Gas Management Strategy

Fassaroe Historical Landfills

JER8764
Gas Management Strategy
3
2
31 March 2022

rpsgroup.com

Quality Management

Version	Revision	Authored by	Reviewed by	Approved by	Date
2	1	Adam Parker	Phil Thomas	Phil Thomas	11 September 2020
3	1	Adam Parker	Phil Thomas	Phil Thomas	30 November 2021
3	2	Adam Parker	Phil Thomas	Phil Thomas	31 March 2022

Approval for issue

Philip Thomas	BSc, MSc, RoGEP, SiLC		31 March 2022

File Name

220329 R JER8746 Gas Management Strategy Fassaroe 2022 Update

Prepared by:

RPS

Philip Thomas

Technical Director

260 Park Avenue
Almondsbury
Bristol
BS32 4SY

T +44 1454 853 000

E thomasp@rpsgroup.com

Prepared for:

Cosgrave Property Group

Contents

Tables

Figures

Appendices

1 INTRODUCTION

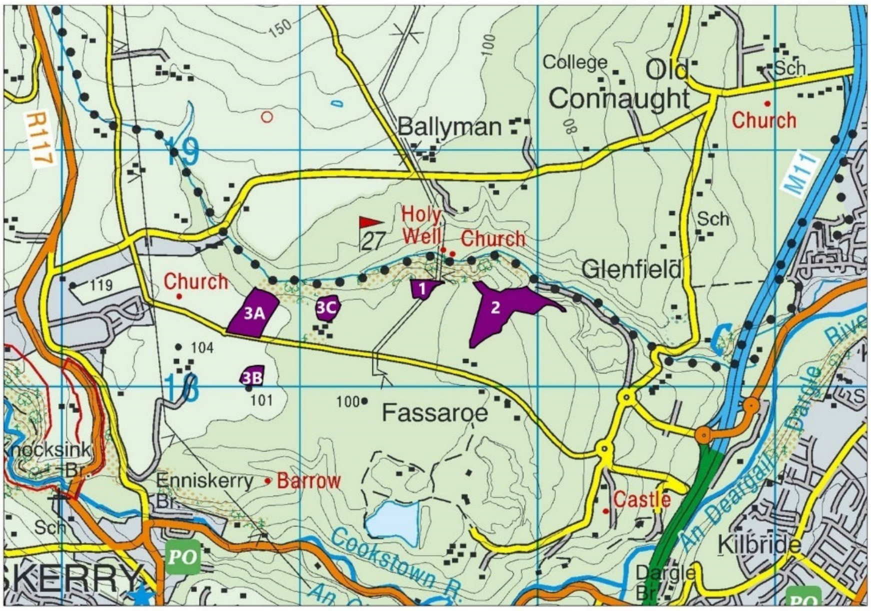
1.1.1 RPS Consulting Engineers (RPS) was commissioned by Cosgrave Property Group (CPG) to prepare a Gas Management Strategy Report for their proposed Phase 1 development on and adjacent to the historical landfills at Fassaroe, Co. Wicklow. The development will comprise mixed use including residential, commercial units and parkland amenities as listed in section 1.7 below. A development layout is provided within **Appendix A** of to the accompanying RPS, *Addendum to Environmental Risk Assessment Report* , December 2021 (**EIAR Volume 4-Part 4**) (updated in March 2022).

1.1.2 The historical landfills (Site 1, Site 2, Site 3A, Site 3B, Site 3C) are located as shown on **Figure 1.1** along with an outline of the proposed development on the site.

1.1.3 A number of the figures referred to in this report, where not embedded into the report, have been included at A1 paper size in Appendix A. An Environmental Risk Assessment (ERA) was previously carried out by RPS Fassaroe Historic Landfill – Environmental Risk Assessment, 2018 – Document Ref. DR1206Rp0007 (**EIAR Volume 4 – Part 3**)) to assess and present the potential risks to human or environmental receptors associated with the presence of the waste material in the historical landfills. That ERA was prepared for the purposes of Certificate of Authorisation (CoA) applications by Wicklow County Council to the EPA which were subsequently granted in 2019. The ERA also provided an outline assessment of options for managing the risks identified and set out recommendations for remedial options. An addendum to the ERA has now been prepared in a separate report prepared in 2021 and updated in 2022 (RPS, 2022) (**EIAR Volume 4-Part 4)** to accompany the CPG Phase 1 Fassaroe Strategic Housing Development (SHD) application to An Bord Pleanála. The addendum ERA considers data from landfill gas pumping trials undertaken in 2020 as part of a condition of the CoAs, and the static monitoring data from 2016 to 2021 together with the currently proposed SHD development layout and presents an updated appraisal in relation to ground gas.

1.1.4 This report sets out the gas remediation strategy based on previous investigations and assessments undertaken at the site and does not discuss risks associated with controlled waters or human health. These are discussed in the RPS 2018 ERA and the 2022 Addendum to the ERA. This strategy identifies the gas protection measures that can be installed to limit gas migration from the landfills and the protection measures that will be required to properties, supported by relevant appraisal.

Figure 1-1: Location of Historic Landfill Sites



1.2 Objectives

1.2.1 This report presents the gas management strategy for the landfill gas being generated as a result of the decomposition of biodegradable waste within the historical landfills on the site. The implementation of the gas management strategy will mitigate the landfill gas risks to the proposed Fassaroe Phase 1 SHD development and existing adjacent structures. As outlined within the ERA and section 4 of this report, further data collection is required to support detailed design of the gas protection measures.

1.2.2 This document provides an assessment which integrates relevant data obtained from the recent and previous site investigation data. The objectives of the report are to:

- Collate and review available site investigation data.
- Develop a Conceptual Site Model (CSM) based on the available date.
- Identify and evaluate uncertainties and data information gaps within the information currently available and the works required to address the identified data gaps.
- Undertake a remedial options appraisal to identify appropriate techniques.
- Utilise the available site information to develop a gas management strategy.
- Develop a preliminary design for the management of gas from the identified sources.
- Develop a monitoring and sampling plan that will allow the effectiveness of the remedial measures to be verified.

1.3 Guidance and previous site investigations

1.3.1 The gas management strategy has been developed following a review of the following guidance and previous site reports:

- Ground Gas Handbook – S. Wilson, G. Card, S. Haines (2009).
- CIRIA Report 149 - Protecting development from methane (1995).
- CIRIA Report 151 - Interpreting measurements of gas in the ground (1995).
- Landfill Directive‘s Guidance on the management of landfill gas by SEPA and Environment Agency.
- CIRIA C665 Assessing risks posed by hazardous ground gases to buildings (2007).
- Department of the Environment – Protection of New Buildings and Occupants from Landfill Gas (1994).
- BS 8485:2015+A1:2019 - Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new building (2019).
- UK Waste Management Paper 27 (WMP 27) (Department of Environment, 1991), now superseded by more recent EA guidance (Environment Agency, 2004a)
- Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, (December 2012, amended April 2013).
- Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services (April 2013).
- Fassaroe Business Park Geotechnical Interpretative Report – Atkins McCarthy (July 2001).
- Fassaroe Historic Landfill Environmental Risk Assessment – Atkins (June 2010).

- Fassaroe AGS and Excel ground investigation data (IGSL and Glovers logs) received from Atkins (19th of October 2015).
- Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates (January 1998).
- Environmental Risk Assessment Report for Historic Landfills at Fassaroe – RPS Group (2018).
- EPA Landfill Operational Practices - Environmental Protection Agency Ireland (1997).
- EPA Landfill Monitoring 2nd Edition - Environmental Protection Agency Ireland) (2003).
- EPA Landfill Manual – Landfill Site Design - Environmental Protection Agency Ireland (2000).

1.4 Overall methodology

1.4.1 In order to achieve the above objectives the following scope of works was undertaken:

- **Data Review:** Review and summary of factual information.
- **Gas Conceptual Site Model (CSM):** Development of a gas CSM assessing the gas source, pathways and receptors in details.
- **Further Requirements and Data Collection**: Completion of a gap analysis identifying the areas of uncertainty, as defined by the gas CSM.
- **Options Appraisal**: Completion of an options appraisal considering the viability of the potential remedial options. This will identify the viable option(s).
- **Gas Management Strategy**: Development of a gas management strategy to minimise gas migration from the landfills to areas of the development that will contain occupied structures.
- **Monitoring and Sampling Plan**: Development of a monitoring and sampling plan that will set out the scope of monitoring and sampling required to verify the effectiveness of the suggested gas protection measures.

1.5 Report limitations and conditions

1.5.1 The findings and opinions provided in this document are given in good faith and are subject to the limitations and constraints imposed by the information sources described in this report.

1.5.2 Where comments and opinions have been provided based on ground investigation works and reports carried out by third parties, RPS can accept no liability for the accuracy or reliability of such information.

1.5.3 Any figure or opinion on the possible configuration of contamination or other spatially variable features between or beyond investigation positions is conjectural and given for guidance only.

1.5.4 Historical boreholes are in existence across Site 2, however borehole logs were not available, therefore the integrity of monitoring infrastructure associated with these wells could not be established and these monitoring wells were not utilised during the monitoring regime.

1.6 Report format

1.6.1 The gas remediation strategy report is presented in accordance with the following format:

- Section 2 – Data Review
- Section 3 – Gas Conceptual Site Model
- Section 4 – Further Requirements
- Section 5 – Remedial Options Appraisal
- Section 6 – Preliminary Design
- Section 7 – Monitoring and Sampling Plan

1.7 Proposed development

1.7.1 Development at Fassaroe as provided for in the Bray Municipal District Local Area Plan will comprise of a mixed use development over a series of phases. A detailed layout has been developed by the applicant CPG for Phase 1 of the development with general land uses being defined in a CPG masterplan for subsequent phases of development falling within its lands at Fassaroe. The Phase 1 development presented in the current SHD planning application comprises:

- 650 no. residential units, comprising 241 no. houses and 409 no. apartments;
- Stage 1 of Neighbourhood Centre to be provided comprising of 1,395 sq.m. of retail / retail services / commercial / café space, with residential development overhead. A community concierge area (480 sq.m.) will also be provided at the neighbourhood centre which will serve the entire Fassaroe future development. Note: Stage 2 of the Neighbourhood Centre will be provided within a later phase of the overall development at Fassaroe as the on-site population expands;
- 733 sq.m approx. crèche with capacity for approx. 138 no. childcare spaces;
- Retail / café kiosk (108 sq.m.) in district park;
- East-west Road link (2.4km) connecting N11 to Ballyman Road;
- Pedestrian / cycle route along east-west road link, across the N11 to Dargle Road via a new bridge and connecting to the Dargle Road Upper and to proposed Dargle River Greenway (to be delivered by WCC by early 2023);
- 15.3ha of District Park / Active Open Space;
- Demolition of an existing dwelling at Berryfield Lane;
- Rerouting and undergrounding of overhead ESB lines (110kV and 38kV lines);
- Site development / ground works on future development areas; and
- Water supply, foul and surface water drainage proposals.

1.7.2 It should be noted that the further building proposed for the further development phases are not accounted for in the unit numbers and square meterage's set out above.

2 DATA REVIEW

2.1 Previous Site Investigation

2.1.1 The following historical investigation reports were provided by Cosgrave Property Group and were reviewed as part of the Tier 1 ERA desk study. A summary of relevant gas information has been provided on a site-by-site basis.

- Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013).
- Disused Wicklow County Council Landfill Sites 3A, 3B and 3C at Fassaroe, County Wicklow Appropriate Assessment Screening Report – Altemar in association with Environmental Management Services, April 2013.
- Fassaroe Business Park Geotechnical Interpretative Report – Atkins McCarthy, July 2001.
- Fassaroe Historic Landfill Environmental Risk Assessment – Atkins, June 2010.
- Fassaroe AGS and Excel ground investigation data (IGSL and Glovers logs) received from Atkins on the 19th of October 2015.
- Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998.

Site 1

2.1.2 To RPS's knowledge no previous gas monitoring was completed at Site 1.

Site 2

2.1.3 As part of the environmental evaluation of Site 2, Muir Associates supervised the excavation of nine trial pits within the vicinity of Site 2 and three within the surrounding environs (refer to **Table 2.1** and **Figure 2.1**). The trial pits varied in depth from 2.70 metres below ground level (mbgl) to 4.80mbgl.

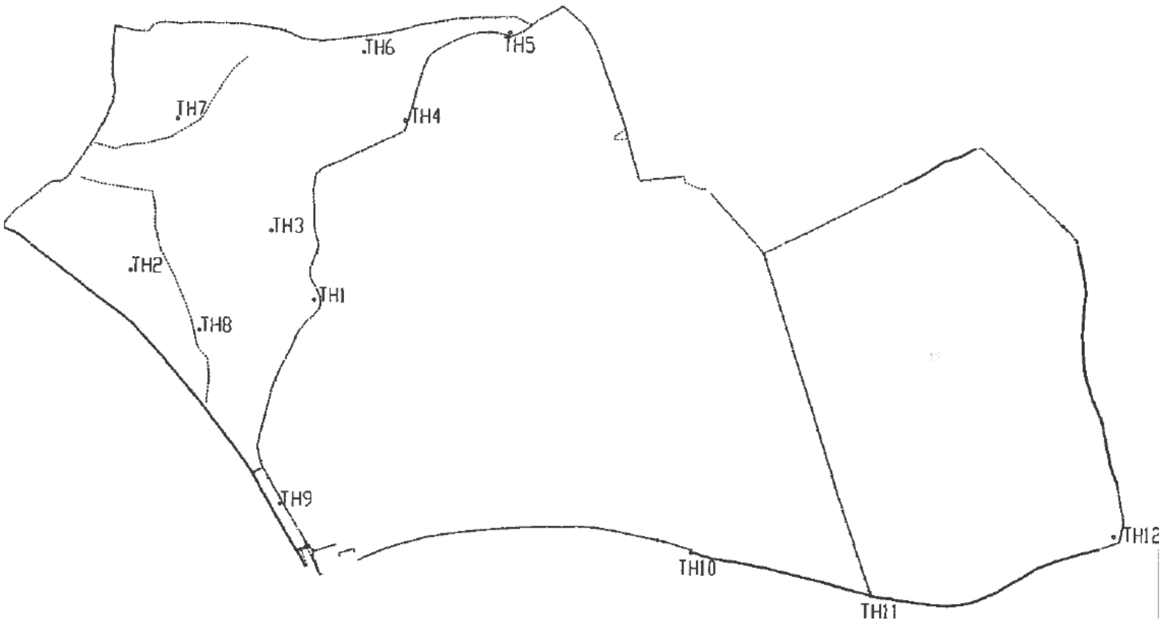
Table 2-1 - Site 2: Historical Site Investigation Data

Trial Pit	Depth (m)	Base of waste (m)	Waste Type
TH1	2.90	1.30	Domestic waste including plastic bags and bottles
TH2*	2.70	-	No waste encountered
TH3	3.60	>3.60	Domestic waste including plastic bags, bottles, concrete, fabric, timber, wavin piping and newspaper
TH4	4.30	1.50	Domestic waste including plastic bags
TH5	4.80	1.30	Domestic waste including plastic bags, bottles, concrete
TH6	3.10	>3.10	Domestic waste including plastic bags and bottles
TH7*	3.40	-	No waste encountered
TH8	3.40	>3.40	Domestic waste including plastic bags, bottles and tins
TH9	3.30	-	No waste encountered (MADEGROUND hardcore fill noted)
TH10*	3.30	-	No waste encountered (MADEGROUND hardcore fill noted)
TH11*	3.50	-	No waste encountered
TH12*	3.60	-	No waste encountered

Source: Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998

* Outside landfill boundary

Figure 2-1 - Site 2: Historical Site Investigation Locations (Muir)



Source: Environmental Ground and Geotechnical Site Evaluation Report for Site at Fassaroe, Bray – Muir Associates, January 1998

2.1.4 Gas monitoring (for methane only) was completed at trial pits 1-8 inclusive and elevated methane concentrations were recorded across the site. No gas pressure or flow analysis was conducted. These results are of limited value and are not considered suitable for quantitative assessment as they were atmospheric concentrations recorded at open pits. They do however positively identify the presence of methane at elevated concentrations.

2.1.5 Gas monitoring was also completed by Atkins and City Analysts in May 2010. Sampling of landfill gas was undertaken using Geotechnical Instruments GA9 landfill gas analyser. At the time of sampling, it was noted that in the nine years since installation some damage and wear and tear had occurred to the borehole installations. These boreholes were located on the landfill site only. Methane, carbon dioxide and oxygen levels were recorded at the time. Elevated concentrations of methane (max. 74% v/v) and carbon dioxide (max. 27% v/v) were recorded across the site. Vegetation die back was also noted across the site which is suggestive of the presence of vertical fugitive gas emissions. Flow rates and differential pressures were not monitored.

2.1.6 The gas monitoring results should also be interpreted with caution due to the lack of information regarding the integrity of the monitoring boreholes, coupled with the lack of gas valves at monitoring locations (with boreholes passively venting prior to monitoring). Nevertheless, the results indicate that at the time of monitoring, gas production within the landfill was likely to be ongoing.

Site 3A

2.1.7 Wicklow County Council (WCC) completed a Tier 2 investigation of Site 3A in 2012 which comprised twelve trial pits and two boreholes (MW3 and MW4). Municipal waste was encountered in all trial pits excavated at Site 3A. The base of waste body was not encountered.

2.1.8 Boreholes MW3 and MW4 included the installation of gas monitoring standpipes within the waste body. MW3 also included a groundwater monitoring standpipe installed within the gravels beneath the waste body. The results of the borehole logs are summarised in **Table 2.2**.

Table 2-2 - Site 3A: Historical Site Investigation Data - Boreholes

Borehole	Topsoil Depth (m)	Clay/Capping Depth (m)	Waste Depth (m)	Borehole Total Depth (m)	Waste Thickness (m)	Slotted pipe interval	Waste Type
MW3	0.10	0.10-2.50	2.50-11.90	17.70	9.40	3-11 & 14.1-18.1	MSW
MW4	0.10	0.10-1.85	1.85-10.50	13.30	8.65	2-10	MSW

Source: Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

2.1.9 Gas monitoring was completed at the two boreholes installed on the site in September and November 2012. Elevated concentrations of methane, ranging from 46.7%v/v to 67.4%v/v, and carbon dioxide, ranging from 17.2%v/v to 35.3% v/v, were recorded. RPS is unaware of the availability of any flow data or differential pressure data for Site 3A. Vegetation die back was noted across the surface of the landfill site which is suggestive of vertical fugitive gas emissions.

2.1.10 Perimeter and/or off-site gas monitoring boreholes have not been installed at the site therefore the data is not available to establish if gas is migrating laterally from the landfill.

Site 3B

2.1.11 To RPS's knowledge no previous gas monitoring has been completed at Site 3B.

Site 3C

2.1.12 WCC completed a Tier 2 investigation of Site 3C in 2012 which comprised five trial pits and two boreholes (MW1 and MW2). Municipal waste was encountered in all trial pits excavated at Site 3C. The base of waste body was not encountered.

2.1.13 Boreholes MW1 and MW2 included the installation of gas/leachate monitoring standpipes within the waste body. No up-gradient or down-gradient groundwater monitoring boreholes have been installed at the site. The results of the borehole logs are summarised in **Table 2.3**.

Table 2-3 - Site 3C: Historical Site Investigation Data - Boreholes

Borehole	Topsoil Depth (m)	Clay/Capping Depth (m)	Waste Depth (m)	Borehole Total Depth (m)	Waste Thickness (m)	Slotted pipe interval	Waste Type
MW1	0.20	0.20-1.00	1.00-4.00	4.00	>4.00	0.18-3.85	MSW
MW2	0.10	0.10-1.25	1.25-5.40	8.10	4.15	2-5	MSW

Source: Tier 2-3 Environmental Risk Assessment Landfills No. 3A and 3C - Wicklow County Council, December 2012 (amended April 2013)

2.1.14 Gas monitoring was completed at the two boreholes installed on the site in September and November 2012. Elevated concentrations of methane, ranging from 32.4%v/v to 67.7%v/v, and carbon dioxide, ranging from 17.8%v/v to 33.3% v/v, were recorded. RPS is unaware of the availability of any flow data or differential pressure data for Site 3C. Vegetation die back was noted across the surface of the landfill site which is suggestive of vertical fugitive gas emissions.

2.1.15 Perimeter and/or off-site gas monitoring boreholes have not been installed at the site therefore data is not available to establish if gas is migrating laterally from the landfill and this has not been assessed.

2.2 Gas Monitoring: 2016 - 2021

2.2.1 The following landfill gas monitoring has been undertaken at the sites since :

- 8 No. weekly gas monitoring rounds between 7th March and 27th April 2016;
- 10 No. monthly gas monitoring rounds (May 2016 to February 2017); and
- 1 No. round prior to pumping trials (June to July 2020), selected boreholes only.
- 6 no. quarterly rounds in 2020 and 2021 (between quarter 1 in 2020 and quarter 2 in 2021).

2.2.2 **Table 2.4** details the gas monitoring boreholes for each site. As part of gas monitoring completed at Fassaroe the following parameters were typically recorded:

- Methane (CH_4 %v/v);
- Carbon Dioxide (CO_2 % v/v);
- Oxygen (O_2 % v/v);
- Hydrogen Sulphide (ppm);
- Atmospheric pressure (mbar);
- Temperature (°C);
- Flow Rate (l/hr);
- Carbon Monoxide (ppm);
- Hexane (%) and
- Water level (mbgl).

Table 2-4 – 2016 to 2021 Gas Monitoring Boreholes

Site ID		Borehole ID
Site 1	Onsite	LG11,LG12,LG13
	Offsite	BH05,G06,G07,G08,G10,G18,G19
Site 2	Onsite	LG01,LG02,LG03,LG04,LG05,LG06, LG07,LG08,LG09,LG10
	Offsite	BH01,BH03,BH04,BH11,BH13,G01,G02,G03,G04,G05,G13,G20,G21,G22,G23,G24,G25
Site 3A	Onsite	LG15,LG19,LG20,MW3,MW4
	Offsite	BH07,BH09,BH10,G12,G14
Site 3B	Onsite	LG16,LG17,LG21
	Offsite	BH08,G15,G16,G17
Site 3C	Onsite	LG14,LG18,MW2
	Offsite	BH06,G09,G11

2.2.3 Eight rounds of gas monitoring were completed on a weekly basis during the period 7th March to 27th April 2016. Monthly monitoring was then undertaken between May 2016 and February 2017. This gave a dataset over one whole year, comprising circa 18 monitoring rounds. A further monitoring round was undertaken prior to the pumping trials at the site during June and July 2020. Following on from this, monitoring was undertaken of the boreholes on a quarterly basis up to quarter 2 in 2021 (six no. rounds in total) , albeit flow rate data was not recorded during these monitoring rounds.

2.2.4 These data sets should allow a comprehensive assessment of ground gas concentrations which takes account of potential seasonal variations.

Site 1

2.2.5 In total ten boreholes were monitored for gas at Site 1, three onsite combined gas/leachate boreholes and seven offsite boreholes including six gas boreholes and one groundwater borehole. The data from these boreholes in summarised in **Table 2.5**.

Table 2-5 - Site 1 Gas Monitoring Borehole Details

BH ID	BH Ground elevation (mAOD)	Standpipe level (mAOD)	Casing Height (cm)	Total drilled depth (mbgl)	Blank pipe Interval (mbgl)	Slotted Pipe Interval (mbgl)	Screened Geology
				ONSITE			
LG11	95.371	95.638	31	17.0	0-1	1 - 13	Waste
LG12	95.955	96.182	44	24.0	0-1	1-12	Waste
LG13	96.048	96.476	53	20.0	0-1	1-9	Waste
				OFFSITE			
BH05	96.06		48	29	0-19	19-29	Sand
G06	90.99	91.303	41	12	0-1	1-11	Sandy gravel
G07	93.033	93.236	40	14	0-1	1-14	Gravel/ sandy gravel/ sand
G08	94.286	94.602	45	14	0-1	1-14	Gravel
G10	98.856	98.947	37	20	0-1	1-18	Sand/ clay/ gravel/ silty sand
G18	93.73	93.834	30	14	0-1	1-14	Sandy clay/ gravel/ gravelly sand
G19	98.244	98.393	40	14	0-1	1-14	Sandy clay/ gravel/ gravelly sand

Site 2

2.2.6 A total of twenty-seven boreholes were monitored for gas at Site 2 which included ten onsite combined gas/leachate boreholes, seventeen offsite boreholes comprising twelve gas boreholes and five groundwater monitoring boreholes. The data from these boreholes is summarised in **Table 2.6**.

Table 2-6 - Site 2 Gas Monitoring Borehole Details

BH ID	BH Ground elevation (mAOD)	Standpipe level (mAOD)	Casing Height	Total drilled depth (mbgl)	Blank pipe interval (mbgl)	Slotted Pipe Interval (mbgl)	Screened Geology
ONSITE							
LG01	83.758	84.16	34	16.0	0-1	1-5	Waste
LG02	83.185	83.408	31	12.0	0-1	1-9	Waste
LG03	82.248	82.525	23	29.0	0-1	1-18	Waste
LG04	81.883	82.044	19	18.0	0-1	1-15	Waste
LG05	80.14	80.199	38	25.5	0-1	1-14	Waste
LG06	82.678	83.119	40	17.5	0-1	1-6.4	Waste
LG07	74.868	75.126	27	17.1	0-1	1-16.1	Waste (base of waste not reached)
LG08	70.767	70.938	26	19.5	0-1	1-8	Waste
LG09	71.057	71.236	26	25.5	0-1	1-17	Waste
LG10	66.373	66.623	49	21.0	0-1	1-18	Waste
OFFSITE							
BH01	79.222	79.464	28	21	0-5	5-21	Clay with boulder content/ clayey sand/ clay gravel/ clay
BH03	78.651	78.796	33	19.5	0-2	2-19.5	Sand/ sandy gravel
BH04	84.409	84.532	42	25.5	0-13.5	13.5-25.5	Clayey gravel/ sandy gravel/ sand
BH11	82.653	82.826	42	33	0-1	1-33	Sandy clay/ sandy gravel/ gravel/ sand
BH13	87.985	87.99	30	19.5	0-4.5	4.5-19.5	Sandy clayey gravel/ sand/ sandy gravel/ gravel/ silty sandy clay
G01	84.991	85.397	43	19.5	0-1	1-17.5	sandy gravel/ gravel
G02	72.662	72.638	36	19.5	0-1	1-19.5	Clay/ sand/ gravel/ sandy gravel
G03	69.504	69.626	45	19.5	0-1	1-19.5	Clay/ gravel/ sandy gravel/ gravel with boulder content/ sand

BH ID	BH Ground elevation (mAOD)	Standpipe level (mAOD)	Casing Height	Total drilled depth (mbgl)	Blank pipe interval (mbgl)	Slotted Pipe Interval (mbgl)	Screened Geology
G04	85.617	85.971	36	20	0-3	3-17	Sandy gravel/ sandy clayey gravel/ gravel/ gravel
G05	86.723	86.857	37	20	0-1	1-20	Sandy clayey gravel/ sandy gravel/ sand
G13	75.822	76.001	44	20	0-1	1-20	Sandy clay/ sandy gravel/ sand
G20	85.551	85.826	45	27	0-1	1-20	
G21	86.662	87.003	43	19	0-1	1-17	Sandy clay/ sandy gravel/ sand
G22	63.675	63.85	34	20	0-1	1-15	Sandy clay/ sandy gravel/ sand
G23	78.954	78.943	42	20	0-1	1-20	Sandy silty clay gravel/ sand
G24	86.831	86.835	22	20.5	0-1.5	1.5-20.5	Sandy gravel/ gravel/ sand
G25	85.635	86.027	49	34	0-1	1-20	

Site 3A

2.2.7 A total of ten boreholes were monitored for gas at Site 3A; five onsite comprising three combined gas/leachate boreholes and two existing boreholes, five offsite comprising two gas boreholes and three groundwater boreholes. The data from these boreholes in summarised in **Table 2.7**.

Table 2-7 - Site 3a Gas Monitoring Borehole Details

BH ID	BH Ground elevation (mAOD)	Standpipe level (mAOD)	Casing Height	Total depth (mbgl)	Blank pipe interval (mbgl)	Slotted Pipe Interval (mbgl)	Screened Geology
ONSITE							
LG15	103.972	104.13	33	19.0	0-1	1-8	Waste
LG19	103.897	104.179	27	26.0	0-1	1-15	Waste
LG20	103.823	104.354	51	23.0	0-1	1-12	Waste
MW3	103.105	104.254	115	11	0-3	3-11	Waste
				18.1	0-14.1	14.1-18.1	Gravel & sand
MW4	104.543	105.587	108	13.3	0-2	2-10	Waste
OFFSITE							
BH07	106.107	106.371	38	21	0-11	11-21	Sandy clayey gravel/ gravel/ sandy gravelly clay silt
BH09	97.969	98.14	32	12	0-2	2-12	Sandy clayey gravel/ gravelly sand/ sandy gravel
BH10	99.305	99.505	17	14	0-4	4-14	Sand/ sandy gravel/ sandy clayey gravel
G12	98.913	99.016	21	14	0-1	1-14	Sandy clayey gravel/ sandy gravel
G14	98.624	98.834	25.5	14	0-1	1-14	Sandy clay gravel/ wet gravel/ dry silty sandy clay

Site 3B

2.2.8 A total of seven boreholes were monitored for gas at Site 3B; three onsite combined gas/leachate boreholes and four offsite boreholes comprising three gas boreholes and one groundwater borehole. The data from these boreholes in summarised in **Table 2.8**.

Table 2-8 - Site 3B Gas Monitoring Borehole Details

BH ID	BH Ground elevation (mAOD)	Standpipe level (mAOD)	Casing Height	Total depth (mbgl)	Blank pipe interval (mbgl)	Slotted Pipe Interval (mbgl)	Screened Geology
				ONSITE			
LG16	99.516	99.725	33	16.0	0-1	1-2.5	Waste
LG17	100.506	100.874	38	5.40	0-1	1-3.9	Waste
LG21	100.58	100.849	28	5.75	0-1	01-Apr	Waste
				OFFSITE			
BH08	98.801	98.95	14	13.5	0-1	1-4.5	Sandy gravel/ sand
G15	99.172	99.509	35	6	0-1	1-6	Gravel
G16	100.38	100.762	41	6	0-1	1-6	Sandy clay/ sandy clay gravel
G17	98.415	98.764	27	6	0-1	1-6	Sandy clay/ sandy clay gravel

Site 3C

2.2.9 A total of six boreholes were monitored for gas at Site 3C; three onsite boreholes comprising two combined gas/leachate boreholes and one historical borehole and three offsite boreholes comprising two gas boreholes and one groundwater borehole. The data from these boreholes in summarised in **Table 2.9**.

Table 2-9 - Site 3c Gas Monitoring Borehole Details

BH ID	BH Ground elevation (mAOD)	Standpipe level (mAOD)	Casing Height	Total depth (mbgl)	Blank pipe interval (mbgl)	Slotted Pipe Interval (mbgl)	Screened Geology
ONSITE							
LG14	93.44	93.873	45	23.0	0-1	1-12	Waste
LG18	92.417	92.854	45	22.0	0-1	1-10	Waste
MW2	93.398	94.222	92	8.1	0-2	2-5	Waste
OFFSITE							
BH06	95.273		38	14	0-2	2-14	Sandy gravel/ silty sandy gravel
G09	93.562	93.875	29	14	0-1	1-14	Sandy clay/ gravelly sand/ sandy clay gravel
G11	97.207	97.395	32	15	0-1	1-15	Sandy clay/ sandy gravel/ sand/ gravel

2.3 PUMPING TRIALS: 2020

2.3.1 In addition to the standard gas monitoring data undertaken (as summarised in *Section 2.2*), pumping gas trials have been undertaken for each site to assess the potential for sustainable active extraction of landfill gas at the landfill sites. These tests comprised a combination of static and dynamic gas abstraction tests. The data obtained from such trial provides useful information providing an indication of the rate of gas production / volume of storage, and connectivity between boreholes within and adjacent to the landfills.

2.3.2 The trials were undertaken by Automatic Flare Systems Limited (AFS) with the methodology, results and conclusions detailed in the following report provided at Appendix C of the Addendum to the ERA (**EIAR Volume 4 – Part 4**):

- AFS, Report on the Gas Abstraction Pumping, Fassaroe Closed Landfill Sites, for Wicklow County Council, 28 July 2020).

2.3.3 The temporary gas extraction trial system setup involved connection of designated extraction wells to a temporary flare (200 m^3/hr Lo-Cal specification) powered by a generator with a separate fuel bowser. The extraction was undertaken for about a week.

2.3.4 Monitoring of landfill gases was undertaken usually three times a day from the extraction wells and surrounding monitoring wells. The wells subject to extraction during the pumping trials are detailed below:

- Sites 1 and 2: Pumping test conducted between 21st and 28th June (8 days) using the same flare extraction system from extraction wells LG5, LG7 LG9, LG10 (site 2), LG12 and LG13 (site 1);
- Site 3B: Pumping test conducted between 4th and 10th July (7 days) using the same flare extraction system from extraction wells LG16, LG17 and LG21;
- Site 3A and 3C: Pumping test conducted between 14th and 20th July (7 days) using the same extraction system from extraction wells LG15, LG19, LG20 (site 3A), LG14 and LG18 (site 3C).

2.3.5 Prior to the pumping trial, one round of static ground gas monitoring was undertaken for the boreholes (as set out in the previous section).

2.3.6 The wells that were monitored as part of the pumping trials are detailed in **Table 2.10**.

Table 2-10 – Boreholes Monitoring During Pumping Trials

Landfill Site	Monitored Extraction Boreholes	Monitored Non-Extraction Boreholes
1	LG12, LG13	LG11, G07, G08, G18, G19
2	LG05, LG07, LG09, LG10	LG01, LG02, LG03, LG04, LG08, BH01, BH13, G04, G05, G25
3A	LG15, LG19, LG20	MW3, MW4
3B	LG16, LG17, LG21	BH07, BH08, BH09, G16, G17
3C	LG14, LG18	MW2, G09

2.3.7 The data from the pumping trials is presented in the Addendum to ERA report (2020).

2.4 2016 and 2017 Groundwater Monitoring

2.4.1 Groundwater level monitoring in 2016 and 2017 was undertaken at the same intervals as the ground gas monitoring (circa 18 rounds). The full results are presented in the Addendum to ERA report (RPS, 2022).

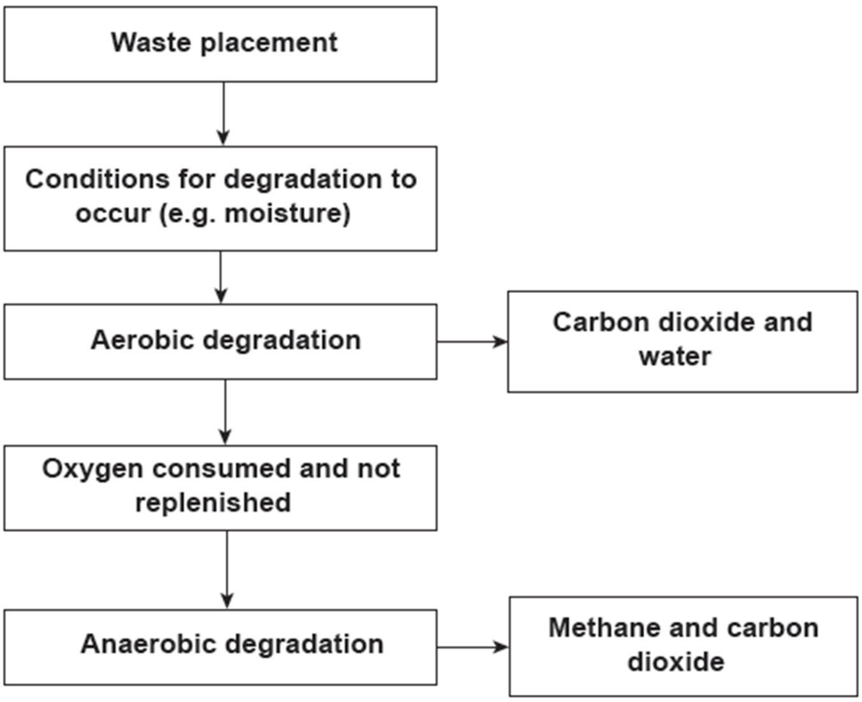
3 GAS CONCEPTUAL SITE MODEL

General Principles

3.1.1 The rate of gas production at a landfill site varies throughout the life of a landfill and is dependent on factors such as waste types, depths, moisture content, degree of compaction, available oxygen, landfill pH, temperature and the length of time since the waste was deposited.

3.1.2 According to Ground Gas Handbook (2009) to understand how methane and carbon dioxide are produced knowledge of the biochemical and microbiological breakdown of organic matter in landfill waste is required. A simple summary of the process is shown in **Figure 3.1**.

Figure 3-1 - Degradation of Organic Matter in the Ground

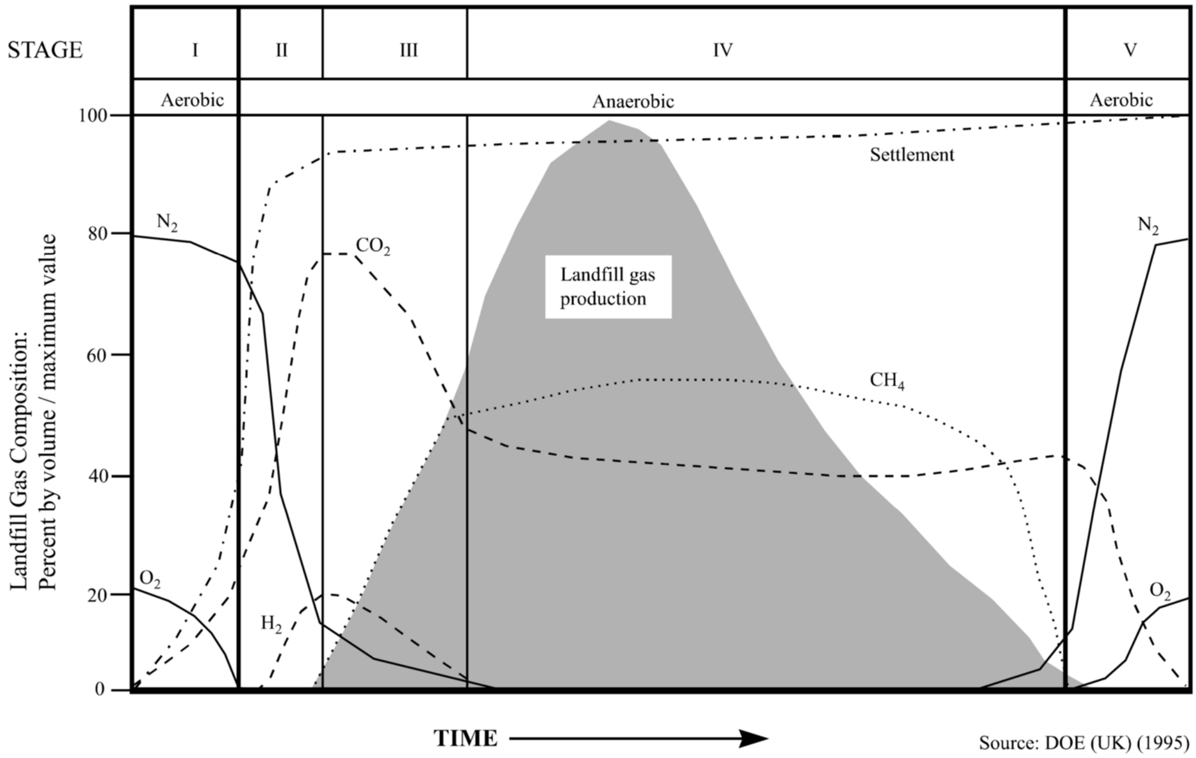


Source: Ground Gas Handbook (2009)

3.1.3 The historical landfills at Fassaroe are currently producing methane and carbon dioxide and can therefore be considered to be in the anaerobic degradation phase.

3.1.4 Landfill gas production can be divided into five phases as illustrated in **Figure 3.2**. Phase I is aerobic with phases II – IV anaerobic. The final phase v is aerobic. The process through which decomposing waste starts to produce methane is referred to a methanogenesis. This process will occur once certain conditions have been met including the transition from aerobic to anaerobic conditions, the moisture content of the waste is at the right levels, and there is a biodegradable content within waste.

Figure 3-2 - Phases of Gas Production



3.1.5 As detailed in CIRIA 151 the highest rates of gas production generally occur when abundant but not inhibitory concentrations of volatile fatty acids, particularly acetic acid are present in the waste body. In such circumstances which occur in the late phase (III) or early phase (IV) of the landfill decomposition as defined by Farquhar and Rovers (1973), methanogenesis is not limited by availability of substrates. In later stages, decomposition of organic matter, principally cellulose, limits the rate of methane production and rates, though still high, are likely to be lower than before. Rates of hydrogen production may also be high during phase (II), although, field data for this period are scarce.

3.1.6 According to the Ground Gas Handbook (2009) if conditions are suitable, the maximum methane and carbon dioxide generation will occur in the first 10-15 years after filling. After this period the gas generation will decline to a much lower residual level. It is important to note that in some cases gas generation may not have commenced because it is dry, even though the waste has been in the ground for a long while.

3.1.7 For Fassaroe, the EPA Section 22 Register dates the end date for acceptance of waste at Site 2 as 1991 and Sites 3B and 3C as 1995. There are no known records detailing the end dates for Site 1 and Site 3A. Given the waste is over 20 years old with a low to moderate flow production, this suggests the gas production is likely to be in the later stages of degradation and in line with Phase IV.

3.1.8 If the deposited waste at Fassaroe is left undisturbed it is considered that the factors affecting landfill gas production rates will be stable and therefore the limiting factors in landfill gas production will be the composition of the waste, oxygen levels and moisture content.

3.1.9 In order to reduce the risks to the proposed development from the landfill gas, it is proposed to cap waste areas 1, 2 and 3B as part of the redevelopment process. This will impact the conditions within the landfills resulting in changes to the gas regime. This is discussed further within **Section 3.6**.

3.2 Source

3.2.1 A review of gas sources at the site has identified the primary gas generation sources as the closed landfills and areas of made ground adjacent to the existing 33” watermain running south to north between Site 1 and Site 2.

3.2.2 The existing 33” watermain was constructed by Dublin Corporation in the 1860s and connects the Vartry reservoir with two storage reservoirs in Stillorgan in County Dublin. The watermain is included on the OSI historical map (1888 – 1913).

3.2.3 It should be noted that the natural geology of the area may also provide minor contributions to gas generation. **Figure 3.3** sets out these features and shows the five historical landfills located at Fassaroe, Co. Wicklow: Site 1, Site 2, Site 3A, Site 3B and Site 3C. This is presented within **Appendix A**.

Site 1

3.2.4 The waste source at Site 1 has been well defined through a series of site investigations including a site walk-over, trial pits, boreholes and geophysical surveys. The waste material is dominantly comprised of construction and demolition (C&D) waste with pockets of municipal waste. The maximum measured depth of waste is 14 mbgl with an estimated area of 0.53Ha. There may be a local perched leachate head towards the northern extent of the waste body as indicated by borehole LG13.

3.2.5 Based on lateral and vertical extent as defined by site investigations, an estimated 100,000 tonnes of waste is present at Site 1.

3.2.6 There was no data available for Site 1 on the EPA Section 22 register. However during the 2015 trial pitting waste was discovered dating back to 1976.

3.2.7 For site 1 all onsite and offsite readings for H_2S were zero (to one decimal place). For CO the offsite readings were all zero however onsite the highest reading was 10ppm in LG11 on 07/03/2016. The majority of results were zero for onsite boreholes.

Summary of Site 1 Gas Conditions Onsite

3.2.8 For the 2016 and 2017 monitoring rounds, the gas monitoring data collected from onsite monitoring boreholes at Site 1 recorded methane concentrations up to 13.6% v/v and carbon dioxide concentrations up to 18.9% v/v. During the 2020 and 2021 monitoring rounds, a maximum methane concentration of 31.7% v/v was encountered, with a maximum carbon dioxide concentration of 22.2% v/v. The observed conditions encountered during site investigation indicate Site 1 predominantly comprises construction and demolition (C&D) waste with some municipal waste.

3.2.9 There is some suggestion of possible increasing methane and carbon dioxide concentrations within the waste mass on Site 1. Flows are typically very low and do not exceed 4.0 l/hr in any borehole. Flow data has not been provided for the 2020 and 2021 monitoring rounds.

3.2.10 The static monitoring round undertaken Immediately before the pumping trial in 2020 identified methane and carbon dioxide concentrations that were higher than identified during the 2016 and 2017 monitoring rounds (and as the pumping trial progressed over the first two to three days, methane and carbon dioxide concentrations were on average higher than the previous monitoring results. As time progressed the concentrations generally further reduced to low levels as flow rates dropped to zero. The concentrations and patterns within both boreholes during the pumping trials suggest a relatively consistent gas regime over the area represented by these boreholes. Oxygen levels spiked within boreholes LG12 and LG13 during the 25^{th} June 2020 monitoring round (between days 3 and 4 of the trial), indicating that oxygen may have been drawn into the landfill mass at this point. After this was recorded, wells LG12 and LG13 were turned off for the remainder of the trial. The results show a sudden drop then steady rise in oxygen after this event as these wells were monitored without extraction. This may indicate a high level of connectivity between the landfill site and the surrounding area.

3.2.11 The consistent moderately elevated gas concentrations during static monitoring suggests that the gas source within the landfill is significant with regard to stored volumes or ongoing production. However, during the pumping trial, the influx of oxygen paired with low levels of methane, as pumping progressed suggests that there may be connectivity with the surrounding area.

Summary of Site 1 Gas Conditions Offsite

3.2.12 In 2016 and 2017, with the exception of G06, methane concentrations in off-site boreholes were zero and carbon dioxide concentrations low, typically below 3.0% v.v. In contrast G06 had elevated methane concentrations of 11 to 23.9% v/v and carbon dioxide concentration of 3.2 to 8.1% v.v. Monitoring point G06 is located immediately to the west of the existing 33” water main which runs in a north south direction.

3.2.13 On review of the 2016 and 2017 site investigation data it was noted that elevated Electrical Conductivity (EC) has been recorded within the vicinity of G06. This appears to correspond to the backfilling activities associated with the water main routing in this area, as shown in the geophysical survey provided in **Figure 3.3**.

3.2.14 The methane concentrations recorded at G06 were significantly higher than those recorded at the initially perceived source (worst case) location i.e. within Site 1, and may therefore be reflective of a separate gassing regime associated with the made ground/backfill surrounding the water main.

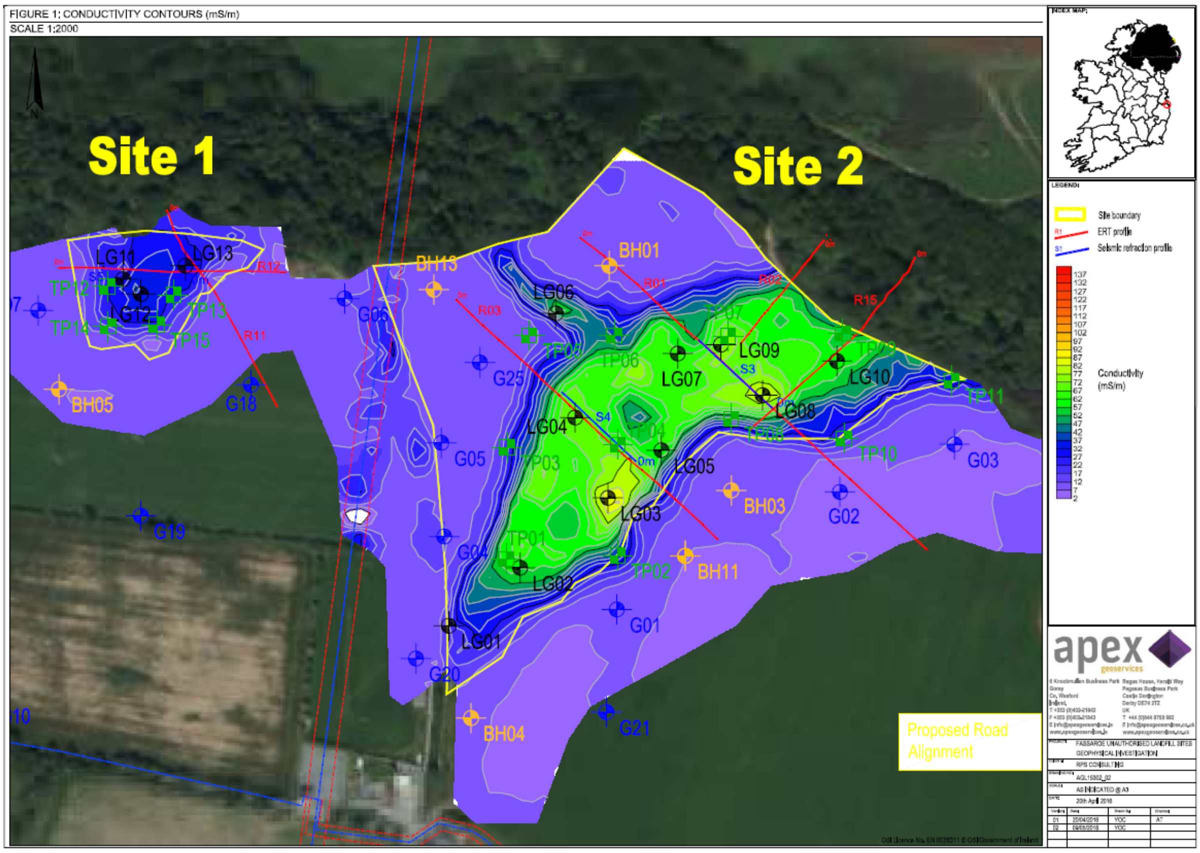
3.2.15 The static measurements in June 2020 prior to the pumping tests indicated relatively high concentrations in G18 (methane - 9.2% v/v; carbon dioxide - 4.7% v/v) which exceeded that encountered in the 2016 and 2017 monitoring.   Location G19 also gave a peak concentration of 3.5% v/v carbon dioxide during the pumping trial which exceeded previous monitoring results. This suggests a possible increase in gas migration from Site 1.

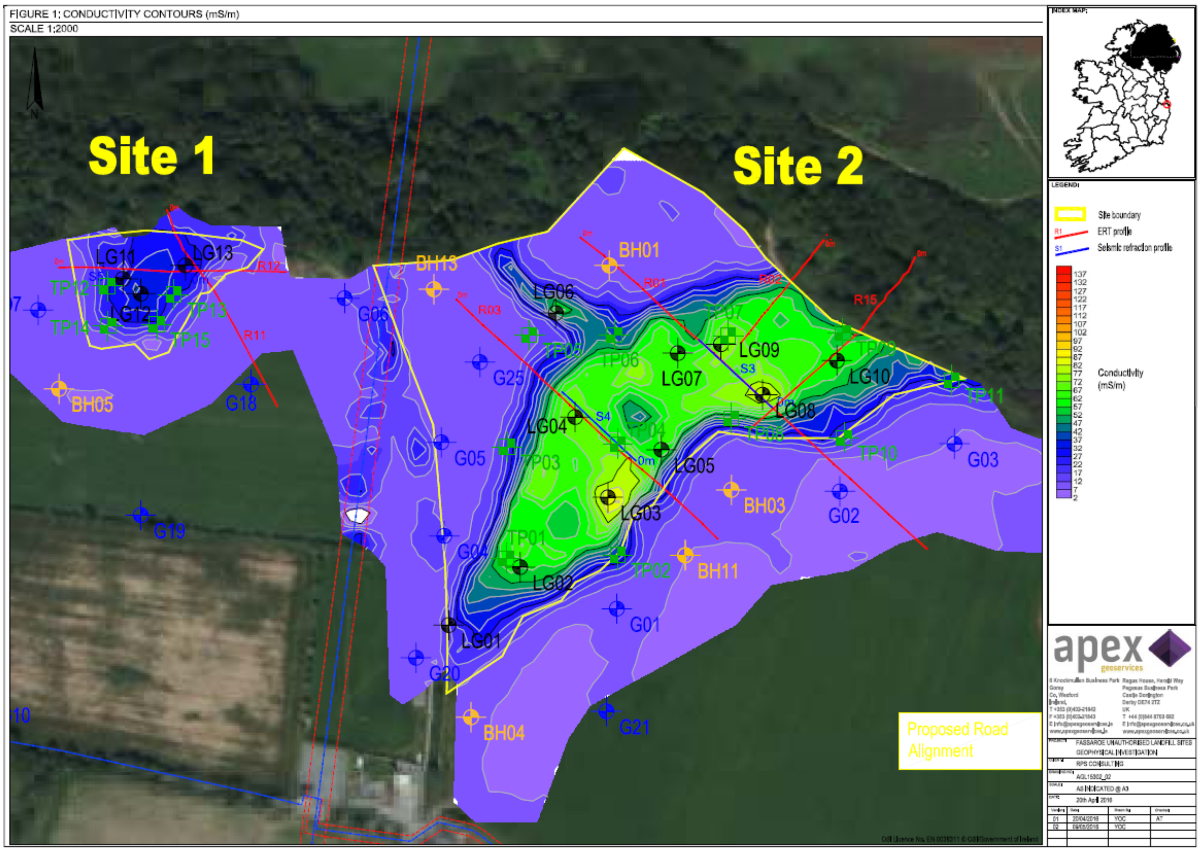
3.2.16 These results suggest that in particular an increase in concentration of methane has been observed in G18 in 2020, but this does not appear to be directly related to the pumping test as the figures were not significant different during this trial.

3.2.17 Boreholes G06 and BH05 were not monitored during the trial so a direct comparison of these results could not be made at the time.

3.2.18 In 2020 and 2021, the off-site concentrations of methane and carbon dioxide reached maximum concentrations of 9.2% v/v (in G18 in Q2 2020 as above) and 5.7% v/v respectively (in BH05 in Q1 2021).

Figure 3-3- Site 1 and 2 Conductivity Contours (extract from Apex Geophysical Survey)





3.2.19 Time series graphs of gas flow rate (l/h), methane concentration (%), carbon dioxide concentration (%) and oxygen concentration (%) are presented on **Figure 3.6** (included in **Appendix A**). These graphs do not include the most recent rounds undertaken in 2020 and 2021.

3.2.20 Using the National House Building Council (NHBC) guidance (NHBC, 2007) the maximum concentrations of methane and carbon dioxide have been characterised onsite and offsite for Site 1 in **Figure 3.6**. These figures have not been updated to include the data from the 2020 and 2021 monitoring rounds as gas flow rates were not included. Please note that the NHBC guidance is a U.K. reference and is considered relevant to reference as it is our understanding that there is no comparable guidance in Republic of Ireland.

3.2.21 The existing 33" watermain runs in a south to north direction and is located to the east of Site 1 and the west of Site 2.

3.2.22 Gas monitoring boreholes G05 and G25, located between the watermain and Site 2, recorded methane concentrations of up to 55.7% v/v and 55.3% v/v of which concentrations are consistent with that from the onsite landfill sources.

3.2.23 At borehole BH13, located to the east of the watermain and to the northwest of G25, has shown elevated concentrations of carbon dioxide up to a maximum concentration of 13.3% v/v.

Site 2

3.2.24 The waste source at Site 2 has been well defined though a series of site investigations including the site walk-over, trial pits, boreholes and geophysical surveys. The waste material is dominantly comprised of municipal waste with a maximum measured depth of 19 mbgl and an estimated area of 4.5 Ha.

3.2.25 Based on lateral and vertical extent as defined by site investigations, an estimated 340,000 tonnes of waste is present at Site 2.

3.2.26 The EPA Section 22 register dated the filling phases for Site 2 as 1979 to 1991, this dates the youngest waste as 25 years old.

3.2.27 For Site 2 all onsite and offsite readings for H_2S were zero with the exception of an isolated high concentration encountered onsite at LG05 of 50 ppm. All offsite CO readings were zero however CO was encountered in onsite boreholes with a maximum reading of 14 ppm in LG08, 10 ppm in LG04 and LG07, 7 ppm in LG10 and 2 ppm in LG09. In other boreholes the concentrations were zero.

Summary of Site 2 Gas Conditions Onsite

3.2.28 The gas monitoring data collected for onsite monitoring locations within Site 2 over the complete monitoring period recorded methane concentrations ranging from no detection to 76.5% v/v and carbon dioxide concentrations ranging from no detection to 36.6% v/v. Methane concentrations were consistently elevated with peak readings in excess of 60% v/v in LG02, LG03, LG05, LG06, LG07, LG09 and LG10. Flow rates were extremely variable ranging from -6.2 to +7.6 l/hr.

3.2.29 The concentrations of methane in the extraction boreholes during the June 2020 pumping trials indicated elevated levels of methane (maximum of 64.9% v/v at LG9) which reduced in concentrations over time to lower levels (33.8 - 54.1% v/v). The peak concentrations were generally lower than the 2016 and 2017 monitoring rounds however the high levels were constant during the trial. The carbon dioxide concentrations generally remained stable over the course of the trial (c. 21 - 26% v/v) with similar peak concentrations to those identified in the 2016 to 2021 monitoring rounds however fluctuations to lower levels were observed for the latter. The concentrations within the boreholes during the pumping trials suggest a slightly variable gas regime over the area represented by these boreholes, albeit with similar trends, indicating a level of connectivity. The consistently high gas concentrations indicates that the gas source within the landfill is significant, indicating large stored volumes or ongoing production.

Summary of Site 2 Gas Conditions Offsite

3.2.30 In the 2016 to 2021 monitoring rounds, the gas monitoring data collected for offsite monitoring locations generally recorded no detections or very low methane concentrations in the majority of monitoring locations (G02, G04, G13, G20-24, BH01 and BH04). The notable exceptions are G25, G05 and BH13 where methane concentrations range from zero up to 55.3% v/v, 55.7% v/v and 21.7% v/v respectively. It is notable that methane concentrations recorded at the 3 locations typically increase after 5th April 2016. It should be noted G05 and G25, which recorded methane concentration consistent with that from the onsite source, are located between the existing 33" watermain and Site 2. The concentrations have remained highly elevated at locations G05 and G25 in 2020 and 2021, with fluctuating concentrations encountered in BH13.

3.2.31 Offsite carbon dioxide concentrations are extremely variable ranging from 0 to 16.9 % v/v, but are elevated on occasion at most offsite monitoring locations. Sustained elevated concentrations are characteristic of G25 and BH13 (the latter located between the existing 33" water main and Site 2).

3.2.32 Flow rates are correspondingly variable, ranging between -16 l/hr to +19.8 l/hr.

3.2.33 The pumping trial in June 2020 also showed elevated methane concentrations at G25, G05 and BH13, where a maximum concentration of 35.6% v/v was encountered. Carbon dioxide also reached a maximum concentration of 8.9% v/v (G05). The concentrations appeared to generally increase by the end of the pumping period. The peak concentrations were lower than those observed during the 2016 and 2017 monitoring rounds and subsequent 2020 and 2021 monitoring rounds although the concentrations were similar overall

3.2.34 None of the boreholes to the southeast of the site boundary (G01, G02, G03, G20, G21, BH03, BH04, BH11) were monitored during the pumping trial. The concentrations in these boreholes during the 2016 and 2017 monitoring ranged from very low concentrations to 16.3% v/v for methane (BH11) and 17.2% v/v for carbon dioxide (G03). The concentrations showed similar concentrations in the 2020 and 2021 monitoring rounds with lower methane and carbon dioxide peak concentrations than in 2016 and 2017.

3.2.35 Time series graphs of gas flow rate (l/h), methane concentration (%), carbon dioxide concentration (%) and oxygen concentration (%) are presented in **Figure 3.7** contained in **Appendix A**. These graphs do not include the most recent rounds in 2020 and 2021.

3.2.36 Using the NHBC regime, the maximum concentrations of methane and carbon dioxide have been characterised onsite and offsite for Site 3A in **Figure 3.7** included in **Appendix A**. These figures have not been updated to include the data from the 2020 and 2021 monitoring rounds as gas flow rates were not included with this data.

Site 3A

3.2.37 The waste source at Site 3A has been well defined though a series of site investigations including the site walk-over, trial pits, boreholes and geophysical surveys. The waste material is dominantly comprised of municipal waste, with a maximum measured depth of 16mbgl and an estimated area of 1.9Ha.

3.2.38 Based on lateral and vertical extent as defined by site investigations, an estimated 120,000 tonnes of waste is present at Site 3A.

3.2.39 The EPA Section 22 register did not include any details for Site 3A. The age of waste at Site 3A is unknown. However, as per the WCC Tier 2 ERA, this landfill was operated between the early 1970s and the mid-1990s so the waste can be estimated to be approximately 20-25 years old.

3.2.40 For Site 3A, H_2S, maximum readings of 87 ppm, 40 ppm, 30 ppm and 25 ppm were encountered in LG20, MW4, LG19 and MW3 (19 dia. pipe) were encountered. All offsite reading for H_2S were zero for Site 3A.

3.2.41 The maximum reading of CO was 12 ppm in LG19, with maximum readings of 10 ppm encountered in LG15 and LG20. The majority of onsite borehole readings were zero and all offsite readings were zero.

Summary of Site 3A Gas Conditions Onsite

3.2.42 The gas monitoring data collected at onsite monitoring boreholes recorded methane concentrations ranging from 0% v/v to 72.8% v/v (maximum in Q1 2020) with carbon dioxide concentrations ranging from 0% v/v to 37% v/v (maximum in Q3 2020). The lowest gas concentrations were observed at the dual installation within MW3.. Typically methane concentrations are elevated between 30 and 70 % v/v. Similarly carbon dioxide concentrations are continuously elevated between 10 and 30 % v/v. The concentrations between 2016 and 2021 for these gases remained at high concentrations.

3.2.43 Flow rates were extremely variable, although high flow rates typically in excess of 30 l/hr have been recorded at all in-waste boreholes. The results of the flow readings are considered to be consistent with a waste mass that is still degrading in pockets or ‘hot spots’ of the landfill. This is likely to be producing large volumes of gas under pressure driven, advective flow conditions.

3.2.44 The pumping trial in June 2020 showed elevated methane and carbon dioxide concentrations at abstraction boreholes LG15, LG19, LG20 which decreased over time but more gradually as the trial progressed. The concentrations within the boreholes during the pumping trials suggest a slightly variable gas regime over the area represented by these boreholes. Boreholes LG15 and LG19 show different concentrations, albeit with similar trends, indicating a level of connectivity. Borehole LG20 shows different concentrations and a different trend, and significantly higher oxygen concentrations. This may indicate that oxygen was drawn into the landfill at this location. Whilst concentrations are variable the consistently high gas concentrations does indicate that the gas source within the landfill is significant, indicating large stored volumes or ongoing production.

3.2.45 In-waste boreholes MW3 and MW4 were monitored and showed similar elevated concentrations to those observed during the 2016 and 2017 monitoring rounds. Flow rates of between 2 and 7 m^3/hr were typically recorded in these in-waste boreholes. There were no boreholes monitored in the immediate surrounding area.

Summary of Site 3A Gas Conditions Offsite

3.2.46 The gas monitoring data collected at offsite monitoring locations did not record any methane detections during the course of the monitoring period from 2016 to 2021 and carbon dioxide concentrations ranging from no detection to 3.2% v/v.

3.2.47 Flow rates in boreholes located outside the landfill body have remained consistently low, typically below 1.6 l/hr.

3.2.48 There were no boreholes monitored in the immediate surrounding area of the landfill site during the pumping trials in June 2020.

3.2.49 Time series graphs of gas flow rate (l/h), methane concentration (%), carbon dioxide concentration (%) and oxygen concentration (%) are presented on **Figure 3.8** included in **Appendix A**. These graphs do not include the most recent rounds undertaken in 2020 and 2021

3.2.50 Using the NHBC regime, the maximum concentrations of methane and carbon dioxide have been characterised onsite and offsite for Site 3A in **Figure 3.8** included in **Appendix A**. These figures have not been updated to include the data from the 2020 and 2021 monitoring rounds as gas flow rates were not included.

Site 3B

3.2.51 The waste source at Site 3B has been well defined though a series of site investigations including the site walk-over, trial pits, boreholes and geophysical surveys. The relatively shallow waste material is dominantly comprised of municipal waste with a maximum measured depth of 4.9mbgl with an estimated area of 0.44Ha.

3.2.52 Based on lateral and vertical extent as defined by site investigations, an estimated 8,500 tonnes of waste is present at Site 3B.

3.2.53 According to the EPA Section 22 register waste was disposed at Site 3B between 1994 and 1995. This would indicate the youngest waste is approximately 21 years old.

3.2.54 All readings for H_2S at site 3B were zero onsite and offsite. Readings for CO onsite and offsite are zero with the exception of LG16 and LG17 which had maximum readings of 32 ppm and 10 ppm respectively.

Summary of Site 3B Gas Conditions Onsite

3.2.55 The gas monitoring data collected at onsite monitoring locations recorded consistently elevated methane concentrations ranging from 22.0% v/v to 73.1% v/v and carbon dioxide ranging from 17.2% v/v and 39.3% v/v. No measurable flow rate was recorded during several monitoring periods with peak reading of 3.3 l/hr, 6.2 l/hr and 2.5 l/hr recorded at LG16, LG17 and LG21 respectively. The concentrations within the boreholes during the pumping trials suggest a variable gas regime over the area represented by these boreholes, with variable concentrations and trends. This indicates a lower level of connectivity than observed in the aforementioned landfills. Borehole LG16 shows different concentrations and a different trend, and significantly higher oxygen concentrations. This may indicate that oxygen was drawn into the landfill at this location. The absolute concentrations and trends indicate lower stored volumes and / ongoing production.

3.2.56 With regard to the pumping trials in June 2020 in LG16, LG17 and LG21, methane and carbon dioxide concentrations appeared to show generally lower concentrations than the spot monitoring rounds undertaken between 2016 and 2021particularly as the trial progressed and the concentrations continued to lower. The flow rates generated were similar to the spot monitoring rounds in 2016 and 2017

Summary of Site 3B Gas Conditions Offsite

3.2.57 The spot gas monitoring data obtained from 2016 to 2021 collected at offsite monitoring locations only recorded methane during one monitoring period at G16 (2.1% v/v on the 12/4/2016). Carbon dioxide concentrations ranged from 0% v/v to 4.4% v/v. Flow rates were typically low, albeit variable ranging from -0.5 l/hr to 2.2 l/hr.

3.2.58 In the pumping trials in June 2020, carbon dioxide concentrations slightly elevated above the previous monitoring results were encountered within the boreholes on site with carbon dioxide peaking at 5.6% in BH09. Methane was zero at all locations.

3.2.59 Time series graphs of gas flow rate (l/h), methane concentration (%), carbon dioxide concentration (%), oxygen concentration (%), hydrogen sulphide concentration (ppm), carbon monoxide concentration (ppm) and atmospheric pressure (hPa) are presented on **Figure 3.9** included in **Appendix A**. These graphs do not include the most recent rounds undertaken in 2020 and 2021.

3.2.60 Using the NHBC regime, the maximum concentrations of methane and carbon dioxide have been characterised onsite and offsite for Site 3B in **Figure 3.9**. These figures have not been updated to include the data from the 2020 and 2021 monitoring rounds as gas flow rates were not included.

Site 3C

3.2.61 The waste source at Site 3C has been well defined though a series of site investigations including the site walk-over, trial pits, boreholes and geophysical surveys. The waste material is dominantly comprised of municipal waste with a maximum measured depth of 13 mbgl and an estimated areal extent of 0.9 Ha.

3.2.62 Based on lateral and vertical extent as defined by site investigations, an estimated 47,000 tonnes of waste is present at Site 3C.

3.2.63 The EPA Section 22 register detailed that waste was disposed of at Site 3C from 1992 to 1995. This would indicate the youngest waste is approximately 21 years old.

3.2.64 In comparison to the other four sites, Site 3C showed an increase in onsite readings for H_2S. Readings for MW2 range from 25-210 ppm, LG14 range from 25-50 ppm and LG18 range from 25-40 ppm. All offsite readings for H_2S are zero with the exception of G09 where a reading of 2 ppm was identified.

3.2.65 For Site 3C the onsite readings did not exceed 2 ppm and offsite reading for CO only exceeded 1 ppm at one location, this being G11 with a reading of 10ppm on 12/04/2016.

Summary of Site 3C Gas Conditions Onsite

3.2.66 The gas monitoring data collected from onsite monitoring locations recorded methane concentrations ranging from 5.9% v/v to 83.5% v/v with carbon dioxide concentrations ranging from 4.1% v/v to 37.2% v/v. Methane concentrations are typically stable with a concentration between 60% v/v and 75% v/v. Similarly, the carbon dioxide concentrations typically exceed 25%. Flow readings were typically low (i.e. below 2 l/hr) with the exception of 11.7 l/hr recorded at MW2 on 12/04/2016. The elevated gas concentrations are consistent with an actively gassing municipal landfill.

3.2.67 The pumping trial in June 2020 showed elevated methane and carbon dioxide concentrations at abstraction boreholes LG14 and LG18 which stabilised at low levels after one day. The stabilised concentrations appeared to be at a consistently low level, without the fluctuations shown in the spot monitoring between 2016 and 2021. Flow rates were 6-9 m^3/hr in these boreholes.

3.2.68 In-waste borehole MW2 was monitored and showed similar elevated concentrations to those observed during the spot monitoring rounds.

Summary of Site 3C Gas Conditions Offsite

3.2.69 The monitoring of offsite monitoring locations recorded methane concentrations ranging from no detectable concentration to 22.2% v/v and carbon dioxide concentrations ranging from no detectable concentration to 19.6% v/v. Methane concentrations show significant variability with absence of methane at all locations between July and November 2016, and in the 2020 and 2021 quarterly monitoring rounds. This variability is also seen with carbon dioxide, although non-zero concentrations are typically observed over this period. No measurable flow was recorded with the exception of 0.4 l/hr in G09 and 0.3 l/hr in BH06 on 05.04.2016.

3.2.70 G11 located to the west of the site did not record any detectable concentrations of methane for the duration of the monitoring period. G09 and BH06 are located to the east and south of the historic landfill however it should be noted that they are located in close proximity to the lateral extent of the waste body and not c.20m from the waste extent as proposed by best practice. Access was restricted within these locations due to ownership restrictions and minimisation of impact to local crops. Borehole logs for G09 and BH06 did not record the presence of any waste however these monitoring locations could be considered peripheral rather than offsite perimeter locations.

3.2.71 During the pumping trial in June 2020, location G09 to the east of the landfill site showed low methane concentrations which did not exceed the maximum concentrations observed in the 2016 and 2017 monitoring rounds. The concentrations gradually reduced as the trial progressed.

3.2.72 Time series graphs of methane concentration (%), carbon dioxide concentration (%) and oxygen concentration (%) are presented on **Figure 3.10** included in **Appendix A**. These graphs do not include the most recent rounds undertaken in 2020 and 2021.

3.2.73 Using the NHBC regime, the maximum concentrations of methane and carbon dioxide have been characterised onsite and offsite for Site 3C in **Figure 3.10**. These figures have not been updated to include the data from the 2020 and 2021 monitoring rounds as gas flow rates were not included.

3.2.74 **Figure 3.11** included in **Appendix A** details methane and carbon dioxide classifications onsite and offsite for all five historical landfill sites. In general, the carbon dioxide and methane concentrations are reduced offsite in comparison to onsite results. This is discussed in further detail above for each site. The exception to this trend is boreholes G05, G06, G25 and BH13 which support the suggestion that the existing 33” watermain situated between Site 1 and Site 2 is a source of gas. These figures have not been updated to include the data from the 2020 and 2021 monitoring rounds as gas flow rates were not included.

3.2.75 The ground gas monitoring has been completed over a period of one year which provides a sufficient period of time to be able to undertake the above detailed analysis.

3.3 Pathways

3.3.1 A review of the wider site setting identifies the following migration pathways:

- Vertical migration through the landfill surface. The prevalence of carbon dioxide and the absence of methane within the peripheral boreholes suggest that this may be a significant mechanism.
- Horizontal migration through the shallow superficial deposits within the unsaturated zone. Given the nature of these deposits (sands and gravels) this is considered to be the primary migration pathway.
- Horizontal migration within the bedrock. This is considered likely to be a minor pathway due to its likely low permeability (slate, phyllite & schist).
- Horizontal migration through dissolved gases within groundwater and perched water. This is considered to be a minor pathway as the hydrogeological conditions should not lead to significant gas concentrations in solution.
- Horizontal migration through service trenches associated bedding material and proposed roads ‘/ other structures. This is considered a potentially significant local pathway.

3.3.2 These contaminant pathways are considered below in relation to each of the identified sources.

Site 1

3.3.3 The waste at Site 1 is present to a depth of 14.5mbgl and sits within the high permeability unconsolidated sands and gravel deposits above the groundwater table. There is a circa 5 – 6.5 m unsaturated zone below the waste deposits as is suggested by the 2016 and 2017 monitoring rounds. The current data suggests that the groundwater flow direction is to the northeast and that the groundwater table is unconfined coming to the surface within springs or discharging into the river.

3.3.4 A potential preferential pathway exists in the form of the existing 33” watermain which runs in a south-north direction to the east of the waste mass.

3.3.5 The ground investigation data indicates that the landfill is overlain by a clay cap which is likely to allow venting of gases that are lighter than air.

3.3.6 Based on this setting it is considered that the identified pathways have the following significance in relation to Site 1:

- Vertical migration through the landfill surface is considered likely given the nature of the overlying deposits. The prevalence of carbon dioxide and the absence of methane within the majority of peripheral boreholes suggest that this may be a significant pathway for gases that are lighter than air.

- Horizontal migration through the shallow superficial deposits within the unsaturated zone is considered to be the primary pathway (where gases are not migrating through the cap) on the basis that the waste deposits sit fully within these materials. The direction of flow is likely to be driven by the concentrations gradients within the shallow zone. It should however be noted that, for gases that are heavier than air, the direction of migration may be dictated by the water table dip. On this basis there may be an element of preferential migration towards the east and north east. Localised flow with a component to the south can also not be discounted.
- Horizontal migration within the bedrock. This is considered unlikely to be a major pathway due to its likely low permeability (slate, phyllite & schist) and substantial depth below the site (not encountered at 33 mbgl in nearby borehole BH11)
- Horizontal migration through dissolved gases within groundwater and perched water is considered to be a minor pathway as the hydrogeological conditions should not lead to significant gas concentrations in solution, the groundwater being unconfined with gases able to leave solution along the groundwater migration pathway.
- Horizontal migration through service trenches and bedding material. This is considered a potentially significant local pathway.

3.3.7 The existing 33" watermain runs in a south-north direction to the east of the waste infill area and could provide a potential pathway for landfill gas. This is discussed further in Section 3.3.6.

Site 2

3.3.8 The waste at Site 2 is present to a depth of approximately 19 mbgl. Most of the waste body is within the high permeability unconsolidated sands and gravel deposits above the groundwater table with the lowest levels of the waste body saturated. The current data suggests that the groundwater flow direction is to the north east and the groundwater table is unconfined coming to the surface with springs.

3.3.9 The areas of saturated waste body could result in a potential pathway for soluble gases in groundwater however there are some clay layers mapped between the base of the waste and the deeper gravels. It appears that the clay layers finger out to the north and the leachate and groundwater head are at the same level as indicated by LG10. Leachate from the landfill site may also contain dissolved gases or may potentially degrade during migration to produce methane and carbon dioxide.

3.3.10 A potential preferential pathway exists in the form of the existing 33" watermain.

3.3.11 The ground investigation data indicates that the landfill is overlain by clay material. Conceptually, if consistent across the landfill such a layer would be expected to prevent methane migration through the cap. The data does indicate a lack of horizontal methane migration, suggesting a dominant vertical pathway either through the cap or the natural materials immediately adjacent to the landfill.

3.3.12 Based on this setting it is considered that the identified pathways have the following significance in relation to Site 2:

- Vertical migration through the landfill surface or immediately surrounding areas is considered likely based on the monitoring results. The prevalence of carbon dioxide and the absence of methane within the majority of peripheral boreholes suggest that this may be a significant pathway for gases that are lighter than air.
- Horizontal migration through the shallow superficial deposits within the unsaturated zone is considered to be the primary pathway (where gases are not migrating vertically through the cap or immediately adjacent areas) on the basis that the waste deposits sit fully within these materials. The direction of flow is likely to be driven by the concentration gradients within the shallow zone. It should however be noted that for gases that are heavier the direction of migration may be dictated by the water table dip. On this basis there may be an element of preferential migration towards the east and north east.

- Horizontal migration within the bedrock is considered unlikely to be a significant pathway due to its likely low permeability (slate, phyllite & schist) and significant depth to bedrock.
- Horizontal migration through dissolved gases within groundwater and perched water is considered to be a minor pathway as the hydrogeological conditions should not lead to significant gas concentrations in solution, the groundwater being unconfined with gases able to leave solution along the groundwater migration pathway.
- Horizontal migration through service trenches and bedding material is considered a potentially significant local pathway. The proposed development proposes a road alignment through the southern margin of Site 2 which may result in the potential development of additional pathways for landfill gas migration through the road structure and associated service/utility routings. This could also be the case for any service connections to the proposed pond and the cycle path.

Site 3A

3.3.13 The waste at Site 3A is present to a depth of 16mbgl based on recent site investigations. The waste body appears to be mainly unsaturated with only a minor depth of leachate head to the north of the site. The groundwater table is considered to be located directly beneath the waste mass but there may be a marginal unsaturated zone between the two. Monitoring of neighbouring boreholes suggested a depth of 6-14 mbgl. An unsaturated sand and gravel zone can provide both lateral and vertical migration pathways via pore spaces for landfill gas at the site. The general groundwater flow within the sandy gravel deposits is in a northeast direction towards the river. The ground investigation data indicates that the landfill is overlain by a clay material. Conceptually, if consistent across the landfill such a layer would be expected to prevent methane migration through the cap. The data does indicate a lack of horizontal methane migration, suggesting a dominant vertical pathway either through the cap or the natural materials immediately adjacent to the landfill.

3.3.14 Based on this setting it is considered that the identified pathways have the following significance in relation to site 3A:

- Vertical migration through the landfill surface or immediately surrounding areas is considered likely based on the monitoring results. The prevalence of carbon dioxide and the absence of methane within the majority of peripheral boreholes suggest that this may be a significant pathway for gases that are lighter than air.
- Horizontal migration through the shallow superficial deposits within the unsaturated zone is considered to be the primary pathway (where gases are not migrating through the cap or immediately adjacent areas) on the basis that the waste deposits site fully within these materials. The direction of flow is likely to be driven by the concentrations’ gradients within the shallow zone. It should however be noted that for gases that are heavier the direction of migration may be dictated by the water table dip. On this basis there may be an element of preferential migration towards the east and north east.
- Horizontal migration within the bedrock. This is considered unlikely to be a significant pathway due to its likely low permeability (slate, phyllite & schist) and significant depth to bedrock.
- Horizontal migration through dissolved gases within groundwater and perched water is considered to be a minor pathway as the hydrogeological conditions should not lead to significant gas concentrations in solution, the groundwater being unconfined with gases able to leave solution along the groundwater migration pathway.
- Horizontal migration through service trenches and bedding material is considered a potentially significant local pathway should future development occur on/ near Site 3A. There is currently no planned development at Site 3A.

Site 3B

3.3.15 The waste at Site 3B is present to a depth of 4.9mbgl based on recent site investigations. The groundwater table is relatively shallow at Site 3B (c. 4 – 5 mbgl) and it would appear that the waste body sits within the high permeability unconsolidated sands and gravel deposits and is perched above the groundwater table. Some deeper portions of the waste are saturated to the north and could result in the migration of dissolved gas in groundwater. The current data suggests that the groundwater flow is in a northeast direction towards the river. The ground investigation data indicates that the landfill is overlain by a clay material. Conceptually, if consistent across the landfill such a layer would be expected to prevent methane migration through the cap. The data does indicate a lack of horizontal methane migration, suggesting a dominant vertical pathway either through the cap or the natural materials immediately adjacent to the landfill.

3.3.16 Based on this setting it is considered that the identified pathways have the following significance in relation to Site 3B:

- Vertical migration through the landfill surface or immediately adjacent materials is considered likely based on the gas monitoring results. The prevalence of carbon dioxide and the absence of methane within the majority of peripheral boreholes suggest that this may be a significant pathway for gases that are lighter than air.
- Horizontal migration through the shallow superficial deposits within the unsaturated zone is considered to be the primary pathway (where gases are not migrating through the cap or immediately adjacent areas) on the basis that the waste deposits site fully within these materials. The direction of flow is likely to be driven by the concentrations' gradients within the shallow zone. It should however be noted that for gases that are heavier the direction of migration may be dictated by the water table dip. On this basis there may be an element of preferential migration towards the east and north east.
- Horizontal migration within the bedrock. This is considered unlikely to be a significant pathway due to its likely low permeability (slate, phyllite & schist) and significant depth to bedrock
- Horizontal migration through dissolved gases within groundwater and perched water is considered to be a minor pathway as the hydrogeological conditions should not lead to significant gas concentrations in solution, the groundwater being unconfined with gases able to leave solution along the groundwater migration pathway.
- Horizontal migration through service trenches and bedding material is considered a potentially significant local pathway. A road cut through Site 3B is proposed as part of the overall development which has the potential to represent an additional pathway for landfill gas migration through the road structure and associated utilities/services.

Site 3C

3.3.17 The waste at Site 3C is present to a depth of 13mbgl based on recent site investigation data. The base of the waste would appear to be saturated and in direct connection with the groundwater-table in the underlying high permeability unconsolidated sand and gravel deposits (a depth of c. 6 mbgl was indicated in borehole BH06 on the southern boundary). Based on current data, the general groundwater flow within the sandy gravel deposits is in a northeast direction towards the river. The ground investigation data indicates that the landfill is overlain by a clay material. Conceptually, if consistent across the landfill such a layer would be expected to prevent methane migration through the cap. The data does indicate a lack of horizontal methane migration, suggesting a dominant vertical pathway either through the cap or the natural materials immediately adjacent to the landfill.

3.3.18 Site 3C is currently not in regular use and generally comprises scrub. It should be noted that there are a number of buildings located immediately to the south of the site which are in use/occupied and the potential for gas migration to such should be considered.

3.3.19 Based on this setting it is considered that the identified pathways have the following significance in relation to site 3C:

- Vertical migration through the landfill surface or immediately adjacent materials is considered likely based on the gas monitoring results. The prevalence of carbon dioxide and the absence of methane within the majority of peripheral boreholes suggest that this may be a significant pathway for gases that are lighter than air.
- Horizontal migration through the shallow superficial deposits within the unsaturated zone is considered to be the primary pathway (where gases are not migrating through the cap) on the basis that the waste deposits site fully within these materials. The direction of flow is likely to be driven by the concentrations' gradients within the shallow zone. It should however be noted that for gases that are heavier than air the direction of migration may be dictated by the water table dip. On this basis there may be an element of preferential migration towards the east and north east.
- Horizontal migration within the bedrock. This is considered unlikely to be a significant pathway due to its likely low permeability (slate, phyllite & schist) and significant depth to bedrock.
- Horizontal migration through dissolved gases within groundwater and perched water is considered to be a minor pathway as the hydrogeological conditions should not lead to significant gas concentrations in solution, the groundwater being unconfined with gases able to leave solution along the groundwater migration pathway.
- Horizontal migration through service trenches and bedding material is considered a potentially significant local pathway.

Existing 33" Watermain

3.3.20 As illustrated in Figure 3.3 and discussed in Section 3.2.1 the bedding material for the existing 33" watermain is a potential pathway for gas migration. The geophysical survey carried out in December 2015 shows elevated conductivity along the existing 33" watermain.

3.3.21 Given the age of the watermain (possibly over 150 years old) there are no known details of the bedding and surround or the backfill used around the watermain. The carbon dioxide/ methane levels in the boreholes located in the vicinity of the watermain indicate higher than expected levels of carbon dioxide and methane for offsite boreholes. This suggests the existing 33" watermain is a potential pathway for gas migration.

3.3.22 As discussed in Section 4.4 it is considered essential to characterise the bedding and surround material along the route of the watermain. This will assist in designing the appropriate scope of gas protection measures.

3.4 Receptors

3.4.1 The receptors relating to the identified gas sources and pathways are:

- Future properties and their occupiers.
- The future site users in open spaces and where they will have access to confined low-lying areas.
- Existing adjacent properties and their occupiers.
- Proposed adjacent properties and their occupiers.

3.4.2 These are discussed in more detail below.

Future Properties and their Occupiers

3.4.3 **Figure 3-4** presents the proposed Phase 1 development including the habitable and open spaces. Buildings and occupants will be in close proximity to waste landfills that are actively producing landfill gas. The location of the landfill sites and the closets proposed development are shown on **Figure 3-5**. The proposed development suggests that the minimum distance of the development from the boundary of the surface of the landfills is approximately 20m from Site 1 (to the north of the site) and c. 10 m from Site 2 (east and southeast of the site). The development plans detail an area designated as additional apartments subject to future planning (previous identified as block 5) located at about c. 50 m to the southeast of site 1 which was indicated in Drawing 15011.1-PL147 to have a basement floor level of c. 90.5 mAOD and a ground level of 93.875mAOD. Contours indicate that the landfill site in this area is c. 94-96 mAOD on plans provided in Appendix 1.

Figure 3-4: Proposed Fassaroe Phase 1 SHD Layout

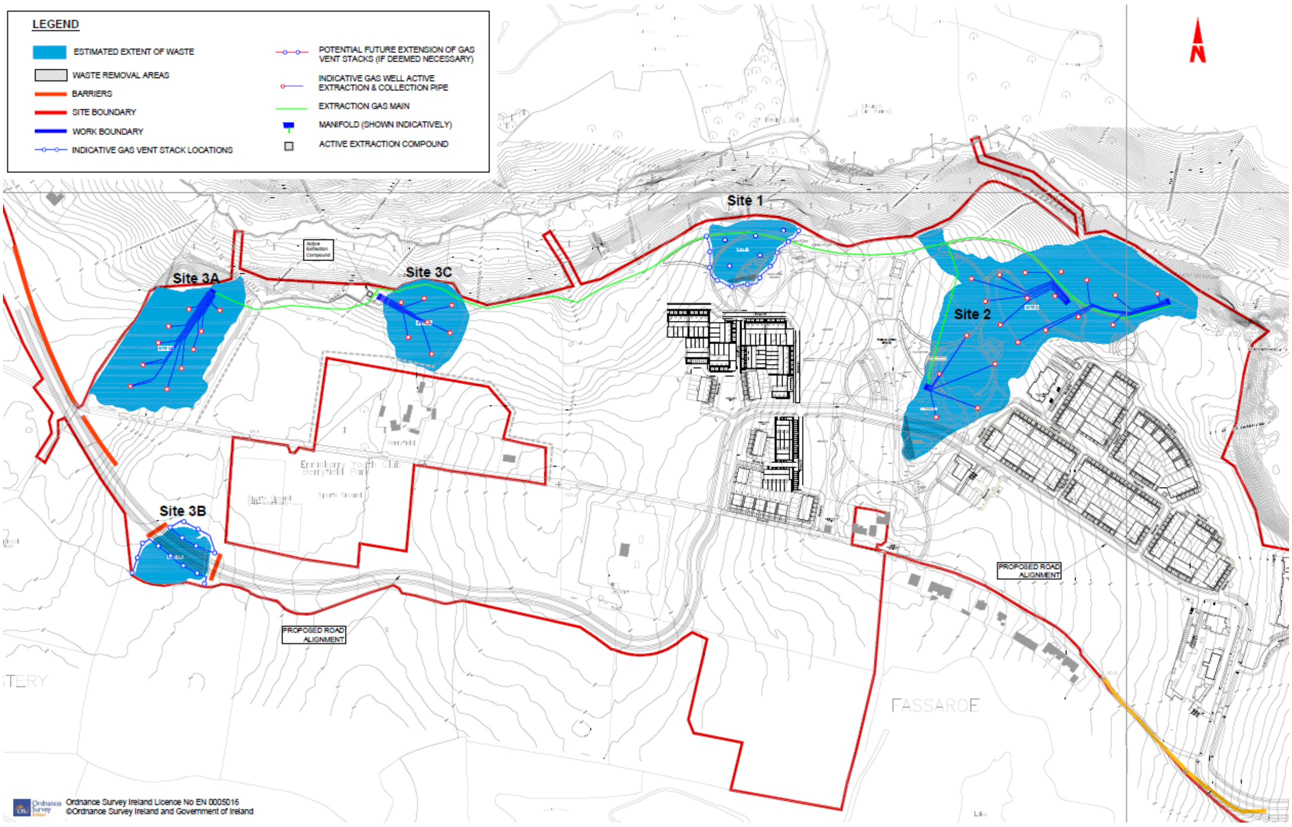
3.4.4 For site 1, the majority of low-rise development appears to be at a minimum of c. 25 – 35 m from the landfill site, and c. 35 – 45 m from the 'landfill remediation zone' identified in the proposed Phase 1 scheme. For site 2, the housing and apartments are c. 10 – 20 m from the landfill site and a creche at about c. 25 m from the edge of the site. Apartment block 4 is located on the development boundary although this does not appear to have a basement. The elevations of the ground level of the standard housing and apartments (without basements) appears to be similar to the surface of the landfill site, for sites 1 and 2.

3.4.5 The NHBC has developed a characterisation system (traffic light system) to allow designation of gas protection that is specific to low-rise housing development with a clear ventilated underfloor void. This system does not provide guidance on the characterisation of buildings with basements. This will require specific consideration once detailed design for basements has been confirmed.

Future Site Users Open Spaces

3.4.6 The risk to future site users within open spaces will only persist in confined low lying areas where gases that are heavier than air may accumulate. As shown in **Figure 1.1** the proposed development will consist of attenuation ponds. The ponds gradually step down in height with the attenuated waters flowing from one into the next. It is understood that the he base elevation of these ponds do not extend below the elevation of the top of the waste mass. The detailed capping design will account for installing an impermeable barrier to prevent landfill gases from vertically migrating or diffusing through the attenuation ponds. Cross sections of these features are shown in Drawings LFAS-MAL-XX-XX-DR-L-0201 and LFAS-MAL-XX-XX-DR-L-0203, presented within Appendix B.

Figure 3-5: Location of Historic Landfill Sites and Closest Proposed Phase 1 Development Elements



Current Offsite Structures

3.4.7 Current structures offsite are located c. 80m to south of Site 2, c. 170m to west of Site 3A. The Enniskerry AFC sports clubhouse on Berryfield Lane (within ownership boundary) is 132 m to the southeast of Site 3A and 100 m to northeast of Site 3B. There are buildings at about 50 m to south of Site 3C (within ownership boundary). There are also residential properties at about 170 m to the west of Site 3B. There is a residential property at c. 300 m to the northeast of Site C.

3.4.8 The occupiers of these properties and users of these buildings may be at risk if basement structures are present or if the properties are sited within depressions. A review of the topography indicates that the properties are not located within depressions.

Proposed Adjacent Properties and Their Occupiers

3.4.9 It is important to note that new receptors could be introduced through development of the surroundings areas as part of future planning applications. As with the existing properties the risk is considered to be most significant where the proposed properties have basement structures or are sited within depressions. It is however considered that this risk should be considered within the assessments for any future offsite development.

3.4.10 The only significant additional proposed development in the areas immediately surrounding these features are areas zoned for housing and identified for future planning phases in the CPG Masterplan between Sites 3A and 3C, and to the east of Site 3C. There is no confirmed layout for this housing at present, but the area is outside of the footprint of the landfills.

3.5 Summary of Gas Risk Assessment

3.5.1 The risks associated with landfill gas for the proposed development are as follows:

- The primary source of gas is the waste within the landfills. The existing 33" watermain located between Site 1 and Site 2 is identified as a potential secondary source and potentially a pathway too.
- The majority of the waste body across all five sites is located above the water-table within an unsaturated zone. The unsaturated sand and gravel deposits provide both lateral and vertical migration pathways via pore spaces for landfill gas generated at the site.
- Leachate from the landfill sites may also contain dissolved gases or may degrade during migration to produce methane and carbon dioxide.
- The proposed development includes a road alignment through the southern margin of Site 2 and a road cut through Site 3B which may result in the potential development of additional pathways for landfill gas migration through the road structure and associated service/utility routings.
- An initial review of methane and carbon dioxide concentrations within and outside the waste mass (during the standard monitoring and pumping trials) typically identifies considerably lower concentrations outside the waste mass than within. The decrease in concentrations is more pronounced for methane than for carbon dioxide indicating that methane may be venting vertically through the landfill cap and natural deposits. There are a small number of occasions where higher concentrations of recorded gases are present outside the recorded areas of the waste mass. It is considered that these may be related to preferential pathways. These locations require further consideration. The data does not appear to suggest any clear link between groundwater levels and gas flow rates.
- The receptors for all five sites include the underlying sand and gravel aquifer, existing and future site users and existing, and proposed offsite buildings and structures.
- Buildings and occupants will be in close proximity to waste landfills that are actively producing landfill gas. The current proposed Fassaroe Phase 1 development contains properties (low rise development and apartment blocks) that will be a minimum distance of approximately 20 m from Site 1 (to the west of the site) and c. 10 m from Site 2 (east and southeast of the site) from the boundary of the landfills.
- Current structures offsite are located c. 80m from to south of Site 2 and c. 170m to west of Site 3A. The Enniskerry AFC sports clubhouse (within ownership boundary) is 132 m to the southeast of Site 3A and 100 m to northeast of Site 3B. There are buildings at about 50 m to south of Site 3C (within ownership boundary). There are also residential properties at about 170 m to the west of Site 3B. There is a residential property at c. 300 m to the northeast of Site 3C. It is important to note that new receptors could be introduced through development of the surrounding areas as part of future planning applications.
- The proposed development will include for attenuation ponds and an amphitheatre. The ponds are planned for construction at an elevation above the top of the waste. The detailed capping design will account for installing an impermeable barrier to prevent landfill gases from vertically migrating or diffusing through the attenuation ponds.

3.6 Predicted Changes to Gas Regime

3.6.1 At present without the proposed redevelopment works it is considered that the factors effecting landfill gas production rates will be stable and therefore the key influencing factor would be the composition of the waste. It should however be noted that capping of the landfills is proposed as part of the Phase 1 development which is likely to impact the conditions within the landfill including the gas regime. Additionally, the development will introduce the risk of new pathways due to forced lateral migration of gases as a result of the installation of an impermeable barrier restricting vertical gas migration.

3.6.2 As part of the Phase 1 development works the following remedial and construction activities are proposed upon or directly adjacent to the landfill masses which may impact the gas regime:

- Capping of the landfill to address risks to controlled waters and human health.
- Construction of shallow leachate cut off trench.
- Construction of an access road bisecting Site 3B and crossing the southern corner of Site 2.
- Construction of service runs and roadways.
- Construction of foundations to the properties.
- Construction of attenuation features.
- Virtual gas curtain (VGC) with specific requirements as specified in the CoA.

3.6.3 These construction activities have the potential to impact the gas regime as set out within the remainder of this section.

3.6.4 Additionally, the AFS Report (July 2020) recommends installation of a gas flare system comprising:

- Installation of gas wells to depths just above the water table connected into a common gas main that leads to a small 100m^3/hr Lo-Cal flare for sites 2 and 3A.
- Vent pipes and rotating cowls to produce a negative suction in the waste mass, with vent trenches around the perimeter of the site for sites 1, 3B and 3C

3.6.5 Such a gas collection and flare system are provided for in the current proposed Phase 1 development. It will provide a flare for Sites 2, 3A and 3C (while not deemed necessary following the gas pumped trial, because the collection system will pass by Site 3C and as the 100m3/hr Lo-Cal flare will have capacity, Site 3C will be connected to the flare).

Capping of the Landfills

3.6.6 The proposed capping system will affect the rate of landfill gas generation. The capping layer affects the rate of rainfall infiltration and thus moisture conditions. The loading of the capping system may also alter the void ratio and oxygen ingress to the landfills. The cap will also prohibit the venting of gas through the surface of the landfill which is likely to increase lateral migration.

Construction of Shallow Leachate Cut off Trench

3.6.7 A leachate interceptor drain will be constructed on the downstream gradient perimeter of Site 1 to collect leachate that may seep or build up beneath the capping system. It is expected that the quantities collected would be intermittent and minimal. However, this may result in a preferential gas migration pathway.

Construction of an Access Road Bisecting Site 3B and Crossing the Southern Corner of Site 2

3.6.8 It is anticipated that the construction of an access road as part of the proposed cap will result in similar issues to those described in **Section 3.6.1**. In addition to these issues the construction of a road upon the landfill is likely to result in a preferential migration pathway, associated with the road subbase and capping layers and associated service runs. This may facilitate the migration of gas at significant distance from the landfills.

Construction of Service Runs and Roadways within the Main Development

3.6.9 The construction of roads within the main development may generate preferential migration pathways associated with the road subbase and capping layers and associated service runs. This may transport gas a significant distance from the landfills, depending on the proximity of the road to the landfill.

Construction of Foundations and Basements to the Properties

3.6.10 The construction of foundations or basements to properties has the potential to create vertical migration pathways that may lead to significant point source gas emissions.

3.6.11 The foundation and basement details will be designed at detailed design stage.

Construction of Attenuation Features and Other Low Lying Features

3.6.12 The construction of drainage attenuation features (ponds) and the proposed amphitheatre is likely to create low lying areas in which gases may accumulate, particularly where these gases are heavier than air and a pathway exists. Where these features extend below the elevation of the waste surface mitigation should be considered to prevent the accumulation of gases. .

3.6.13 The impact of the proposed construction works is difficult to predict and this uncertainty needs to be reflected in the scope of gas protection measures selected in Section 6 of this report. Attenuation features comprising ponds are planned in the southern area of Site 2 in the proposed Phase 1 scheme. An amphitheatre is also proposed in Phase 1.

Installation of a Gas Abstraction and Flare System

3.6.14 The purpose of the gas abstraction and flare systems is to reduce the volumes of gas within the landfill and therefore the pressure gradients promoting gas flow from the landfills. The pumping trial results indicate falls in methane and to a lesser extent carbon dioxide concentrations within landfill 3A, 3B and 3C. The same effect was not evident within the data for landfills 1 and 2. The flare system is also likely to alter the amount of oxygen entering the landfill which may alter the speciation of the gases within the landfills.

4 FURTHER REQUIREMENTS

4.1 Introduction

4.1.1 A range of further characterisation works were detailed in 2016 Gas Management Strategy. These have been reviewed and updated to take account of the further monitoring data and the updated conceptual model. The gas management strategies outlined in this report are considered worst case scenario requirements. The following further characterisation works are discussed below:

1. Characterisation of the dissolved gas concentrations within the groundwater.
2. Characterisation of the full thickness of pathways.
3. Determination of gas concentrations at greater distance from landfill Site 3C.
4. Characterisation of material surrounding the existing 33" watermain, including arising gases if any.
5. Surface emission rates through the landfills, surrounding areas and watermain.
6. Extension of the monitoring period and dataset.
7. Development phase gas monitoring.
8. Design details for development foundations.
9. Pumping Trials.

4.2 Dissolved Gas in Groundwater

4.2.1 As part of the recommendations of the ERA (RPS, 2018), it was proposed to complete analysis of dissolved gas in groundwater as part of further groundwater monitoring round. Limited further testing has been undertaken to date which has indicated some elevated concentrations of dissolved carbon dioxide (30 mg/l n BH01 to north of site 2) but limited or no dissolved gas at other locations. The significant depth to groundwater identified in boreholes to the east and southeast of site 2 in the direction of the proposed development suggests that the risk from dissolved gases in groundwater is likely to be low with regard to the development in this area. However, it would be prudent to obtain an up-to-date assessment of the dissolved gas in groundwater concentrations across the sites by undertaking a further sampling round to allow a more comprehensive assessment of the groundwater and ground gas conditions. As elevated carbon dioxide has been identified in the area of site 2, this is of particular importance to the south and southeast of site 2 where most of the development is located. One or two deep boreholes are recommended to assess ground gas and groundwater levels and dissolved gas in groundwater concentrations which extend deeper the maximum depth of the previous investigation (33 mbgl in borehole BH11). This is recommended to obtain a greater understanding of the groundwater and ground gas conditions in this area

4.3 Pathway Thickness

4.3.1 The thickness of the migration pathway is considered to be defined by the shallower of the groundwater table (should it be continuous) or the anticipated low permeability bedrock deposits (migration of dissolved gases through the groundwater being characterised by the works proposed in **Section 4.1**). The investigation data indicates the presence of a laterally continuous groundwater table. Further boreholes can be used to confirm the thickness of the gas migration pathway to support the detailed design of the gas protection measures.

4.4 Boreholes at Site 3C

4.4.1 Initially the extent of waste for Site 3C was determined following a review of OSI mapping. Following the site investigations and geophysical survey the extent of the waste was redefined. This resulted in the borehole to the east of the site (G09) now being considered to be a proximity borehole rather than an offsite borehole. An offsite borehole is recommended in order to fully determine if gas is migrating offsite that can be used to inform the gas management strategy.

4.5 Existing 33" Watermain

4.5.1 The boreholes nearest to the existing 33" watermain are currently showing methane and carbon dioxide levels that are higher than the other boreholes located offsite. This is suspected to be as a result of the fill placed over or adjacent to the watermain or a preferential flow path for landfill gases existing as a result of the bedding and surround to the watermain. It is considered that further investigation in the vicinity of the watermain is required in order to inform the detailed design of gas protection measures. This will be completed by digging down to the backfill material and testing this material. Any works completed in the vicinity of the existing 33" watermain will require permission from Irish Water. These works should be completed in support of the final detailed design and should be completed prior to the commencement of the proposed development and a determination made if the protection measures detailed in Section 7.7 are required.

4.6 Surface Emission Rates

4.6.1 The developed conceptual model indicates the primary gas migration for methane as vertical loss through the existing landfill cap and or adjacent materials. It is recommended that an assessment of surface emissions is undertaken targeting the landfills, adjacent areas and the watermain to inform detailed design. This is required in order to fully determine the quantity of gas currently venting through the existing cap and the corresponding impact of the loss of this venting activity once the low permeability capping layer is in place. This has been taken into consideration as part of the development of this "worst-case" gas management strategy, but this further assessment is recommended in order to provide more comprehensive information for the detailed design of the gas protection measures. This assessment will be undertaken as part of the future proposed monitoring and the gas management strategy report updated as necessary.

4.7 Gas Monitoring Data

4.7.1 RPS has conducted ground gas monitoring of the landfill site as required by the CoA over a period of one year (Mar 2016 – Feb 2017) to allow a comprehensive assessment of the gas management requirements. Additionally, a ground gas monitoring was undertaken during the static pumping trials in 2020 with spot monitoring undertaken from the first quarter of 2020 to the second quarter of 2021..This monitoring is considered to provide a comprehensive dataset which covers a change in weather conditions and varying atmospheric pressure have been undertaken which are considered to be compliant with CIRIA C665, albeit representing the current gas regime.

4.8 Development Phase Gas Monitoring

4.8.1 The proposed development works, installation of a gas abstraction system and the proposed remedial works are all likely to alter the gas regime at the site over a period of time. It is recommended that a programme of ongoing monitoring is undertaken across the site and development areas to allow refinement of the proposed in-property protection measures. It is recommended that further boreholes are installed within the development zones and that ongoing monitoring is undertaken during the remediation and redevelopment works.

4.9 Proposed Building Foundations

4.9.1 The foundation details for the development will be confirmed at detailed design stage. An assessment will be completed to assess if the detailed design of the foundations have the potential to introduce preferential vertical migration pathways.

4.9.2 If this pathway exists, appropriate in-ground and in-building remedial measures will be implemented to protect the developments. For example, deeper foundations could create a pathway for the gas to travel into the development.

4.10 Pumping Trials

4.10.1 The pumping trials undertaken by AFS indicate that a gas abstraction system and a flare will be required for the landfills at the site. Further trails should be undertaken where considered necessary to develop the detailed design for the required systems. Where further pumping trials are required, extended monitoring of the perimeter boreholes would be prudent.

5 ACTIVE GAS CONTROL REQUIREMENTS

5.1 Pumping Trial Results

5.1.1 The full results of the June and July 2020 pumping trials are presented in Appendix C of the Addendum to ERA report (2021) (EIAR Volume 4 – Part 4) (updated in March 2022).

5.1.2 Additionally, the AFS Report (July 2020) recommends installation of a gas flare system comprising:

- Installation of gas wells to depths just above the water table connected into a common gas main that leads to a small 100m^3/hr Lo-Cal flare for sites 2 and 3A.
- Vent pipes and rotating cowls to produce a negative suction in the waste mass, with vent trenches around the perimeter of the site for sites 1, 3B and 3C

5.1.3 Such a gas collection and flare system are now provided for in the current proposed Phase 1 development. It will provide a flare for Sites 2, 3A and 3C (while not deemed necessary following the gas pumped trial, because the collection system will pass by Site 3C and as the 100m^3/hr Lo-Cal flare will have capacity, Site 3C will be connected to the flare).

6 REMEDIAL OPTION APPRAISAL

6.1 Landfill Gas Control

6.1.1 As identified in the ERA there are unacceptable risks associated with the levels of gas found on the sites and the potential migration of these gases towards the proposed residential development.

6.1.2 Landfill gas may migrate by diffusion, convection or by water transport. These modes of transport of gases are independent of each other but may occur simultaneously so that migration control measures may mitigate one without removing the risk presented by the others.

6.1.3 The main remedial options for managing landfill gas at landfill facilities are classified as one of the following categories:

- Source Removal - Excavation and Disposal;
- Barriers;
- Dilution and Dispersion; and
- Gas monitoring and Alarms.

6.1.4 A combination of landfill gas control measures can be implemented to address an identified gas risk. The available techniques are illustrated in **Figure 6.1** adapted from the CIRIA Report 149.

Figure 6-1: Principal Ground Gas Protection Measures

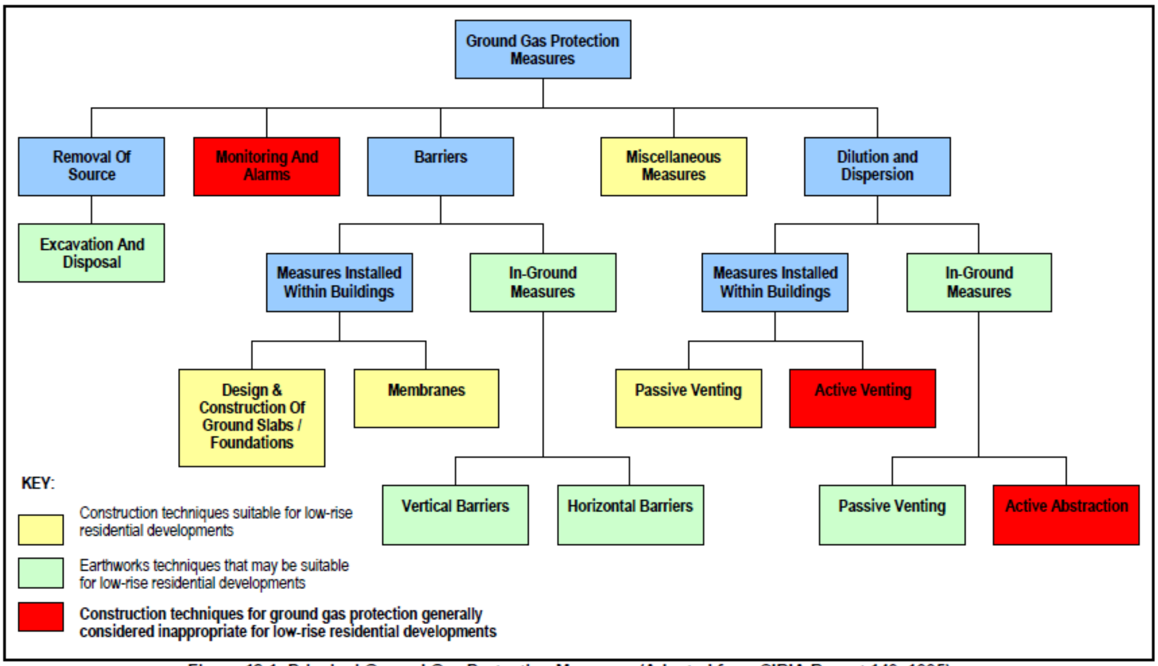


Figure 12.1: Principal Ground Gas Protection Measures (Adapted from CIRIA Report 149, 1995)

6.2 Remedial options appraisal Objectives

6.2.1 This section sets out the remedial options appraisal that has been undertaken in accordance with CLR11: Model procedures for the management of land contamination, produced by the Environment Agency, UK. The appraisal identifies the feasible remedial options and presents a detailed evaluation to identify the most appropriate option(s).

6.2.2 Remediation is required to protect the proposed development from gas generated within the five number landfills. The site is to be redeveloped for a mixed commercial and residential end use.

The potential hazards include explosion / flammability, asphyxiation, chronic exposure, odour, and vegetation die-back.

6.2.3 The specific objectives are set out below:

- To remediate identified contamination such that no unacceptable risk is presented to the future end users onsite;
- To remediate the identified contamination such that no unacceptable risk is presented to adjacent site users (current or future); and
- Ensure offsite receptors are not subject to nuisance dust, noise or odour and are not exposed to contaminated dust and/or vapours etc.

6.2.4 **Table 6.1** details the factors and associated criteria that will be used to evaluate the remedial options with respect to the site-specific conditions, constraints and the level and nature of the contamination.

Table 6-1 - Remedial Option Selection Criteria

Factor	Criteria
Effectiveness	Performance with respect to reducing the respective pollutants to levels that are acceptable or breaking pathways. Therefore, options that are not suitable for the particular physical and chemical characteristics of the Assessment Site are not considered any further.
Timescale	Remediation techniques that require a significant period of time to successfully meet the remedial objectives are not considered suitable for this Assessment Site given the proposed development timetable.
Cost	Only remedial options that fulfil the remedial objectives within an acceptable cost bracket have been considered any further.
Durability	All remedial options must be long lasting and minimise the potential for residual impacts to become apparent as the requirement for further remedial works post development of the Assessment Site is unacceptable.
Commercial Availability	There are many remediation technologies that have been used within the UK and Ireland, however only a limited number of these are commercially available in the UK and Ireland.
Track Record	Only remedial options with a proven track record in the UK and Ireland have been selected. Options with no or poor UK / Ireland rack records may impact on other factors in this table such as effectiveness, timescale and cost.
Environmental Impact	Some remedial options have not been selected because of the likely environmental impacts. Examples include energy and material requirements.
Compatibility	The remedial options are considered with respects to their compatibility with the proposed landfill capping works and the leachate collection trench.
Permissions	Some remedial options will require forms of waste management licences & potentially other forms of licensing such as discharge consents etc. The form of licence may influence the selection of the remediation technique because of the likely timescales required for applications and the cost of application.
Site Constraints	The Assessment Site conditions may limit the likely effectiveness of a given remedial technique due to issues such as access, available space, ground conditions, land ownership and ecological constraints such as the adjacent Special Area of Conservation (SAC).

6.3 Remedial Options Appraisal

6.3.1 **Table 6.2** summarises some of the remedial options that should be considered. The implementation of remedial options will be an iterative process supported by further monitoring. Where the implemented remediation prove successful, on-going monitoring requirements may be relaxed. Where the implemented remediation demonstrates that issues or risks remain, supplementary remedial options will be considered and implemented to reduce the risk to acceptable levels.

Table 6-2 - Remedial Options Appraisal

Source	Treatment Options	Brief Description	Suitability
Source: Gas presenting a risk to human health and structures	Source Removal - Excavation and disposal	If source of gas is relatively small, removal will render the site hazard free. The method involves excavation of the gassing material and its replacement with clean, inert fill.	Effectiveness: Removes contamination source. However, leachate plume beneath the waste will still be present. Timescales: Where limited volumes are present timescales will be short. Cost: Cost effective for small volumes but not large. Would require significant waste disposal costs at a licenced facility. However, cost will increase where large volumes are addressed, as is the case here due to the fact the waste is quite deep on the sites. Placement of backfill will also increase the cost. Durability: Permanent. Commercial Availability: Widely available. Track record: Proven track record. Environmental Impact: Requires haulage and will require imported fill materials to backfill voids created. Short term dust and odour nuisance may be created during works. May lead to short term mobilisation of contamination impacting controlled waters or mobilisation of asbestos fibres. Compatibility: No compatibility issues. Permissions: Any activity undertaken with regard to waste may be subject to Local Authority or EPA permitting or licensing. Site Constraints: Private land ownership adjacent to the site could have an impact.
	Gas Monitoring and alarms	Monitoring is important to ensure remedial measures are working correctly. Gas monitoring boreholes can be installed around the sensitive receptors and gas source. These can be checked periodically or systems can be installed that continuously monitor gas levels. Alarms can be linked that produce an audible sound or send a remote signal if pre-set gas concentrations are exceeded.	Effectiveness: The use of alarms in isolation from other remedial techniques is not considered to be effective. This is as a result of the acute nature of the risks associated with ground gas. They are considered as a potentially useful tool to compliment other remedial techniques. The use of alarms is unlikely to be acceptable to the future purchasers of the residential properties. Timescales: The timeframe for alarms and detectors install is quick. Monitoring is either periodic or continuous but may be reduced after a period of time if it is shown that the gas risk is low. Cost: Cost effective Durability: Durable but may be subject to some degradation over long periods. Commercial Availability: Widely available. Track record: Proven track record. Environmental Impact: Low impact Compatibility: No compatibility issues. Permissions: None. Site Constraints: There may be site constraints when development is built regarding alarm locations in close proximity to development.
	Barriers - In-ground Cement bentonite slurry trench cut-off wall	Slurry trench cut-off walls are used predominantly for the containment of landfill sites to control both leachate and landfill gas migration. Cement slurries are usually self-hardening slurries simply left in the trench to set at the end of excavation.	Effectiveness: Can be effective in creating an impermeable barrier in most soil types. However, if the soil is a coarse material such as gravel a low-permeability barrier will not form. The soil type under the waste for some sites is gravel so this method may not be suitable in this case. Without full encapsulation and gas collection impermeable barriers can lead to the redirection of gases to other parts of a site creating risk elsewhere. Timescales: Relatively quick to install. Cost: High. Given the depths of waste in the landfills at Fassaroe and the depth to bedrock or the clay layer, the costs of providing a sufficiently deep slurry trench would be very high Durability: May be vulnerable to attack in aggressive groundwater's including industrial wastes which can impair the swelling properties of bentonite; the use of specially formulated bentonite (saline seal) can be used which after hydration and swelling will not deteriorate as rapidly when exposed to high levels of ionic contaminants Commercial Availability: Widely available and well understood technology. Track record: Proven track record. Environmental Impact: Excavation and disposal of contaminated soils. Disposal of bentonite slurry also required. Would also have an impact on the groundwater regime adjacent to the SAC. Compatibility: May have soil compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: The likely location for installation of an effective slurry trench would be on very steep ground for some landfill sites leading to constructability issues.
	Barriers - In-ground Clay filled trench	Clay is an effective low permeability barrier to gas movement. Clay is utilised as a barrier against lateral migration of soil gases.	Effectiveness: Maximum economically achievable depth is circa 5 m so would not be effective or suitable for the landfill sites but could be suitable for the existing watermain or proposed access road. Without full encapsulation and gas collection impermeable barriers, this option can lead to the redirection of gases to other parts of a site creating risk elsewhere. Timescales: Relatively quick to install. Cost: The cost of advancement of a deep trench is significant. Given the depths of waste in the landfills at Fassaroe and the depth to bedrock or the clay layer, the costs of providing a sufficiently deep clay trench would be very high. Durability: Drying out of clay can create fissures. Commercial Availability: Widely available and well understood technology. Track record: Proven track record. Environmental Impact: Excavation and disposal of contaminated soils. Would also have an impact on the groundwater regime adjacent to the SAC. Compatibility: No compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: Private land ownership adjacent to site could have an impact.

Source	Treatment Options	Brief Description	Suitability
	Barriers - In-ground Membrane in trench	Synthetic membranes that would be used comprise PVC, uPVC, LDPE, HDPE and composite liners reinforced to minimise elongation with aluminium layers to reduce permeability	Effectiveness: Depth limit to about 5m so would not be effective or suitable for the landfill sites but could be suitable for the existing watermain or proposed access road. Without full encapsulation and gas collection impermeable barriers can lead to the redirection of gases to other parts of a site creating risk elsewhere. Timescales: Relatively quick to install. Cost: Relatively cost effective where arisings can be reused. The cost of advancement of a deep trench is significant. Given the depths of waste in the landfills and the depth to bedrock or the clay layer, the costs of providing a sufficiently deep slurry trench would be very high Durability: Durable but membrane can become damaged during backfilling if it is not adequately protected and specified. Commercial Availability: Widely available and well understood technology. Track record: Proven track record. Environmental Impact: Excavation and disposal of contaminated soils. Would also have an impact on the groundwater regime adjacent to the SAC. Compatibility: No compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: Private land ownership adjacent to site could have an impact.
	Barriers - In-ground Driven Sheet Pilling	Driven sheet piles can be used to form continuous walls within soil to form an in ground barrier. Drive in sheet piles with clutches sealed to prevent gas migration.	Effectiveness: The integrity of sheet pile walls in terms of their permeability is difficult to validate with potential for gapping and deflection, particularly at depth and in coarse ground conditions. Without full encapsulation and gas collection impermeable barriers can lead to the redirection of gases to other parts of a site creating risk elsewhere. Timescales: Relatively quick. Cost: Other protective measures would have to be considered as part of an overall system to prevent gas migration which could prove relatively expensive. Given the depth of penetration steel sheet piles would be required making the material costs very high. Given the depths of waste in the landfills at Fassaroe and the depth to bedrock or the clay layer, the costs of providing a sufficiently deep slurry trench would be very high Durability: Durable but may be subject to some degradation over long periods. Commercial Availability: Widely available. Track record: Variable depending on site conditions and depth of installation. Environmental Impact: Noise and vibration issues and use of raw materials. Would also have an impact on the groundwater regime adjacent to the SAC. Compatibility: No compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: Private land ownership adjacent to site could have an impact.
	Barriers - In-ground Venting Trench	A venting trench is a vertical barrier. The venting trench should extend below the maximum depth that significant gas migration is considered likely to occur. The trench is then backfilled with a granular material of high permeability to gas relative to the surrounding ground.	Effectiveness: Maximum economically achievable depth is circa 5m so would not be effective or suitable for the landfill sites but could be suitable for the existing watermain. Timescales: Relatively quick to install. Cost: The cost of advancement of a deep trench is significant. Given the depths of waste in the landfills at Fassaroe and the depth to bedrock or the clay layer, the costs of providing a sufficiently deep venting trench would be very high Durability: Durable but may be subject to some degradation over long periods and venting medium becoming clogged. Commercial Availability: Widely available. Track record: Proven track record in shallow applications. Environmental Impact: May pose a risk of impact to the qualifying features of the SAC. Compatibility: No compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: Private land ownership adjacent to site could have an impact.
	Barriers - Building: Floor slab	Floor slabs are passive horizontal barriers. There are many different types including reinforced concrete, block and beam slabs, and ground bearing slabs. The barrier provides a greater resistance to gas migration than the surrounding ground so that gases are encouraged to migrate in another direction away from the building.	Effectiveness: For a development, additional protection should be considered with floor slabs such as active venting and monitoring and alarms as floor slabs are not effective on their own. It is considered that building based measures where adopted will need to be supported by non-building methods (in ground barriers or source removal) to provide the required level of confidence. Timescales: Relatively quick to install. Cost: Relatively cost effective. Durability: Permanent. Commercial Availability: Widely available. Track record: Proven track record. Environmental Impact: Low environmental impact if any. Compatibility: No compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: None.
	Dilution and Dispersion - In ground:	Passive in-ground venting is the controlled release and dispersal of gas from the ground to atmosphere via a preferential path and special surface outlets.	Effectiveness: effective but high densities of venting boreholes may be required in situations where high flow rates and gas concentrations are present. Timescales: Relatively quick installation, especially when comparing to vent trenches and impermeable barriers. Cost: The associated cost is moderate.

Source	Treatment Options	Brief Description	Suitability
	Passive Venting: Virtual Curtain	Passive in-ground venting is based on the principle that gas is allowed to migrate and disperse to the atmosphere from the ground by the processes of diffusion and advection.	Durability: Effective for a long period of time. Open vents at ground surface can become 'clogged' or blocked with intrusion of surrounding soil or micro-organisms or groundwater. Commercial Availability: Widely available. Track record: Proven track record. Environmental Impact: Minimal excavation and disposal of contaminated soils. Noise and vibration issues and use of raw materials. Compatibility: No compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: Vents may disperse gas near planned development apartments or housing and this could cause health and safety issues.
	Dilution and Dispersion - Buildings: Passive Venting	Passive venting to buildings or structures can be defined as the movement of air through openings in the building or structure fabric by the action of natural climatic conditions. A Void is formed between the building and the underlying ground. It is connected by vents to an external envelope of the building.	Effectiveness: Effective when in conjunction with floor slabs or membranes. It is considered that building based measures where adopted will need to be supported by non-building methods (in ground barriers or source removal) to provide the required level of confidence. Timescales: Relatively quick to install if done as part of building construction Cost: Relatively low cost Durability: Effective for a long period of time. Commercial Availability: Widely available. Track record: Proven track record. Environmental Impact: Low environmental impact if any. Compatibility: No compatibility issues. Permissions: Constitutes development that would require planning permission. Site Constraints: Vents may disperse gas near planned development apartments or housing and this could cause health and safety issues
	Dilution and Dispersion – In ground: Vertical Active Abstraction System	Mechanical pumping of gas from a collection system comprising perforated pipework laid in the ground. The collected gas is either vented and released to atmosphere at a specific location via a vent stack or flared off if the abstracted gas is potentially combustible. The collected gas could also be utilised for power generation.	Effectiveness: Very effective in rapidly reducing gas levels once the system is operating. Can be effective to control high gas concentrations and emission rates. It will not provide the same effectiveness for managing short term high levels of horizontal migration. Sufficient generation over a prolonged period is required to allow flare to operate effectively. The lack of available data regarding the waste deposits is likely to make design difficult. Timescales: Can take a long time to design. Relatively quick to install once a pumping trial and detailed design has been completed. Cost: Can be quite costly to construct. Further costs post construction as this system would require regular maintenance to minimise downtime. However if collected gas is utilised for power generation then this can offset install costs. Durability: Durability will be dependent on maintenance and repair. Commercial Availability: Widely available. Track record: Proven track record. Environmental Impact: Collected gas can be flared, thus no noxious or hazardous gases released to atmosphere. Compatibility: No compatibility issues. Permissions: A permit is likely to be required. Constitutes development that would require planning permission. Site Constraints: Location of flare stacks should this be required could be a site constraint.

6.4 Selected Remediation Techniques

6.4.1 A number of the options outlined in Table 6.2 have already been ruled out with reference to the Certificates of Authorisation issued by the EPA in 2019.

6.4.2 Taking account of the above assessment the remedial options and the previous agreements under the CaO the options outlined within **Table 6.3** are considered the most appropriate for the management of landfill gas at Fassaroe based on the information available at this time. These are consistent with the EPA approved through the CoA process.

Table 6-3 - Selected Remedial Options

Technique	Notes
Passive venting - Virtual Gas Curtain	Considered suitable where development is being undertaken outside the waste mass areas.
Barrier - In Ground – Venting Trench & Membrane in Trench	Considered suitable where waste deposits are thin (less than 5m). This would be a gas mitigation measure for the existing 33” watermain and potentially where the proposed road intersects and is adjacent to the landfill sites only. Further monitoring required to assess if it is actually required.
Excavation and disposal	Considered suitable for targeted areas where shallow waste deposits are present in close proximity to sensitive structures.
Building protection measures - Floor slabs and passive venting in the form of void spaces under sub floors	Considered to be required in buildings and should be in detail incorporated into the detailed design. At this stage such measures are only considered appropriate in conjunction with other remediation techniques and should take account of these.

6.4.3 These measures are in addition to the gas abstraction and flare system recommended by AFS.

7 PRELIMINARY DESIGN

7.1.1 This section sets out the selected remedial options, preliminary works, general details of the approach to delivery and details of the specific application of the selected remediation techniques to each area of the site

7.2 Remedial options

7.2.1 The most suitable remedial options for controlling the gas on the Fassaroe sites are:

- Passive venting - Virtual Gas Curtain.
- In-Ground Barriers.
- Excavation and disposal.
- Building protection measures - Floor slabs / membranes and passive venting.
- Flare.

7.2.2 The application of these protection measures to the landfill sites is considered in the following sections. The Virtual Gas Curtain and flare are specifically identified as requirements in the CoA.

7.3 Preliminary Works

7.3.1 Prior to undertaking any remediation on the landfill sites steps should be made to address the steps proposed in **Section 4**.

7.3.2 Additionally, it is considered that further investigations of the existing 33” watermain is essential to defining an appropriate scope of gas protection measures adjacent to the pipe should it be determined that there is a preferential pathway close to and adjacent to the watermain route.

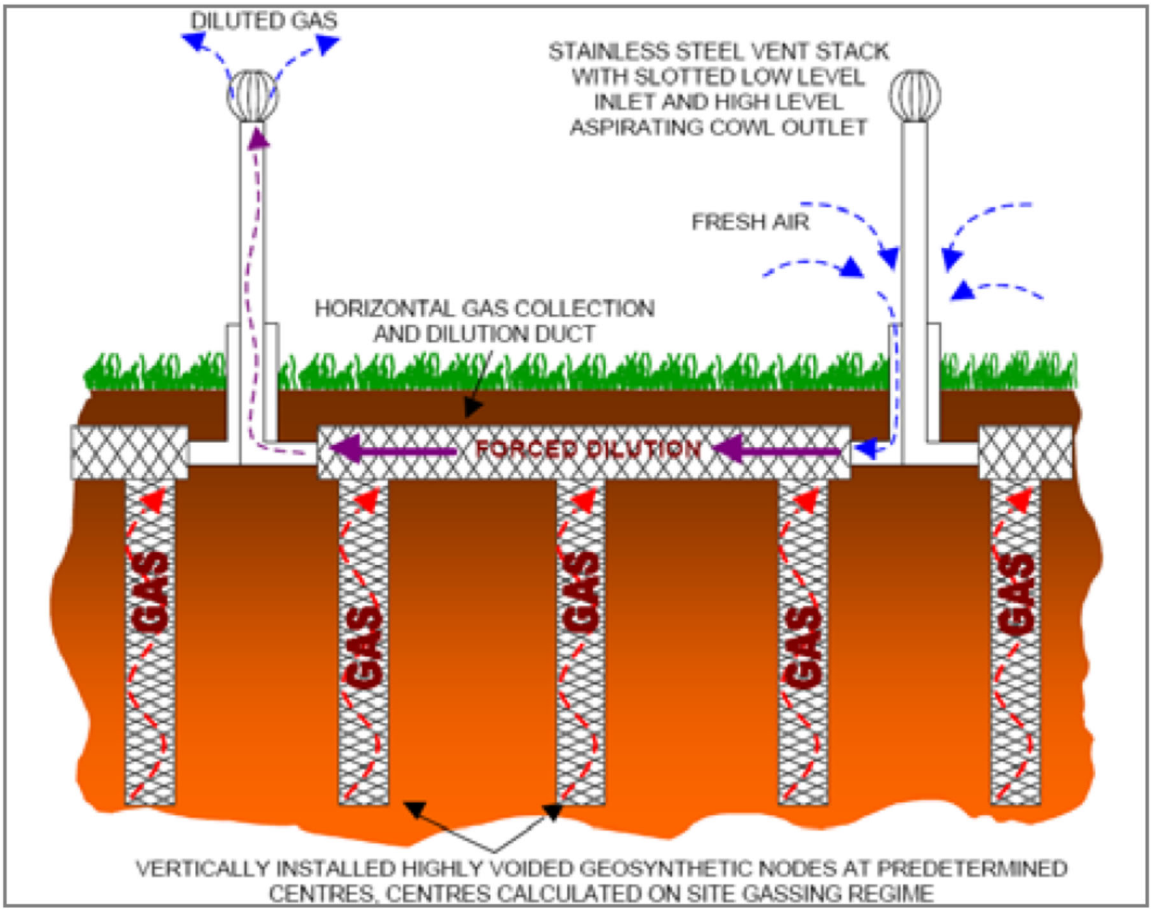
7.3.3 At this time, the most viable options from the remedial options appraisal and those consented to by the EPA are being considered. All of the options outlined are subject to detailed design.

7.4 Passive Venting: Virtual Gas Curtain

7.4.1 A Virtual Gas Curtain (VGC) is an effective means of controlling gas migration, due to its durability and ease of installation. The VGC reduces the risk posed by the presence of landfill gas to adjacent buildings by intercepting the preferential lateral pathway for gas migration out of the landfill site and thus breaking the source:pathway:receptor linkage.

7.4.2 The VGC forms a low pressure or low gas concentration area relative to the surrounding gassing ground to encourage gas to flow towards the VGC barrier, and allow subsequent venting to atmosphere.

Figure 7-1 – Virtual Gas Curtain Cross Section



Installation

Method

7.4.3 Geo-composite nodes are inserted at 1m intervals along the curtain length with 3m high vent stacks located at every 20 – 25 m intervals. A collection duct is constructed over the nodes which dilutes any gas and vents it to the atmosphere via vent bollards.

7.4.4 The barrier would be advanced to a depth of circa 10 mbgl surrounding the landfill sites to intercept any migrating gases. A header pipe connects all the vent nodes together.

7.4.5 The nodes are vibrated into the ground using a mandrel attached to an excavator. The installation thus reduces the volume of spoil that requires disposal from site. If obstructions and hard ground conditions are encountered then pre-digging to remove them can be used at shallow depth, or the nodes can be repositioned.

7.4.6 The vent nodes and collection duct are constructed using robust geosynthetic units that are able to be driven over by construction plant with only minimal protective soil cover.

Vibration

7.4.7 The installation technique uses a high frequency excavator mounted vibrator to vibrate the mandrel into the ground. This has been used on numerous sites close to existing structures (within 5m) without causing structural damage.

7.4.8 The effects of the vibrations on others will be minimised because the vibrations will not be continuous and there will be a break between each node installation.

7.5 In-ground Barriers

7.5.1 An impermeable in-ground barrier is an effective remedial option in areas where waste deposits are less than 5m. It is widely available and easily installed. It is designed to stop the gas from migrating to sensitive areas.

Shallow Venting Trench

Method

7.5.2 A trench is constructed using conventional excavating plant sufficiently deep to intercept the lowest possible layer through which gas may migrate and is keyed into an underlying low-permeability stratum. The trench is then backfilled with a granular material of high permeability relative to the surrounding ground, e.g. natural aggregate, crushed concrete or broken brick.

7.5.3 Granular material ranging in size from 20 to 150 mm has been used, but the actual sizing should be selected in relation to the particle size distribution of the surrounding soil in order to minimise ingress of fines (i.e. clay, silt and sand) which can clog the backfill and impair gas migration.

Membrane in Trench

7.5.4 Low permeability membranes can be used in conjunction with the shallow venting trench as an additional protection layer in order to control gas migration and to reduce high concentrations of methane and carbon dioxide to safe and acceptable levels.

7.5.5 The in-ground barrier can also be used as a protection measure on its own, separate to the venting trench.

7.5.6 The membrane would be placed at a depth beneath the gassing source to prevent lateral migration of the gas. A synthetic barrier with material such as HDPE or LDPE could be used, alternatively a natural material such as clay.

7.5.7 For depths to approximately 5m, a trench can be excavated using conventional plant and proprietary trench support systems. The liner is placed in the trench as a continuous roll and the trench backfilled.

7.6 Excavation and Disposal

7.6.1 Localised excavation will be necessary to accommodate some roadworks and some of the remediation works.

7.6.2 Excavation can also be used for source removal as this is an effective method to completely remove the waste in the landfill areas. It eliminates the gas source and the potential for long-term or continuing gas migration affecting the development. However, the excavated waste must be disposed of to a licensed waste management facility. At current landfill disposal rates, this option is not considered feasible except in isolated areas where developed within the waste body is required.

7.6.3 Excavation involves removal of the landfilled waste material and its replacement with clean, inert fill.

Method

7.6.4 Excavation of waste should be completed in a controlled and appropriate manner.

7.6.5 Contaminated soil is excavated using standard construction equipment, like backhoes and excavator trackhoes. Excavation is accomplished by digging up the contaminated soils and loading them onto trucks for hauling. Where suitable the material will be utilised on site in an appropriate manner to assist in the reprofiling of the waste body, and excess material will be transported offsite to a disposal site licensed to accept non-inert waste.

7.6.6 Proper safety precautions are employed during excavation, including, but not limited to, the use of covered dump trucks, construction equipment with closed cabs, dust reduction procedures and air quality monitoring.

7.6.7 On no account should excavation equipment be operated in proximity to live power lines. The Health and Safety Authority and/or the Electricity Supply Board should be contacted for advice in respect of landfill sites in close proximity to overhead cables.

7.6.8 Efforts should be made to minimize stockpiles. Where stockpiling is necessary the material should be placed in a bunded hardstand or polyethylene sheeted area and covered with polyethylene sheeting to prevent the migration of contaminants or additional environmental pollution.

7.6.9 Soil testing must be conducted in the walls and bottom of the excavated area to ensure that all of the contaminated soil has been removed. Excavation is complete when test results show that the remaining soil around the hole meets established clean-up levels. After excavation, the replacement fill should be clean, inert material, i.e. free of major constituents which might themselves be a potential source of gas.

7.7 Building Protection Measures

7.7.1 Buildings should be designed with protection measures installed. The ERA has determined the site classification with respects to CIRIA C665 and the NHBC Traffic Light System and the resulting required protection measures. These are set out in the Remainder of this Section.

CIRIA C665

7.7.2 In accordance with CIRIA C665 the landfill sites can be classified as set out in Table 7.1.

Table 7-1 - Gas Screening Value Calculation (Wilson and Card Methodology)

Location	Max of Flow (Peak)	Max of CH4 (%)	Max of CO2 (%)	Gas Screening Value	Class
Site 1					
Onsite	0.7	37.1	22.2	0.26	CS2
Offsite	9	23.9	8.1	2.15	CS3
Site 2					
Onsite	7.6	76.5	36.6	5.81	CS4
Offsite	19.8	55.7	25.5	11.03	CS4
Site 3A					
Onsite	45	72.8	37	32.76	CS5
Offsite	1.6	0	3.2	0.05	CS1
Site 3B					
Onsite	6.2	73.1	39.4	4.53	CS4
Offsite	2.2	2.1	4.4	0.096	CS2
Site 3C					
Onsite	11.7	83.5	37.2	9.77	CS3
Offsite	3.1	22.2	19.6	0.69	CS2

7.7.3 The guidance set out within Table 8.6 of CIRIA C665 (presenting a typical scope of gas protection measures for each characteristic situation) has now been superseded and replaced by BS 8485:2019 – Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings (BSI, 2019). BS8485 defines the minimum gas protection score of each characteristic situation within Table 7.2 below.

Table 7-2 - Gas Protection Score by CS and Type of Building (from BS8485)

CS	Minimum gas protection score (points)			
	High risk		Medium risk	Low risk
	Type A building	Type B building	Type C building	Type D building
1	0	0	0	0
2	3.5	3.5	2.5	1.5
3	4.5	4	3	2.5
4	6.5 A)	5.5 A)	4.5	3.5
5	— B)	A1 6 A1 A)	5.5	4.5
6	— B)	— B)	A1 — B) A1	A1 6 A1

A) Residential buildings should not be built on CS4 or higher sites unless the type of construction or site circumstances allow additional levels of protection to be incorporated, e.g. high-performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system, e.g. in institutional and/or fully serviced contractual situations.

B) The gas hazard is too high for this empirical method to be used to define the gas protection measures.

7.7.4 The proposed development comprises building type A (private ownership with no building management controls), building type B (private or commercial property with central building management control), and building type C (commercial building with central building management control). Based on this, gas protection scores ranging from 0 to 5.5 will be required.

7.7.5 Measures can include Structural Barriers, Ventilation Measures, Membranes and IN-ground Pathway Intervention. BS8485 defines the number of gas protection points provided by each measure. Design measures can be selected based on the gas protection points required and the specific nature of the structures.

NHBC

7.7.6 In Accordance with the NHBC traffic Light System the sites can be classified as set out in Table 7.3.

Table 7-3 Traffic Light Classification

Site Number	Position	Traffic Light Classification
1	Onsite	Red
	Offsite	Red
2	Onsite	Red
	Offsite	Red
3A	Onsite	Red
	Offsite	Green
3B	Onsite	Red
	Offsite	Green
3C	Onsite	Red
	Offsite	Amber2

7.7.7 The required protection measures for the above classifications are set out with Table 7.4 below.

Table 7-4 - Proposed Building Protection Measures – Traffic Light System

Traffic light classification	Site Number	Protection measures required
Green	Site 3A offsite Site 3B offsite	Negligible gas regime identified and gas protection measures are not considered necessary
Amber 1		Low to intermediate gas regime identified, which requires low-level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into buildings. Gas protection measures should be as prescribed in BRE Report 414 (Johnson, 2001). Ventilation of the sub-floor void should facilitate a minimum of one complete volume change per 24 hours.
Amber 2	Site 1 onsite	Intermediate to high gas regime identified, which requires high-level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to prevent the ingress of gas into buildings. Gas protection measures should be as prescribed in BRE Report 414 (Johnson, 2001). Membranes should always be fitted by a specialist contractor. As with amber 1, ventilation of the sub-floor void should facilitate a minimum of one complete volume change per 24 hours. Certification that these passive protection measures have been installed correctly should be provided.
Red	Site 1 Offsite Site 2 onsite & offsite Site 3A onsite Site 3B onsite Site 3C onsite & offsite	High gas regime identified. It is considered that standard residential housing would not normally be acceptable without a further gas risk assessment and/ or possible remedial migration measures to reduce and/or remove the source of gas.

7.7.8 These recommended measures will require review post installation of the in-ground remedial options as these will change the regime of the gas. The detailed design should be based on the other protection measures and make consideration to the detailed design of building foundations and basements that will be constructed.

7.8 Site Specific Remedial Measures

Site 1

7.8.1 A combination of remedial options is proposed at Site 1.

7.8.2 The primary gas management remedial measure is the VGC. As shown in **Figure 6.2** it is proposed to install this around the east, west and south of the landfill boundary as these are the perimeters that are closest to the proposed development. The curtain can be extended around the northern perimeter if detail design deems this to be necessary.

7.8.3 Furthermore, it is proposed to excavate and reuse or dispose of a narrow strip of waste that intersects with the proposed access road. This is on the southern boundary of the landfill site. The boundary of the landfill will be set back as a result. The reason for this measure is to ensure there is no VGC vent stacks in the middle of the access road. Waste is not believed to be very deep in this area, circa 4m. The area estimated for excavation is approximately 120m^2. This measure could be designed out in detailed design if the VGC can be realigned.

Site 2

7.8.4 A combination of remedial options is proposed at Site 2.

7.8.5 The primary gas management remedial measure is the VGC. As shown in **Figure 6.2** it is proposed to install this around the east, west and south of the landfill boundary as these are the perimeters that are closest to the proposed development. The offset of the VGC from the landfill boundary is also greater in this area as a result of the residential park. The curtain can be extended around the northern perimeter if detail design deems this to be necessary.

7.8.6 Further, we propose to potentially excavate and reuse or dispose of a small section of waste that intersects with the planned access road. This is on the southern boundary of the landfill site. The boundary of the landfill will be set back as a result. The reason for this measure is to ensure there is no VGC vent stacks in the middle of the access road. This area will be approx. 380m^2. We believe the waste in this area to be approx. 6m deep based on the nearest borehole, LG01. This measure could be designed out in detailed design if the VGC can be realigned.

7.8.7 These measures are in addition to the gas abstraction and flare system recommended by AFS.

Site 3A

7.8.8 There is an area designated as an additional housing cell subject to future planning located at c. 50 m to the east of Site 3A. Also, the main access road runs to the west of this area. If development does occur in these areas, it is proposed that a VGC is installed along the eastern and southern boundaries of the landfill site. It is proposed to install a low permeability in-ground barrier to the west of Site 3A along the outside of the road corridor as the road may act as a shortcut to the offsite development as shown in **Figure 6.2.**

7.8.9 These measures are in addition to the gas abstraction and flare system recommended by AFS.

Site 3B

7.8.10 Excavation and redistribution or disposal of a portion of waste is required where the proposed road bisects the landfill as shown in **Figure 6.2** (presented within Appendix A). This is required for engineering and construction purposes. Waste in this area is between 4- 4.5m deep. The amount of waste to be excavated is 6,920 m^3.

7.8.11 The primary gas protection measure will be to install the VGC around the perimeter of the remaining landfill areas with the exception of the southern perimeter. Potentially the VGC can be extended around the southern perimeter in detail design if it is deemed required.

7.8.12 A low permeability in-ground barrier will be required under the base of the road where the road enters and leaves the old landfill site to prevent a preferential pathway for the remaining landfill gas.

7.8.13

Site 3C

7.8.14 The development proposals include an area designated as additional apartments subject to future planning which is located at about 20 m to the east of Site 3C, as well as an area designated as additional housing cells subject to future planning to the west. Berryfield Farm is also located south of the southern boundary of the site. If development does occur in these areas, it is proposed that a VGC is installed along the eastern, southern and western boundaries of the landfill site. Further information to inform detailed design of remedial measures can be provided following the future pending analysis of an additional borehole to the east of the site as detailed in Section 4.3.

7.8.15 These measures are in addition to the gas abstraction and flare system recommended by AFS.

Existing 33” Watermain

7.8.16 This watermain runs between Site 1 and Site 2. Further monitoring and testing is required in this area as recommended in **Section 4** of this report. It may be deemed necessary to install a shallow venting trench running parallel to either side of the watermain to prevent the lateral migration of gas south towards the proposed development. If this proposal is required post-testing, prior approval from Irish Water would be required due to their ownership of the watermain.

7.9 Monitoring and Sampling Plan

Introduction

7.9.1 Gas monitoring is an important aspect of the Gas Management Strategy in order to:

- demonstrate effectiveness of protection measures installed;
- provide confidence to owners/occupiers that risk is under control;
- give early warning of a hazardous situation;
- identify malfunction in a gas-control system to enable remedial action to be taken;
- keep the developer/ property management company informed and actively engaged in the long-term management of the gas protection measures; and
- Identify reduction in gas levels and period of acceptable risk when system can be switched off, i.e. protection no longer required.

7.9.2 The extent of gas monitoring required post development depends on the nature of the gas regime, the quality and reliability of the monitoring data obtained and the scope of protection measures adopted.

Monitoring Plan

7.9.3 A monitoring plan should be developed in accordance with the EPA Manual for Landfill Monitoring, 2nd edition 2003. It should be undertaken to address the requirements of the CoA, confirm the effectiveness of the gas flaring and protection measures and support detailed design / design refinement.

7.9.4 For this development, monitoring boreholes in the gas flow path can be installed and monitored to demonstrate the remedial measures, in particular, the Virtual Gas Curtain, are working and identify any changes in the gas regime as a result of the remedial works, flaring and development works. This can be achieved with real time ongoing monitoring in the first instance. Alarms can be installed also to give advanced warning when gas levels exceed certain pre-set criteria.

7.9.5 Once the level of certainty in the effectiveness of the remedial measures has increased to an acceptable level, monitoring frequency can be reduced to only periodically.

7.9.6 A Monitoring plan should be developed to include:

- Gas monitoring plan from specific monitoring points located in vent stacks.
- Regular servicing and maintenance of the gas-control system including prevention of weeds and soil accumulating in venting trenches and around external vents to properties.
- Preventing uncontrolled excavation, lighting of tires, construction of outbuildings and / or building extensions without consent.

Operations Manual

7.9.7 An operations’ manual or handbook should be produced by the designer / installer of each of the gas-control systems. The manual would record details of:

- The gas hazards present and the potential risks.
- The gas protection measures that have been installed.
- How the gas-protection measures operate.
- The level of gas monitoring required.
- Procedures that have to be followed to maintain and service the protection measures
- What measures are to be taken in the event of failure and / or trigger of an alarm (if fitted)
- How long the management scheme should operate.

REFERENCES

BRE Report 414. Protective measures for housing on gas-contaminated land. 2001.

BS 8485:2019 – Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.

CIRIA Report 149 - Protecting Development from Methane. January 1995.

CIRIA Report C665. Assessing risks posed by hazardous ground gases to buildings. 2007.

National House-Building Council (NHBC) & RSK Group Plc. Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present. Report Edition No. 04. March 2007.RPS, Environmental Risk Assessment, Fassaroe Historic Landfills, 2018 (Ref. DR1206Rp0007).

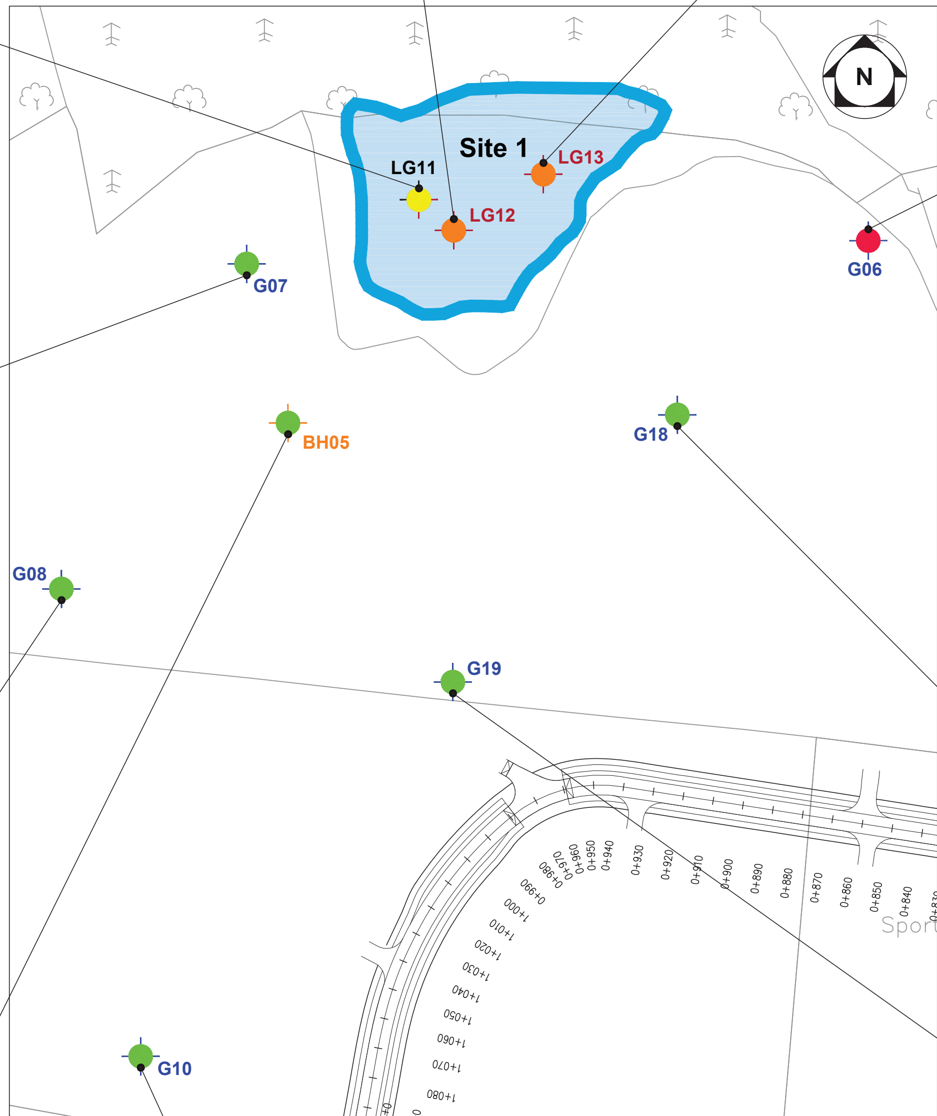
RPS, Gas Management Strategy, Fassaroe Historic Landfills, 2016 (Ref. MDR1206Rp0005).

RPS, Update to Environmental Risk Assessment, Fassaroe Historical Landfills, March 2022..

Appendices

Appendix A

Figures



LEGEND

Estimated Extent of Waste

MW1 Existing Boreholes

G01 Gas Monitoring Borehole

LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)

LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)

Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)

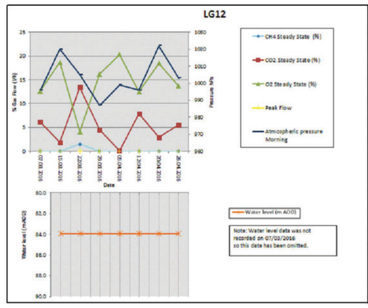
BH01 Combined Groundwater/Gas Monitoring Boreholes

Carbon Dioxide / Methane Site Classification 3B

Traffic Light Classification	Max. Concentration (% v/v)	
	Carbon Dioxide	Methane
Green	0-5	0-1
Amber 1	5-10	1-5
Amber 2	10-30	5-20
Red	30+	20+

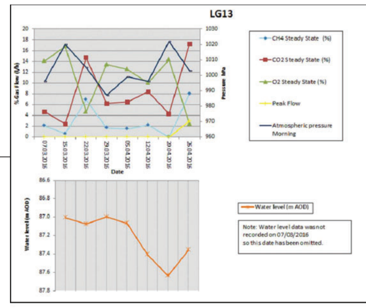
Classification shows the worst case scenario for concentration of methane and carbon dioxide onsite and offsite.

LG12



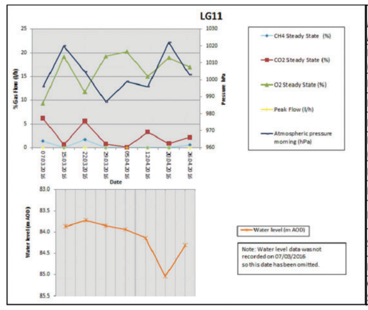
LG12 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	1.5	22/03/2016
Max Steady State CO2 (%)	13.4	22/03/2016
Max Stead State O2 (%)	20.3	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	0	
Slotted pipe interval (mbgl)	1-12	
Max Water Level (mbgl)	83.955	All
Geology Surrounding Slotted Section	Superficial - Waste	

LG13



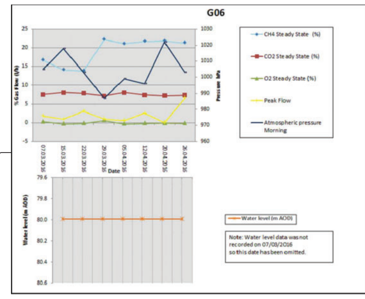
LG13 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	8	26/04/2016
Max Steady State CO2 (%)	17.2	26/04/2016
Max Stead State O2 (%)	16.8	15/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	3	26/04/2016
Slotted pipe interval (mbgl)	1-9	
Max Water Level (mbgl)	87.636	20/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

LG11



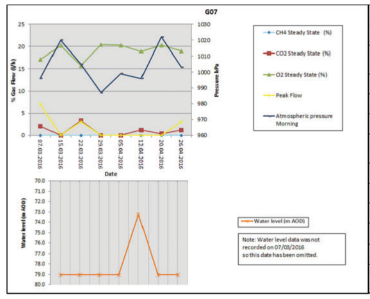
LG11 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	1.7	22/03/2016
Max Steady State CO2 (%)	6.2	07/03/2016
Max Stead State O2 (%)	20.3	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	10	07/03/2016
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	0	
Slotted pipe interval (mbgl)	1-13	
Max Water Level (mbgl)	85.038	20/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

G06



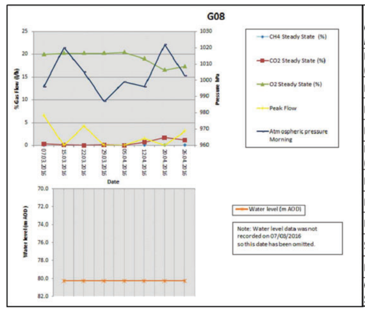
G06 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	22.2	29/03/2016
Max Steady State CO2 (%)	8.1	05/04/2016
Max Stead State O2 (%)	0.6	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.5	26/04/2016
Peak Flow (l/h)	6.6	26/04/2016
Slotted pipe interval (mbgl)	1-11	
Max Water Level (mbgl)	79.99	All
Geology Surrounding Slotted Section	Superficial - Sandy gravel	

G07



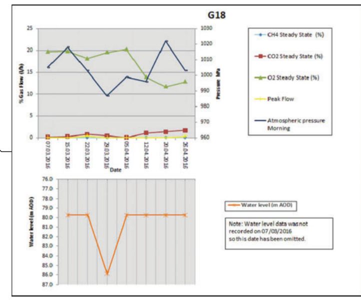
G07 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	3.3	22/03/2016
Max Stead State O2 (%)	20.4	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	6.9	07/03/2016
Peak Flow (l/h)	7.1	07/03/2016
Slotted pipe interval (mbgl)	1-14	
Max Water Level (mbgl)	79.033	Multiple
Geology Surrounding Slotted Section	Superficial - Gravel/ sandy gravel/ sand	

G08



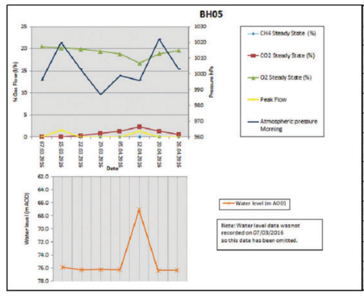
G08 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.7	20/04/2016
Max Stead State O2 (%)	20.4	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	6.3	07/03/2016
Peak Flow (l/h)	6.5	07/03/2016
Slotted pipe interval (mbgl)	1-14	
Max Water Level (mbgl)	80.286	All
Geology Surrounding Slotted Section	Superficial - Gravel	

G18



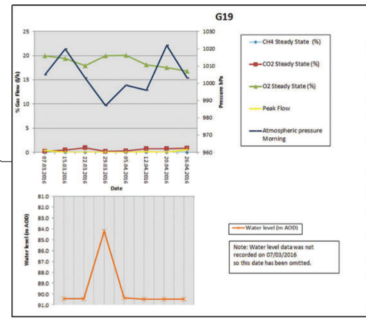
G18 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.7	26/04/2016
Max Stead State O2 (%)	20.2	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0.3	22/03/2016
Peak Flow (l/h)	0.4	22/03/2016
Slotted pipe interval (mbgl)	1-14	
Max Water Level (mbgl)	85.864	29/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clay/ gravel/ gravelly sand	

BH05



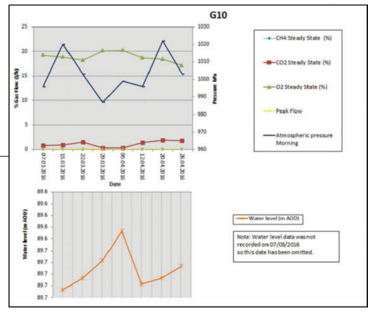
BH05 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.3	12/04/2016
Max Stead State O2 (%)	20.5	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1	12/04/2016
Peak Flow (l/h)	1.6	15/03/2016
Slotted pipe interval (mbgl)	19-29	
Max Water Level (m AOD)	76.371	20/04/2016
Geology Surrounding Slotted Section	Superficial - Sand	

G19



G19 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1	22/03/2016
Max Stead State O2 (%)	20.1	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	0.6	26/04/2016
Slotted pipe interval (mbgl)	1-14	
Max Water Level (mbgl)	90.493	20/04/2016
Geology Surrounding Slotted Section	Superficial - Sandy clay/ gravel/ gravelly sand	

G10



G10 Determinand	*Reading*	*Date of Reading*
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.9	20/04/2016
Max Stead State O2 (%)	20.2	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	0.1	22/03/2016
Slotted pipe interval (mbgl)	1-18	
Max Water Level (mbgl)	89.727	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sand/ clay/ gravel/ silty sand	

Client: Cosgrave

General Notes

(i) This drawing is the property of RPS Consulting Engineers, it is a confidential document and must not be copied, used, or its content divulged without prior written consent.

(ii) All Levels refer to Ordnance Survey Datum, Malin Head.

(iii) DO NOT SCALE, use figured dimensions only, if in doubt ask.

(iv) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.

No.	Date	Drn. Chk.	Amendment / Issue	App
F01	July'16	RH MS	FINAL ISSUE	MS

RPS
West Pier Business Campus
Dun Laoghaire
Co Dublin
T +353 1 4882900
F +353 1 2835676
W www.rpsgroup.com/ireland
E ireland@rpsgroup.com

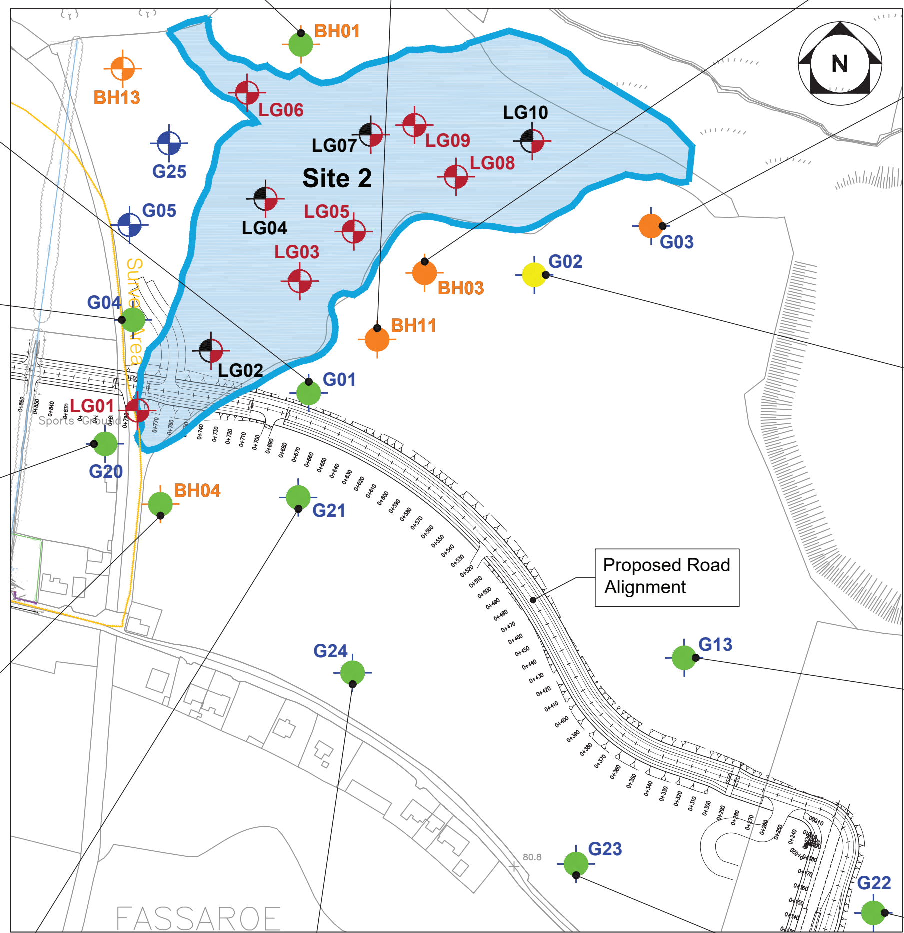
Drawn RH
Checked LD
Approved CC
Date July 2016
Scale 1:2,500 @ A1 NTS @ A3

Project: FASSAROE HISTORIC LANDFILL

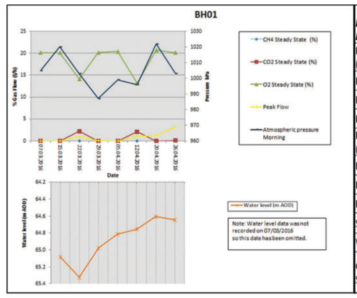
Title: GAS FLUX TIME SERIES GRAPHS & MAXIMUM VALUE TABLES - SITE 1

Job No. MDR1206 | File Ref. MDR1206FG0003.5D01.dwg | Drg. No. Figure 3.5 | Rev. D01

R:\MDR1206 - Fassaroe Historic Landfill\8.0 Drawings\FIGURES - GAS STRATEGY\MDR1206FG0003.5D01.dwg

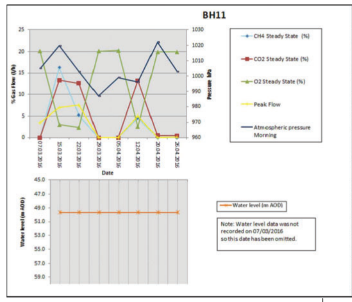


BH01



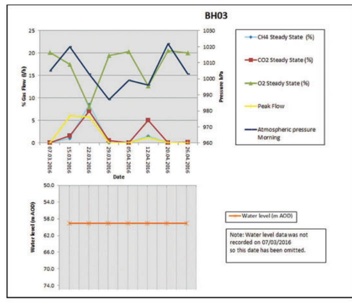
BH01 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.2	22/03/2016
Max Stead State O2 (%)	20.7	20/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1.8	26/04/2016
Peak Flow (l/h)	3.2	26/04/2016
Slotted pipe interval (mbgl)	5-21	
Water Level (m AOD)	65.324	22/03/2016
Geology Surrounding Slotted Section	Superficial - Clay with boulder content/ clayey sand/ clay	

BH11



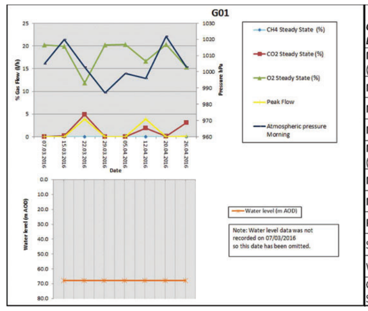
BH11 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	16.3	15/03/2016
Max Steady State CO2 (%)	13.3	15/03/2016
Max Stead State O2 (%)	20.3	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	6.7	22/03/2016
Peak Flow (l/h)	7.5	22/03/2016
Slotted pipe interval (mbgl)	1-33	
Water Level (m AOD)	49.653	All
Geology Surrounding Slotted Section	Superficial - Sandy clay/ gravel/ gravel/ sand	

BH03



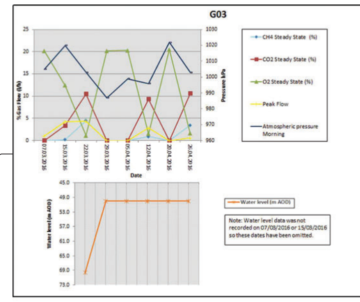
BH03 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	8.6	22/03/2016
Max Steady State CO2 (%)	7.1	22/03/2016
Max Stead State O2 (%)	20.5	20/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	5.8	15/03/2016
Peak Flow (l/h)	6	15/03/2016
Slotted pipe interval (mbgl)	2-19.5	
Water Level (m AOD)	59.151	All
Geology Surrounding Slotted Section	Superficial - Sand/ sandy gravel	

G01



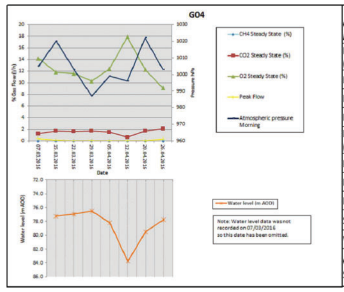
G01 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	4.9	22/03/2016
Max Stead State O2 (%)	20.3	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.8	22/03/2016
Peak Flow (l/h)	3.9	22/03 & 12/04/16
Slotted pipe interval (mbgl)	1-17.5	
Water Level (m AOD)	67.891	All
Geology Surrounding Slotted Section	Superficial - sandy gravel/ gravel	

G03



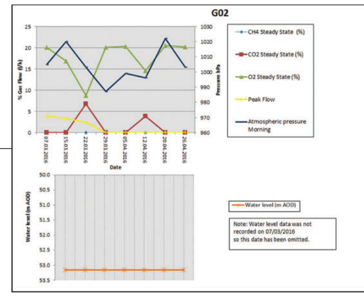
G03 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	4.5	22/03/2016
Max Steady State CO2 (%)	10.6	26/04/2016
Max Stead State O2 (%)	20.5	20/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	4.2	22/03/2016
Peak Flow (l/h)	4.3	22/03/2016
Slotted pipe interval (mbgl)	1-19.5	
Water Level (m AOD)	69.626	22/03/2016
Geology Surrounding Slotted Section	Superficial - Clay/ gravel/ sandy gravel/ gravel with boulder content/ sand	

G04



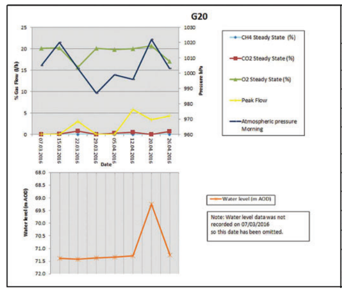
G04 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.1	26/04/2016
Max Stead State O2 (%)	17.9	12/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	0.4	07/03/2016
Slotted pipe interval (mbgl)	3-17	
Water Level (m AOD)	83.781	12/04/2016
Geology Surrounding Slotted Section	Superficial - Sandy gravel/ sandy clayey gravel/ gravel	

G02



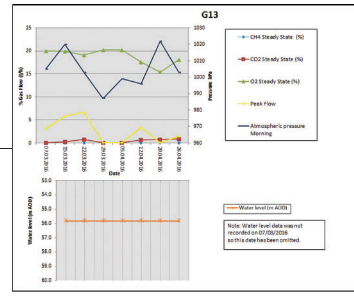
G02 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	6.8	22/03/2016
Max Stead State O2 (%)	20.5	20/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.2	15/03/2016
Peak Flow (l/h)	3.9	07/03/2016
Slotted pipe interval (mbgl)	1-19.5	
Water Level (m AOD)	53.162	All
Geology Surrounding Slotted Section	Superficial - Clay/ sand/ gravel/ sandy gravel	

G20



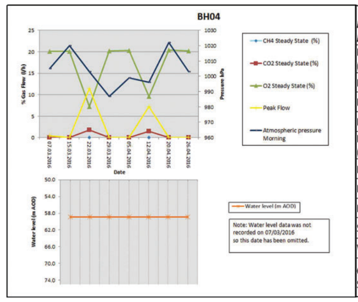
G20 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	0.8	22/03/2016
Max Stead State O2 (%)	20.7	20/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	5.5	12/04/2016
Peak Flow (l/h)	5.8	12/04/2016
Slotted pipe interval (mbgl)	1-20	
Water Level (m AOD)	71.416	22/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clayey gravel/ gravel/ sand	

G13



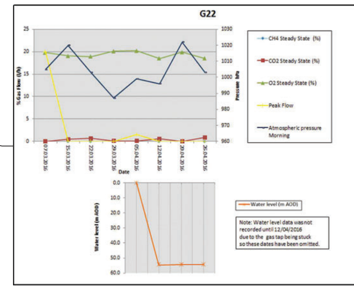
G13 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	0.8	26/04/2016
Max Stead State O2 (%)	20.2	29/03 & 05/04/16
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	6.4	22/03/2016
Peak Flow (l/h)	6.7	22/03/2016
Slotted pipe interval (mbgl)	1-20	
Water Level (m AOD)	55.822	All
Geology Surrounding Slotted Section	Superficial - Sandy clay/ sandy gravel/ sand	

BH04



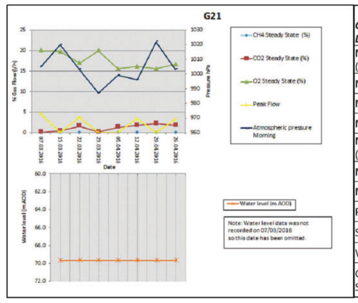
BH04 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.8	22/03/2016
Max Stead State O2 (%)	20.4	20/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	10.8	22/03/2016
Peak Flow (l/h)	11.4	22/03/2016
Slotted pipe interval (mbgl)	13.5-25.5	
Water Level (m AOD)	58.909	All
Geology Surrounding Slotted Section	Superficial - Clayey gravel/ sandy gravel/ sand	

G22



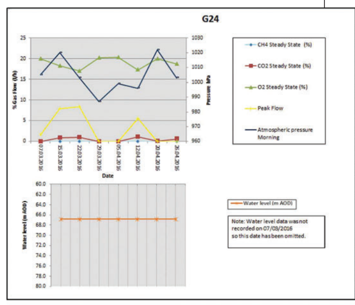
G22 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	0.9	26/04/2016
Max Stead State O2 (%)	20.2	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	19.8	07/03/2016
Peak Flow (l/h)	20	07/03/2016
Slotted pipe interval (mbgl)	1-15	
Water Level (m AOD)	54.58	12/04/2016
Geology Surrounding Slotted Section	Superficial - Sandy clay/ sandy gravel/ sand	

G21



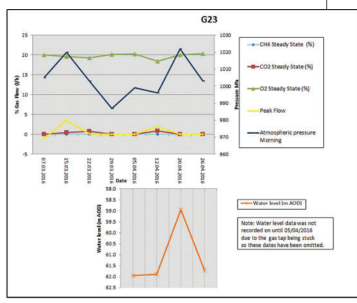
G21 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.2	20/04/2016
Max Stead State O2 (%)	20	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.4	22/03/2016
Peak Flow (l/h)	4.6	07/03/2016
Slotted pipe interval (mbgl)	1-17	
Water Level (m AOD)	69.662	All
Geology Surrounding Slotted Section	Superficial - Sandy clay/ sandy gravel/ sand	

G24



G24 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.1	12/04/2016
Max Stead State O2 (%)	20.3	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	8.4	22/03/2016
Peak Flow (l/h)	8.4	22/03/2016
Slotted pipe interval (mbgl)	1.5-20.5	
Water Level (m AOD)	66.831	All
Geology Surrounding Slotted Section	Superficial - Sandy gravel/ gravel/ sand	

G23



G23 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	0.9	12/04/2016
Max Stead State O2 (%)	20.4	26/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.4	15/03/2016
Peak Flow (l/h)	3.5	15/03/2016
Slotted pipe interval (mbgl)	1-20	
Water Level (m AOD)	61.943	05/04/2016
Geology Surrounding Slotted Section	Superficial - Sandy silty clay gravel/ sand	

LEGEND

- Estimated Extent of Waste
- MW1 Existing Boreholes
- G01 Gas Monitoring Borehole
- LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)
- LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)
- Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)
- BH01 Combined Groundwater/Gas Monitoring Boreholes

Carbon Dioxide / Methane Site Classification 3B

Traffic Light Classification	Max. Concentration (% v/v) Carbon Dioxide	Methane
Green	0-5	0-1
Amber 1	5-10	1-5
Amber 2	10-30	5-20
Red	30+	20+

Classification shows the worst case scenario for concentration of methane and carbon dioxide onsite and offsite.

Client: Cosgrave

General Notes

(i) This drawing is the property of RPS Consulting Engineers, it is a confidential document and must not be copied, used, or its content divulged without prior written consent.

(ii) All Levels refer to Ordnance Survey Datum, Malin Head.

(iii) DO NOT SCALE, use figured dimensions only, if in doubt ask.

(iv) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.

No.	Date	Drn	Chk	Amendment / Issue	App
F01	July'16	RH	MS	FINAL ISSUE	MS

RPS
West Pier
Business Campus
Dun Laoghaire
Co Dublin
T +353 1 4882900
F +353 1 2835676
W www.rpsgroup.com/ireland
E ireland@rpsgroup.com

Drawn	RH
Checked	LD
Approved	CC
Date	July 2016
Scale	1:2,500 @ A1, NTS @ A3
Job No.	MDR1206

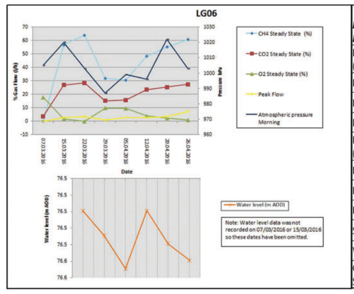
Project: FASSAROE HISTORIC LANDFILL

Title: GAS FLUX TIME SERIES GRAPHS & MAXIMUM VALUE TABLES - SITE 2

File Ref. MDR1206FG0003.6D01.dwg | Drg. No. Figure 3.6 | Rev. F01

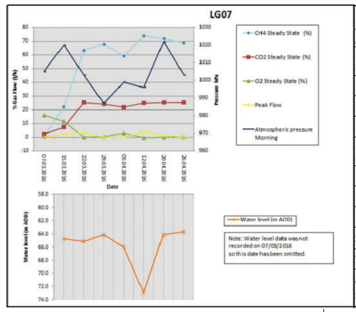
R:\MDR1206 - Fassaroe Historic Landfill\8.0 Drawings\FG\FIGURES - GAS STRATEGY\MDR1206FG0003.6D01.dwg

LG06



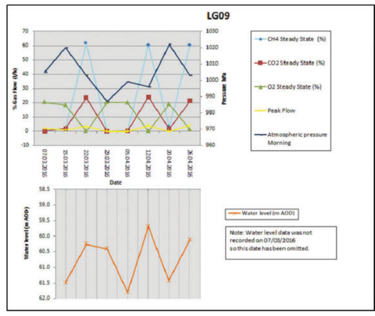
LG06 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	64	22/03/2016
Max Steady State CO_2 (%)	28.5	22/03/2016
Max Stead State O_2 (%)	17.8	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.3	20/04/2016
Peak Flow (l/h)	7.3	26/04/2016
Slotted pipe interval (mbgl)	1-6.4	
Water Level (m AOD)	76.569	05/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

LG07



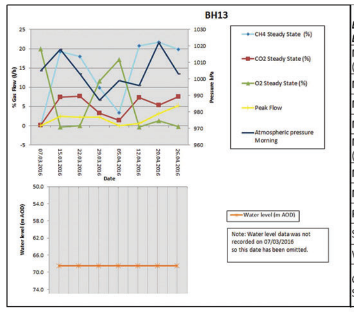
LG07 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	73.7	12/04/2016
Max Steady State CO_2 (%)	25.2	20/04/2016
Max Stead State O_2 (%)	16	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	10	07/03/2016
Max Steady State Flow (l/h)	3.9	12/04/2016
Peak Flow (l/h)	3.9	12/04/2016
Slotted pipe interval (mbgl)	1-16.1	
Water Level (m AOD)	72.916	12/04/2016
Geology Surrounding Slotted Section	Superficial - Waste (base of waste not reached)	

LG09



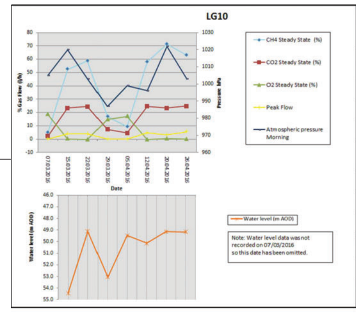
LG09 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	61.6	22/03/2016
Max Steady State CO_2 (%)	24	12/04/2016
Max Stead State O_2 (%)	20.3	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.9	12/04/2016
Peak Flow (l/h)	4	26/04/2016
Slotted pipe interval (mbgl)	1-17	
Water Level (m AOD)	61.796	05/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

BH13



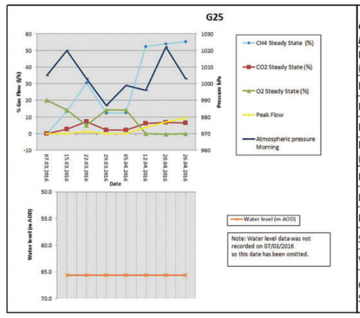
BH13 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	21.7	20/04/2016
Max Steady State CO_2 (%)	7.7	22/03/2016
Max Stead State O_2 (%)	20	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	4.7	26/04/2016
Peak Flow (l/h)	5.2	26/04/2016
Slotted pipe interval (mbgl)	4.5-19.5	
Water Level (m AOD)	68.485	All
Geology Surrounding Slotted Section	Superficial - Sandy clayey gravel/ sand/ sandy gravel/ gravel/ silty sandy clay	

LG10



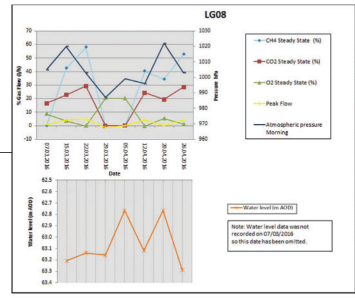
LG10 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	71.3	20/04/2016
Max Steady State CO_2 (%)	24.9	26/04/2016
Max Stead State O_2 (%)	18.6	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	4.8	26/04/2016
Peak Flow (l/h)	5.5	26/04/2016
Slotted pipe interval (mbgl)	1-18	
Water Level (m AOD)	54.423	15/03/2016
Geology Surrounding Slotted Section	Superficial - Waste	

G25



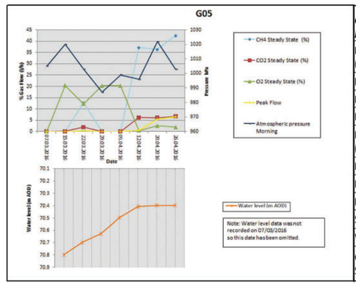
G25 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	55.3	26/04/2016
Max Steady State CO_2 (%)	7.3	22/03/2016
Max Stead State O_2 (%)	20	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	9	26/04/2016
Peak Flow (l/h)	9.3	26/04/2016
Slotted pipe interval (mbgl)	1-20	
Water Level (m AOD)	65.635	All
Geology Surrounding Slotted Section	Superficial - Sandy clay/ sandy clayey gravel/ gravel/ sandy gravel/ sand	

LG08



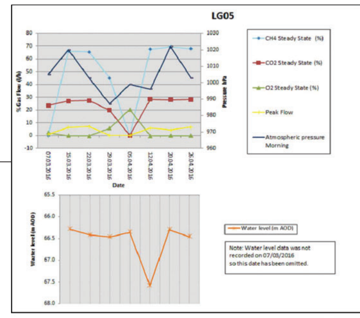
LG08 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	57.9	22/03/2016
Max Steady State CO_2 (%)	29.3	22/03/2016
Max Stead State O_2 (%)	20.3	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	14	12/04/2016
Max Steady State Flow (l/h)	4.6	22/03/2016
Peak Flow (l/h)	4.9	22/03/2016
Slotted pipe interval (mbgl)	1-8	
Water Level (m AOD)	63.288	26/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

G05



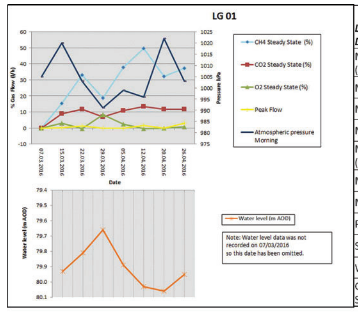
G05 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	42.4	26/04/2016
Max Steady State CO_2 (%)	6.7	26/04/2016
Max Stead State O_2 (%)	20.4	15/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	6.3	26/04/2016
Peak Flow (l/h)	6.5	26/04/2016
Slotted pipe interval (mbgl)	1-20	
Water Level (m AOD)	70.797	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clayey gravel/ sandy gravel/ sand	

LG05



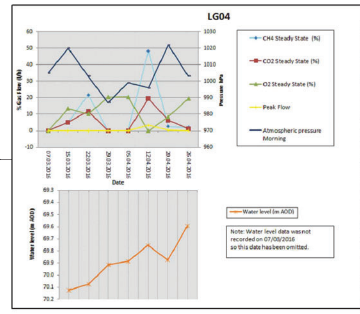
LG05 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	69.5	20/04/2016
Max Steady State CO_2 (%)	28.5	12/04/2016
Max Stead State O_2 (%)	20.5	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	7	22/03/2016
Peak Flow (l/h)	7.1	22/03/2016
Slotted pipe interval (mbgl)	1-14	
Water Level (m AOD)	67.579	12/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

LG 01



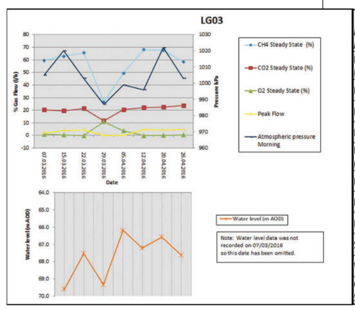
LG01 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	49.6	12/04/2016
Max Steady State CO_2 (%)	13.3	12/04/2016
Max Stead State O_2 (%)	8.3	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	2.5	26/04/2016
Peak Flow (l/h)	3.1	26/04/2016
Slotted pipe interval (mbgl)	1-5	
Water Level (m AOD)	80.06	20/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

LG04



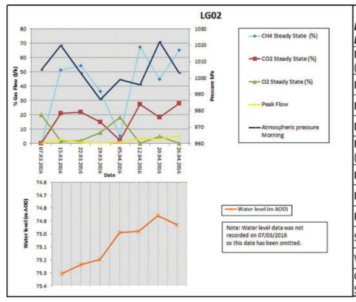
LG04 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	48.2	12/04/2016
Max Steady State CO_2 (%)	19.4	12/04/2016
Max Stead State O_2 (%)	20.5	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	10	15/03 & 20/04/16
Max Steady State Flow (l/h)	3.1	12/04/2016
Peak Flow (l/h)	3.3	12/04/2016
Slotted pipe interval (mbgl)	1-15	
Water Level (m AOD)	70.124	15/03/2016
Geology Surrounding Slotted Section	Superficial - Waste	

LG03

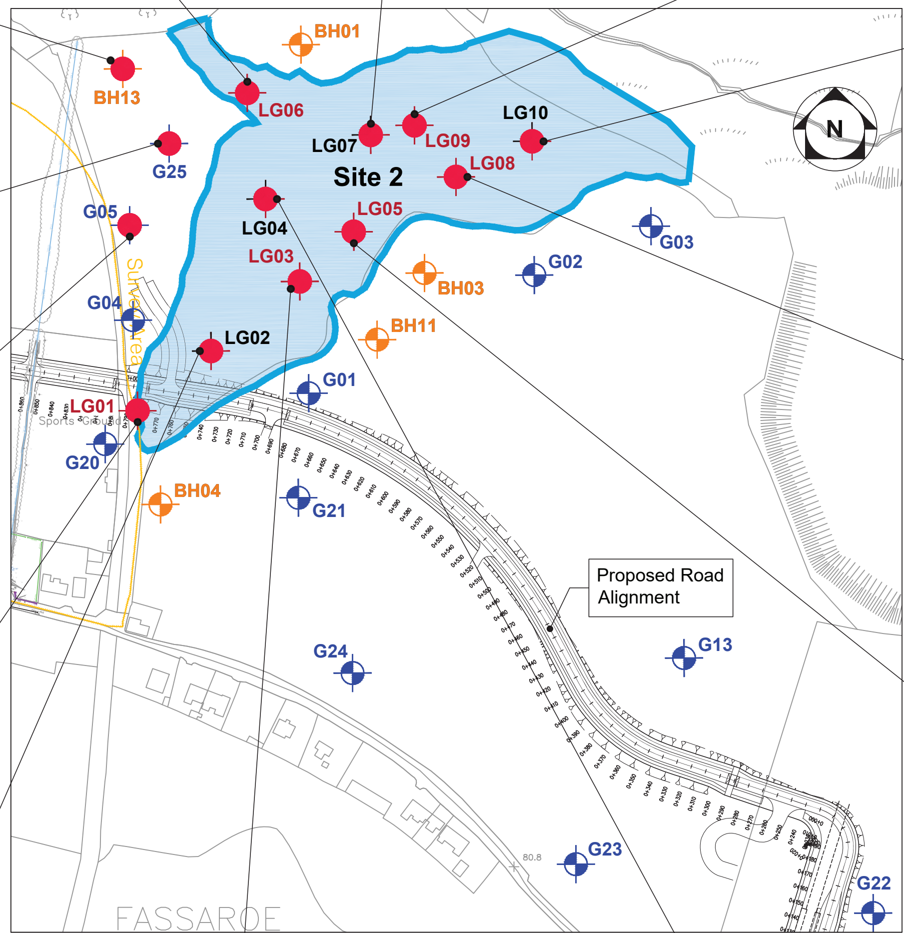


LG03 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	68.2	12/04/2016
Max Steady State CO_2 (%)	23.7	26/04/2016
Max Stead State O_2 (%)	11	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	4.3	12/04/2016
Peak Flow (l/h)	4.6	26/04/2016
Slotted pipe interval (mbgl)	1-18	
Water Level (m AOD)	69.595	15/03/2016
Geology Surrounding Slotted Section	Superficial - Waste	

LG02



LG02 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1022	20/04/2016
Max Steady State CH_4 (%)	67.4	12/04/2016
Max Steady State CO_2 (%)	27.9	26/04/2016
Max Stead State O_2 (%)	20	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	4.7	26/04/2016
Peak Flow (l/h)	5.2	26/04/2016
Slotted pipe interval (mbgl)	1-9	
Water Level (m AOD)	75.308	15/03/2016
Geology Surrounding Slotted Section	Superficial - Waste	



LEGEND

Estimated Extent of Waste

MW1 Existing Boreholes

G01 Gas Monitoring Borehole

LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)

LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)

Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)

BH01 Combined Groundwater/Gas Monitoring Boreholes

Carbon Dioxide / Methane Site Classification 3B

Traffic Light Classification	Max. Concentration (% v/v) Carbon Dioxide	Methane
Green	0-5	0-1
Amber 1	5-10	1-5
Amber 2	10-30	5-20
Red	30+	20+

Classification shows the worst case scenario for concentration of methane and carbon dioxide onsite and offsite.

Client: Cosgrave

General Notes

(i) This drawing is the property of RPS Consulting Engineers, it is a confidential document and must not be copied, used, or its content divulged without prior written consent.

(ii) All Levels refer to Ordnance Survey Datum, Malin Head.

(iii) DO NOT SCALE, use figured dimensions only, if in doubt ask.

(iv) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.

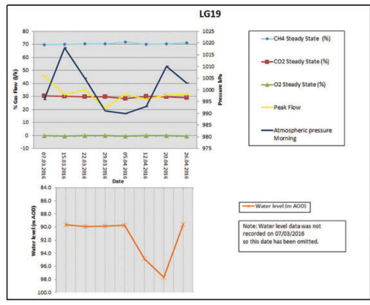
No.	Date	Drn. Chk.	Amendment / Issue	App
F01	July'16	RH MS	FINAL ISSUE	MS

RPS
West Pier Business Campus
Dun Laoghaire
Co Dublin
T +353 1 4882900
F +353 1 2835676
W www.rpsgroup.com/ireland
E ireland@rpsgroup.com

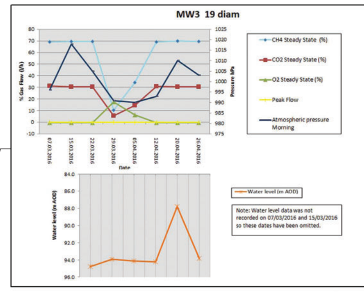
Drawn	RH
Checked	LD
Approved	CC
Date	July 2016
Scale	1:2,500 @ A1 NTS @ A3
Job No.	MDR1206
File Ref.	MDR1206FG0003.7D01.dwg
Drg. No.	Figure 3.7
Rev.	F01

Project: FASSAROE HISTORIC LANDFILL

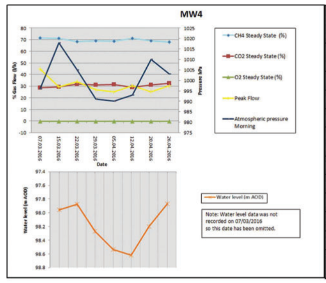
Title: GAS FLUX TIME SERIES GRAPHS & MAXIMUM VALUE TABLES - SITE 2



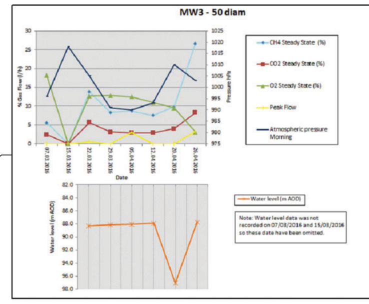
LG19 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	71.7	05/04/2016
Max Steady State CO2 (%)	30.4	07/03/2016
Max Stead State O2 (%)	-0.1	20/04/2016
Max Hydrogen Sulphide (ppm)	30	05/04 & 26/04/16
Max CO (ppm)	0	
Max Steady State Flow (l/h)	45	07/03/2016
Peak Flow (l/h)	45.6	07/03/2016
Slotted pipe interval (mbgl)	1-15	
Water Level (m AOD)	97.709	20/04/2016
Geology Surrounding Slotted Section	Superficial Waste	



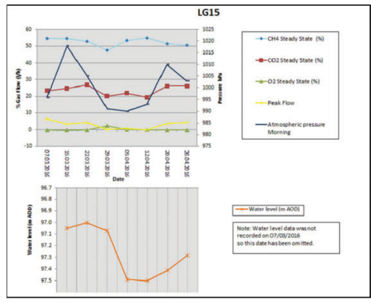
MW3 - 19 diam Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	69.7	20/04/2016
Max Steady State CO2 (%)	31.3	07/03/2016
Max Stead State O2 (%)	17.5	29/03/2016
Max Hydrogen Sulphide (ppm)	25	Multiple
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	0	
Slotted pipe interval (mbgl)	3-11	
Water Level (m AOD)	94.754	22/03/2016
Geology Surrounding Slotted Section	Superficial Waste	



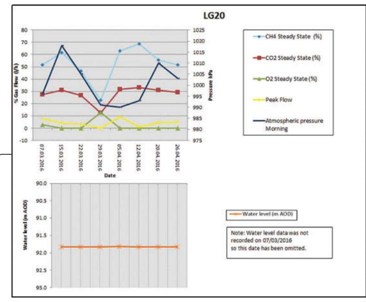
MW4 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	71.5	07/03/2016
Max Steady State CO2 (%)	32.4	26/04/2016
Max Stead State O2 (%)	-0.1	20/04/2016
Max Hydrogen Sulphide (ppm)	40	29/03/2016
Max CO (ppm)	0	
Max Steady State Flow (l/h)	43.5	07/03/2016
Peak Flow (l/h)	44.8	07/03/2016
Slotted pipe interval (mbgl)	2-10	
Water Level (m AOD)	98.617	12/04/2016
Geology Surrounding Slotted Section	Superficial Waste	



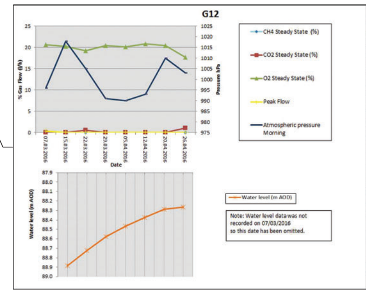
MW3 - 50 diam Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	26.7	26/04/2016
Max Steady State CO2 (%)	8.3	26/04/2016
Max Stead State O2 (%)	18.2	07/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.2	26/04/2016
Peak Flow (l/h)	3.3	26/04/2016
Slotted pipe interval (mbgl)	14.1-18.1	
Water Level (m AOD)	97.064	20/04/2016
Geology Surrounding Slotted Section	Superficial Waste	



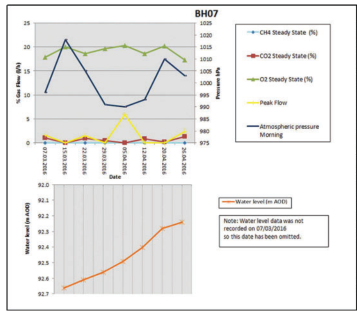
LG15 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	55	12/04/2016
Max Steady State CO2 (%)	26.8	22/03/2016
Max Stead State O2 (%)	2.3	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	10	12/04/2016
Max Steady State Flow (l/h)	5.8	07/03/2016
Peak Flow (l/h)	6.4	07/03/2016
Slotted pipe interval (mbgl)	1-8	
Water Level (m AOD)	97.5	12/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	



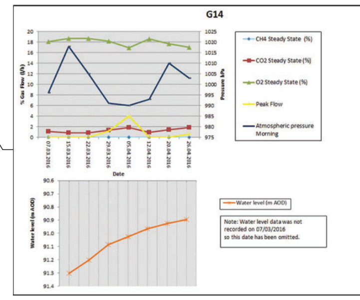
LG20 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	68.9	12/04/2016
Max Steady State CO2 (%)	33.1	12/04/2016
Max Stead State O2 (%)	12.7	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	10	22/03/2016
Max Steady State Flow (l/h)	7.5	07/03/2016
Peak Flow (l/h)	9.1	05/04/2016
Slotted pipe interval (mbgl)	1-12	
Water Level (m AOD)	91.823	All
Geology Surrounding Slotted Section	Superficial Waste	



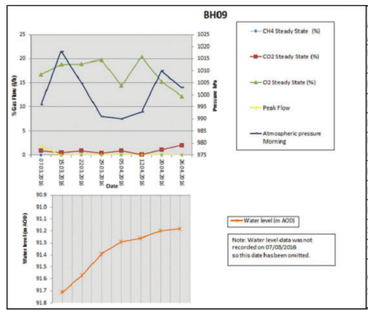
G12 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.1	26/04/2016
Max Stead State O2 (%)	20.8	12/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	0.4	07/03/2016
Slotted pipe interval (mbgl)	1-14	
Water Level (m AOD)	88.886	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clayey gravel/ sandy gravel	



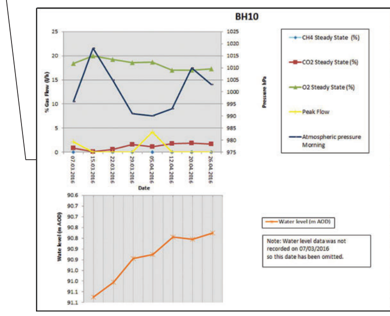
BH07 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.3	26/04/2016
Max Stead State O2 (%)	20.3	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1.9	05/04/2016
Peak Flow (l/h)	5.9	05/04/2016
Slotted pipe interval (mbgl)	11-21	
Water Level (m AOD)	92.661	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clayey gravel/ gravel/ sandy gravelly clay silt	



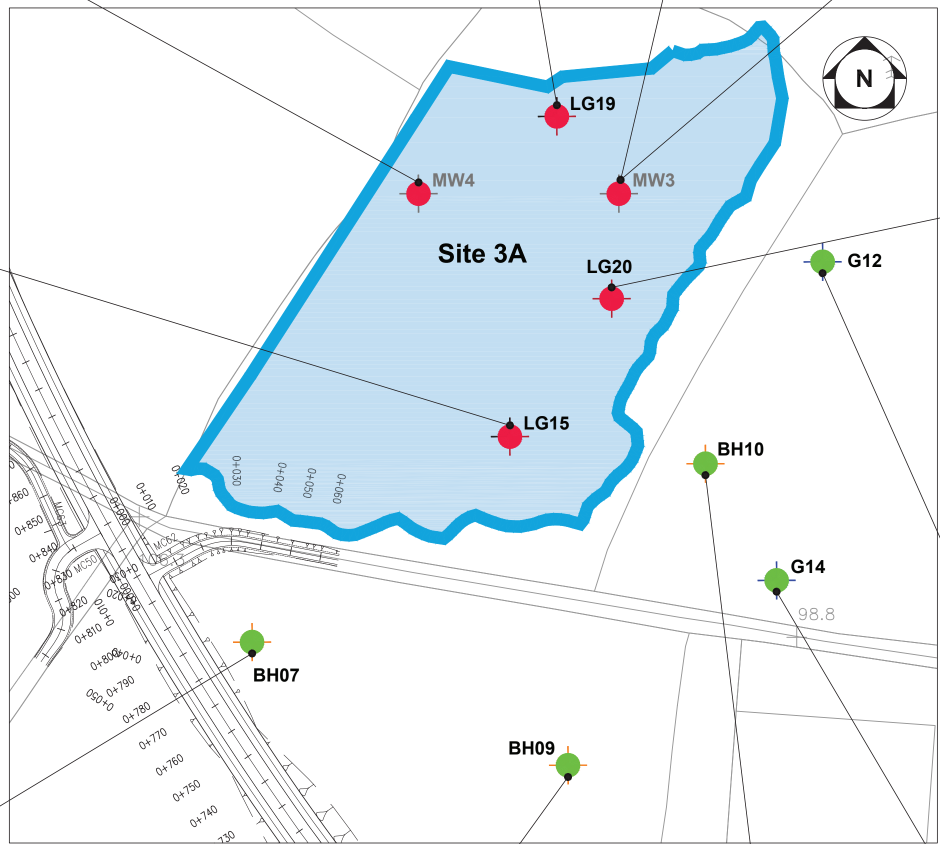
G14 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.8	05/04/2016
Max Stead State O2 (%)	18.7	15/03 & 22/03/16
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	4	05/04/2016
Slotted pipe interval (mbgl)	1-14	
Water Level (m AOD)	91.304	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clay gravel/ wet gravel/ dry silty sandy clay	



BH09 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.1	26/04/2016
Max Stead State O2 (%)	20.4	12/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	1.9	07/03/2016
Slotted pipe interval (mbgl)	2-12	
Water Level (m AOD)	91.71	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clayey gravel/ gravelly sand/ sandy gravel	



BH10 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	1.9	20/04/2016
Max Stead State O2 (%)	20	15/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1.6	07/03/2016
Peak Flow (l/h)	4.2	05/04/2016
Slotted pipe interval (mbgl)	4-14	
Water Level (m AOD)	91.075	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sand/ sandy gravel/ sandy clayey gravel	



LEGEND

- Estimated Extent of Waste
- MW1 Existing Boreholes
- G01 Gas Monitoring Borehole
- LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)
- LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)
- Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)
- BH01 Combined Groundwater/Gas Monitoring Boreholes

Carbon Dioxide / Methane Site Classification 3B

Traffic Light Classification	Max. Concentration (% v/v) Carbon Dioxide	Methane
Green	0-5	0-1
Amber 1	5-10	1-5
Amber 2	10-30	5-20
Red	30+	20+

Classification shows the worst case scenario for concentration of methane and carbon dioxide onsite and offsite.

Client: Cosgrave

General Notes

(i) This drawing is the property of RPS Consulting Engineers, it is a confidential document and must not be copied, used, or its content divulged without prior written consent.

(ii) All Levels refer to Ordnance Survey Datum, Malin Head.

(iii) DO NOT SCALE, use figured dimensions only, if in doubt ask.

(iv) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.

No.	Date	Drn. Chk.	Amendment / Issue	App
F01	July'16	RH MS	FINAL ISSUE	MS

RPS
West Pier
Business Campus
Dun Laoghaire
Co Dublin
T +353 1 4882900
F +353 1 2835676
W www.rpsgroup.com/ireland
E ireland@rpsgroup.com

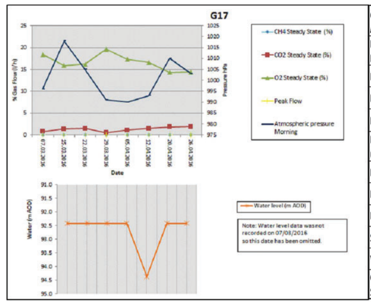
Drawn: RH
Checked: LD
Approved: CC
Date: July 2016
Scale: 1:1,250 @ A1; NTS @ A3
Job No. MDR1206

Project: FASSAROE HISTORIC LANDFILL

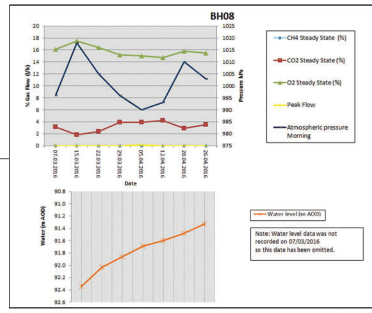
Title: GAS FLUX TIME SERIES GRAPHS & MAXIMUM VALUE TABLES - SITE 3A

File Ref. MDR1206FG0003.8D01.dwg
Drg. No. Figure 3.8
Rev. F01

R:\MDR1206 - Fassaroe Historic Landfill\8.0 Drawings\FG\FIGURES - GAS STRATEGY\MDR1206FG0003.8D01.dwg



G17 Determinand	Reading	Date of Reading
Morning Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.2	31/05/2016
Max Stead State O2 (%)	19.6	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1.1	31/05/2016
Peak Flow (l/h)	1.3	31/05/2016
Slotted pipe interval (mbgl)	1-6	
Water Level (m AOD)	94.364	12/04/2016
Geology Surrounding Slotted Section	Superficial - Sandy clay/ sandy clay gravel	



BH08 Determinand	Reading	Date of Reading
Morning Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	Multiple
Max Steady State CO2 (%)	4.2	12/04/2016
Max Stead State O2 (%)	17.5	15/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1.4	31/05/2016
Peak Flow (l/h)	1.6	31/05/2016
Slotted pipe interval (mbgl)	1-4.5	
Water Level (m AOD)	92.34	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy gravel/ sand	

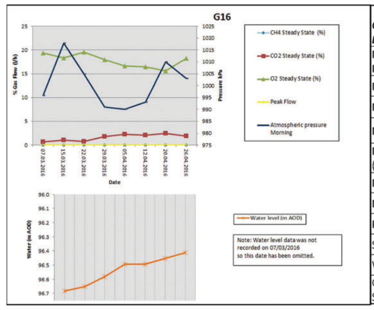
LEGEND

- Estimated Extent of Waste
- MW1 Existing Boreholes
- G01 Gas Monitoring Borehole
- LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)
- LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)
- Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)
- BH01 Combined Groundwater/Gas Monitoring Boreholes

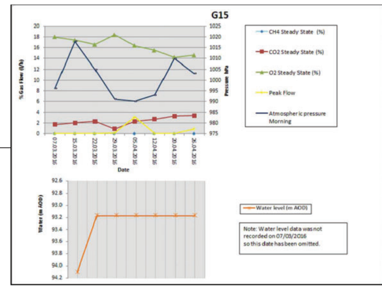
Carbon Dioxide / Methane Site Classification 3B

Traffic Light Classification	Max. Concentration (% v/v)	
	Carbon Dioxide	Methane
Green	0-5	0-1
Amber 1	5-10	1-5
Amber 2	10-30	5-20
Red	30+	20+

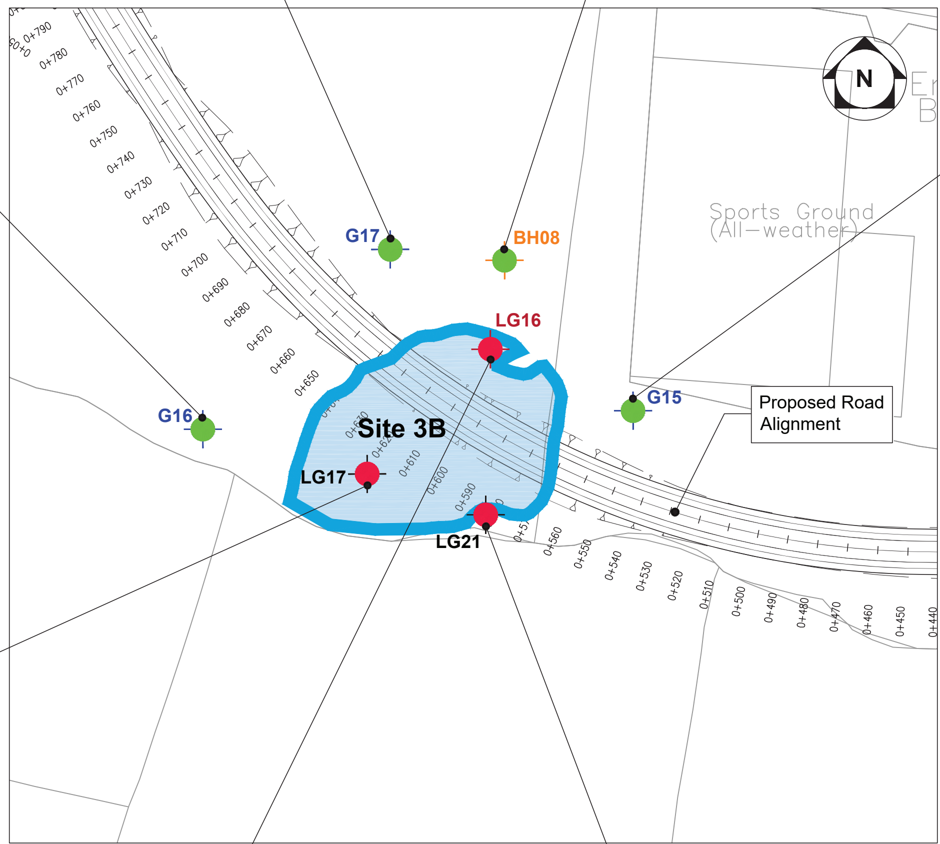
Classification shows the worst case scenario for concentration of methane and carbon dioxide onsite and offsite.

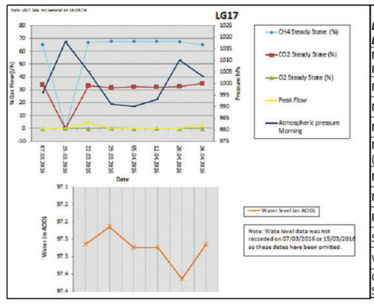


G16 Determinand	Reading	Date of Reading
Morning Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.5	20/04/2016
Max Stead State O2 (%)	19.6	22/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0.1	31/05/2016
Peak Flow (l/h)	0.3	31/05/2016
Slotted pipe interval (mbgl)	1-6	
Water Level (m AOD)	96.682	15/03/2016
Geology Surrounding Slotted Section	Superficial Sandy clay/ sandy clay gravel	

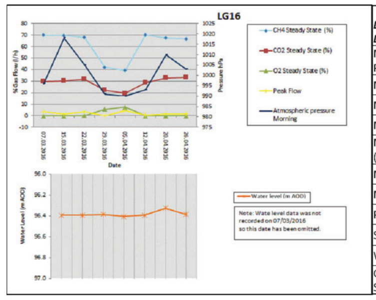


G15 Determinand	Reading	Date of Reading
Morning Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	3.6	31/05/2016
Max Stead State O2 (%)	18.4	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1.3	31/05/2016
Peak Flow (l/h)	3.1	05/04/2016
Slotted pipe interval (mbgl)	1-6	
Water Level (m AOD)	94.099	15/03/2016
Geology Surrounding Slotted Section	Superficial - Gravel	

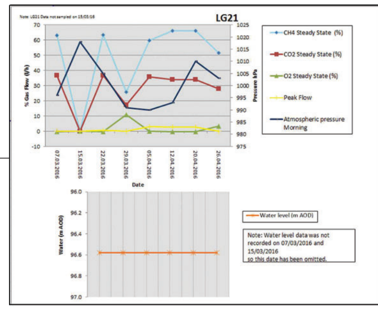




LG17 Determinand	Reading	Date of Reading
Morning Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	67.7	29/03 & 05/04/16
Max Steady State CO2 (%)	36.3	31/05/2016
Max Stead State O2 (%)	0.3	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	10	07/03 & 31/05/16
Max Steady State Flow (l/h)	4.5	22/03/2016
Peak Flow (l/h)	4.6	22/03/2016
Slotted pipe interval (mbgl)	1-3.9	
Water Level (m AOD)	97.364	20/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	



LG16 Determinand	Reading	Date of Reading
Morning Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	70.4	12/04/2016
Max Steady State CO2 (%)	34.3	31/05/2016
Max Stead State O2 (%)	7.4	05/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	3.3	07/03/2016
Peak Flow (l/h)	4.3	05/04/2016
Slotted pipe interval (mbgl)	1-2.5	
Water Level (m AOD)	96.405	05/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	



LG21 Determinand	Reading	Date of Reading
Morning Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	66.2	12/04/2016
Max Steady State CO2 (%)	37.4	31/05/2016
Max Stead State O2 (%)	10.9	29/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	2.5	12/04/2016
Peak Flow (l/h)	3.1	05/04/2016
Slotted pipe interval (mbgl)	1-4	
Water Level (m AOD)	96.58	All
Geology Surrounding Slotted Section	Superficial - Waste	

Client: Cosgrave

General Notes

(i) This drawing is the property of RPS Consulting Engineers, it is a confidential document and must not be copied, used, or its content divulged without prior written consent.

(ii) All Levels refer to Ordnance Survey Datum, Malin Head.

(iii) DO NOT SCALE, use figured dimensions only, if in doubt ask.

(iv) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.

No.	Date	Drn. / Chk.	Amendment / Issue	App
F01	July'16	RH / MS	FINAL ISSUE	MS

RPS
West Pier
Business Campus
Dun Laoghaire
Co Dublin
T +353 1 4882900
F +353 1 2835676
W www.rpsgroup.com/ireland
E ireland@rpsgroup.com

Drawn	RH
Checked	LD
Approved	CC
Date	July 2016
Scale	1:1,250 @ A1; NTS @ A3
Job No.	MDR1206

Project: **FASSAROE HISTORIC LANDFILL**

Title: GAS FLUX TIME SERIES GRAPHS & MAXIMUM VALUE TABLES - SITE 3B

File Ref. MDR1206FG0003.9D01.dwg | Drg. No. Figure 3.9 | Rev. F01

LEGEND

Estimated Extent of Waste

MW1 Existing Boreholes

G01 Gas Monitoring Borehole

LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)

LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)

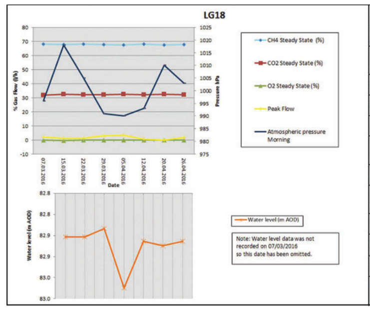
Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)

BH01 Combined Groundwater/Gas Monitoring Boreholes

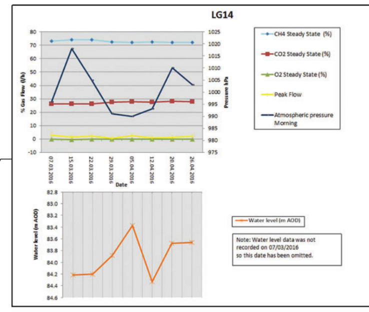
Carbon Dioxide / Methane Site Classification 3B

Traffic Light Classification	Max. Concentration (% v/v)	
	Carbon Dioxide	Methane
Green	0-5	0-1
Amber 1	5-10	1-5
Amber 2	10-30	5-20
Red	30+	20+

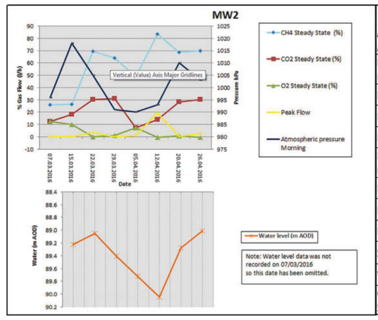
Classification shows the worst case scenario for concentration of methane and carbon dioxide onsite and offsite.



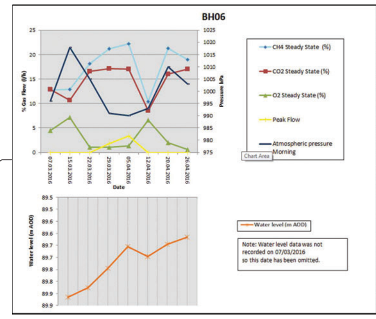
LG18 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	68.2	07/03/2016
Max Steady State CO2 (%)	32.5	05/04/2016
Max Stead State O2 (%)	0	
Max Hydrogen Sulphide (ppm)	40	Multiple
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1	07/03 & 05/04/2016
Peak Flow (l/h)	3.3	05/04/2016
Slotted pipe interval (mbgl)	1-10	
Water Level (m AOD)	82.974	05/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	



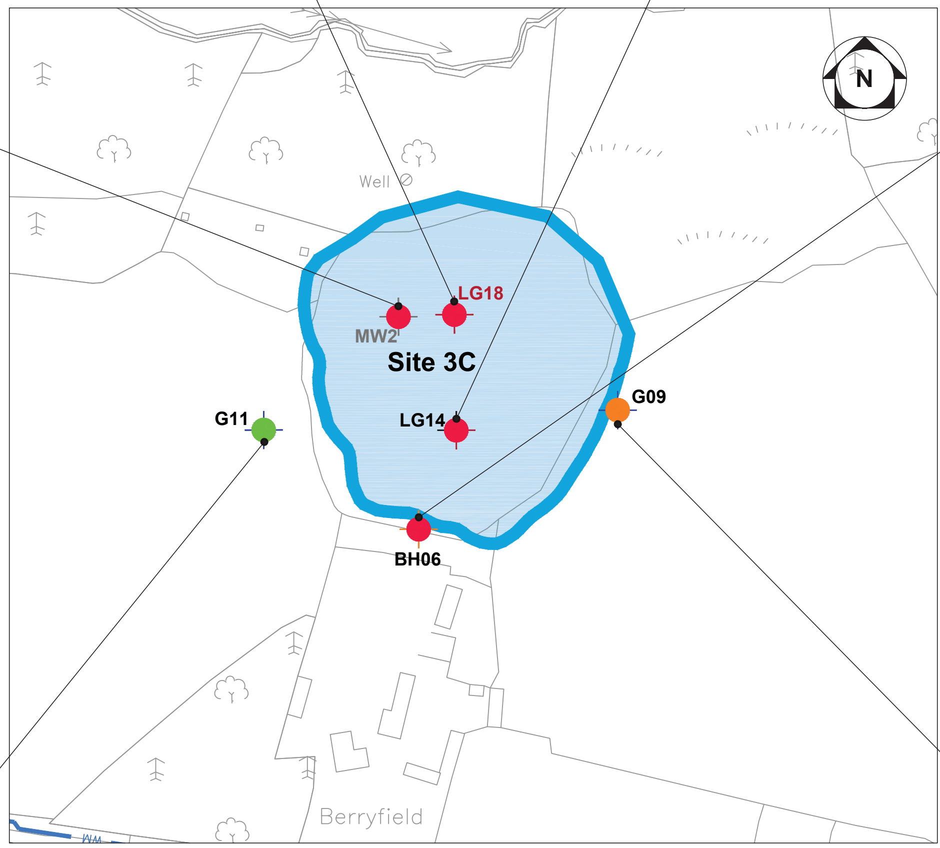
LG14 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	74.1	22/03/2016
Max Steady State CO2 (%)	28.2	20/04/2016
Max Stead State O2 (%)	0	05/04/2016
Max Hydrogen Sulphide (ppm)	50	05/04/2016
Max CO (ppm)	0	
Max Steady State Flow (l/h)	1.9	22/03/2016
Peak Flow (l/h)	2.8	07/03/2016
Slotted pipe interval (mbgl)	1-12	
Water Level (m AOD)	84.333	12/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

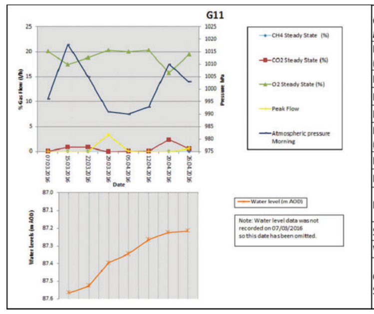


MW2 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	83.5	12/04/2016
Max Steady State CO2 (%)	31.2	29/03/2016
Max Stead State O2 (%)	12.4	07/03/2016
Max Hydrogen Sulphide (ppm)	60	26/04/2016
Max CO (ppm)	0	
Max Steady State Flow (l/h)	11.7	12/04/2016
Peak Flow (l/h)	19.5	12/04/2016
Slotted pipe interval (mbgl)	2-5	
Water Level (m AOD)	90.042	12/04/2016
Geology Surrounding Slotted Section	Superficial - Waste	

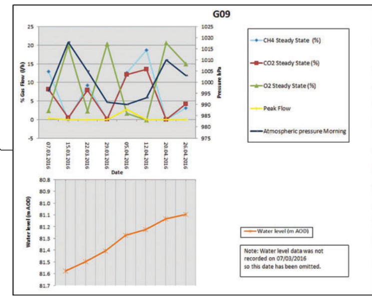


BH06 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	22.2	05/04/2016
Max Steady State CO2 (%)	17.1	29/03/2016
Max Stead State O2 (%)	7.2	15/03/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0.3	05/04/2016
Peak Flow (l/h)	3.4	05/04/2016
Slotted pipe interval (mbgl)	2-14	
Water Level (m AOD)	89.866	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy gravel/ silty sandy gravel	





G11 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	0	
Max Steady State CO2 (%)	2.4	20/04/2016
Max Stead State O2 (%)	20.3	29/03 & 12/04/16
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	10	12/04/2016
Max Steady State Flow (l/h)	0	
Peak Flow (l/h)	3.4	29/03/2016
Slotted pipe interval (mbgl)	1-15	
Water Level (m AOD)	87.565	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clay/ sandy gravel/ sand/ gravel	



G09 Determinand	Reading	Date of Reading
Max Atmospheric Pressure (hPa)	1018	15/03/2016
Max Steady State CH4 (%)	18.6	12/04/2016
Max Steady State CO2 (%)	13.5	12/04/2016
Max Stead State O2 (%)	20.6	20/04/2016
Max Hydrogen Sulphide (ppm)	0	
Max CO (ppm)	0	
Max Steady State Flow (l/h)	0.4	05/04/2016
Peak Flow (l/h)	2.7	05/04/2016
Slotted pipe interval (mbgl)	1-14	
Water Level (m AOD)	81.575	15/03/2016
Geology Surrounding Slotted Section	Superficial - Sandy clay/ gravelly sand/ sandy clay gravel	

Client: Cosgrave

General Notes

(i) This drawing is the property of RPS Consulting Engineers, it is a confidential document and must not be copied, used, or its content divulged without prior written consent.

(ii) All Levels refer to Ordnance Survey Datum, Malin Head.

(iii) DO NOT SCALE, use figured dimensions only, if in doubt ask.

(iv) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.

No.	Date	Drn	Chk	Amendment / Issue	App
F01	July'16	RH	MS	FINAL ISSUE	MS

RPS
West Pier
Business Campus
Dun Laoghaire
Co Dublin
T +353 1 4882900
F +353 1 2835676
W www.rpsgroup.com/ireland
E ireland@rpsgroup.com

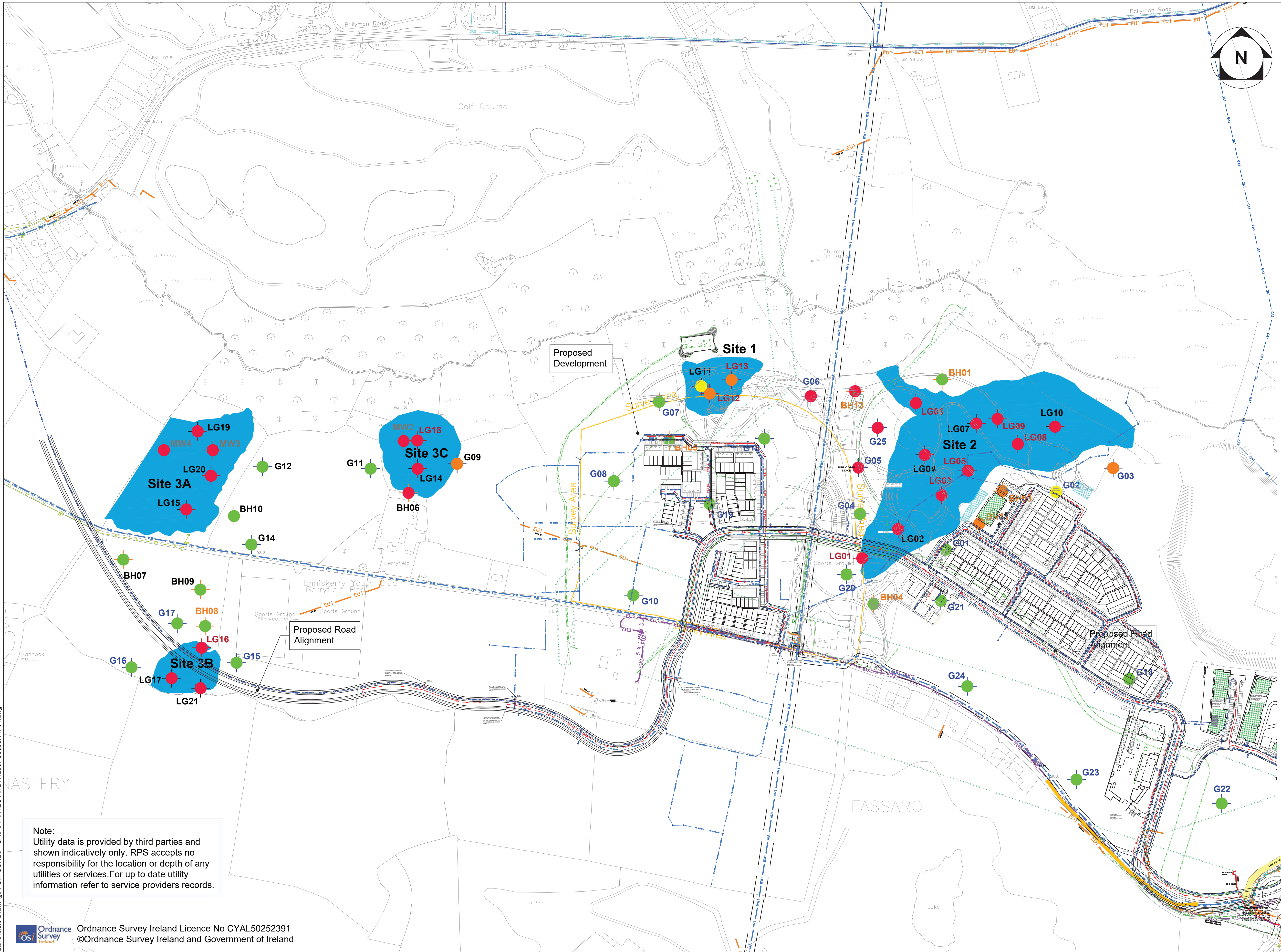
Drawn: RH
Checked: LD
Approved: CC
Date: July 2016
Scale: 1:1,250 @ A1, NTS @ A3
Job No.: MDR1206

Project: FASSAROE HISTORIC LANDFILL

Title: GAS FLUX TIME SERIES GRAPHS & MAXIMUM VALUE TABLES - SITE 3C

File Ref.: MDR1206FG0003.10D01.dwg
Drg. No.: Figure 3.10
Rev.: F01

R:\MDR1206 - Fassaroe Historic Landfill\8.0 Drawings\FG\FIGURES - GAS STRATEGY\MDR1206FG0003.10D01.dwg



LEGEND

- Extent of Waste
- Existing 33" Watermain
- Existing Watermain
- Existing Foul System
- Existing Storm System
- Existing Gas Network
- Existing Eircom
- Existing Public Lighting
- Existing UPC
- ESB Underground (38kv)
- ESB Underground (MV & LV)
- ESB Underground (Spare)
- Proposed Watermain Network
- Proposed Stormwater Network
- Proposed Foul Sewer Network
- Proposed ESB Underground (38kv)
- Proposed ESB Underground (110kv)
- Proposed ESB Underground Ducts
- MW1 Existing Boreholes
- G01 Gas Monitoring Borehole
- LG01 Combined Gas/Leachate Monitoring Boreholes (Rotary)
- LG02 Combined Gas/Leachate Monitoring Boreholes (Cable Percussive)
- Combined Gas/Leachate Monitoring Boreholes (Cable Percussive with Rotary follow on)
- BH01 Combined Groundwater/Gas Monitoring Boreholes

Carbon Dioxide / Methane Site Classification

Traffic Light Classification	Max. Concentration (% v/v)	
	Carbon Dioxide	Methane
Green	0-5	0-1
Amber 1	5-10	1-5
Amber 2	10-30	5-20
Red	30+	20+

Classification shows the worst case scenario for concentration of methane and carbon dioxide onsite and offsite.

Note:
Utility data is provided by third parties and shown indicatively only. RPS accepts no responsibility for the location or depth of any utilities or services.For up to date utility information refer to service providers records.

R:\MDR1206 - Fassaroe Historic Landfill\8.0 Drawings\FIGURES - GAS STRATEGY\MDR1206FG0003.11F01.dwg

Client: Cosgrave

General Notes
(i) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc.) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.
(ii) DO NOT SCALE, use figured dimensions only.
(iii) This drawing is the property of RPS, it is a project confidential classified document. It must not be copied used or its contents divulged without prior written consent. The needs and expectations of client and RPS must be considered when working with this drawing.
(iv) Information including topographical survey, geotechnical investigation and utility detail used in the design have been provided by others.
(v) All Levels refer to Ordnance Survey Datum, Malin Head.

Rev	Date	Drn / Chk	Amendment / Issue	App
P01	08/03/22	BC / ML	PLANNING ISSUE	DC

rps

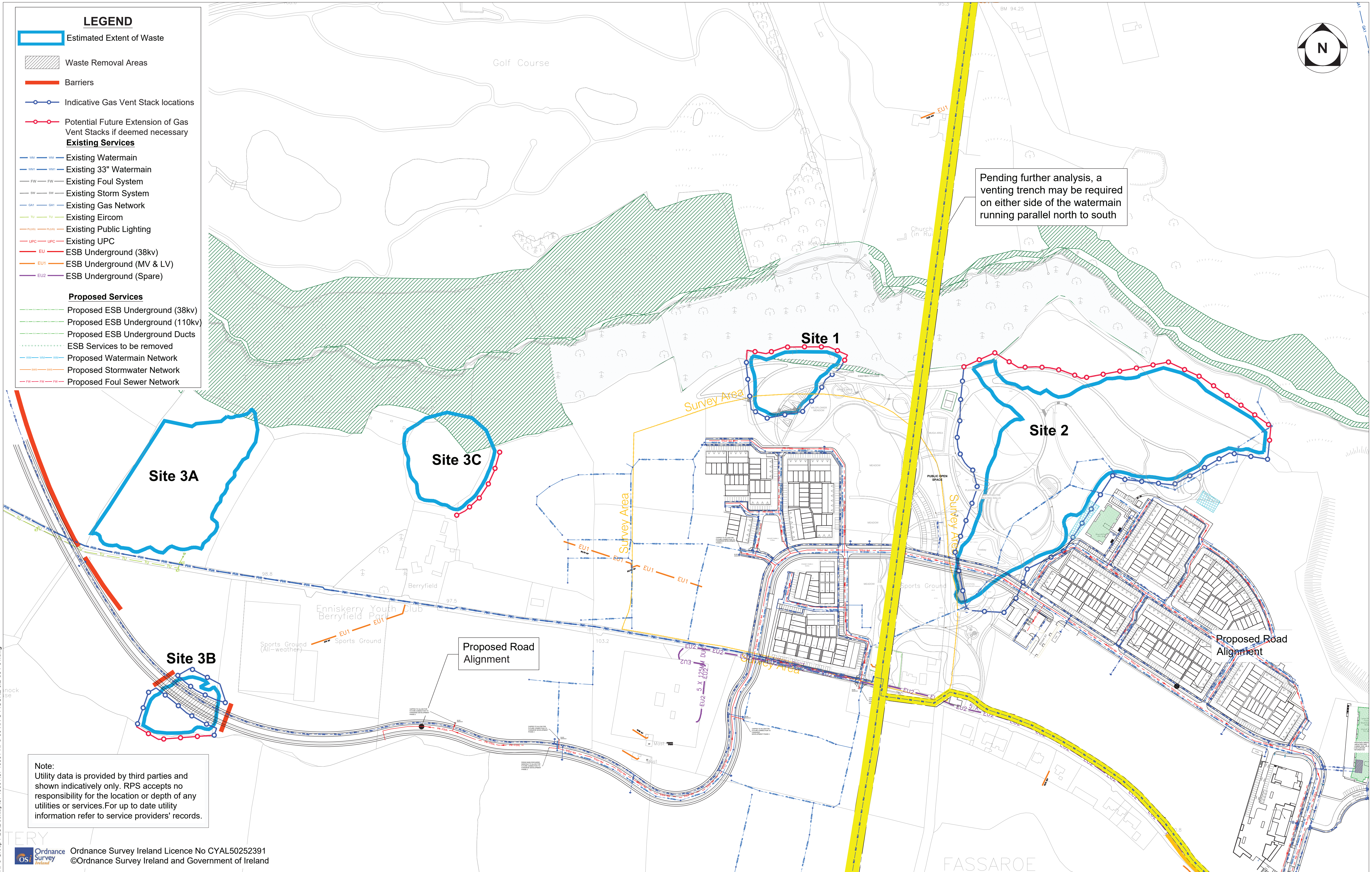
Model File Identifier

Scale: 1:2000 @ A1, 1:4000 @ A3
Created on: 07/10/2020
Sheets: 01 of 01

Project: FASSAROE PHASE 1 DEVELOPMENT

Title: PLAN SHOWING CARBON DIOXIDE/METHANE SITE CLASSIFICATIONS & PROPOSED DEVELOPMENT
Figure 3.11

File Identifier: CP19001-RPS-00-XX-DR-C-FIGURE 3.11
Status: S3
Rev: P01



C:\Users\bryan.coyle\OneDrive - RPS Group PLC\Desktop\CP19001\CP19001-RPS-00-XX-C-FIGURE 6.2 S3 P01.dwg

Client

Cosgrave

General Notes

(i) Hard copies, dwf and pdf will form a controlled issue of the drawing. All other formats (dwg etc.) are deemed to be an uncontrolled issue and any work carried out based on these files is at the recipients own risk. RPS will not accept any responsibility for any errors from the use of these files, either by human error by the recipient, listing of the un-dimensioned measurements, compatibility with the recipients software, and any errors arising when these files are used to aid the recipients drawing production, or setting out on site.

(ii) DO NOT SCALE, use figured dimensions only.

(iii) This drawing is the property of RPS, it is a project confidential classified document. It must not be copied used or its contents divulged without prior written consent. The needs and expectations of client and RPS must be considered when working with this drawing.

(iv) Information including topographical survey, geotechnical investigation and utility detail used in the design have been provided by others.

(v) All Levels refer to Ordnance Survey Datum, Malin Head.

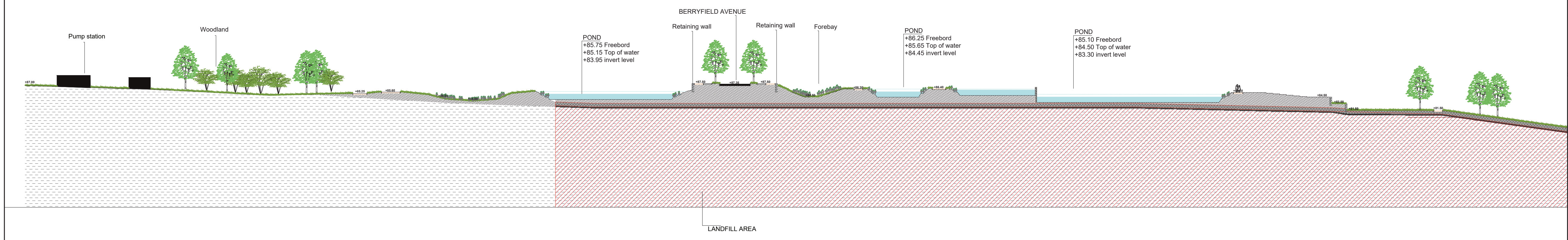
Rev	Date	Drn Chk	Amendment / Issue	App
P01	08/03/22	BC ML	PLANNING ISSUE	DC

Model File Identifier

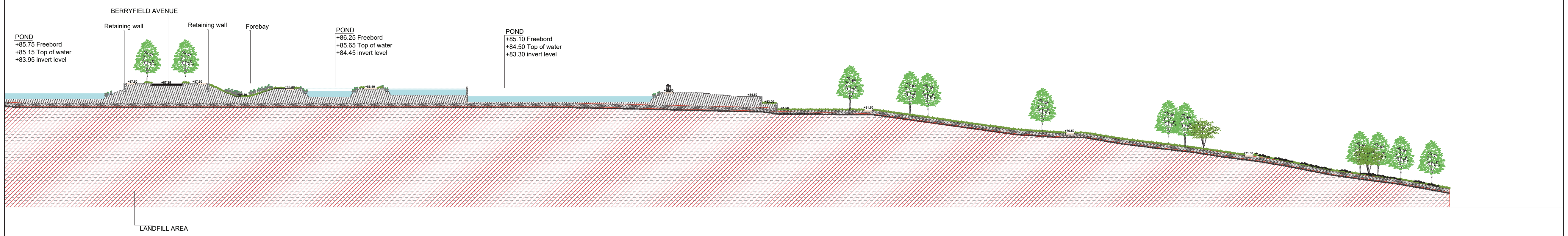
Scale	Project
1:2000 @ A1 1:4000 @ A3	FASSAROE PHASE 1 DEVELOPMENT
Created on: 07/10/2020	Title: PRELIMINARY REMEDIAL DESIGN Figure 6.2
Sheets: 01 of 01	

File Identifier	Status	Rev
CP19001-RPS-00-XX-DR-C-FG0006.2 P01	S3	P01

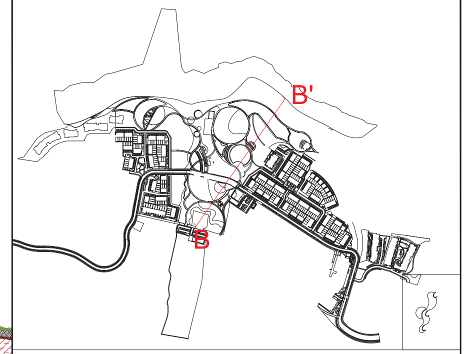
Appendix B
Drawings LFAS-MAL-XX-XX-DR-L-0201 and LFAS-MAL-XX-XX-DR-L-0203



B



B'



REV	DESCRIPTION	ISSUED BY	DATE

MITCHELL + ASSOCIATES
LANDSCAPE ARCHITECTURE URBAN DESIGN

Unit 5, Woodpark, The Rise, Glasnevin, Dublin 9, Ireland t: + 353 1 454 5066 e:info@mitchellassoc.net

PROJECT
Fassaroe

CLIENT
Cosgrave Property Group

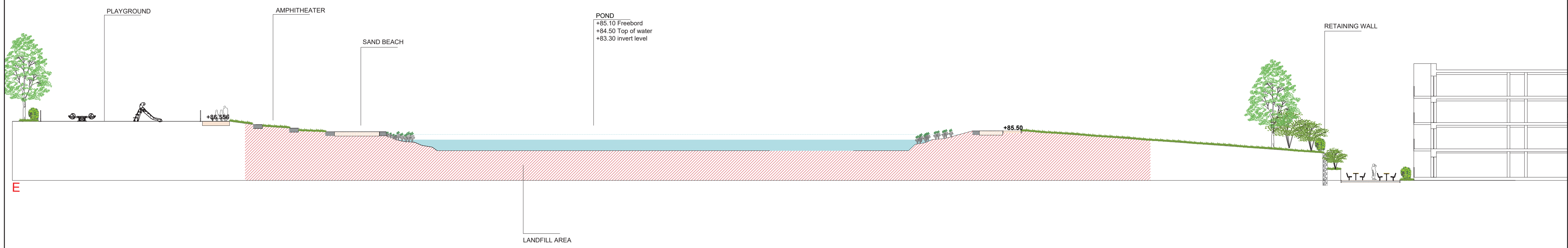
JOB NO.
LFAS006

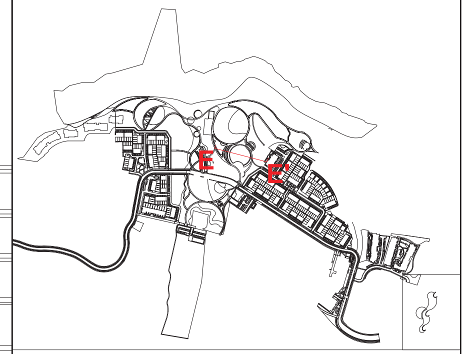
DRAWING
LANDSCAPE - SECTION BB'

DRAWING NO.
201

DRAWN BY	CHECKED	DATE
Constance Freche	AH	20.01.2022
STATUS: Planning	**SCALE** 1:500 @ A1	**REVISION** >REVISION<

NOTES:
All dimensions are in millimeters unless otherwise stated and shall be checked and confirmed by the contractor on site. Any discrepancies shall be immediately reported to the landscape architects. Work to figured dimensions only - Do not scale from drawing. Do Not Scale. Use Figured Dimensions Only. Not for Construction Purposes unless Specifically Marked.





REV	DESCRIPTION	ISSUED BY	DATE

MITCHELL + ASSOCIATES

LANDSCAPE ARCHITECTURE URBAN DESIGN

Unit 5, Woodpark, The Rise, Glasnevin, Dublin 9, Ireland t: + 353 1 454 5066 e:info@mitchellassoc.net

PROJECT
Fassaroe

CLIENT
Cosgrave Property Group

JOB NO.
LFAS006

DRAWING
LANSDCAPE - SECTIONS EE' - Amphitheater and sand beach

DRAWING NO.
203

DRAWN BY	CHECKED	DATE
Constance Freche	AH	20.01.2022
STATUS:	**SCALE**	**REVISION**
Planning	1:250 @ A1	>REVISION<

NOTES:
All dimensions are in millimeters unless otherwise stated and shall be checked and confirmed by the contractor on site. Any discrepancies shall be immediately reported to the landscape architects. Work to figured dimensions only - Do not scale from drawing. Do Not Scale. Use Figured Dimensions Only. Not for Construction Purposes unless Specifically Marked.