Former Gasworks, Dock Road, Limerick

Quarterly Groundwater Monitoring Report – Annual Summary 2013

November 2013

For Bord Gais

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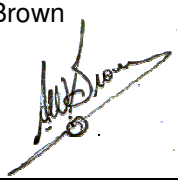
A	First Issue	Laurence Cullen 	Dave Watts 	Tony Brown 

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New information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission.

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1 Introduction

1.1 Terms of Reference

Mouchel were appointed by Bord Gais Eireann, on 31st March 2009, to provide engineering consultancy services for the assessment and remediation of the former gasworks site, on Dock Road, Limerick, Ireland. Mouchel (formerly known as Mouchel Parkman) have had an involvement with the site extending over a period of some ten years having previously undertaken ground investigations at the site.

This report forms part of the larger scheme of works currently being undertaken on the site. Mouchel have been appointed to conduct groundwater quality monitoring programme to establish a baseline data-set for the site prior to the proposed remediation works.

Visit 13 – 16th January 2013; Visit 14 – 24th April 2013; Visit 15 – 23rd & 24th July 2013 and Visit 16 – 16th October 2013.

1.2 Monitoring Visits

To date, sixteen groundwater monitoring visits have been undertaken as part of the groundwater monitoring programme. This annual report summarises the four visits undertaken in 2013 on the following dates;

- Visit 13 – 16th January 2013,
- Visit 14 – 24th April 2013,
- Visit 15 – 23rd & 24th July 2013,
- Visit 16 – 16th October 2013.

For further information on the site characterisation fieldwork, sampling and chemical testing, please refer to the Mouchel Site Characterisation Factual Report, 1021927/R/02 version C dated November 2011.

2 Hydrogeological Site Model

2.1 Groundwater source and flow direction

The site specific hydrogeology is discussed in depth in the 2010 Quantitative Risk Assessment, Options Appraisal and Remediation Report, reference 1021927/R/03 and the subsequent Addendum Report 1021927/R/18. The findings of the QRA report have been reviewed following completion of four years worth of groundwater monitoring. Drawing 1021927/R02/OD/001 presents the exploratory hole locations and the grid cells referred to below.

The results indicate that the flow direction is generally consistent all year round but the groundwater levels are influenced by seasonal rainfall variations. The results to date suggest that there may be two sources of groundwater entering the site.

- Source 1 – Originating from the southern corner of the site from within the rock outcrop (picked up by monitoring well J10).
- Source 2 – Originating from the south east section where water is draining into the site (picked up by monitoring well K5).

These two sources seem to be partially split by the bedrock which is located at the surface around cells J10, J09, K08, K09, K10, L08, L09 and L10.

The water appears to accumulate in the quarry area and flow towards the south west (A11 / corner of Dock Road and St. Alphonsus Street) and to the west (A3 – A4 / Dock Road). Flow is therefore in an approximately westerly direction as would be expected close to the river (the angle of flow will be to the river - west north west) but with a vector in the direction of river flow, i.e. westerly.

2.2 Groundwater levels

The results of the 2013 groundwater monitoring visits are presented overleaf (the DNAPL depths are displayed in brackets). Groundwater contour plots for all four visits undertaken during 2013 are presented as Appendix A.

Borehole	Response zone strata	Water level m MHD (DNAPL level m MHD)						
		2011 Annual average	2012 Annual average	Jan 2013 Visit 13	Apr 2013 Visit 14	July 2013 Visit 15	October 2013 Visit 16	2013 Annual Average
A1	Limestone	N/A	3.97	3.86	3.77	3.71	3.96	3.83
A3	Limestone	2.78	2.90	2.93	2.86	2.81	2.98	2.90
A4	Limestone	2.63	2.49	2.48	2.44	2.36	2.52	2.45
A9	Made ground	N/A	3.95	3.69	3.69	3.60	3.88	3.72
A11	Limestone	2.87	2.70	3.74	2.66	2.63	3.74	3.19
B8	Made ground	N/A	N/A	Blocked	Blocked	Blocked	Blocked	Blocked
C2	Made ground	N/A	4.14	4.06	3.99	3.93	4.26	4.06
C7	Limestone	3.77	3.92 (-0.97)	3.92 (-0.65)	3.82 (-0.742)	3.67 (-0.642)	3.83 (-1.632)	3.81 (-0.920)
C11	Natural clay	3.14	3.15	3.18	3.16	3.13	3.21	3.17
D1	Limestone	4.07	4.21 (3.05)	4.33 (2.87)	4.21 (2.884)	4.14 (3.054)	4.41 (2.904)	4.27 (2.928)
D5	Made ground	5.22	5.33	5.36	5.26	5.08	5.37	5.27
E8	Made ground	4.95	5.06	5.08	5.04	4.69	5.10	4.98
F11	Limestone	5.05	5.09	5.13	5.11	4.94	5.23	5.10
G2	Limestone	4.98	5.17	5.26	5.10	4.88	5.06	5.08
G3	Made ground	5.00	5.21	5.25	5.17	4.94	5.05	5.10
G4	Limestone	5.00	5.18 (-2.24)	5.26 (-2.36)	5.11 (-2.369)	4.93 (-2.349)	5.07 (-2.379)	5.09 (-2.364)
G5	Made ground	5.02	5.30	5.35	5.18	4.92	5.09	5.14
G8	Limestone	6.80	6.93	6.99	6.94	6.38	7.01	6.83
H12	Limestone	5.63	5.72	5.71	5.67	5.46	5.72	5.64
J10	Limestone	6.66	6.82	6.90	6.83	5.74	6.92	6.60
K1	Made ground	6.02	6.08	6.03	6.23	5.72	6.12	6.03
K5	Made ground	7.91	8.11	8.16	8.10	7.96	8.22	8.11
L7	Limestone	5.89**	5.93**	5.89	5.98	5.89	5.88	5.91
M3	Limestone	5.31	5.46	5.49	5.41	5.09	5.17	5.29

*Depth estimated from installation details from 2010 QRA report (1021927/R/03).

**Installation was dry during monitoring; the depth stated is the base of the monitoring well.

2.3 Hydraulic gradient estimates

The results equate to the following estimates of hydraulic gradient across the site:

2010 annual average for visits 1-5

G8 – E8 (approximately 1.84 / 13.5m) = 0.136

G3 – A3 (approximately 2.17m / 59.9m) = 0.036

F11 – A11 (approximately 2.71m / 47.15m) = 0.057

Average across the three = 0.076

2011 annual average for visits 6-8

G8 – E8 (approximately 1.85m / 13.5m) = 0.137

G3 – A3 (approximately 2.22m / 59.9m) = 0.036

F11 – A11 (approximately 2.18m / 47.15m) = 0.046

Average across the three = 0.073

2012 annual average for visits 9-12

G8 – E8 (approximately 1.87m / 13.5m) = 0.138

G3 – A3 (approximately 2.31m / 59.9m) = 0.038

F11 – A11 (approximately 2.18m / 47.15m) = 0.05

Average across the three = 0.075

2013 annual average for visits 13-16

G8 – E8 (approximately 1.85 / 13.5m) = 0.137

G3 – A3 (approximately 2.21m / 59.9m) = 0.037

F11 – A11 (approximately 1.91m / 47.15m) = 0.041

Average across the three = 0.072

The average hydraulic gradient is generally consistent with the 2010, 2011 and 2012 averages. However, the F11 to A11 gradient has decreased slightly between 2012 and 2013, possibly due to the lower rainfall experienced in 2013 to date as indicated by MET Eireann (**http://www.met.ie/climate/monthly-summary.asp**).

3 Chemical distribution

3.1 Visual, olfactory and DNAPL thickness results

Whilst undertaking the groundwater monitoring programme, samples collected were inspected for any visual and olfactory evidence of contamination. This ranged from various odours, hydrocarbon sheens and the presence of DNAPL. These results have been collated for the four visits undertaken during 2013 and have been summarised in the table below:

Visit	DNAPL detected	Hydrocarbon sheen / odour	Ammonia odour	No visual or olfactory evidence of significant contamination
13	C7, D1 & G4.	A1, A3, A4, C2, C7, C11, D1, D5, E8, F11, G2, G3, G4, G8, H12, J10, K1 & K5.	-	A9, A11, G5, L7, M3.
14	C7, D1, G4 & speckles at K5.	A1, A3, A4, C7, C11, D1, E8, F11, G2, G4, G5, G8, H12, J10, K1, K5 & M3.	-	A9, A11, C2, D5, G3 & L7.
15	C7, D1, G4 & speckles at K5.	A1, A3, A4, A9, C2, C7, C11, D1, D5, E8, F11, G2, G3, G4, G5, G8, H12, K1 & K5	-	A11, J10, L7 & M3.
16	C7, D1, G4 & speckles at K5.	A1, A3, A4, A9, C7, C11, D1, E8, F11, G2, G3, G4, G5, H12 and K5.	-	A11, C2, D5, G8, J10, K1, L7 & M3.

A sheen / odour was regularly noted around the former gasholders and the quarry area (C7, D1, G4, G5 and K5). During visits 14, 15 and 16, yellow coloured water was retrieved from E8. This water also frothed easily which may indicate the presence of dissolved gases.

DNAPL was generally encountered around the former gasholders and within the deeper parts of the former quarry where response zones were placed in the Limestone bedrock.

3.2 Chemical results

The groundwater testing methodology and legislation is discussed in full in the Mouchel Quantitative Risk Assessment, Options Appraisal and Remedial Strategy report reference 1021927/R/03, dated March 2010.

Chemical test results for the four quarterly monitoring visits for 2013 are discussed on a visit by visit basis in the quarterly monitoring reports.

Chemical test results from all four visits are presented as Appendix C. EQS and DWS screening tables for each visit are presented as Appendix D.

Borehole A11 was inundated with rainwater at the time of the July and October 2013 monitoring visits. No sample was taken on either occasion as it would not have been representative of the true groundwater conditions.

Across all four visits during 2013, the chemical test results generally correspond with the visual and olfactory evidence. The locations that appeared to be the most contaminated generally recorded the highest concentrations of contaminants. Concentrations of contaminants varied between visits but generally the following contaminants recorded exceedences of the stated standards:-

Environmental Quality Standards (EQS)

Concentrations commonly exceed the screening values in more than 50% of the samples for selenium, ammonaical nitrogen, phenols, cyanide, xylene, total TPH C_5-C_{35} and most of the speciated PAH's.

Exceedences were recorded in less than 50% of the samples (although not necessarily on every occasion) for arsenic, nickel, sulphate, benzene, toluene, ethyl benzene, anthracene, styrene, acenaphthene, mercury, fluorene, naphthalene, phenanthrene and trichloroethene.

Drinking Water Standards (DWS)

Concentrations commonly exceed the screening values in more than 50% of the samples for ammonium, cyanide, total TPH C_5-C_{35}, total PAH, GRO C4-C12 and benzo(a)pyrene.

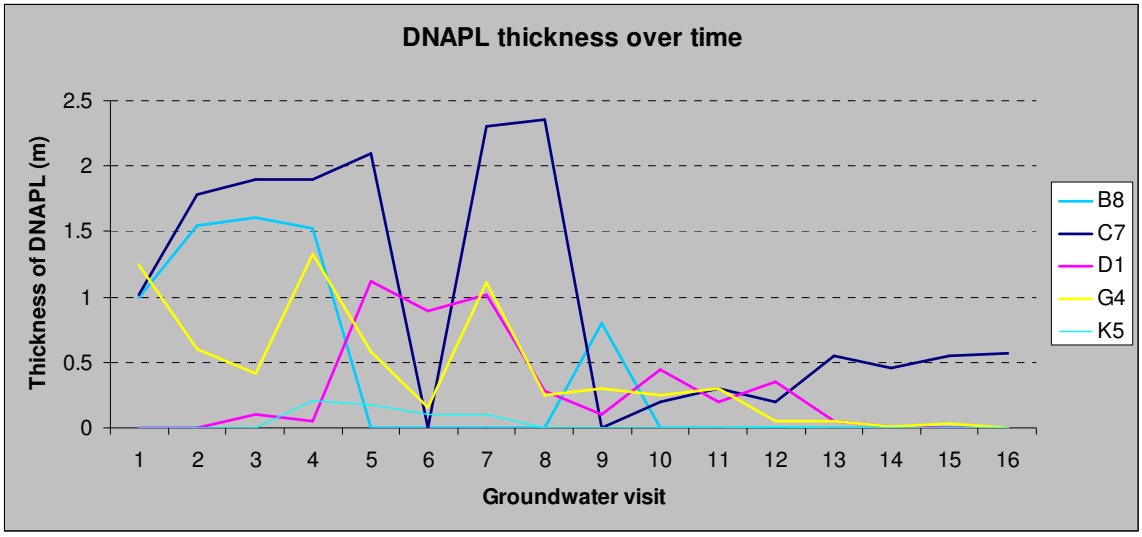
Exceedences were recorded in less than 50% of the samples (although not necessarily on every occasion) for arsenic, nickel, selenium, ethylbenzene, toluene, xylene, sulphate, fluoranthene and styrene.

3.3 Temporal Variation

The DNAPL thicknesses from all sixteen visits to date and chemical analytical data from the previous 8 visits have been compared to assess any potential temporal changes and identify any seasonal patterns. Temporal variation plots are presented in Appendix B.

The graphs indicate that although there is some variation in contaminant concentrations, there does not appear to be any consistent increase or decline for the majority of locations over time. Ammonium and arsenic concentrations at K5 appear reduced for 2013 visits when compared to 2012 concentrations. GRO and TPH concentrations at C7 showed a large reduction in concentrations between visits 12 and 13. The majority of variation between visits is less than one order of magnitude and therefore is not considered to reflect a change in contaminant mobility or migration.

DNAPL was detected at three locations (C7, D1 and G4) during the 2013 monitoring period. The graph below indicates the variation in the thickness of DNAPL across all sixteen visits undertaken to date. The depth of DNAPL at C7 has remained consistent at approximately 50cm for all 2013 visits although a general trend of reducing thickness is indicated for most locations. This may be due to disturbance and occasional removal of DNAPL during purging and water sampling. The viscosity of the DNAPL may restrict the recharge of DNAPL into the base of the borehole.



4 Conclusions

4.1 Hydrology

The results indicate that the groundwater levels and flow direction are generally consistent all year round. The results to date suggest that there may be two sources of groundwater entering the site along the southern boundary.

Groundwater flow appears to be in a westerly direction, as would be expected close to the river. The angle of flow will be to the river (west north west) but with a vector in the direction of river flow, (i.e. westerly).

The average results of the four visits to date this year equate to an estimated hydraulic gradient across the site of 0.072m.

4.2 Chemical distribution

4.2.1 Visual, olfactory and DNAPL thickness results

Visual and olfactory evidence of contamination has remained generally consistent for 2013.

The DNAPL level in C7 appears to have been stable throughout the year at approximately 50cm above the base of the borehole, although there has been some difficulty measuring the true depth of this borehole location. The DNAPL levels in D1 and G4 have remained low (≤5cm) throughout 2013 with no measurable depth recorded at either location during visit 16. No measurable depth of DNAPL was recorded in K5 throughout 2013 which continues the trend observed since the latter part of 2011.

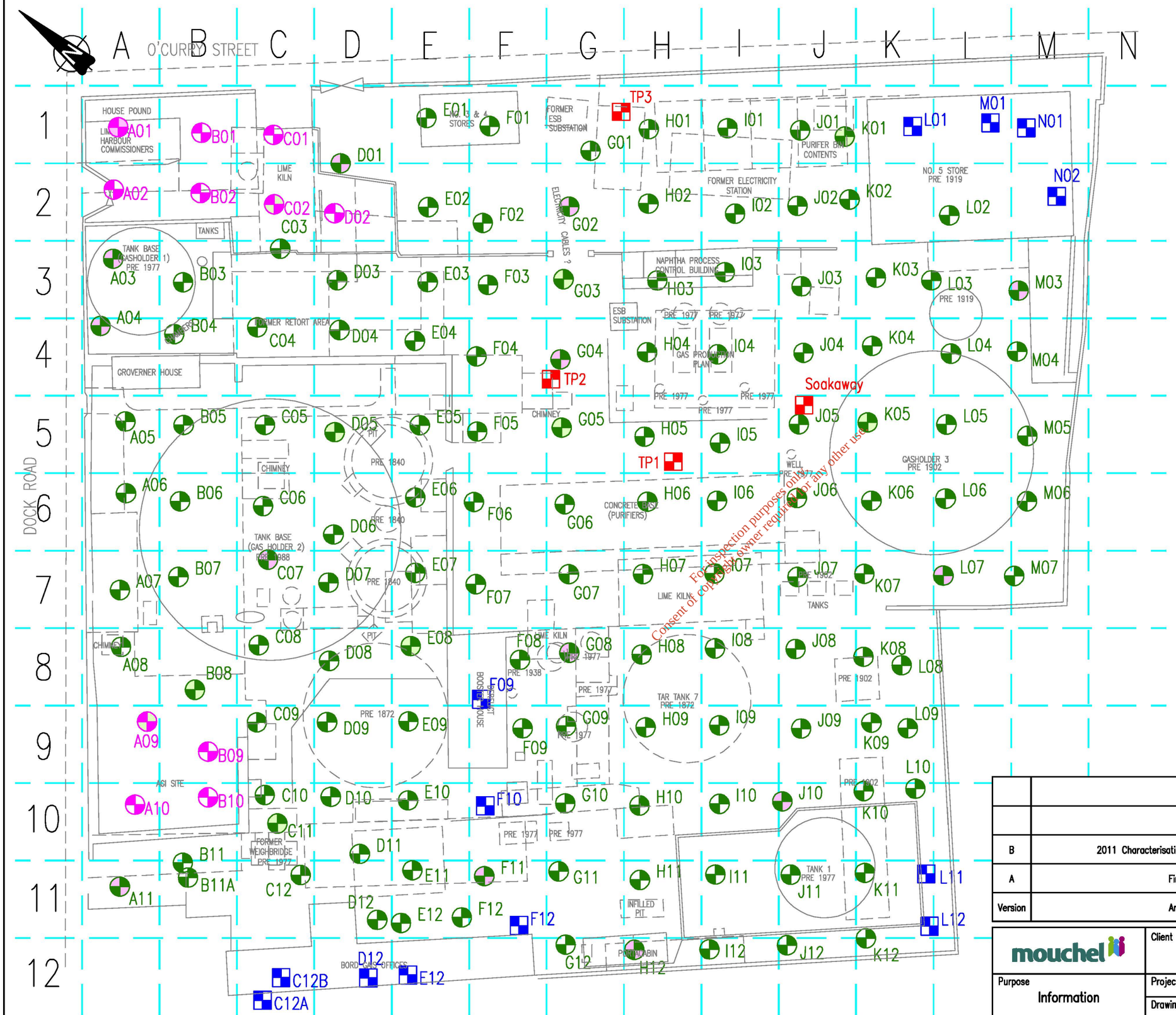
4.2.2 Chemical results

Several contaminants were recorded in concentrations above the EQS and DWS. A Tier 3 Groundwater QRA was undertaken in the QRA report which concluded that although a theoretical risk exists in respect to the River Shannon, this is unlikely to be realised due to the timescales required for contaminants to flow to the receptor and the presence of the wet dock and graving docks (with significant walls) impeding flow. It is also noted that cohesive alluvial deposits may be present in the vicinity of the river further impeding any groundwater flow directly into the river.

It is concluded that the limestone aquifer is not productive due to the brackish nature of the groundwater and the thin water bearing stratum (in the near surface weathered zone). There are also no abstractions within the vicinity of the site.

4.2.3 Seasonal Pattern

The chemical results to date have fluctuated slightly but there does not appear to be any consistent increase or decline for the majority of locations over time. Recorded variations are typically less than one order of magnitude between visits. It is therefore considered unlikely that there has been any significant change in contaminant mobility or migration.



Key

Approximate Location of Former Structure

2009 Site Investigation

- Sonic Drilled Boreholes
- 10m Grid
- Window Sample Location
- Trial Pit
- Installation in made ground
- Installation in limestone rock

2011 Site Characterisation

- Sonic Drilled Boreholes
- Installation in made ground
- Installation in limestone rock

Version	Amendment	Originated by and date	Checked by and date	Approved by and date
B	2011 Characterisation Sonic Boreholes Added	N.Henrys 15/11/11	N.Balderstane 15/11/11	D.Watts 15/11/11
A	First Issue	K.Hodgkinson 02/02/10	D.Megson 02/02/10	D.Watts 02/02/10

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Client: BORD GÁIS

Purpose: Information

Project: Limerick Gasworks

Drawing Title: Characterisation Exploratory Hole Location Plan

Draft: ●

Issue:

Scale (at A3 size): 1:500

Issuing Office: Ellesmere Port

Telephone: 0151 356 5555

Drawing number: 1021927/R02/OD/001

Version: B