment are initially provided (Section 9.1), followed by the results of a soil vapour investigation (Section 9.2). The results of theoretical computer simulations are then presented in order to provide further insight into the soil vapour generation potential at the Former Gasworks site (Section 9.3), with a comparison between the field measurements and computer analysis then presented (Section 9.4).*

### 9.1 Screening Assessment

The previous investigations identified elevated concentrations of volatile compounds in the soils and groundwater that could form an exposure pathway for contaminants. However, the amount of data that was available was not sufficient to allow a site-specific assessment to be made of the risks posed by soil vapours to the health of future site users and surrounding residents.

This study has sought to address this data gap by collecting soil-gas data at locations across the Former Gasworks site considered to pose the highest potential risks from volatile organic contamination. The investigation also targeted those potential contaminants of concern (as listed in **Section 5.6.2**) that are sufficiently toxic and volatile to present a potential risk to users of the site and adjoining properties. These compounds were identified using the screening process provided in the US EPA (February 2004) "*User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings*".

The screening process involves a qualitative assessment of these chemicals in terms of their toxicity, volatility and whether they have been detected at elevated concentrations in soil and groundwater samples at the site. The qualitative data on the toxicity and volatility of the chemicals has been obtained from Table 1 in the US EPA (February 2004) study, while a review of the laboratory data summary tables in **Appendix B** has been used to determine whether the compounds have been found at elevated concentrations at the Former Gasworks site.

The outcomes of the screening analysis for the potential contaminants of concern at the Former Gasworks site are provided in **Table 17A**. In the table, the volatile chemicals that present the greatest risks to the site and surrounding properties are those that are considered to be sufficiently toxic and volatile and present at elevated concentrations. The assessment has identified two groups of chemicals that meet these conditions at the Former Gasworks site, these being PAH compounds (acenaphthene, benz(b)fluoranthene, chrysene, fluorene, naphthalene, pyrene) and monocyclic aromatic compounds (benzene, toluene, ethylbenzene and xylenes).



Table 17A Screening Assessment for Soil Vapour Assessment

CAS No.	Chemical	Is Chemical Sufficiently Toxic ?	Is Chemical Sufficiently Volatile ?	Is Chemical Present at Elevated Levels ?
<b>PAHs</b>				
83329	Acenaphthene	YES	YES	YES
120127	Anthracene	NO	YES	YES
56553	Benz(a)anthracene	YES	NO	YES
50328	Benzo(a)pyrene	YES	NO	YES
205992	Benzo(b)fluoranthene	YES	YES	YES
207089	Benzo(k)fluoranthene	NO	NO	YES
218019	Chrysene	YES	YES	YES
53703	Dibenz(a,h)anthracene	YES	NO	NO
86737	Fluorene	YES	YES	YES
91203	Naphthalene	YES	YES	YES
129000	Pyrene	YES	YES	YES
<b>Monocyclic aromatic hydrocarbons</b>				
71432	Benzene	YES	YES	YES
108883	Toluene	YES	YES	YES
100414	Ethylbenzene	YES	YES	YES
108383	m-Xylene	YES	YES	YES
95476	o-Xylene	YES	YES	
106423	p-Xylene	YES	YES	
<b>Other Chemicals</b>				
108952	Phenol	YES	NO	NO
7439976	Mercury (elemental)	YES	YES	NO

Note: Source of qualitative toxicity and volatility data from US EPA (February 2004)

For these 10 target chemicals, the area where volatile gas emissions are likely to be of most concern at the site has been identified on the basis of the water quality in the shallow aquifer and the soil concentrations in the unsaturated soils located above the water table. The condition of the deeper aquifer and deeper soils are not considered as critical in the vapour assessment since the volatile concentrations in the shallow aquifer would tend to include the contributions made by the vertical migration of volatiles from deeper saturated soils and deeper aquifers. This is because the volatile vapours produced by these deeper sources would tend to be absorbed in the shallow groundwater and be accounted in its water quality.

A review of the water quality in the shallow aquifer has found that the highest concentrations of the target chemicals are located towards the centre of the former gasworks where the gasholders and



purifiers operated. The data shows that an intermittent plume of volatile chemical contamination has formed in the shallow aquifer, which is defined by the results obtained from the shallow monitoring wells MW03S, MW06S, MW07S and MW20S. Practically all other wells have shown non-detectable concentrations of these target chemicals, the only exceptions being some wells with relatively minor PAH concentrations (MW04S naphthalene = 5µg/L; MW12S naphthalene = 2µg/L, acenaphthene = 9µg/L, fluorene = 15µg/L, phenanthrene = 8µg/L; MW13S acenaphthene = 5µg/L, fluorene = 7µg/L, phenanthrene = 2µg/L, MW36S pyrene = 2µg/L; MW37S acenaphthene = 14µg/L, fluorene = 15µg/L). The results of computer analyses presented in **Section 9.3** also show that these low PAH concentrations do not influence the outcome of the risk analysis.

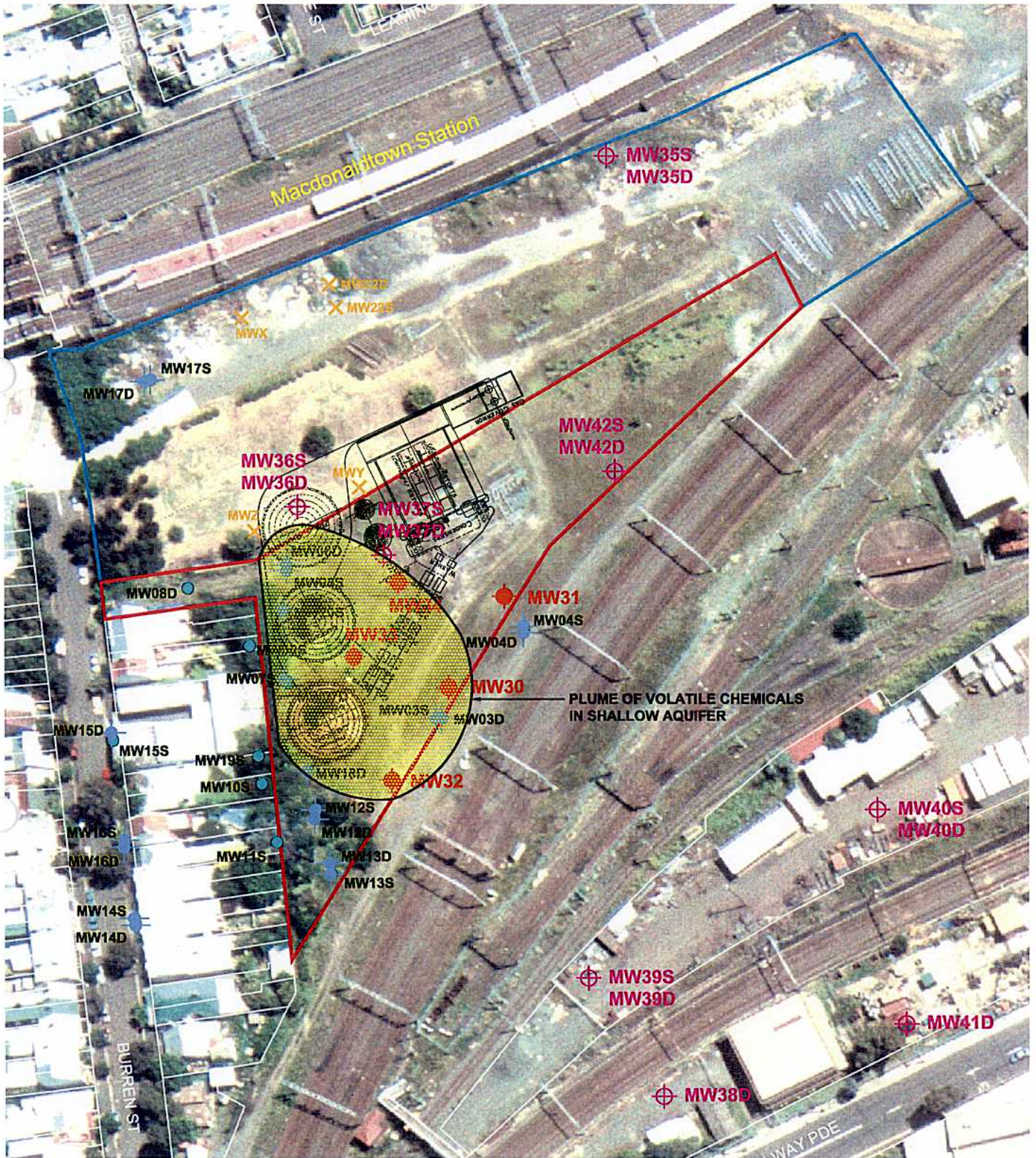
A summary of the PAH and BTEX concentrations that have been measured in the three rounds of groundwater testing for the shallow aquifer plume are summarised in **Table 17B** with the estimated extent of the plume shown in **Figure 15**.

■ **Table 17B Levels of Target Volatiles Measured in Shallow Aquifer Plume**

	MW03S			MW06S			MW07S			MW20S			Average
	5/11/00	4/10/01	2/3/05	5/11/00	4/10/01	2/3/05	5/11/00	4/10/01	2/3/05	5/11/00	4/10/01	2/3/05	
Benzene	74	0			17	0		704			0	0	114
Toluene	0	0			0	0		0			0	0	0
Ethylbenzene	28	0			8	0		213			7	0	37
Xylenes	15	0			72	0		417			5	0	73
Naphthalene	86	0			0	24		1460			23	9	229
Acenaphthene	2	0			0	0		14				4	3
Fluorene	1	0			0	0		15				3	3
Pyrene	0	0			0	2		0				0	0
Chrysene	0	0			0	0		0				0	0
Benzo(b,k)fluoranthene	0	0			0	0		0				0	0

Note: All units in ug/L

With regard to the shallow unsaturated soils located in this area, the laboratory data indicate the soils have very low BTEX concentrations but highly variable PAH concentrations. The soil borcholes located in the shallow plume area are SB03, SB04, SB06, SB18, MW03S, MW06S, MW07S, MW20S and MW30-MW34. **Table 17C** provides a summary of all available laboratory results for the target volatile chemicals tested in soil samples taken in the plume area at a depth of 0 – 1.5m.



**LEGEND**

- ▭ GASWORKS SITE
- ▭ CLEANING SHED SITE
- CH2MHILL MONITORING WELL LOCATIONS
- ✕ CH2MHILL MONITORING WELL LOCATIONS NOT PREVIOUS IDENTIFIED
- ⊕ SKM GROUNDWATER MONITORING WELL LOCATIONS (1 DEEP AND 1 SHALLOW)

⊕ SOIL VAPOUR MONITORING WELLS

0 10 20 30 40 50 60 m





Table 17C Volatile Chemical Results for Shallow Unsaturated Soils in Plume Area

	CH2M HILL SB03 April 2000 0.00-0.10	CH2M HILL SB03 April 2000 1.00-1.10	CH2M HILL SB04 April 2000 0.00-0.10	CH2M HILL SB04 April 2000 0.70-0.80	CH2M HILL SB06 April 2000 0.20-0.30	CH2M HILL SB06 April 2000 0.30-0.40	CH2M HILL SB18 April 2000 0.20-0.30	CH2M HILL MW20S Oct 2001 0.9-1.0	SKM MW30 Dec 2004 0-0.45	SKM MW32 Dec 2004 1.2	Average
Benzene	0	0		0	0	0	0	0	0	0	0.0
Toluene	0	0		0	0	0	0	0	0	0	0.0
Ethylbenzene	0	0		0	0	0	0	0	0	0	0.0
Total Xylenes	0	0		0	3	0	0	0	0	0	0.3
Naphthalene	3.4	0	0	28	99	0	280	0			51.3
Acenaphthene	0.8	0	0	12	29	0	33	0			9.4
Fluorene	4.2	0	0	66	120	0	120	0.5			38.8
Pyrene	48	0	0	240	320	20	600	12.7			155.1
Chrysene	21	0	0	80	96	9.2	200	6.5			51.6
Benzo[b,k]fluoranthene	37	0	0	170	250	26	310	8			100.1

All units in mg/kg

The intermittent BTEX levels measured in the shallow groundwater and the very low BTEX levels measured in the shallow soils suggests that the source of the volatile contaminants measured in the shallow aquifer may be from deeper sources that cause the volatile contamination to migrate vertically after heavy rainfall periods.

## 9.2 Additional Soil Vapour Investigation

A soil vapour investigation was undertaken as part of this risk assessment to obtain measured soil vapour concentrations in the area of the shallow groundwater plume described in the previous section. The investigation involved the installation of 5 soil-gas monitoring probes (MW30-MW34) located in and around this area, as shown by **Figure 15**. MW30 and MW31 were placed close to previous drilled monitoring wells MW03S where shallow groundwater contamination had been recorded. MW33 was located in close proximity to MW07S where the most significant groundwater contamination was observed. MW34 was located in close proximity to the former retort house and MW20S, while MW32 was positioned down gradient of the former gasholder structures and MW20S.

The vapour wells were installed in December 2004 along with the additional groundwater wells. The sampling of these wells was undertaken in March 2005, allowing contaminant vapours to accumulate within the well casing for a period of three months. No purging was undertaken prior to sampling. The wells were sampled with SKC 226-01 tubes for BTEX and SKC 226-30-04 tubes for PAHs. Both tubes comprising two sections of sorbent matrix to measure possible 'breakthrough'. The laboratory test results found all BTEX and PAH compounds were detected in the front sections of tubes, with no 'breakthrough' recorded in the back section of the tube.

Summary tables of the chemical analyses performed on the soil samples are provided in **Table 18A** and **Table 18B**, with copies of the laboratory test certificates provided in **Appendix E**.



Table 18A BTEX Soil Vapour Results

BTEX Concentration in Air by SKC sampling - $\mu\text{g}/\text{m}^3$								
	Sampling Flow Rate (ml/min)	Sampling Time (mins)	Sampling Volume ( $\text{m}^3$ )	Benzene	Toluene	Ethyl Benzene	m&p xylene	o-xylene
<b>Assessment Criteria<sup>(1)</sup></b>				<b>16,000</b>	<b>377,000</b>	<b>434,000</b>	<b>350,000</b>	
MW30 (Front)	600	50	0.03	<16.7	14,400	<16.7	<50	
MW30 (Back)	600	50	0.03	<16.7	<16.7	<16.7	<50	
MW31 (Front)	600	50	0.03	<16.7	263	<16.7	<50	
MW31 (Back)	600	50	0.03	<16.7	<16.7	<16.7	<50	
MW32 (Front)	600	50	0.03	16.7	1,527	<16.7	<50	
MW32 (Back)	600	50	0.03	<16.7	<16.7	<16.7	<50	
MW33 (Front)	600	52	0.0312	<16.0	<32.1	<16.7	<50	
MW33 (Back)	600	52	0.0312	<16.0	<16.0	<16.7	<50	
MW34 (Front)	600	50	0.03	<16.7	28,000	<16.7	<50	
MW34 (Back)	600	50	0.03	<16.7	<16.7	<16.7	<50	

Concentrations exceed assessment criteria

**16.7** Contaminant mass recorded above laboratory detection limits

Table 18B PAH Soil Vapour Results

PAH Concentration in Air by SKC sampling - $\mu\text{g}/\text{m}^3$								
	Sampling Flow Rate (ml/min)	Sampling Time (mins)	Sampling Volume ( $\text{m}^3$ )	Naphthalene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(a)pyrene
<b>MIL</b>								<b>200</b>
MW30 (Front)	2000	110	0.220	2.73	<0.454	<0.454	<0.454	<0.454
MW30 (Back)	2000	110	0.220	<0.454	<0.454	<0.454	<0.454	<0.454
MW31 (Front)	2000	108	0.216	2.78	<0.463	<0.463	<0.463	<0.463
MW31 (Back)	2000	108	0.216	<0.463	<0.463	<0.463	<0.463	<0.463
MW32 (Front)	2000	110	0.220	2.27	<0.454	<0.454	<0.454	<0.454
MW32 (Back)	2000	110	0.220	<0.454	<0.454	<0.454	<0.454	<0.454
MW33 (Front)	2000	111	0.222	2.70	<0.450	<0.450	<0.450	<0.450
MW33 (Back)	2000	111	0.222	<0.450	<0.450	<0.450	<0.450	<0.450
MW34 (Front)	2000	111	0.222	5.41	<0.450	<0.450	<0.450	<0.450
MW34 (Back)	2000	111	0.222	1.35	<0.450	<0.450	<0.450	<0.450

Concentrations exceeding MIL value

NOTE: All other PAH contaminants were below laboratory detection limits



In these tables the results are compared with the volatile gas Investigation Levels adopted for this study (**Section 8.4**), which correspond to the Worksafe Australia Exposure Standards for Atmospheric Contaminants in the Occupational Environment.

All test results measured concentrations of BTEX and PAHs well below the Workcover Exposure Guidelines. BTEX concentrations were found to be below the laboratory detection limits at most sampling locations. The maximum benzene concentration was recorded at MW32 where the concentration was measured at the detection limit of  $16.7 \mu\text{g}/\text{m}^3$ . Toluene was recorded at MW30, MW32 and MW34 and o-xylene recorded at MW32.

These results suggest there may be a low risk that soil-gas vapours at the former gasworks site are an environmental media of concern because:

- All test results measured concentrations of BTEX and PAHs well below the Workcover Exposure Guidelines;
- The locations sampled targeted areas of the site considered to have the highest potential for containing elevated volatile soil-gas levels; and
- The contaminant vapours were allowed to collect within the headspace of the monitoring well for a period of 3 months prior to sampling. This situation represents to some degree the accumulation of vapours in a poorly ventilated room constructed above the Site.

However, it is recognised that the available data are limited and it is likely that significant variations could occur if additional sampling rounds were conducted. This is because of the inherent sensitivity of the test to minor variations in test procedures and environmental conditions, as is evidenced by such factors as:

- The soil vapour tests were conducted at only five discrete locations across the former gasworks site and it is likely that the results do not represent the worst-case;
- The groundwater test data that have been collected on three occasions between 2000 and 2005 show a high degree of variability; and
- The high toluene levels measured in the soil vapour tests appear to be inconsistent with the soil and groundwater data that show relatively low toluene levels below *Investigation Levels*, as shown by the exceedances summarised in **Table 21 (Section 11.1)**.

In order to address these uncertainties, a computer analysis of the soil vapour generation potential of contamination in the shallow soils and aquifer at the Former Gasworks site has been undertaken, with the results presented in the following section.