H2M HILL		ATER BORE LOG	Monitoring	itoring Bore No. <u>MW03S</u>		
L AUSTRALIA Pty Ltd			Sheet 1 of	1		
110158	Easting (AMG)	317137.911	Excavation Equip:	Rotary Air Circulation		
Eveleigh Gasworks	Northing (AMG)	1247683.304	Contractor:	Maquarie Drilling		
Macdonaldtown Triangle	Elevation (mAHD):	18.38	Logged By:	Lee Moore		
20-Apr-00	Water Level (mbtc):	2.31m	Project Manager:	Lee Moore		
Fine	Final Depth (mbgl):	3.5 m	Checked By:			
	L AUSTRALIA Pty Ltd 110158 Eveleigh Gasworks Macdonaldtown Triangle 20-Apr-00	L AUSTRALIA Pty Ltd 110158 Easting (AMG) Eveleigh Gasworks Northing (AMG) Macdonaldtown Triangle Elevation (mAHD): 20-Apr-00 Water Level (mbtc):	L AUSTRALIA Pty Ltd 110158 Easting (AMG) 317137.911 Eveleigh Gasworks Northing (AMG) 1247683.304 Macdonaldtown Triangle Elevation (mAHD): 18.38 20-Apr-00 Water Level (mbtc): 2.31m	L AUSTRALIA Pty Ltd Sheet 1 of 110158 Easting (AMG) 317137.911 Excavation Equip: Eveleigh Gasworks Northing (AMG) 1247683.304 Contractor: Macdonaldtown Triangle Elevation (mAHD): 18.38 Logged By: 20-Apr-00 Water Level (mbtc): 2.31m Project Manager:		

Depth Wate	r Sa	mple	Graphic	Soil Description	Observation/Comments Monitor
(m) Foun		No.	Log	(soil type, colour, moisture content, plasticity, grain size,	(visual contamination, odour, side Bore
-				stiffness, etc.) FILL, Sandy GRAVEL, gravel less than 3cm diameter, medium to coarse grained, grey/brown, dry, loose.	collapse, etc.) Detai
0.5		MW03- 1.00-1.10		Gravelly CLAY, low plasticity, soft/firm, sub-angular gravel less than 2cm diameter, light brown, moist.	
2.0 — — — — 2.31 m 2.5 —	nbtc	MW03- 2.00-2.10		Sandy CLAY, low plasticity, soft/firm, fine grained, grey/brown, slight organic odours.	
		MW03- 3.00-3.10		Silty CLAY, low to medium plasticity, stiff, brown, wet, no odours.	
3.5				EOH 3.5m	
mAHD: metres Aus	stralian He	ight Datum		mbgl: metres below ground level mbtc: metres below t	op of casing
Water Found		.g.n Baturn			
Water L GNE Ground			Water Inf ered	low Water Outflow	

) (CH2I		-L	МС	GROUNDW		Monitoring	Bore No. <u>MW03</u>	D
Н2М Н			A Pty Ltd				Sheet 1 of	1	
oject No:					Easting (AMG)	317139.485	Excavation Equip:	Rotary Air Circulation	
•		h Gaswo	rks		Northing (AMG)	1247683.339	Contractor:	Maquarie Drilling	
		aldtown			Elevation (mAHD):	18.33	Logged By:	Lee Moore	
te:	19-Apr-0		Thangle		Water Level (mbtc):	4.03m	Project Manager:	Lee Moore	
	Fine				Final Depth (mbgl):	13.5 m	Checked By:		
autor.	1 1110				· · · · · · · · · · · · · · · · · · ·	10.0 11	Onoonou Dy:		
Depth	Water	Sar	nple	Graphic	So	il Description		Observation/Comments	Moni
	Found		No.	Log	(soil type, colour, mois			al contamination, odour, side collapse	Bor
(111)	round	FID	NO.	LUG	stiffness, etc.)		etc.)		Deta
					FILL, Sandy GRAVE medium to coarse grai				
0.5						inou, groy/brown, ur	y, 10000.		
			MW03-						
1.0			1.00-1.10		Gravelly CLAY, low p	lasticity, soft/firm, s	ub-angular gravel		
1.5					less than 2cm diamete	er, light brown, moist	t.		
1.5									
2.0			MW03-			1 10 10 10 10			1
			2.00-2.10		Sandy CLAY, low grey/brown, slight orga		n, fine grained,		1
2.5					a. ay, arawn, angni olya				1
			MW03-	•					1
3.0			3.00-3.10						1
3.5				1					1
0.0					Silty CLAY, low to me	edium plasticity, stif	f, brown, wet, no		1
4.0	4.03 mb	to	MW03-		odours.				1
	4.03 mb	tC	4.00-4.10						
4.5									
5.0									
5.5									
5.5									
6.0									
6.5									
	1								
7.0									
7.5									
3									
8.0					Siltstone, low plasticity	/, stiff, brown/red/gre	ey, dry, no odours		
8.5									
9.0									
9.5									
3									
10.0									
10.5									
11.0	I I								
11.0	11.0 m								
11.5									
12.0									
					Shale, hard, grey, folia	ated, slight odour.			
12.5									
13.0									
13.5									
10.0					EOH 13.5m				
-	1			L					1
<u>tes</u>									
		alian Hei	ght Datum		mbgl: metres below gr	ound level mbt	tc: metres below top of	casing	
ter Fou				14/	1				
a <mark>ter Found</mark> Water InflowWater Outflow									

	CH2M HILL	GROUNDWATER MONITORING BORE LOG		Monitoring	Bore No	MW04S
CH2M H	ILL AUSTRALIA Pty Ltd			Sheet 1 of	1	
Project No	z <u>110158</u>	Easting (AMG)	317159.418	Excavation Equip:	Rotary Air Circulation	
Project:	Eveleigh Gasworks	Northing (AMG)	1247704.764	Contractor:	Maquarie Drilling	
Site:	Macdonaldtown Triangle	Elevation (mAHD):	18.4	Logged By:	Lee Moore	
Date:	20-Apr-00	Water Level (mbtc):	2.29m	Project Manager:	Lee Moore	
Weather:	Fine	Final Depth (mbgl):	3.5 m	Checked By:		

Depth	Water	Sa	mple	Graphic	Soil Description	Observation/Comments	Monitor.
	Found		No.	Log	(soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	(visual contamination, odour, side	Bore Details
- - - 0.5—					sumess, etc.) FILL, Sandy GRAVEL, angular gravel less than 5cm diameter, coarse grained, grey/black, dry, loose, no odours.		Details
- - - - - - - - - - - - - - - - - - -	1.80 m		MW04- 1.00-1.10		Sandy CLAY, low plasticity, soft/firm, medium grained, red/brown, moist.		
2.0 — - - -	 2.29 mb	tc	MW04- 2.00-2.10		Silty CLAY, low plasticity, soft, grey/brown, wet, slight organics odour.		
2.5 — - - 3.0 — - - - -			MW04- 3.00-3.10		Sandy CLAY, low plasticity, firm/stiff, medium grained, red/brown, wet.		
3.5 -					EOH 3.5m		
lotes							
nAHD: met		alian He	ight Datum		mbgl: metres below ground level mbtc: metres below t	op of casing	
	/ater Lev		 t Encounte	Water Inf	low Water Outflow		

		MHI	LL	MO	GROUNDV		Monitoring	Bore No.	MW04D
							Sheet 1 of	1	
CH2M HI			A Pty Ltd		F (1 (1140)	017150.011			
Project No:					Easting (AMG)	317158.641	Excavation Equip:	Rotary Air Circulation	
Project:		h Gaswo			Northing (AMG)	1247703.451	Contractor:	Maquarie Drilling	
Site:			Triangle		Elevation (mAHD):	18.37	Logged By:	Lee Moore	
Date:	19-Apr-0	00			Water Level (mbtc):	3.78m	Project Manager:	Lee Moore	
Weather:	Fine				Final Depth (mbgl):	<u>11.5 m</u>	Checked By:		
Denth	Water	0.		Graphic				Observetien / Comme	
Depth			mple			oil Description isture content, plastici	tv. grain size. (visu	Observation/Comme ual contamination, odour, side	
(m)	Found	PID	No.	Log	stiffness, etc.)		etc.)		Details
-					FILL, Sandy GRA	/EL, angular gravel	less than 5cm		
0.5					diameter, coarse gra	ined, grey/black, dry, l	oose, no odours.		
-									
1.0			MW04- 1.00-1.10				and the second second		
			1.00-1.10	-	red/brown, moist.	plasticity, soft/firm, n	nedium grained,		
1.5									
2.0	1		MW04-						
2.0	1		2.00-2.10			asticity, soft, grey/bro	own, wet, slight		
2.5					organics odour.				
-									
3.0	1		MW04- 3.00-3.10						
. =			3.00-3.10						
3.5	1								
4.0	3.78 mb	otc				plasticity, firm/stiff, n	nedium grained,		
4.0					red/brown, wet.				
4.5									
5.0									
5.5									
6.0									
6.5									
7.0									
=									
7.5									
					Siltstone, low plastic	ity, stiff, red/brown/gre	y, dry.		
8.0									
8.5									
0.0	1								
9.0	1								
=	1								
9.5									
10.0									
10.0	10 m								
10.5	1								
	1				Shale, hard, grey, fo	liated, wet, no odours.			
11.0									
=									
11.5					EOH 11.5m				
	1								
12.0	1								
12.5									
12.0									
13.0									
	1								
13.5	1								
otes									
	res Austi	ralian Hei	ight Datum		mbgl: metres below	ground level mbto	c: metres below top of	casing	
Vater Fo					<u> </u>				
	ater Le		I	Water Inf	flow	Wat	ter Outflow		
GNE G	roundwa	ater Not	Encounte	ered					

	CH2M HILL	GROUNDW MONITORING E		Monitoring	Monitoring Bore No. <u>MW</u>	
СН2М Н	IILL AUSTRALIA Pty Ltd			Sheet 1 of	1	
Project No	o: 110158	Easting (AMG)	317103.196	Excavation Equip:	Rotary Air Circulation	
Project:	Eveleigh Gasworks	Northing (AMG)	1247719.155	Contractor:	Maquarie Drilling	
Site:	Macdonaldtown Triangle	Elevation (mAHD):	18.96	Logged By:	Lee Moore	
Date:	20-Apr-00	Water Level (mbtc):	2.33m	Project Manager:	Lee Moore	
Weather:	Fine	Final Depth (mbgl):	3.5m	Checked By:		

Depth	Water	Sa	mple	Graphic		Observation/Comments	Monito
(m)	Found	PID	No.	Log	(soil type, colour, moisture content, plasticity, grain size, stiffness, etc.)	(visual contamination, odour, side collapse, etc.)	Bore Detail
					FILL, Bitumen		Detail
_							
_			6-0.2-0.3		FILL, Brown/black, coke fill, dry, crumbly, light, minor		
_			6-0.3-0.4		coarse black sand.		
0.5 —							
_							
_					FILL, Red/grey, sandy clay, red weathered shale.		
_							
_							
1.0 —							
			6-1.0-1.1				
-							
-							
1.5 —							
_					Dark grey plastic silty clay, roots.		
_							
_	I						
1	1.80 m						
-							
2.0 —			6-2.0-2.1				
-			2.3 2.1				
-							
_	_						
_	2.33 mb	tc					
2.5 —							
2.5							
-							
-					Red, clay, compacted, dry, weathered shale red.		
-							
3.0 —							
_			6-3.0-3.1				
_							
3.5 —					EOH @ 3.5m		
-							
-							
							1
<u>tes</u>							
		alian He	ight Datum		mbgl: metres below ground level mbtc: metres below to	op of casing	
ter Fou	<mark>und</mark> ater Lev	(a)		Water Inf	low Water Outflow		
		ا لت <i>ا</i>		vvater int	IOW VVater Outflow		

	CH2M HILL						ing Bore No. <u>MW06D</u>		
				NITORING E	BORE LOG				
		TRALIA Pty L	td		017100 71	Sheet 1 of			
Project No Droject				Easting (AMG) Northing (AMG)	317102.514 1247720.496	Excavation Equip		tion	
Project: Site:		h Gasworks naldtown Triangl	e	Elevation (mAHD):	18.97	Contractor: Logged By:	Maquarie Drilling Lee Moore		
Date:	19-Apr-0			Water Level (mbtc):	2.29m	Project Manager:	-		
Weather:	Fine			Final Depth (mbgl):	15.0 m	Checked By:			
			_						
Depth	Water		Graphic	Soli type, colour, moi	oil Description	ity grain size (vis	Observation/C sual contamination, od		Monitor. Bore
(m)	Found	PID No.	Log	stiffness, etc.)		col	lapse, etc.)		Details
		6-0.2-0	.3	coarse black sand	coke illi, dry, cruit	iory, light, minor			
0.5-		6-0.3-0	.4	FILL, Red/grey, sand	y clay, red weathered	l shale.			
1.0		6-1.0-1	.1						
1.5-				Dark grey plastic silty	clay, roots.				
2.0		6-2.0-2	.1						
2.5-	2.29 mb								
2.5									
3.0-	Ŧ	6-3.0-3	.1						
3.5-	1								
	3								
4.0	1								
4.5				Red, clay, compacted	dry weathered sha	lo rod			
				Red, clay, compacted	i, dry, weathered sha	ie ieu.			
5.0									
5.5									
6.0									
6.5									
7.0	3								
7.0									
7.5									
8.0									
9.0									
9.5									
10.0	1								
10.5	E								
10.5	1 .								
11.0	ا 11.0 m			Shale, hard, grey, foli	ated, slight odour.				
11.5	1								
	Ξ								
12.0	1								
12.5	3								
10.0	1								
13.0	3								
13.5	1								
14.0	3								
14.0	3								
14.5	3								
15.0	3								
13.0	1			EOH @ 15.0m					
Notes			÷			•			
	etres Austr	alian Height Datu	m	mbgl: metres below g	round level mb	tc: metres below top c	of casing		
Water Fo	ound								
	Vater Lev		Water Inf	low	Wa	ter Outflow			
	oroundwa	ater Not Encou	ilered						



APPENDIX F

LABORATORY ANALYTICAL RESULTS AND CHAIN OF CUSTODY

13 June 2000 110158.141



APPENDIX F HAS BEEN PROVIDED AS VOLUME TWO



APPENDIX G

NATURAL ATTENUATION BACKGROUND INFORMATION

13 June 2000 110158.141



It must be noted that to obtain an indication as to whether natural attenuation of organic contaminants is occurring in the aquifer, multiple groundwater sampling events and analysis are required. It is not possible to determine whether natural attenuation is occurring from one monitoring round. The following information indicates whether there is a potential for natural attenuation in the surficial and Ashfield Shale aquifers at the Macdonaldtown Triangle.

Natural attenuation of hydrocarbon contamination in groundwater can occur by the natural replacement of hydrogen ions by either aerobic or anaerobic processes. In order to quantify this potential, electron acceptor analysis has been undertaken on the surficial groundwater present beneath the site. The natural attenuation parameters analysed from the groundwater during the groundwater sampling event includes sulphate, nitrate, dissolved oxygen and ferrous iron.

The table below presents the analytical and field measured natural attenuation parameters for the groundwater collected from the surficial and Ashfield Shale aquifers.

Summa	Summary of Natural Attenuation Data							
Well	SO_4	NO ₃	Diss O ₂	Ferrous Fe				
Surficial Aquifer	Surficial Aquifer							
MW03S	240	nd	1.1	55.6				
MW04S	41	nd	1.1	35.3				
MW06S	130	1.42	3.9	1.5				
Ashfield Shale Aqu	uifer							
MW03D	580	0.01	3.1	36.5				
MW04D	610	0.02	2.2	12.8				
MW06D*	650	nd	3.1	6.8				

NOTE:

* - Background Monitoring Well

nd – not reported above laboratory PQL

All results in mg/L

There are two main processes by which natural attenuation of hydrocarbon contamination can occur in groundwater, aerobic and anaerobic biodegradation. For the purposes of discussion benzene has been used as an example of a hydrocarbon contaminant.

Aerobic biodegradation can occur when oxygenated groundwater intersects a hydrocarbon contaminant plume. Dissolved oxygen concentrations in groundwater measured during the purging and sampling process indicates the amount of oxygen present within the aquifer. The chemical reaction for the aerobic degradation of benzene is described as:

$$C_6H_6 + 7.50_2 \rightarrow 6CO_2 + 3H_20$$

Based on this process, approximately 3 mg of oxygen is required to degrade 1 mg of benzene. Using a stochiometric approach, the amount of oxygen required to degrade hydrocarbons in the $C_{15} - C_{28}$ chainlength can be estimated to be approximately three times greater than for a C_6 chainlength hydrocarbon. Therefore, approximately 9 mg of oxygen would be required to



degrade 1 mg of C_{18} chainlength hydrocarbon. This calculation provides a conservative overestimate of the potential biodegradation of hydrocarbon compounds.

The average dissolved oxygen concentration recorded in the surficial aquifer at the site was 2.03 mg/L. Therefore, based on the above equation, at this dissolved oxygen concentration the surficial aquifer has the potential to degrade approximately 0.225 mg/L of C_{18} chainlength hydrocarbon.

The average dissolved oxygen concentration recorded in the Ashfield Shale aquifer at the site was 2.8 mg/L. Therefore, based on the above equation, at this dissolved oxygen concentration the Ashfield Shale aquifer has the potential to degrade approximately 0.311 mg/L of C_{18} chainlength hydrocarbon.

The process for anaerobic biodegradation requires a lack of oxygen, carbon, electron acceptors, nutrients and appropriate geochemical conditions for the bacteria to thrive. The presence of dissolved oxygen hinders the anaerobic biodegradation of hydrocarbon compounds. Anaerobic biodegradation will not occur until all of the dissolved oxygen has been removed from the system.

Common anaerobic degradation processes include denitrification, ferric iron reduction, sulfagenesis and methanogensis (Wiedemeier, 1994).

The anaerobic biodegradation process for benzene by denitrification occurs through the following process:

$$6NO_3^- + 6H^+ + C_6H_6 \rightarrow 6CO_{2(g)} + 6H_20 + 3N_{2(g)}$$

Using the same principles outlined for the aerobic degradation of hydrocarbon chainlengths, approximately 14.34 mg of nitrate would be required to degrade 1 mg of C_{18} chainlength hydrocarbon. The average concentration of NO₃ in the surficial groundwater recorded at the site is 0.476 mg/L. Therefore, there the surficial aquifer has the potential to degrade approximately 0.033 mg/L of of C_{18} chainlength hydrocarbon.

The average nitrate concentration recorded in the Ashfield Shale aquifer at the site was 0.012 mg/L. Therefore, based on the above equation, at this nitrate concentration the Ashfield Shale aquifer has the potential to degrade approximately 0.00084 mg/L of C₁₈ chainlength hydrocarbon.

The biodegradation of benzene through iron reduction occurs following the chemical reaction:

$$6OH^+ + 30Fe(OH)_3 + C_6H_6 \rightarrow 6CO_2 + 30Fe^{2+} + 78H_2O$$

Under this process, and using the same approach as described above, approximately 63 mg of Fe would be required to degrade 1 mg of C_{18} chainlength hydrocarbon. Using the average concentration of ferrous iron reported by the laboratory for the surficial aquifer, 30.8 mg/L,



approximately 0.489 mg/L of C_{18} chainlength hydrocarbon would be able to be degraded through iron reduction.

Using the average concentration of ferrous iron reported by the laboratory for the Ashfield Shale aquifer, 18.7 mg/L, approximately 0.296 mg/L of C_{18} chainlength hydrocarbon would be able to be degraded through iron reduction.

Natural attenuation of benzene by sulphate reduction occurs through the following chemical reaction:

$$7.5H^{+} + 3.75SO_{4}^{-} + C_{6}H_{6} \rightarrow 6CO_{2(g)} + 3.75H_{2}S^{o} + 3H_{2}O$$

Using the same approach as described above, approximately 13.8 mg of SO₄ would be required to degrade 1 mg of C_{18} chainlength hydrocarbon. The average concentration of SO₄ reported in the surficial groundwater is 151 mg/L. Therefore, approximately 10.94 mg/L of C_{18} chainlength hydrocarbon could be degraded through sulphate reduction.

The average sulphate concentration recorded in the Ashfield Shale aquifer at the site was 613.3 mg/L. Therefore, based on the above equation, at this sulphate concentration the Ashfield Shale aquifer has the potential to degrade approximately 44.4 mg/L of C_{18} chainlength hydrocarbon.

Co-metabolite

Methane is an *in situ* product of the natural attenuation of hydrocarbons via the process of methanogenesis. The amount of dissolved methane present in the groundwater is a direct indicator as to the degree of hydrocarbon biodegradation.

The reported analytical results for both the surficial and Ashfield Shale aquifers are presented in the table below.

Summary of Dissolved Methane Data						
Well Dissolved Methane						
Surficial Aquifer						
MW03S	230					
MW04S	2500					
MW06S	100					
Ashfield Shale Aquif	er					
MW03D	83					
MW04D	22					
MW06D	47					
NOTE:						
All results in µg/L @25°C						

The biodegradation of benzene by methanogenesis occurs by the following reaction:



$C_6H_6 + 4.5H_2O \rightarrow 2.25CO_2 + 3.75CH_4$

Based on the approaches described above, approximately 2.3 mg of methane is produced as a result of the biodegradation of the of C_{18} chainlength hydrocarbon.

The average concentration of dissolved methane reported in the surficial groundwater is 943.3 mg/L. Therefore, it can be estimated that approximately 410.14 mg/L of C_{18} chainlength hydrocarbon has been degraded through methanogenesis.

The average concentration of dissolved methane reported in the Ashfield Shale aquifer is 50.67 mg/L. Therefore, it can be estimated that approximately 22.02 mg/L of C₁₈ chainlength hydrocarbon has been degraded through methanogenesis.

The various metabolic processes listed above are not mutually exclusive. As liable organic matter enters an oxygenated aquifer, microbial metabolism will likely degrade the contaminating substrate. That is, the indigenous microorganisms utilise the pollutant, as an electron donor to support heterotrophic microbial respiration. The aquifer microbiota use oxygen as a co-substrate and as an electron acceptor to support their respiratory activities. When oxygen becomes limiting, aerobic respiration slows, but other groups of microorganisms may then come into play and continue to degrade the contaminating organic matter. Under conditions of anoxia, anaerobic bacteria can use organic chemicals or several inorganic chemicals or several inorganic chemicals or several inorganic anions as alternate electron acceptors.

These concentrations suggest that the surficial aquifer has a potential assimilative capacity of 1.6 mg/L of hydrocarbons, which indicates a moderate potential for hydrocarbon degradation in the aquifer.

Using both aerobic and anaerobic pathways these concentrations suggest that the Ashfield Shale aquifer has a potential assimilative capacity of 44.7 mg/L of hydrocarbons, which indicates a good potential for hydrocarbon degradation in the aquifer.

In addition, the presence of co-metabolite methane in both the surficial and Ashfield Shale aquifers suggests that the natural attenuation of hydrocarbons is actively occurring in the aquifers.

