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- Table 21 (cont'd) Sample Exceedances of Soil & groundwater Investigation Levels at the Former Gasworks Site

Location	Environmental Media	Contaminant	Concentration	Investigation Level	Type
BH16	Fill	BaP	11 mg/kg	5 mg/kg	Health
SB18	Fill	TPH (C10-C36)	38,400 mg/kg	600 mg/kg	
		Benzene	7 mg/kg	1 mg/kg	
		Ethylbenzene	80 mg/kg	50 mg/kg	
		Xylene	210 mg/kg	25 mg/kg	
		Total PAHs	2161-3953 mg/kg	100 mg/kg	
		BaP	28-220 mg/kg	5 mg/kg	
MW04	Natural	Benzene	4 mg/kg	1 mg/kg	
TPA	Fill	Benzene	1.6 mg/kg	1 mg/kg	
		Xylene	65 mg/kg	25 mg/kg	
		Total PAHs	537 mg/kg	100 mg/kg	
		BaP	8.4 mg/kg	5 mg/kg	
		TPH (C6-C9)	100 mg/kg	65 mg/kg	
		TPH (C10-C36)	3,200 mg/kg	600 mg/kg	
TPC	Fill	Total PAHs	751 mg/kg	100 mg/kg	
		BaP	8.4 mg/kg	5 mg/kg	
		Xylene	48 mg/kg	25 mg/kg	
TPD	Fill	BaP	6.2 mg/kg	5 mg/kg	
A29 (Adjacent to MW10S)	Fill	Total PAHs	131 mg/kg	100 mg/kg	
		BaP	12.3 mg/kg	5 mg/kg	
		TPH (C10-C36)	1,654 mg/kg	1,000 mg/kg	
MW10S	Fill	BaP	5.7 mg/kg	5 mg/kg	
MW12D	Fill	BaP	7.7 mg/kg	5 mg/kg	Health
	Groundwater	TPH (C6-C9)	960 µg/L	150 µg/L	Aquatic
MW13S	Fill	TPH (C10-C36)	6,444 mg/kg	1,000 mg/kg	Health
		Total PAHs	346 mg/kg	100 mg/kg	
		BaP	34.9 mg/kg	5 mg/kg	
MW20S	Fill	BaP	6.1 mg/kg	5 mg/kg	
MW33	Natural	>C16-C35 Aromatics	2,124 mg/kg	450 mg/kg	
MW37S	Groundwater	TPH (C10-C36)	1,480 µg/L	600 µg/L	Aquatic
MW37D	Groundwater	Naphthalene	18 µg/L	16 µg/L	Aquatic Aesthetic
		TPH (C10-C36)	920 µg/L	600 µg/L	Aquatic

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- Table 21 (cont'd) Sample Exceedances of Soil & groundwater Investigation Levels at the Former Gasworks Site

Location	Environmental Media	Contaminant	Concentration	Investigation Level	Type
MW04S	Groundwater	TPH (C10-C36)	700 µg/L	600 µg/L	Aquatic
MW04D	Groundwater	Naphthalene	54 µg/L	16 µg/L	Aquatic Aesthetic
		TPH (C6-C9)	1040 µg/L	150 µg/L	Aquatic
MW03D	Groundwater	Naphthalene	629 µg/L	16 µg/L	Aquatic Aesthetic
		Benzene	1,380 µg/L	1 µg/L	Aquatic Health
		Ethylbenzene	317 µg/L	3 µg/L	Aquatic Health
		TPH (C6-C9)	28800 µg/L	150 µg/L	Aquatic
		TPH (C10-C36)	3,770 µg/L	600 µg/L	Aquatic
MW07S	Groundwater	TPH (C6-C9)	2170 µg/L	150 µg/L	Aquatic
MW07D	Groundwater	Naphthalene	3,840 µg/L	16 µg/L	Aquatic Aesthetic
		Benzene	2,670 µg/L	1 µg/L	Aquatic Health
		Ethylbenzene	201 µg/L	3 µg/L	Aquatic
		TPH (C6-C9)	1280 µg/L	150 µg/L	Aquatic
		TPH (C10-C36)	18,220 µg/L	600 µg/L	Aquatic
MW12S	Groundwater	Naphthalene	16 µg/L	16 µg/L	Aquatic Aesthetic
		TPH (C6-C9)	373 µg/L	150 µg/L	Aquatic
MW18D	Groundwater	Naphthalene	40 µg/L	16 µg/L	Aquatic Aesthetic
		TPH (C6-C9)	210 µg/L	150 µg/L	Aquatic
MW06S	Groundwater	Naphthalene	24 µg/L	16 µg/L	Aquatic Aesthetic
		TPH (C6-C9)	177 µg/L	150 µg/L	Aquatic
MW06D	Groundwater	Benzene	16 µg/L	1 µg/L	Aquatic Health
		TPH (C6-C9)	200 µg/L	150 µg/L	Aquatic
MW36S	Groundwater	TPH (C10-C36)	800 µg/L	600 µg/L	Aquatic
MW36D	Groundwater	Naphthalene	82 µg/L	16 µg/L	Aquatic Aesthetic

The data provided in **Table 21** and the assessment provided in **Section 5.7.1** indicate that the main contaminants of concern for a site-specific risk assessment at the Former Gasworks site are, for soils:

- PAHs particularly benzo(a)pyrene;
- TPH C10-C36; and
- Benzene and xylenes.

For groundwater, the main contaminants of concern are:

- TPH C_6-C_9 & C_{10}-C_{36};
- Benzene and ethylbenzene; and
- PAHs particularly naphthalene.

The data also indicate that the environmental media of concern are the fill layer, underlying natural material and groundwater. The investigations have found that soil gas is not an environmental media of concern due to the low levels of volatile organic compounds (BTEX and light-end PAHs) that have been measured (**Section 9.1**).

In addition to the volatile contaminants of concern, benzo(a)pyrene, ammonia and heavy metals have also been detected in the groundwater at concentrations significantly exceeding the adopted site investigation criteria, indicating that these are also contaminants of concern.

For volatile soil vapours, the study presented in **Section 9** concluded that much higher soil gas vapours than were measured by the investigation may be present at the site. This is because the results of computer analyses showed that much higher soil gas levels may occur if the higher volatile concentrations measured in the earlier groundwater monitoring rounds and/or higher soil concentrations measured in some shallow soil samples are more representative of site conditions. Due to this high degree of variability, there is potential for elevated levels of soil gas vapours to be emitted from the ground surface of the site. For volatile soil vapours, a screening assessment provided in **Section 9.1** found that the main contaminants of concern at the Former Gasworks site are PAH compounds (acenaphthene, benz(b)fluoranthene, chrysene, fluorene, naphthalene, pyrene) and monocyclic aromatic compounds (benzene, toluene, ethylbenzene and xylenes).

11.2 Exposure Pathways & Potential Receptors

The study has identified 7 potential migration pathways for ground contamination at the Former Gasworks site, these being:

- Groundwater transport;
- Impacted groundwater extracted for beneficial use;
- Volatilisation from shallow soils and/or groundwater and vapour transport into buildings;

- Volatilisation from shallow soil and/or groundwater and vapour transport to outdoor air;
- Contaminant source in surface soils (fill layer); and
- Leaching to groundwater and migration.

The exposure media include shallow soil, groundwater, surface water, indoor air and outdoor air. The exposure routes include ingestion, dermal adsorption and inhalation.

The conceptual site contamination model, previously described in **Section 5.6.4**, has identified the potential receptors of ground contamination from the Former Gasworks site to be:

- Future long-term commercial/industrial users of the Former gasworks site (RailCorp workers);
- Future maintenance / construction workers at the Former Gasworks site and surrounding areas;
- The community who live in residential land adjacent to the western boundary of the site (**Figure 4**), off-site construction workers and users of any groundwater extracted from wells down-gradient of the site; and
- Freshwater aquatic ecosystems in the headwaters of Alexandra Canal.

Freshwater aquatic ecosystems have been included as a potential receptor in this study even though the nearest water body is Alexandra Canal (Sheas Creek) located some 1.3km to the south. This is because there is a risk that extracted groundwater could be discharged into the stormwater system that would discharge into the headwaters of Alexandra Canal. An example of such an exposure pathway is the possible interception of contaminated groundwater by drainage systems inside the Eastern Suburbs/Illawarra railway line tunnel that is located approximately 100m from the southern boundary of the Macdonaldtown Triangle area or from deep basements in the residential properties to the west of the Former Gasworks site, as shown in **Figure 4**.

The potential exposure pathways for each of these receptors have been assessed and summarised in **Table 22**.

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Table 22 Exposure Pathway Analysis

Source Media	Migration Pathway	Exposure Media	Exposure Routes	Potential receptors
Outdoor air	None	Outdoor air	Inhalation	None
Indoor air	None	Indoor air	Inhalation	None
Surface Water	None	Surface water	Ingestion dermal adsorption during swimming	None
Groundwater	**Impacted groundwater extracted or intercepted**	**Groundwater**	**Ingestion & dermal adsorption**	**Construction workers; Surrounding community; Freshwater ecosystems**
	Volatilisation during showering	Indoor air	Inhalation	None
	Groundwater transport	**Groundwater**	**Ingestion & dermal adsorption**	**Construction workers; Surrounding community; Freshwater ecosystems**
	Groundwater transport followed by volatilisation during showering	Indoor air	Inhalation	None
	Volatilisation and vapour transport into buildings	**Indoor air**	**Inhalation**	**Construction workers; Site workers; Surrounding community**
	Volatilisation and vapour transport to outdoor air	**Outdoor air**	**Inhalation**	**Construction workers; Site workers; Surrounding community**
Soil (surface & subsurface)	**Contaminant source in surface soils (fill layer)**	**Surface soil**	**Ingestion & dermal adsorption**	**Construction/maintenance workers; Site workers**
	Volatilisation and vapour transport	**Outdoor air**	**Inhalation**	**Construction workers; Site workers; Surrounding community**
	Volatilisation and vapour transport	**Indoor air**	**Inhalation**	**Construction workers; Site workers; Surrounding community**
	Leaching to g/water & migration	**Groundwater**	**Ingestion & dermal adsorption**	**Construction workers; Surrounding community; Freshwater ecosystems**
	Leaching to g/water, migration then volatilisation during showering	Indoor air	Inhalation	None

Legend: Potential exposure pathway for Former Gasworks site

The main exposure pathways for future long-term site workers at the Former Gasworks site are considered to be:

- Ingestion and dermal contact with contaminated surface soils;
- Inhalation of vapours emitted into the outdoor air and indoor air (within buildings) generated by contaminated soils in the unsaturated zone above the shallow aquifer; and
- Inhalation of vapours emitted into the outdoor air and indoor air (within buildings) generated by contaminated groundwater in the shallow aquifer.

Future site workers are unlikely to be ingest or have dermal contact with contaminated groundwater because:

- The water table in the shallow aquifer is on average approximately 1.5m below the ground surface;
- Groundwater is unlikely to be extracted for beneficial reuse due to the availability of good quality mains water and the poor quality of the groundwater at the 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.

A long-term Site Management Plan (SMP) will need to be placed on the Former Gasworks site in order to ensure that the risk to site workers from ingestion or dermal contact with contaminated groundwater remains low. Restrictions that would need to be part of an SMP include a prohibition on the extraction and reuse of groundwater at the Former Gasworks site and a prohibition on the construction of drained basements or deep pits that intersected the groundwater table. These recommendations are included in **Section 14.2** of this report.

The main exposure pathways for construction workers at the Former Gasworks site are considered to be the same as those for long-term site workers plus the ingestion and dermal contact with contaminated groundwater. This additional exposure pathway has been included because of the potential for excavations to extend deeper than 1.5m and past the shallow aquifer water table.

Construction workers at the site may also be subjected to volatile soil gas vapours and inhalation of dusts, particularly when excavating in highly contaminated areas such as near areas that contained tar pits, retorts and gasholders. However, a site-specific risk assessment has not been undertaken for these exposure pathways since these health risks should be managed as part of an occupational health and safety plan covering any earthworks conducted at the Former Gasworks site. The requirement for such safety procedures will need to be incorporated into the long-term SMP to be placed on the Former Gasworks site. This recommendation is included in **Section 14.2** of this report.

The main exposure pathways for residents and off-site construction workers at properties surrounding the Former Gasworks site are considered to be:

- Ingestion and dermal contact with contaminated groundwater;
- Inhalation of vapours emitted into the outdoor air and indoor air (within buildings) generated by contaminated soils in the unsaturated zone above the shallow aquifer; and
- Inhalation of vapours emitted into the outdoor air and indoor air (within buildings) generated by contaminated groundwater in the shallow aquifer.

Surrounding residents are considered to have a low risk from ingestion and dermal contact with contaminated near-surface soils because:

- It is understood that RailCorp has removed contaminated soils from the properties adjacent to the western site boundary under a remediation program completed in 2005; and
- Access to the Former Gasworks site is restricted to authorised personnel, who would largely be on-site workers.

A long-term SMP will also need to be placed on the Former gasworks site in order to ensure that the risk to the surrounding residential community from on-site soil contamination remains low. Restrictions that would need to be part of an SMP include the erection and maintenance of security fencing and controlling site access. These recommendations are included in **Section 14.2** of this report.

The main exposure pathways for the freshwater ecosystems in the headwaters of Alexandra Canal are considered to be the extraction and discharging of contaminated groundwater to the stormwater system that would be discharged into the headwaters of Alexandra Canal.

11.3 Exposure Concentrations

The exposure pathway analysis presented in **Table 22** identified five migration pathways for potential receptors to be exposed to contamination from the Former Gasworks site. These pathways are:

- Groundwater transport;
- Extracted and intercepted groundwater;
- Volatilisation and vapour transport from contaminated soils and groundwater; and
- Contaminated surface soils; and
- Leaching to groundwater and migration.

This section of the risk assessment provides estimates of the exposure concentrations applicable for each of these migration pathways.

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11.3.1 Groundwater Transport

The groundwater assessment presented in **Section 10** found that groundwater at the Former Gasworks site is contaminated primarily with PAHs, TPH, benzene, ethylbenzene and heavy metals. The available data indicate that the primary source of this contamination is most likely to be tarry liquid wastes and dumped material that remain in the area of the former tar wells, gasholders and retort house, as shown in **Figure 4**. This is because:

- The historical data (**Section 4**) indicate that the former tar wells are located in the Former Gasworks area close to the southern boundary of the Former Cleaning Shed site, while the northern end of the former retort house appears to extend some 10-15m into the Former Cleaning Shed site;
- Experience gained in remediating other gasworks sites in NSW suggest that tarry waste materials may remain at the base of the gasholder annulus and tar tanks that were not cleaned out when the former gasworks facilities were demolished;
- The historical data also indicate that the bulk of the Former Cleaning Shed site consisted of a above ground structures such as a large train storage shed and rail track, which do not represent potential sources of the tarry liquid wastes; and
- The groundwater quality in the monitoring wells in the northern portion of the Former Cleaning Shed site (ie. MW17S, MW17D, MW35S and MW35D) is generally consistent with background water quality, as discussed in **Section 10.5**.

The groundwater assessment also indicates that the groundwater level in the shallow aquifer at the Former Gasworks site is located some 1 to 4m below the present ground surface and flows in south to south-easterly direction. This is shown by the piezometric contours for the deep aquifer presented in **Figure 19**, which are similar to the shallow aquifer as shown by the groundwater elevation data in **Table 19 (Section 10.3)**. The higher groundwater contaminant concentrations occur near the gasholder wells, which form an artificial groundwater rise and recharge source. The groundwater in the deeper aquifer is by its very nature also located at depth below the shallow aquifer.

The groundwater in both aquifers appears not to flow towards the residential properties located along the eastern side of Burren Street, who represent the closest community receptors. This groundwater flow direction is shown in **Figure 19** by the orientation of the piezometric contours and the absence of exceedances of the Groundwater Investigation Levels in wells located to the south-west of the Former gasworks site (eg. wells MW08-MW11) and in the residential area to the west (eg. wells MW14-MW16). A sewer main is also known to run inside the western site boundary in a south-easterly direction, which may also be acting as a groundwater cut-off drain. The drain is understood to be several metres below the ground surface.