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10 Assessment of Groundwater Contamination

This section of the report presents the results of the groundwater contamination assessment for the Former Gasworks site and surrounding areas. The assessment initially describes the hydrogeological conditions that were revealed by the investigations, which includes consideration of the hydrogeological system, permeability, groundwater flow direction and intrinsic water quality. An assessment is then provided of the background groundwater quality, followed by an assessment of groundwater contamination. Conclusions drawn from the assessment are then presented.

Summary tables of the chemical analyses performed on the groundwater samples are provided in Tables E and F, with copies of the laboratory test certificates provided in Appendix E.

10.1 Hydrogeological System

The groundwater investigations have confirmed the nature of the hydrogeological system that operates at the Site and surrounding areas is consistent with the regional groundwater system described in technical literature, as reviewed in **Section 3.4**.

The investigation has shown that the geological sequence at the Site comprises fill material underlain by lower permeability clays, which are underlain by weathered to competent shale. There are considered to be two main water-bearing strata at the Site, the first is the layer of fill material above the clay and the second is the shale bedrock. Fill material was encountered to a depth of 3.5m in the southern portion of the site at BH1. In the vicinity of the former retort house fill material was encountered to a maximum depth of 2.3 m. Elsewhere on the Site, clays and weathered shale generally occur below 1-2 m. Investigations indicate that the shale aquifer extends to a depth of at least 15 m, but the base of the aquifer could not be established.

The shale bedrock probably operates as a semi-confined aquifer at the Site due to the presence of an overlying clay layer at a depth of between 1-10 m. This clay layer was encountered in all locations across the Site, with the exception of those locations in the vicinity of the former retort house where refusal was encountered on concrete or brick material.

Underground structures are considered to have a significant affect on the hydrogeological system at the Site. These structures include:

- The large gasholder that was constructed to a depth of more than 4 m below ground level;
- Underground tar tanks located between the gasholders and retort house at the northern end of the gasworks area, which may still remain at the site; and

- Underground pits and basements associated with the former retort house, which may still remain at the site.

10.2 Permeability

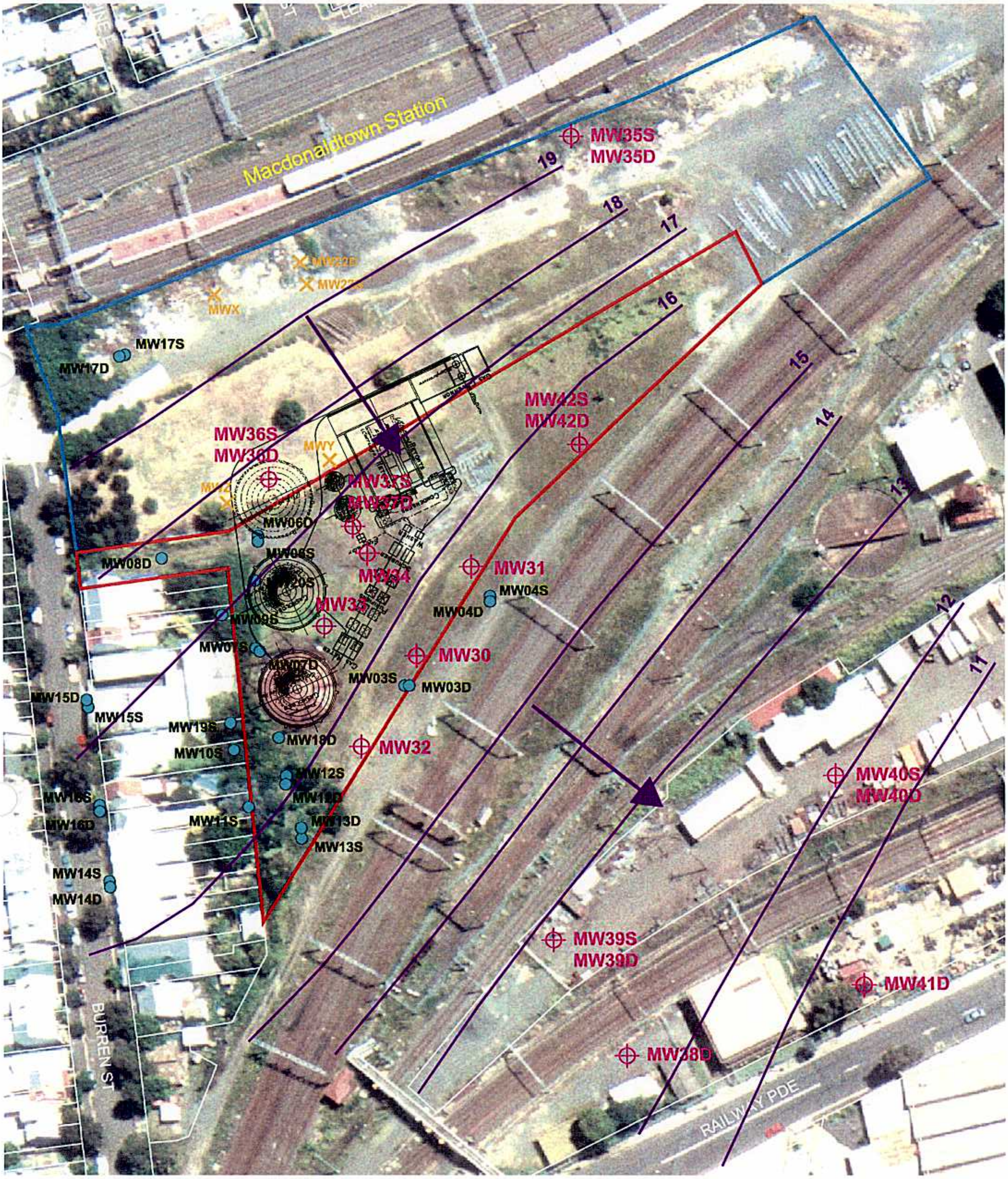
Slug tests were carried out on three wells (MW06S, MW07D and MW38D) at the Site in March 2005 to provide an estimate of the permeability of the underlying soils and therefore the likelihood of any potential contamination migrating off Site. The calculations are based on equations given in the NAVFAC DM-7.1 (May 1982) *"Soil Mechanics Design Manual 7.1"*. The equation calculates insitu permeability values from falling head tests conducted in the wells. The slug test carried out on the shallow well recorded an average permeability of 1.4×10^{-5} m/s for the clay layer. The results for deep wells provided mean permeability estimates between 1.0×10^{-5} and 3.0×10^{-5} m/s.

10.3 Groundwater Heads & Flow Direction

The data provided in the previous site investigations indicated that groundwater flows in a south to south-easterly direction towards the Illawarra railway, which is consistent with the regional groundwater system described in the technical literature, as previously described in **Section 3.4**. However, the data also show significant variations in the shallow ground water flow due to sub-surface obstructions (i.e. former gasholder structure and drains).

The investigations established groundwater flow directions from measurements of the free-standing water levels in the groundwater monitoring wells. These levels were obtained from depth measurements made by SKM that were converted to elevations from survey information collected by the registered surveyors Douglas Gow & Associates. The surface levels of the monitoring wells and groundwater in Australian Height Datum (AHD) are shown below in **Table 19,** with a contour plot of the deep groundwater elevation data across the Site and surrounding areas provided in **Figure 19**.

Figure 19
INFERRED DEEP GROUNDWATER CONTOURS AND FLOW DIRECTION
Macdonaldtown Risk Assessment



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

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- **Table 19 Groundwater Elevations**

Monitoring Well	Surface Level (AHD)	Groundwater Level (AHD)
Shallow Wells		
MW03S	18.38	17.34
MW04S	18.4	17.57
MW06S	18.96	17.63
MW12S	19.99	15.87
MW13S	19.5	19.50
MW14S	16.19	14.49
MW16S	16.655	15.05
MW17S	21.36	18.75
MW20S	19.66	18.93
MW35S	20.402	18.39
MW36S	20.238	17.54
MW37S	18.696	17.89
MW39S	15.746	13.60
MW40S	16.024	13.73
MW42S	18.484	17.88
Deep Wells		
MW03D	18.33	15.40
MW04D	18.37	19.22
MW06D	18.97	17.34
MW07D	19.59	17.25
MW12D	20.02	20.02
MW13D	19.47	15.88
MW14D	16.16	16.16
MW17D	21.33	19.56
MW18D	19.49	16.40
MW35D	20.375	19.28
MW36D	20.257	20.26
MW37D	18.615	17.31
MW38D	14.298	12.34
MW39D	15.73	12.77
MW40D	16.005	12.33
MW41D	13.675	10.56
MW42D	18.592	15.44

The data indicate that the groundwater hydraulic head is highest at the northern end of the Site and progressively decreases towards to the south and east, which indicates that the general groundwater flow is to the south-east. However, the rate at which the hydraulic head decreases does vary.

The data have allowed estimates to be made of the hydraulic gradients that operate at the Site and surrounding areas, the hydraulic gradient (i) being head loss (H) divided by distance (D) over which the head loss is measured.

The highest hydraulic gradient of $3.1x10^{-2}$ was calculated across the western end of the Site between wells MW17S (northern) and MW12S (southern), where a drop of 3.4 m in hydraulic head occurs over a distance of 110 m. The lowest hydraulic gradient of $1.3x10^{-2}$ was calculated between wells MW20S and MW03S (southeast flow direction), where a drop of 1.41 m in hydraulic head occurs over a distance of 105 m. The variation in head difference between the wells is likely to be due to the presence of the gasholder and its affect on shallow groundwater flow. Hence, the average flow head difference is believed to be within these limits.

These results together with the permeability estimates provided in the previous section indicate that the shallow flow velocities at the Site vary between 6.2 and 13.7 m/year, while the deep flow velocities to the Site are probably between 12.2 and 36.5 m/year.

The flow rates for the deep aquifer have been compared against estimates obtained from back-calculations based on the length of the contaminant plume revealed by the groundwater sampling data and the period of time since the gasworks first commenced operation. The groundwater quality data indicate that the PAH contaminants have given rise to the largest plume, presumably because PAHs are more resistant to biodegradation processes compared to other organic contaminants such as BTEX compounds. The data indicate that the PAH plume extends some 160m to the south-east of the tar tanks/gasholder. The historical data (**Section 4**) indicate that the gasworks commenced operation in 1892 and that the travel time for the plume is some 113 years. Assuming that the plume was first formed when the gasworks commenced operations, the average flow velocity is estimated to be 1.4m/year, which is about an order of magnitude lower than estimated from the in-situ permeability tests. This result may indicate that the permeability of soils/bedrock estimated from the in-situ permeability tests is too high and that a permeability of between $1.4x10^{-6}$ and $3.4x10^{-6}$ m/s may be more representative of the deep aquifer materials.

For the shallow aquifer, the data indicate that the PAH plume extends some 75m to the south-east of the tar tanks/gasholder. The average flow velocity is estimated to be 0.66m/year, which again is about an order of magnitude lower than estimated from the in-situ permeability tests. This result may again indicate that the permeability of the shallow soils estimated from the in-situ permeability tests is too high and that a permeability of between $6.8x10^{-7}$ and $1.6x10^{-6}$ m/s may be more representative of the shallow aquifer materials.

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10.4 Physical/Chemical Water Quality

The results of the intrinsic water quality tests conducted at the Site are summarised in **Table 20** and indicate that the groundwater at the Site has a slightly variable pH, which probably reflects the variable nature of the fill material. The salinity measurements varied between 0.01 % and 0.7 %.

Table 20 Intrinsic Water Quality Test Results

Sample	Water Depth (mbg)	pH	Conductivity (ms/cm)	Dissolved Oxygen (mg/l)	Temp (°C)	Salinity (%)	Comments
Sampling in March 2005							
Shallow Wells							
MW03S	1.04	-	-	-	-		-
MW04S	0.83	5.48	0.442	9.06	22.9	0.01	Grey, black slight naphthalene odour
MW06S	1.33	6.05	0.578	6.34	23.6	0.02	Red, orange, moderate odour
MW12S	4.12	4.23	0.738	-	24.8	0.03	Red, orange, slight odour
MW13S	3.745	4.27	0.852	5.45	22.1	0.03	Red, orange silty, no odour
MW14S	1.704	4.31	0.98	7.3	22.9	0.04	Slight orange colour, no odour
MW16S	1.610	4.59	1.96	8.21	21.3	0.09	Slight orange colour, no odour
MW17S	2.615	5.84	0.419	9.6	21.6	0.01	Red, orange, no odour
MW20S	0.735	6.26	0.91	7.52	22.8	0.04	Black turbid, moderate odour
MW35S	2.015	5.03	2.01	8.94	22.3	0.09	Brown, no odour
MW36S	3.295	5.31	0.735	8.87	21.3	0.03	Orange, no odour
MW37S	0.805	6.3	1.22	7.1	22.7	0.05	Brown silty, no odour
MW39S	2.145	6.00	0.835	6.49	23.9	0.03	Orange, no detectable odour
MW40S	2.294	5.97	0.728	9.1	23.7	0.03	Light brown, no odour
MW42S	0.6	6.19	0.762	10.3	22.3	0.03	Clear, no odour
Deep Wells							
MW03D	2.93	5.56	3.82	9.13	21.8	0.19	Clear, hydrocarbon odour
MW04D		5.85	0.419	10.95	22.4	0.01	Clear, toluene odour
MW06D	1.63	4.94	2.41	4.47	20.3	0.11	Clear, slight odour
MW07D	2.342	5.59	1.1	7.89	19.7	0.04	Clear, moderate hydrocarbon odour
MW12D	-	-	-	-	-	-	Well broken
MW13D	3.595	4.27	0.852	5.45	22.1	0.03	Red/orange silty, no odour
MW14D	0	5.07	2.26	5.02	21.3	0.1	Grey black, no odour
MW17D	1.775	5.69	1.4	10.87	22.9	0.06	Slightly brown, no odour
MW18D	3.09	5.32	0.717	8.65	20.4	0.03	Clear, slight odour
MW35D	1.1	5.81	3.42	-	18.8	0.17	Grey silty, no odour
MW36D		5.09	2.5	9.17	20.4	0.12	Grey silty, sulphur odour
MW37D	1.31	5.25	3.32	9.26	20.3	0.16	Dark grey silty, hydrocarbon odour
MW38D	1.96	5.03	3.25	9.29	22.4	0.16	Grey silty

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Sample	Water Depth (mbg)	pH	Conductivity (ms/cm)	Dissolved Oxygen (mg/l)	Temp (°C)	Salinity (%)	Comments
Sampling in March 2005							
MW39D	2.965	5.17	2.92	5.34	20.8	0.16	Grey, black, silty – moderate odour
MW40D	3.679	5.38	1.08	8.96	21.8	0.03	Clear, no odour
MW41D	3.12	6.03	1.01	9.14	21.5	0.04	Grey, no odour
MW42D	3.155	5.36	1.14	9.30	20.1	0.65	Grey silty, no odour

Dissolved oxygen levels were generally between 4.5 and 11 mg/L, which suggests that the main source of groundwater at the Site is infiltrating precipitation. The high oxygen percentage also possibly indicates that there is limited bacterial activity at the Site, as generally, low dissolved oxygen levels are considered to be a sign of microbiological activity. In suitable environmental conditions the identified organic compounds may undergo aerobic degradation through microbiological consumption. The increased consumption of carbon source would also result in a reduction of dissolved oxygen levels in groundwater.

10.5 Background Water Quality

Data on background water quality is provided in previous investigations undertaken at the North Eveleigh Workshop area, with a summary of the data is provided in **Table N**. Data on background groundwater quality in the area of the Site was also obtained from the results of laboratory tests conducted on water samples collected from wells located up-gradient of the Site (wells MW17S, MW17D, MW35S and d MW35D). **Section 5.2** also provides information relating to background water quality in the vicinity of the Site.

The groundwater quality data summarised in **Tables E - F** indicates that background water quality generally meets the groundwater assessment criteria specified in **Section 8.2** for drinking water. Petroleum hydrocarbon and volatile/ semi-volatile organic compound concentrations were below the freshwater ecosystem and drinking water criteria, although there were several heavy metal exceedances.

Four up-gradient wells located along the northern boundary of the former cleaning shed site (MW17D, MW17S, MW35D and MW35S) reported heavy metal concentrations above 95% protection level trigger values for the protection of aquatic ecosystems. The following analyte concentrations exceeded the nominated guidelines:

- Cadmium (up to 0.0003mg/L - freshwater criteria of 0.0002mg/L);

- Copper (up to 0.005mg/L - freshwater criteria of 0.0014mg/L);
- Nickel (up to 0.014mg/L - freshwater criteria of 0.008mg/L); and
- Zinc (up to 0.325mg/L - freshwater criteria of 0.008mg/L).

These concentrations are considered to be consistent with groundwater quality in an urban environment due to the diffuse contamination caused by the use of copper and galvanised water pipes, and galvanised steel in building construction. No further consideration of copper and zinc background levels are considered necessary.

These background concentrations indicate that the use of the NSW EPA-endorsed groundwater acceptance criteria specified in **Section 8.2** are relevant for this Site and no further consideration of cadmium, copper, nickel and zinc background water quality is considered necessary, except for concentrations above background water quality data.

Based on ADWG 1996 and average TDS values (>1000), the groundwater is not suitable for domestic use.

10.6 Heavy Metals and Inorganics

The heavy metal and inorganic laboratory results are summarised in **Tables E and F**. Heavy metal concentrations detected above the adopted ANZECC and ARMCANZ (2000) investigation criteria are shown on **Figure 20**.

Heavy metal impact is widespread across the Site with elevated zinc concentrations recorded at all sampling locations. The deep and shallow wells located along the northern boundary of the Site recorded concentrations of cadmium, copper, nickel, lead and zinc above the adopted assessment criteria. However, based on the up-gradient location of the wells and background levels discussed in **Section 10.5**, these concentrations are considered to be representative of background concentrations.

On site concentrations of cadmium, copper, lead and nickel were found to be highest at MW37D. However, concentrations were significantly lower in the adjacent shallow aquifer well MW37S. Similar exceeding concentrations were also found off site, well beyond the southern boundary.

The highest zinc concentration recorded at the Site was 1570 μg/L at MW13S, located in the south western portion of the site. Zinc concentrations increased beyond the southern boundary, beneath the Illawarra rail line at MW39S and MW42S (2230 and 869 μg/L respectively).