

DETAILED QUANTITATIVE GAS RISK ASSESSMENT

for the land at

PARK FARM AREA, BOORLEY GARDENS

WINCHESTER ROAD, HEDGE END

SOUTHAMPTON, SO32 2UA

on behalf of

BELLWAY HOMES & MILLER HOMES



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

Report:	DETAILED QUANTITATIVE GAS RISK ASSESSMENT
Site:	PARK FARM AREA, BOORLEY GARDENS, WINCHESTER ROAD, HEDGE END, SOUTHAMPTON, SO32 2UA
Client:	BELLWAY HOMES & MILLER HOMES
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**DETAILED QUANTITATIVE GAS RISK ASSESSMENT**

AMENDMENT RECORD

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CONTENTS

EXECUTIVE SUMMARY	i
1.0 INTRODUCTION	1
1.1 Purpose	1
1.2 The Site	1
1.3 Information Sources	3
1.4 Conditions	3
2.0 HISTORIC INFORMATION	5
2.1 Historic maps	5
2.2 Walkover	5
2.3 Geology	6
2.4 Discussion	6
3.0 PREVIOUS INVESTIGATIONS	7
3.1 Visual/olfactory indicators	10
3.2 Organic contaminants - soils	10
3.3 Total organic carbon	11
3.4 Natural soils	11
3.5 Discussion	11
4.0 CURRENT SITE INVESTIGATION	12
4.1 Visual/olfactory indicators	14
4.2 Organic contaminants - soils	14
4.3 Organic contaminants – groundwater	14
4.4 Total organic carbon	14
4.5 Discussion	14
5.0 PRELIMINARY QUALITATIVE RISK ASSESSMENT	16
5.1 Sources	16
5.2 Pathways	16
5.3 Receptors	16
5.4 Ground model	16
6.0 PRELIMINARY QUANTITATIVE RISK ASSESSMENT	18
6.1 Preliminary classification of gas regime	20
7.0 DETAILED RISK ASSESSMENT	23
7.1 WS3, WS101, WS103, WS105 and WS205	23
7.2 WS5	24
7.3 WS202 and WS6	24
7.4 Discussion	25
8.0 CONCLUSIONS AND RECOMMENDATIONS	27
9.0 DISCOVERY STRATEGY	28

FIGURES

FIGURE 1	Site Location
FIGURE 2	The site (purple polygon) in context with larger development area (black polygon)
FIGURE 3	Development proposals
FIGURE 4	Approximate location of exploratory holes
FIGURE 5	Approximate location of 2022 exploratory holes and targeted features
FIGURE 6	Simplistic ground model
FIGURE 7	Standpipe locations and elevated concentrations
FIGURE 8	Headspace gas behaviour in submerged and exposed response zones
FIGURE 9	Submerged response zones
FIGURE 10	Illustration of hydrocarbon contamination restricted by low permeability soils



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

EXECUTIVE SUMMARY		
Site Details	Site Address	Park Farm, Boorley Gardens, Winchester Road, Hedge End, Southampton, SO32 2UA
	National Grid Reference	450346, 115099
	Site Area	2.5ha (approx.)
	Form of Development	The construction of a residential development including private gardens, access roads and associated development infrastructure.
Risk Assessment Summary	Overview	Historic maps indicate that the Site is located within an extensive area of long term agricultural use. No records of historic or current usage are available that suggest a source of bulk gas generation is likely to be located on or in the vicinity of the site. A total of three site investigations have identified a maximum thickness of 0.4m Made Ground overlying the Wittering Formation (Clay with variable silt/sand/gravel content) over the London Clay Formation (Clay). The Made Ground descriptions identified topsoil (with rootlets) with rare anthropogenic inclusions in the form of ash, clinker, brick fragments and mortar. No descriptions are indicative of a potential source of bulk gas generation. Total organic carbon (TOC) analysis of samples taken from the Made Ground across the Site identified concentrations indicative of inert waste, incapable of generating sufficient gas to represent a risk to any proposed development. Localised hydrocarbon contamination was identified in soils and groundwater in the direct vicinity of an above ground diesel storage tank. No organic contamination was identified at concentrations capable of bulk gas generation. No unusual materials were recorded that might be indicative of localised landfilling or waste disposal. As such it can be concluded that: • No potential source of bulk gas generation is present on the Site; and • The presence of localised hydrocarbon contamination, and the long-term use of the site for livestock farming will have resulted in gas 'stored' within soil pores, sorbed to soil particles and dissolved in groundwater. This does not represent a risk to the proposed development. Gas monitoring identified limited elevated concentrations of carbon dioxide and methane, combined with negligible and sometimes negative flow rates. This indicates that the site should be classified as Characteristic Situation 1 and does not require gas protection measures to be incorporated within the proposed development. As such it can be concluded that: • No bulk gases are present across the Site; and • No advective flow is occurring.
	Conclusions	Based on all the lines of evidence presented above, it is considered in relation to the proposed development, that the site should be considered a Characteristic Situation 1 classification, with no requirement for gas protection measures. It is recommended that, following demolition of the existing buildings and removal of floor slabs, additional localised investigation is undertaken in the vicinity of the above ground diesel storage tank.



EXECUTIVE SUMMARY
Further Action: • Submission of this report to the Local Planning Authority in accordance with the extant planning consent.
<i>This Executive Summary is intended to provide a brief summary of the main findings and conclusions of the assessment. For detailed information, the reader is referred to the main report ref. GE20584/DQGRA/JUN22.</i>



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

1.0 INTRODUCTION

1.1 Purpose

Park Farm, Winchester Road, Botley (the Site) forms part of a major development area in Southampton, Hampshire known as Boorley Green. The proposed larger development comprises residential houses with domestic gardens, a primary school, public open space and associated infrastructure. Within the Park Farm site boundary, it is intended to construct low-rise residential properties with private gardens and associated infrastructure.

Previous site investigation and gas monitoring have recorded marginally elevated concentrations of carbon dioxide combined with negligible flow, resulting in a recommendation for the installation of gas protection measures within the Park Farm curtilage. Geo-Environmental Services Limited (GESL) was appointed by Jackson Rowe on behalf of Bellway Homes and Miller Homes (the joint Client) to undertake additional localised site investigation to support a detailed quantitative gas risk assessment, to be reviewed in combination with additional risk assessments undertaken by GESL and others in relation to non-gas contaminants.

This report has been prepared in general accordance with the following documents:

- *Land Contamination Risk Management (LCRM)*, April 2021;
- *Model Procedures for the Management of Contaminated Land, CLR11*. Environment Agency 2004 (withdrawn);
- BS8485:2015 +A1:2019: *Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings (2019)*;
- BS8576:2013: *Guidance on investigations for ground gas – permanent gases and volatile organic compounds (VOCs) (2013)*;
- CIRIA Report C665: *Assessing risks posed by hazardous ground gases to buildings (2007)*;
- *The Local Authority guide to ground gas* Chartered Institute of Environmental Health (2008); and
- CIRIA Report C682: *Investigating, assessing and managing risks from inhalation of volatile organic compounds at land affected by contamination (2009)*;
- NHBC Technical Extra 20: *Ground gas update – site assessment, characterisation and design of gas protection measures (2016)*.

1.2 The Site

The Site is located between Boorley Green (east) and Hedge End (west), approximately 10km to the east of Southampton city centre. It is bounded to the east by Winchester Road, and to the north, south and west by the larger development site. The location of the Site is shown in Figure 1, and in greater detail in Figure 2.

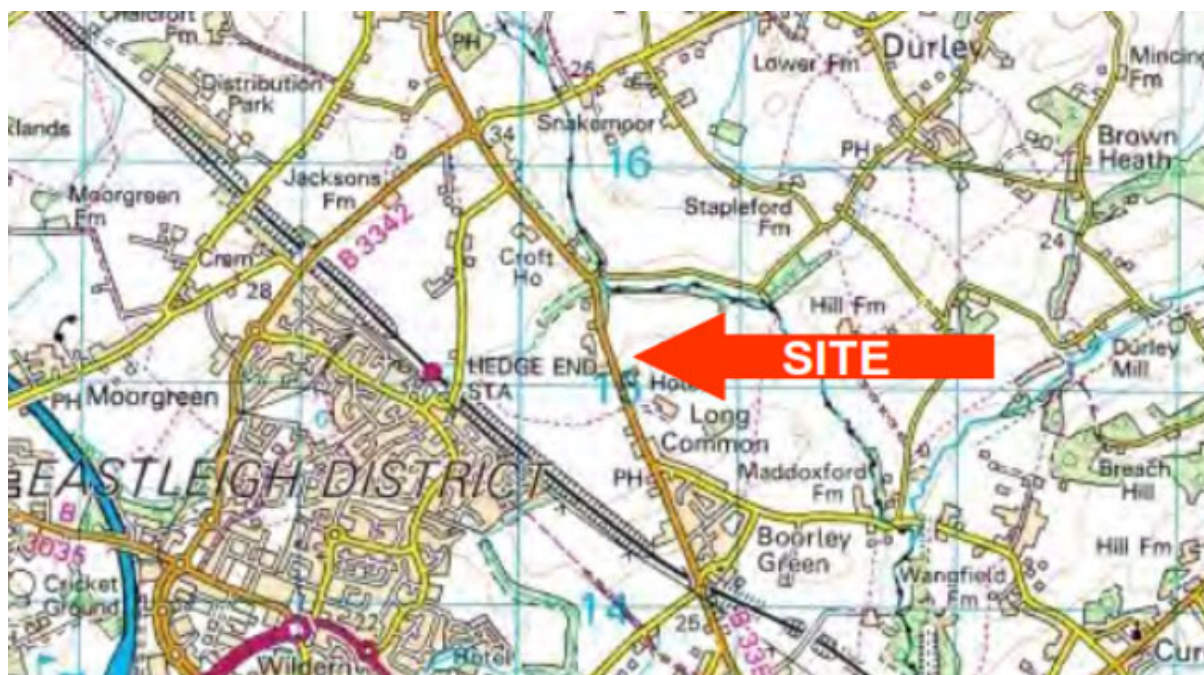


Figure 1: Site location



Figure 2: Site location in context with other plots

The development proposals for the Site comprise low rise residential with private gardens and associated infrastructure, including roads and public open space, as shown in Figure 3.



Figure 3: Development proposals

1.3 Information Sources

This report is based on information obtained from the following sources:

- *Desk study report.* Opus International, November 2014, reference E-E1589.00/LJE/CDS-final;
- *Geo-environmental site investigation report.* BRD Environmental Limited, September 2017, reference BRD2924-OR1-C;
- *Geo-environmental report.* Enzygo Geo-environmental Limited, January 2021, reference CRM.1668.012.GE.R.001;
- *Ground Appraisal Report.* Geo-Environmental Services Limited, June 2022, reference GE20584/GAR/JUN22.

1.4 Conditions

It must be noted that the findings and assessment presented herein are based on the ground and groundwater conditions as encountered at the time of the various phases of each investigation and any associated testing and monitoring. The ground by its very nature is variable and the properties of soils can vary over time, such as due to changes in soil moisture content, disturbance and similar factors. Similarly, groundwater conditions can and do vary over time. As such, if conditions are encountered which differ from those described herein, the Client or their appointed representative, e.g. contractor, must seek advice from this document's authors at the earliest practicable opportunity. It is possible that this could result in changes to the assessment presented herein.

Geo-Environmental assumes all third-party information to be factually correct and accepts no liabilities for any inaccuracies within this third-party information.

The data collected from the investigations have been used to provide an interpretation of the geotechnical and/or environmental conditions pertaining to the site. The recommendations and opinions expressed in this report are



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

based on the data obtained. Geo-Environmental takes no responsibility for conditions that either have not been revealed in the available records, or that occur between or under points of physical investigation. Whilst every effort has been made to interpret the conditions, such information is only indicative and liability cannot be accepted for its accuracy.

It should be noted that in particular the concentrations and levels of mobile liquid and gaseous materials are likely to vary with time. The results obtained may therefore only be representative of the conditions at the time of sampling. This report should not be taken as any guarantee that a site is free of hazardous or potentially contaminative materials.

Information contained in this report is intended for the use of the Client and Geo-Environmental can take no responsibility for the use of this information by any party for uses other than that described in this report. Geo-Environmental makes no warranty or representation whatsoever express or implied with respect to the use of this information by any third party. Geo-Environmental does not indemnify the Client or any third parties against any dispute or claim arising from any finding or other result of this investigation report or any consequential losses.

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Assessment criteria or other parameters developed for the evaluation of contamination on this site are based on a number of assumptions regarding exposure and toxicology. Exposure to contaminants and levels of adverse effects may therefore vary. Whilst reasonable care and expertise has been employed in the development of such criteria, no liability is accepted in this respect. Other criteria or guidance on the development of assessment criteria may be published in the future and no liability is accepted in this respect.

2.1 Historic maps

Table 1: Extracts from historic maps with commentary

Livestock farming can result in (generally) minor potential sources of soil gas in the form of manure, slurry pits etc. No potential sources of bulk gas generation are identified on historic maps within or in the vicinity of the site boundary.

2.2 Walkover

'At the time of the site walkover survey the site predominantly comprised pastureland for sheep and cattle and paddocks for keeping a horse in.

Park Farm was located within the central eastern site border. The farm comprised the farmhouse, which was a detached property with surrounding garden, access road, parking for vehicles and several barns clad in corrugated cement sheeting and timber. The barns were generally used for housing calves and for the storage of hay/straw. A lean-to provided shelter for a parked vehicle, wood store and general farming equipment. Three old 205l metal drums were stored against the lean-to. A milking station was located within the west of the farm. In-between the farm's buildings the surfacing consisted of asphalt and/or concrete, which appeared to be in a fairly worn condition.



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

An above ground heating oil tank was located within the front garden to the farmhouse. The tank appeared to be of single skin construction and had been placed on top of a concrete bund. No visual or olfactory evidence of hydrocarbon contamination was noted on the tank, bund or underlying ground. A fully integrated bunded above ground diesel storage tank was located adjacent to one of the farm buildings. Similarly, no evidence of hydrocarbon contamination was noted around the tank. Anecdotal information from one of the farm's tenants advised that they were not aware of any storage of petroleum having historically taken place at the farm.

A stream was located at the northern boundary of the site, which appeared to flow in a roughly west to east direction. The water visually appeared to be clear. Other drainage ditches located throughout the grounds of the farm contained water that visually appeared to be clear. A sheen was noted on the surface of the water within one of the surface drains, however this was considered to be a humic sheen rather than hydrocarbon contamination within the ditch. A large manure pile was located within the fields in close proximity to the farm buildings.

No significant evidence of contamination was observed during the site walkover. However, it is considered that there may be potential localised contamination associated with the storage of oil/diesel on site.'

The desk study report does not include a plan identifying the location/s of the above features.

Risk assessments in the previous reports identified the Park Farm site as an area where further intrusive investigation would be beneficial. GESL undertook a review of the available information combined with a walkover and identified a number of potentially contaminative features within the curtilage of the farm in the form of above ground fuel storage tanks, a former cesspit and septic tanks.

2.3 Geology

The BGS Geology of Britain viewer identifies that the natural geology across the site comprises bedrock of the Wittering Formation, with no overlying superficial strata. The Wittering Formation comprises sand, silt and clay. The BGS 1:50,000 series sheet 315 *Southampton* indicates that the Wittering Formation is underlain by the London Clay Formation (generally greyish clay interbedded with sand members).

It is likely that, as a result of its extended agricultural use, the majority of the site and the wider development area will be covered by a varied and sometimes significant thickness of topsoil. Some Made Ground may also be present locally as a result of previous uses.

2.4 Discussion

A consideration of the historic usage of the site does not identify any potential sources of bulk gas generation. The storage and/or disposal of animal waste, fuel storage with associated spillage, cess pit usage and filtration/release systems and other similar activities represent potential minor sources of gas generation.



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

3.0 PREVIOUS INVESTIGATIONS

Data from two phases of intrusive investigation were made available to GESL prior to the current phase of investigation, as presented in the 2017 BRD report and the 2021 Enzygo report. The initial investigation (2017 BRD) covered the larger development area, whereas the subsequent investigation (2021 Enzygo) focused on areas of uncertainty identified by BRD. The approximate locations of exploratory holes within or in the vicinity of Park Farm are indicated in Figure 4 below, and the ground conditions as described in the logs summarised within Table 2.

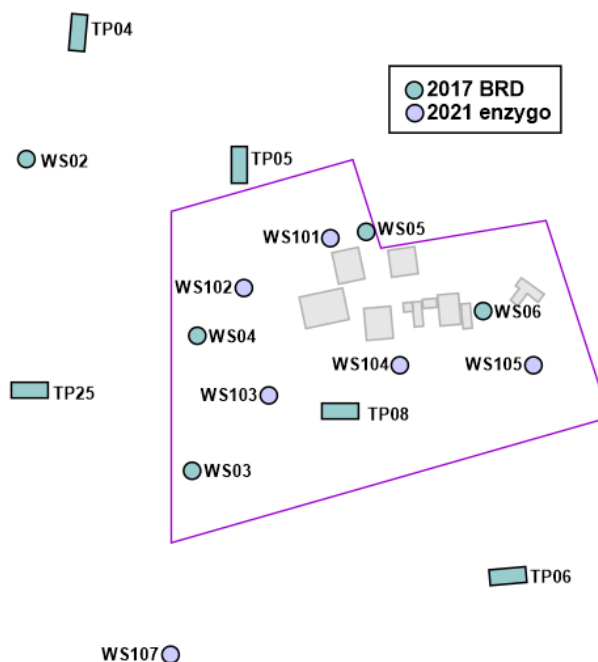


Figure 4: Approximate location of exploratory holes

Table 2: Summary of ground conditions

Reference	Ground Conditions
TP04	GL-0.4: MG/topsoil: grass over dark brown slightly gravelly slightly sandy silty clay with roots and occasional charcoal/clinker fragments, gravel is chert 0.4-1.0: grey mottled orange very silty CLAY with relict rootlets (WF) 1.0-2.5 (end): light grey occasionally mottled orange silty CLAY (WF) Slight seepage at 2.2m
TP05	GL-0.4: Topsoil: grass over dark brown slightly gravelly lightly sandy silty clay with roots, gravel is chert 0.4-1.7: light grey mottled orange silty CLAY with orange silty partings and rare gravel of chert (WF) 1.7-2.9 (end): light grey silty CLAY with grey and brown gravel of mudstone, becoming wet below 2.5m (WF) No groundwater encountered
TP06	GL-0.3: Topsoil: grass over dark brown slightly gravelly slightly sandy silty clay with roots, gravel is chert 0.3-1.0: light grey mottled orange silty CLAY with occasional gravel of chert and green sandy partings. Bed of brown mottled orange gravelly sandy clay at 0.7m (WF) 1.0-2.5 (end): brown mottled orange silty CLAY with orange sandy partings, becoming wet below 2.0m (WF) Groundwater ingress at 2.4m



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

Reference	Ground Conditions
TP08	GL-0.35: Topsoil: grass over dark brown slightly gravelly slightly sandy silty clay with roots, gravel is chert 0.35-0.8: orange and greenish grey, sandy, silty CLAY with occasional gravel of chert (WF) 0.8-1.5: pink CLAY with greenish silty slightly gravelly sand partings, gravel is flint (WF) 1.5-2.5 (end): dark pink and brown silty CLAY with orange sandy silt partings and pockets, becoming wet below 2.3m (WF) Slight seepage at 2.4m
TP25	GL-0.25: Topsoil: grass over dark brown slightly sandy silty clay with roots and rare gravel of chert 0.25-2.0: orange brown mottled greenish grey sandy silty CLAY with occasional gravel of chert, becoming grey below 1.5m (WF) 2.0-2.8 (end): thinly laminated orange, light grey and brownish pink silty CLAY (WF) Slight seepage at 1.1m, seepage at 2.0m
WS02	GL-0.4: Topsoil: grass over brown mottled orange brown sandy slightly gravelly silty clay with frequent rootlets, gravel is quartzite and chert 0.4-2.4: orange brown and light grey slightly sandy slightly gravelly CLAY, gravel is chert (WF) 2.4-3.7: orange brown slightly sandy silty CLAY with gravel of mudstone (WF) 3.7-5.45 (end): grey slightly sandy silty CLAY (LCF) Groundwater strike at 5.0m rising to 1.9m
WS03	GL-0.35: Topsoil: grass over brown mottled orange brown sandy slightly gravelly clay with frequent rootlets, gravel is chert and quartzite 0.35-1.7: orange brown and light grey slightly sandy slightly gravelly CLAY, gravel is chert (WF) 1.7-3.2: orange brown and pinkish brown slightly sandy silty CLAY with gravel of mudstone (WF) 3.2-5.45 (end): light grey slightly sandy silty CLAY (LCF) Groundwater strike at 4.0m rising to 1.2m Standpipe installed, response zone 1.0m to 4.0m
WS04	GL-0.35: Topsoil: grass over brown mottled orange brown sandy slightly gravelly clay with frequent rootlet, gravel is chert and quartzite 0.35-1.7: orange brown and light grey slightly sandy slightly gravelly CLAY, gravel is chert and quartzite (WF) 1.7-4.1: orange brown pinkish brown and reddish brown slightly sandy silty CLAY with gravel of mudstone (WF) 4.1-5.45 (end): light grey slightly sandy silty CLAY (LCF) No groundwater encountered
WS05	GL-0.2: MG: dark brown sandy slightly gravelly clay, gravel is chert with occasional brick and charcoal fragments 0.2-1.2: orange brown and light grey slightly sandy slightly gravelly CLAY, gravel is chert and quartzite (WF) 1.2-2.1: light pinkish brown slightly sandy silty CLAY (WF) 2.1-3.7: orange brown pinkish brown and reddish brown slightly sandy silty CLAY with gravel of mudstone (WF) 3.7-5.45 (end): grey slightly sandy silty CLAY (LCF) No groundwater encountered Standpipe installed, response zone 1.0m to 4.0m
WS06	GL-0.25: MG dark brown and orange brown sandy slightly gravelly clay with occasional rootlets, gravel is chert and quartzite with occasional brick and tarmac fragments 0.25-2.0: orange brown and brown slightly sandy slightly gravelly CLAY, gravel is chert and quartzite, becoming orange brown and light grey below 0.6m (WF) 2.0-3.5: pinkish brown slightly sandy silty CLAY (WF) 3.5-4.45 (end): brownish purple silty CLAY, becoming grey below 4.4m (WF) Slight seepage at 1.5m Standpipe installed, response zone 1.0m to 4.0m



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

Reference	Ground Conditions
WS101	GL-0.3: MG grass over dark brown mottled orange brown gravelly sandy silty clay with frequent rootlets, gravel is flint and rare brick fragments 0.3-0.8: yellow brown mottled grey and yellow brown occasionally slightly gravelly sandy silty CLAY with occasional local rootlets and rare gravel-sized ashy deposits, gravel is flint 0.8-1.5: creamish brown and light green grey mottled orange and yellow brown slightly sandy silty CLAY with occasional rootlets 1.5-2.7: light brown occasionally mottled yellow brown slightly sandy silty CLAY 2.7-4.9: creamish brown mottled light grey and yellow brown locally slightly sandy silty CLAY, becoming light brown mottled orange and yellow below 4.0m 4.9-5.45 (end): grey slightly sandy silty CLAY No groundwater encountered Standpipe installed, response zone 1.0m to 5.0m
WS102	GL-0.4: Topsoil: grass over dark brown mottled orange brown gravelly sandy silty clay with frequent rootlets, gravel is flint 0.4-0.75: yellow brown mottled grey occasionally slightly gravelly sandy silty CLAY with occasional rootlets and rare gravel-sized ashy deposits, gravel is flint 0.75-2.0: creamish brown and light green grey mottled orange and yellow brown slightly sandy silty CLAY with occasional rootlets 2.0-2.45: light green mottled yellow brown slightly sandy silty CLAY 4.7-5.45 (end): grey locally slightly sandy silty CLAY No groundwater encountered
WS103	GL-0.35: MG/topsoil: grass over dark brown mottled orange brown gravelly sandy silty clay with frequent rootlets, gravel is flint and rare brick fragments 0.35-0.7: yellow brown mottled grey slightly gravelly sandy silty CLAY with occasional rootlets, gravel is flint 0.7-1.7: light greenish grey mottled yellow brown slightly gravelly sandy silty CLAY, gravel is flint. Becoming light brown mottled yellow brown below 1.0m, becoming light green mottled brown and very sandy below 1.6m 1.7-3.9: light brown mottled yellow brown sandy silty CLAY 3.9-5.45: grey mottled dark grey slightly sandy silty CLAY No groundwater encountered Standpipe installed, response zone 0.85m to 4.85m
WS104	GL-0.2: Topsoil: grass over dark brown mottled orange brown gravelly sandy silty clay with frequent rootlets, gravel is flint 0.2-0.45: yellow brown mottled grey slightly gravelly sandy silty CLAY with frequent rootlets and occasional black staining, gravel is flint 0.45-1.6: light green mottled yellow brown slightly gravelly sandy silty CLAY with occasional rootlets, gravel is flint 1.6-1.9: cream mottled red brown locally slightly sandy silty CLAY 1.9-2.5: cream brown mottled dark grey, yellow and occasionally light green locally sandy silty CLAY 2.5-3.0: dark brown mottled cream, dark grey, yellow and white slightly sandy silty CLAY 3.0-5.45 (end): grey mottled dark grey silty CLAY, occasional gravel of lignite and claystone No groundwater encountered

**DETAILED QUANTITATIVE GAS RISK ASSESSMENT**

Reference	Ground Conditions
WS105	GL-0.3: MG grass over dark brown mottled orange brown gravelly sandy silty clay with frequent rootlets, gravel is flint with occasional brick fragments and ash 0.3-0.55: brown sandy silty CLAY with frequent rootlets 0.55-0.75: light green mottled yellow brown slightly gravelly sandy silty CLAY with occasional rootlets, gravel is flint 0.75-1.6: light green yellow brown sandy silty CLAY 1.6-3.5: cream mottled yellow brown locally sandy silty CLAY, becoming locally slightly sandy silty CLAY below 2.85m 3.5-4.45 (end): grey mottled dark and light grey locally slightly sandy silty CLAY No groundwater encountered Standpipe installed, response zone 1.0m to 4.0m
WS107	GL-0.35: MG grass over dark brown mottled orange brown gravelly sandy silty clay with frequent rootlets, gravel s flint with rare brick fragments, surface water seeping into borehole 0.35-0.9: yellow brown light greenish grey slightly gravelly sandy silty CLAY with occasional rootlets, gravel is flint 0.9-1.55: light greenish grey mottled yellow brown sandy silty CLAY 1.55-2.7: light greenish grey mottled yellow brown sandy SILT occasionally tending to a sandy silty CLAY, becoming mottled orange brown below 2.6m 2.7-3.0: light grey sandy silty CLAY occasionally tending to a sandy SILT 3.0-3.9: light grey silty SAND 3.9-4.0: light grey sandy silty CLAY 4.0-4.9: light grey silty SAND 4.9-5.45 (end): light grey sandy silty CLAY No groundwater encountered Standpipe installed, response zone 0.8m to 4.8m
Depth is metres below ground level (mBGL) MG is Made Ground WF is Wittering Formation as recorded on logs LCF is London Clay Formation as recorded on logs	

Ground conditions identify a negligible thickness of Made Ground (maximum 0.4m), generally as topsoil, with occasional anthropogenic inclusions in the form of clinker, ash or brick fragments. Ash and clinker comprise complex organic materials that are slow to biodegrade, and do not represent a potential source of bulk gas generation with resultant advective flow. Roots/rootlets were recorded in all locations. These are also complex organic materials.

3.1 Visual/olfactory indicators

Occasional black staining was recorded within WS104 between 0.2mBGL and 0.45mBGL. No olfactory indicators were recorded in any exploratory hole.

3.2 Organic contaminants - soils

During the 2017 investigation, only one sample was identified as containing polyaromatic hydrocarbons (PAH) above the lower limit of detection. The sample was taken from WS06 at 0.2mBGL from the Made Ground and contained fragments of tarmac. During the 2021 investigation, no exceedances were recorded in soil samples, including one taken from 0.2mBGL in WS104.

Analysis for organic contaminants undertaken during both site investigations identified no contaminants with concentrations of concern in terms of the potential for bulk gas generation.



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

No groundwater samples were analysed during either investigation.

3.3 Total organic carbon

The Environment Agency¹ has developed waste acceptance criteria (WAC) with which to identify soils in terms of waste category. In relation to the potential for gas generation, the key criteria included within the WAC is total organic carbon (TOC). In order for material to be designated as inert, it must demonstrate TOC of <3%. TOC gives a crude and conservative estimate of the amount of biodegradable material in soil or waste. It includes both readily available carbon that degrades relatively quickly, and non-readily available carbon that will breakdown and degrade very slowly.

Thirteen samples of Made Ground were analysed for TOC, with an average result of 2.3%. As such, it can be concluded that the organic content within the Made Ground does not represent a potential source of bulk gas generation. It is likely that the slightly elevated average concentration is a result of the long-term use of the site for livestock farming.

3.4 Natural soils

The recorded natural deposits comprised the predominantly clay soils of the Wittering Formation. The London Clay Formation (also predominantly clay) was recorded towards the base of some exploratory holes. Both formations are considered highly impermeable stratum with occasional lenses of more permeable material. Neither formation represents a potential source of bulk soil gases.

3.5 Discussion

A negligible thickness of Made Ground in the form of topsoil with occasional anthropogenic inclusions has been recorded within exploratory holes located across the site. Complex organics in the form of roots/rootlets, occasional ash and clinker have been recorded, but no simple organics. Organic contaminants have not been identified with the exception of relatively low concentrations in a single sample, considered to be associated with fragments of tarmac. Total organic carbon concentrations within Made Ground samples average at 2.3%, which is not indicative of a potential source of bulk gas generation.

In summary, no potential source of bulk gas generation was identified in the initial two phases of site investigation.

¹ *Waste acceptance at landfills – guidance on waste acceptance procedures and criteria*. Environment Agency, 2010.

DETAILED QUANTITATIVE GAS RISK ASSESSMENT

4.0 CURRENT SITE INVESTIGATION

Risk assessments in the previous reports identified the Park Farm site as an area where further intrusive investigation would be beneficial. GESL undertook a review of the available information combined with a walkover and identified a number of potentially contaminative features within the curtilage of the farm. Based on these findings, the recent investigation was focused on potential sources of soil and groundwater contamination (and by extension, gases or vapours) in the form of above ground fuel storage tanks, a former cesspit and septic tanks. It comprised the construction of five boreholes, with standpipes installed within each.

WS201: targeted a steel single skin heating oil AST raised on brick piers to the northwest of the farmhouse, estimated volume 1,200 litres, no staining or leakage evident.

WS202: targeted a diesel AST observed to the northeast of the two easternmost barns. The tank was approximately 2,000 litres in volume, self-bunded and constructed from plastic. Some staining on the tank was noted below the access panel on the front of the tank. It is understood from the farmer that the tank replaced a steel single skin AST which was present from the 1950s.

WS203: targeted a septic tank located in the field to the south of the farmyard, which was understood to be in current usage and to discharge to a ditch on the southern field boundary.

WS204: targeted a former cesspit to the west of the farmhouse identified by the farmer. This overflowed into a septic tank further west (targeted by WS205) which discharged to a drain running through the yard to a ditch to the north of the farmyard.

The approximate locations of the exploratory holes are illustrated on Figure 5 below, together with the associated potential sources. The ground conditions as described in the logs are summarised within Table 3.

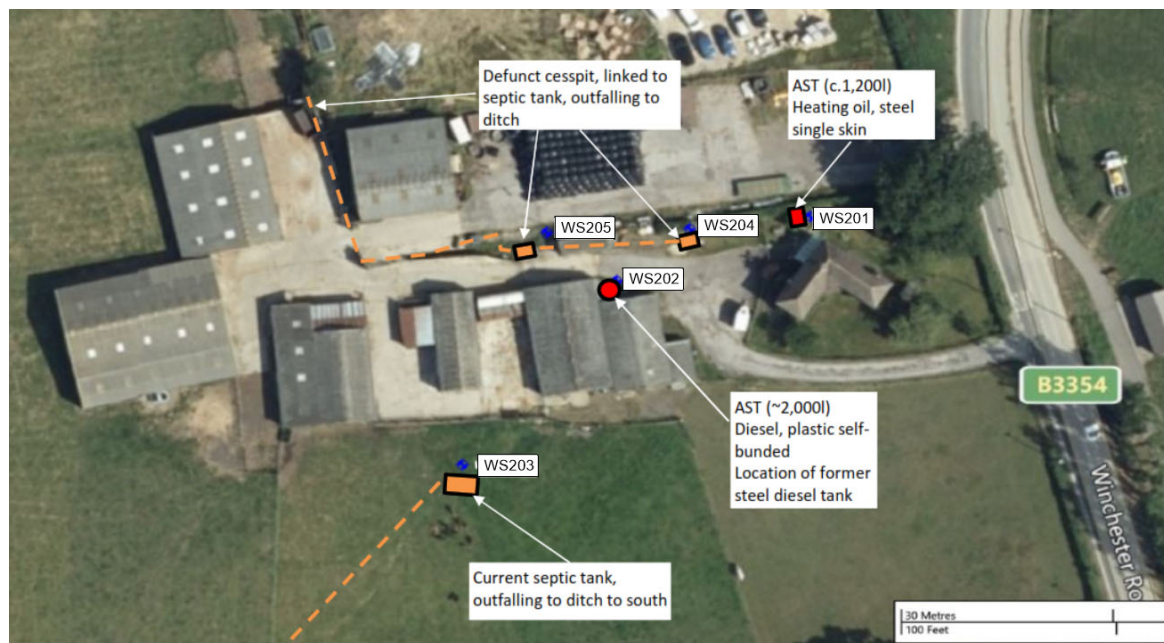


Figure 5: Approximate location of 2022 exploratory holes and targeted features



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

Table 3: Summary of ground conditions

Reference	Ground Conditions
WS201	GL-0.2: Topsoil: grass over brown very silty slightly gravelly sand with some rootlets 0.2-1.25: mottled yellow brown, orange and light grey slightly sandy CLAY, occasional roots (WF) 1.25-2.2: mottled yellow brown, orange and light grey CLAY (WF) 2.2-2.75: pale grey occasionally brown and orange CLAY (WF) 2.75-2.85: brown and dark brown silty CLAY (WF) 2.85-3.6: grey brown with occasional orange pockets CLAY (WF) 3.6-5.0 (end): grey slightly silty CLAY (LCF) No groundwater encountered Standpipe installed, response zone 1.0m to 5.0m
WS202	GL-0.2: Topsoil: grass over dark brown sandy slightly gravelly CLAY with rare rootlets, faint diesel odour 0.2-2.2: mottled greenish grey, brown and orange brown sandy CLAY, mild diesel odour, greenish hue possible staining, dead root at 1.0m (WF) 2.2-3.5: light grey and yellow brown CLAY, faint diesel odour (WF) 3.5-4.0: mottled light grey and yellow brown CLAY (WF) 4.0-4.6: no recovery 4.6-5.0 (end): brown CLAY (LCF) Groundwater strike at 2.0m rising to 1.2m after 20 minutes Standpipe installed, response zone 1.0m to 5.0m
WS203	GL-0.3: MG grass over brown silty slightly gravelly sand, gravel includes brick and lime mortar fragments 0.3-1.5: brown, yellow brown and orange brown very sandy slightly gravelly CLAY, gravel is flint (WF) 1.5-1.9: orange with light grey mottling slightly sandy CLAY (WF) 2.8-3.4: brown to light brown CLAY (WF) 3.4-3.6: dark brown very gravelly CLAY, gravel is mudstone (WF) 3.6-4.0: grey CLAY (LCF) 4.0-4.4: no recovery 4.4-5.0 (end): grey CLAY (LCF) Groundwater strike at 1.45m rising to 1.3m after 20 minutes Standpipe installed, response zone 1.0m to 5.0m
WS204	GL-0.2: Topsoil: grass over brown silty gravelly sand with occasional rootlets 0.2-1.8: grey brown and orange sandy slightly gravelly CLAY, gravel is flint (WF) 1.8-2.3: mottled orange and grey silty sandy slightly gravelly CLAY, gravel is ironstone (WF) 2.3-3.7: yellow brown and light grey CLAY (WF) 3.7-3.8: dark brown and grey CLAY with frequent gravel of mudstone (WF) 3.8-4.1: yellow brown and light grey CLAY (WF) 4.1-5.0 (end): grey CLAY with rare fine brown partings (LCF) No groundwater encountered Standpipe installed, response zone 1.0m to 5.0m
WS205	GL-0.15: Topsoil: grass over brown silty slightly gravelly sand with occasional rootlets 0.15-1.3: grey brown and orange sandy CLAY (WF) 1.3-2.3: mottled orange and light grey slightly sandy CLAY (WF) 2.3-3.0: mottled light grey, orange brown and brown CLAY (WF) 3.0-3.6: no recovery 3.6-4.0: brown and dark brown CLAY with frequent gravel of mudstone (WF) 4.0-4.7: no recovery 4.7-5.0 (end): grey CLAY (LCF) Groundwater strike at 1.15m rising to 0.9m after 20 minutes Standpipe installed, response zone 1.0m to 5.0m

**DETAILED QUANTITATIVE GAS RISK ASSESSMENT**

Reference	Ground Conditions
	Depth is metres below ground level (mBGL) MG is Made Ground WF is Wittering Formation as recorded on logs LCF is London Clay Formation as recorded on logs

Ground conditions identify a negligible thickness of Made Ground (maximum 0.3m), generally as topsoil, with occasional anthropogenic inclusions in the form of brick and lime mortar fragments.

4.1 Visual/olfactory indicators

A faint to mild diesel odour was recorded in WS202 from ground level to 3.5mBGL. Potential staining in the form of a greenish hue was also recorded between 0.2mBGL and 2.2mBGL. WS202 targeted a location where an above ground diesel storage tank has been present reportedly since the 1950s to the current day.

4.2 Organic contaminants - soils

Ten soil samples were analysed for a broad suite of contaminants.

In WS202, where diesel odour was recorded, three samples were analysed, from 0.1mBGL, 1.0mBGL and 3.7mBGL. Of these, only the sample from 1.0m recorded concentrations of petroleum hydrocarbons above the lower limit of detection, with a total petroleum hydrocarbon (TPH) concentration of 1800mg/kg. When broken into aliphatic/aromatic and chain length, none of the recorded concentrations represents a risk to the development in terms of vapour ingress/inhalation. It should, however, be noted that the results recorded in WS202 could be representative of a larger area of soils impacted by hydrocarbons, which (after demolition) may benefit from further investigation in terms of human health due to the sensitivity of the proposed development.

No other contaminants with concentrations of concern in terms of the potential for bulk gas generation were identified in any samples.

4.3 Organic contaminants – groundwater

A groundwater sample was obtained from WS202 and analysed for a broad suite of contaminants. Organic compounds indicative of fuel contamination were identified at above lower level of detection concentrations in the form of Isopropylbenzene, n-propylbenzene and 1,2,4-trimethylbenzene. The recorded concentrations are not sufficient to represent a potential source of either bulk gas generation or vapours, however this could be representative of a larger area of groundwater impacted by hydrocarbons. Given the nature of the natural geology across the footprint of the site (predominantly impermeable clays), and the likely source of the contamination (a relatively small diesel AST) it is considered unlikely that this would be extensive.

4.4 Total organic carbon

Five samples of Made Ground were analysed for TOC (2022 investigation), with an average result of 1.65%. This is in line with the analytical results from the previous investigations and indicates that the organic content within the Made Ground does not represent a potential source of bulk gas generation.

4.5 Discussion

A limited thickness of Made Ground (≤ 400 mm) in the form of topsoil with occasional anthropogenic inclusions has been recorded in exploratory holes located across the site. Complex organics in the form of roots/rootlets,



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

occasional ash and clinker have been recorded, but no simple organics. Organic contamination in the form of hydrocarbons has been identified within soils in one location, however it is not considered that the identified contaminants at the recorded concentrations represent a potential source of bulk gas or vapour generation.

In summary, no potential source of bulk gas generation has been identified.



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

5.0 PRELIMINARY QUALITATIVE RISK ASSESSMENT

Current UK guidance identifies the first steps of the contaminated land risk assessment process as follows:

Step 1: Define conceptual site model

Step 2: Develop risk model and qualitative assessment

Step 3: Pollutant linkage identified?

The risk model develops the conceptual model to identify potential sources of contamination, receptors that could be affected, and possible pathways by which the contaminant could reach the receptors and cause harm.

5.1 Sources

No potential source of bulk gas generation has been identified within the site boundary or near vicinity due to historic usage.

There is the potential for residual organic material to be present from the long-term use of the site as a livestock farm. This may be in the form of manure, spilled or leaked fuel/fuel oil, cess pits or slurry pits. In residual form, these do not represent a source of bulk gas generation, however gas may have been generated from these organic sources over an extended period of time and may be stored within less permeable soils and/or dissolved in groundwater. This will then represent a 'reservoir' of gas which will migrate outwards in all directions by diffusive mechanism along a continuum that equates to atmospheric concentrations at the ground surface and reaches a soil equilibrium at a distance from the source. Over time, various changes will occur, with the central core of the reservoir reducing in size as oxygen infiltrates, concentrations gradually reducing, and methane being oxidised to carbon dioxide.

5.2 Pathways

Gas primarily migrates via either pressure driven (advective) flow or via concentration driven (diffusive) flow. The predominant mechanism for migration of gases stored within soils and groundwater such as those which are likely to be on this site is diffusive, with no driving pressure. As such, gas will diffuse through the soils forming a continuum between the source and ground level, with only minor concentrations of gas reaching ground level, and no perceivable flow. The majority of gas will remain trapped in the soil pores/sorbed to soil particles or dissolved in groundwater.

5.3 Receptors

Receptors at risk from gas include:

- Construction workers (during development);
- Occupants of the new buildings; and
- The new buildings' infrastructure/services.

5.4 Ground model

A simplistic ground model of the site based on the information presented above is illustrated in Figure 6 below.



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

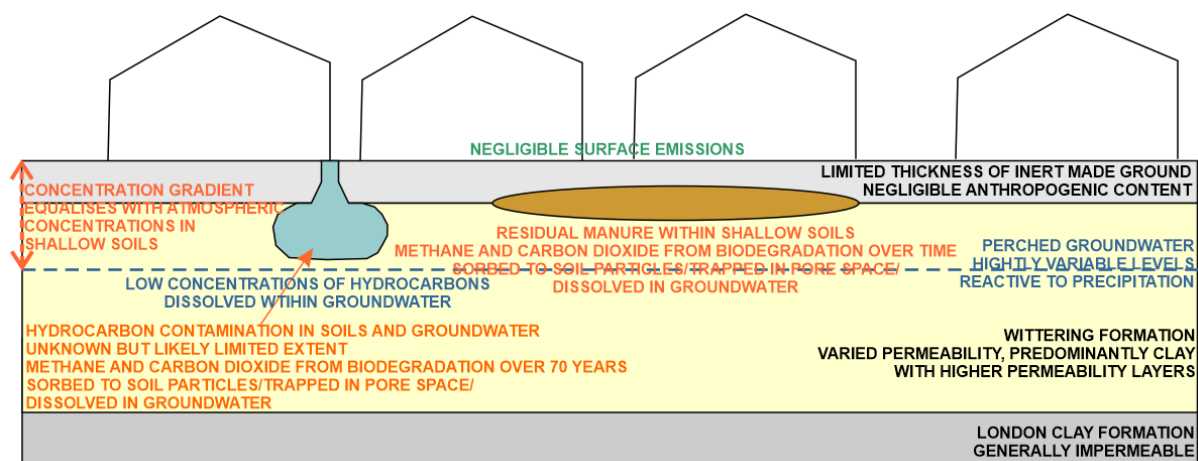


Figure 6: Simplistic ground model

In summary, potential sources of gas were identified in the form of:

1. Limited and localised hydrocarbon contamination within soils and groundwater, biodegradation products in the form of methane and carbon dioxide within soils and groundwater. Predominantly carbon dioxide with the exception of the anaerobic centre.
2. Residual organic material associated with manure, within shallow soils, biodegradation products in the form of methane and carbon dioxide within soils and groundwater. Predominantly carbon dioxide due to lack of anaerobic centre.

**DETAILED QUANTITATIVE GAS RISK ASSESSMENT****6.0 PRELIMINARY QUANTITATIVE RISK ASSESSMENT**

Although no significant potential sources of ground gas were identified during the desk study or site investigations, gas monitoring was undertaken by both BRD and Enzygo. No significant gas concentrations were recorded across the majority of the larger development site, however elevated concentrations of carbon dioxide were recorded within the Park Farm area and as a result it was recommended that gas protection measures should be installed in this development zone.

Three additional monitoring events have been undertaken by GESL in the targeted standpipes installed during the recent site investigation.

These results are summarised in Table 4 below.

Table 4: Summary of gas monitoring results

ID	Date	CH ₄ (%v/v)	CO ₂ (%v/v)	O ₂ (%v/v)	Flow (l/hr)	Atmospheric pressure (mB)	Groundwater (mBGL)
WS3	17/08/17	0.1	2.7	18.2	-0.1	1011	0.78
	23/08/17	0.1	2.3	18.6	0.0	1012	0.75
	01/09/17	0.0	2.1	17.7	0.0	1018	0.82
	07/09/17	0.0	1.9	19.0	0.5	1014	0.98
	14/09/17	0.0	1.7	19.6	-0.3	1006	0.97
WS5	08/08/17	0.1	11.8	13.1	0.3	1012	2.36
	17/08/17	0.0	10.4	14.6	-0.3	1010	1.20
	23/08/17	0.0	4.5	18.7	-0.2	1012	1.36
	01/09/17	0.0	4.6	17.8	0.3	1019	2.22
	07/09/17	0.0	11.8	15.3	0.0	1014	2.11
	14/09/17	0.0	11.5	16.3	0.4	1007	1.57
WS6	08/08/17	NR	NR	NR	NR	NR	0.98
	17/08/17	0.0	0.3	19.7	-0.3	1010	0.92
	23/08/17	0.0	0.7	18.8	-0.4	1011	0.90
	01/09/17	0.0	9.3	5.2	0.0	1019	2.68
	07/09/17	0.0	8.3	7.0	-0.1	1014	1.17
	14/09/17	0.0	7.8	8.1	0.0	1007	1.14
	05/02/21	<0.1	5.2	9.1	<0.1	1006	0.23
	12/02/21	<0.1	6.6	8.8	<0.1	1027	0.81
	19/02/21	<0.1	5.6	12.9	<0.1	998	0.53
	26/02/21	<0.1	6.6	11.5	<0.1	1035	0.76
WS101	22/01/21	<0.1	12.4	8.4	<0.1	986	0.15
	29/01/21	<0.1	16.7	6.1	<0.1	999	0.12
	05/02/21	<0.1	17.3	6.4	<0.1	1006	0.12
	12/02/21	<0.1	16.9	5.2	<0.1	1027	0.72
	19/02/21	<0.1	17.2	5.7	<0.1	998	0.42
	26/02/21	<0.1	16.2	5.4	<0.1	1035	0.43
WS103	22/01/21	<0.1	1.6	20.8	<0.1	986	0.32
	29/01/21	<0.1	1.2	20.1	<0.1	999	0.21
	05/02/21	<0.1	3.7	17.4	<0.1	1006	0.10
	12/02/21	<0.1	5.3	12.2	<0.1	1027	0.25
	19/02/21	<0.1	5.2	13.1	<0.1	998	0.10
	26/02/21	<0.1	4.8	14.5	<0.1	1035	0.29



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

ID	Date	CH ₄ (%v/v)	CO ₂ (%v/v)	O ₂ (%v/v)	Flow (l/hr)	Atmospheric pressure (mB)	Groundwater (mBGL)
WS105	22/01/21	<0.1	5.3	17.1	<0.1	986	0.51
	29/01/21	<0.1	5.6	17.9	<0.1	999	0.12
	05/02/21	<0.1	1.8	10.7	<0.1	1006	0.11
	12/02/21	<0.1	1.7	19.4	<0.1	1027	0.69
	19/02/21	<0.1	1.1	18.1	<0.1	998	0.51
	26/02/21	<0.1	1.6	17.9	<0.1	1035	0.56
WS201	26/05/22	<0.1	2.8	18.3	<0.1	1023	2.98
	08/06/22	<0.1	3.5	17.4	<0.1	1002	2.08
	15/06/22	<0.1	3.4	18.2	<0.1	1015	1.97
WS202	26/05/22	4.2	3.6	0.2	<0.1	1022	1.45
	08/06/22	4.5	5.9	0.4	<0.1	1002	1.00
	15/06/22	4.6	4.9	0.2	<0.1	1016	1.42
WS203	26/05/22	<0.1	2.8	19.3	<0.1	1023	1.19
	08/06/22	<0.1	4.0	18.1	<0.1	1002	1.19
	15/06/22	<0.1	3.2	19.1	<0.1	1015	1.27
WS204	26/05/22	<0.1	1.8	19.1	<0.1	1022	3.51
	08/06/22	<0.1	1.4	19.6	<0.1	1002	1.90
	15/06/22	<0.1	1.1	19.8	<0.1	1015	1.65
WS205	26/05/22	0.2	1.2	17.9	<0.1	1023	0.88
	08/06/22	<0.1	0.4	20.6	<0.1	1002	0.66
	15/06/22	<0.1	3.2	19.5	<0.1	1016	0.59

The methodology of the gas monitoring undertaken by BRD and Enzygo is not known. During GESL's monitoring, each standpipe was monitored over a period of at least 180 seconds on each monitoring event. The concentrations of methane, carbon dioxide and oxygen recorded generally increased or decreased respectively over this period. The values presented in the table above are the highest (flow rate, concentration of carbon dioxide/methane) or lowest recorded (concentration of oxygen).

All standpipes recorded negligible concentrations of methane on all monitoring events, with the exception of WS202, where a maximum concentration of 4.6% methane was recorded.

Marginally elevated concentrations of carbon dioxide were recorded in WS5, WS6, WS101, WS103, WS105 and WS202 on a number of occasions, with a maximum recorded concentration of 17.3% in WS101.

Recorded flow rates were predominantly <0.1l/hr or negative, with positive flow rates recorded only in WS3 (single occasion, 0.5l/hr) and WS5 (three occasions, 0.3l/hr, 0.4l/hr, 0.3l/hr). Negative flow rates were also recorded within WS3 and WS5. This pattern of flow across the site demonstrates that no advective flow is occurring.

Trace gases in the form of carbon monoxide, hydrogen sulphide and volatile organic compounds were recorded during some monitoring events, however only negligible concentrations were identified.

Figure 7 below illustrates the approximate location of all monitoring locations, with those where elevated concentrations of CO₂ and CH₄ were recorded identified.

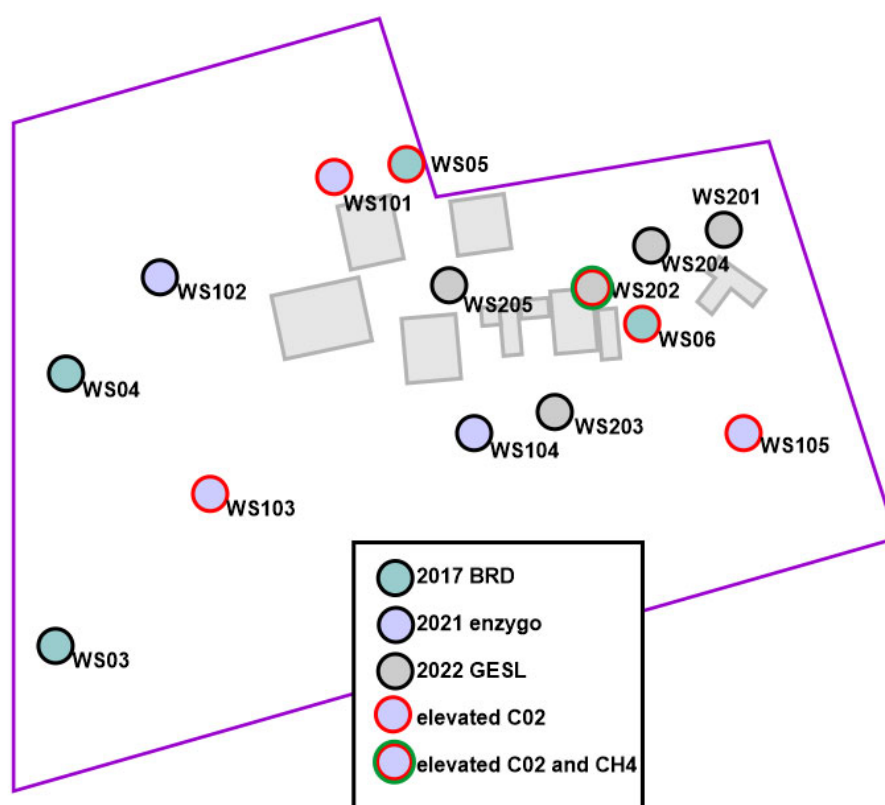


Figure 7: Standpipe locations and elevated concentrations

6.1 Preliminary classification of gas regime

BS8485² details the use of the system proposed by Wilson and Card to aid interpretation of gas monitoring results in terms of actual risk. The method uses both concentration and flow rates to define a characteristic situation for the site. Initially a hazardous gas flow rate (HGFR) is derived, representative of the actual flow of gas from the borehole. This, combined with a consideration of other factors such as maximum concentration, is used to characterise the site. The higher the classification the greater the theoretical risk posed by the presence of gas. The classification system as detailed in BS8485 is presented in Table 5.

Table 5: Modified Wilson and Card approach after BS8485

Characteristic situation (CS)	Risk classification	HGFR l/hr threshold
1	Very low risk	<0.07
2	Low risk	<0.7
3	Moderate risk	<3.5
4	Moderate to high risk	<15

Additional factors for consideration are also provided in BS8485:

CS1: **Typically**, methane <1% and/or carbon dioxide <5%, otherwise **consider** increase to CS2.

CS2: Borehole flow rate not to exceed 70l/hr, otherwise consider increase to CS3.

² BS8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new building. British Standards Institution, 2019

**DETAILED QUANTITATIVE GAS RISK ASSESSMENT**

The system provides guidance on classification based on HGFR, but also typical maximum concentrations of carbon dioxide and/or methane. It also relies on a comprehensive understanding of the source, and the behaviour of gases within soils beneath the site, to enable professional judgement to be applied in terms of whether the maximum concentrations recorded are indicative of a need to increase the classification indicated by the HGFR.

BS8485 specifies that HGFRs should be calculated based on steady state flow and concentration. As flow and concentration had not stabilised on all monitoring events in all standpipes, HGFRs for both methane and carbon dioxide have been calculated based on the maximum concentration and flow rate recorded in each standpipe during any individual monitoring event. These are presented in Table 6 below together with the associated characteristic situation.

Table 6: Preliminary classification of gas regime

ID	Flow ² (l/hr)	CH ₄ ³ (%)	CO ₂ ³ (%)	HGFR CH ₄ (l/hr)	HGFR CO ₂ (l/hr)	CS ¹
WS3	0.1	0.1	2.7	0.0001	0.0027	CS1
	0.1	0.1	2.3	0.0001	0.0023	CS1
	0.1	0.1	2.1	0.0001	0.0021	CS1
	0.5	0.1	1.9	0.0005	0.0095	CS1
	0.1	0.1	1.7	0.0001	0.0017	CS1
WS5	0.1	0.1	11.8	0.0001	0.0118	CS1 (CS2) ⁴
	0.1	0.1	10.4	0.0001	0.0104	CS1 (CS2) ⁴
	0.1	0.1	4.5	0.0001	0.0045	CS1
	0.3	0.1	4.6	0.0003	0.0138	CS1
	0.1	0.1	11.8	0.0001	0.0118	CS1 (CS2) ⁴
	0.4	0.1	11.5	0.0004	0.0460	CS1 (CS2) ⁴
WS6	0.1	0.1	0.3	0.0001	0.0003	CS1
	0.1	0.1	0.7	0.0001	0.0007	CS1
	0.1	0.1	9.3	0.0001	0.0093	CS1 (CS2) ⁴
	0.1	0.1	8.3	0.0001	0.0083	CS1 (CS2) ⁴
	0.1	0.1	7.8	0.0001	0.0078	CS1 (CS2) ⁴
	0.1	0.1	5.2	0.0001	0.0052	CS1 (CS2) ⁴
	0.1	0.1	6.6	0.0001	0.0066	CS1 (CS2) ⁴
	0.1	0.1	5.6	0.0001	0.0056	CS1 (CS2) ⁴
	0.1	0.1	6.6	0.0001	0.0066	CS1 (CS2) ⁴
WS101	0.1	0.1	12.4	0.0001	0.0124	CS1 (CS2) ⁴
	0.1	0.1	16.7	0.0001	0.0167	CS1 (CS2) ⁴
	0.1	0.1	17.3	0.0001	0.0173	CS1 (CS2) ⁴
	0.1	0.1	16.9	0.0001	0.0169	CS1 (CS2) ⁴
	0.1	0.1	17.2	0.0001	0.0172	CS1 (CS2) ⁴
	0.1	0.1	16.2	0.0001	0.0162	CS1 (CS2) ⁴
WS103	0.1	0.1	1.6	0.0001	0.0016	CS1
	0.1	0.1	1.2	0.0001	0.0012	CS1
	0.1	0.1	3.7	0.0001	0.0037	CS1
	0.1	0.1	5.3	0.0001	0.0053	CS1 (CS2) ⁴
	0.1	0.1	5.2	0.0001	0.0052	CS1 (CS2) ⁴
	0.1	0.1	4.8	0.0001	0.0048	CS1
WS105	0.1	0.1	5.3	0.0001	0.0053	CS1 (CS2) ⁴
	0.1	0.1	5.6	0.0001	0.0056	CS1 (CS2) ⁴
	0.1	0.1	1.8	0.0001	0.0018	CS1
	0.1	0.1	1.7	0.0001	0.0017	CS1
	0.1	0.1	1.1	0.0001	0.0011	CS1
	0.1	0.1	1.6	0.0001	0.0016	CS1



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

ID	Flow ² (l/hr)	CH ₄ ³ (%)	CO ₂ ³ (%)	HGFR (l/hr) CH ₄	HGFR (l/hr) CO ₂	CS ¹
WS201	0.1	0.1	2.8	0.0001	0.0028	CS1
	0.1	0.1	3.5	0.0001	0.0035	CS1
	0.1	0.1	3.4	0.0001	0.0034	CS1
WS202	0.1	4.2	3.6	0.0042	0.0036	CS1 (CS2) ⁴
	0.1	4.5	5.9	0.0045	0.0059	CS1 (CS2) ⁴
	0.1	4.6	4.9	0.0046	0.0049	CS1 (CS2) ⁴
WS203	0.1	0.1	2.8	0.0001	0.0028	CS1
	0.1	0.1	4.0	0.0001	0.0040	CS1
	0.1	0.1	3.2	0.0001	0.0032	CS1
WS204	0.1	0.1	1.8	0.0001	0.0018	CS1
	0.1	0.1	1.4	0.0001	0.0014	CS1
	0.1	0.1	1.1	0.0001	0.0011	CS1
WS205	0.1	0.2	1.2	0.0002	0.0012	CS1
	0.1	0.1	0.4	0.0001	0.0004	CS1
	0.1	0.1	3.2	0.0001	0.0032	CS1
1. CS is Characteristic Situation 2. Where maximum recorded flow is negative or <0.1l/hr, 0.1 l/hr has been used as recommended in BS8485 3. Where maximum recorded concentration is <0.1%, 0.1% has been used as recommended in BS8485 4. Where the HGFRs indicate CS1 but the concentrations indicate consideration of CS2, (CS2) is stated						

It can be seen that, based on HGFRs, all standpipes identified a Characteristic Situation 1 (CS1) classification on all monitoring events, with negligible flow rates and negligible or marginally elevated concentrations resulting in very low HGFRs. If concentrations are considered, guidance indicates that a number of monitoring events should **potentially** be considered indicative of CS2 conditions. This consideration requires an understanding of the source-pathway-receptor scenario across the site.

DETAILED QUANTITATIVE GAS RISK ASSESSMENT

7.0 DETAILED RISK ASSESSMENT

No viable source of bulk gas generation has been identified through desk study or intrusive investigation. Gas monitoring has identified that hazardous gas flow rates are indicative of characteristic situation 1 (CS1) conditions, however elevated concentrations were recorded and as such further consideration is required.

With the exception of WS202, elevated concentrations of methane were not recorded in any standpipe on any monitoring event. The other standpipes where a consideration of increasing to CS2 is required due to elevated concentrations of carbon dioxide can be separated into those which had fully submerged response zones during all monitoring events, and those which had exposed response zones during at least one monitoring event (WS6 only).

7.1 WS3, WS101, WS103, WS105 and WS205

The response zones of WS3, WS101, WS103, WS105 and WS205 were fully submerged during all monitoring events and as such the results cannot be considered as representative of the actual gas regime beneath the site. However, the results are useful in that they can provide an indication of gases dissolved within groundwater.

The sole source of gas in the headspace of a standpipe with a fully submerged response zone is from gases dissolved in groundwater. Whilst gases partitioning in and out of groundwater within an open soil structure will form a diffusive continuum between the surface of the groundwater and the ground surface, gases that partition out of groundwater within a sealed standpipe, above the limit of the response zone, will form an equilibrium within the standpipe. This is simply illustrated in Figure 8.

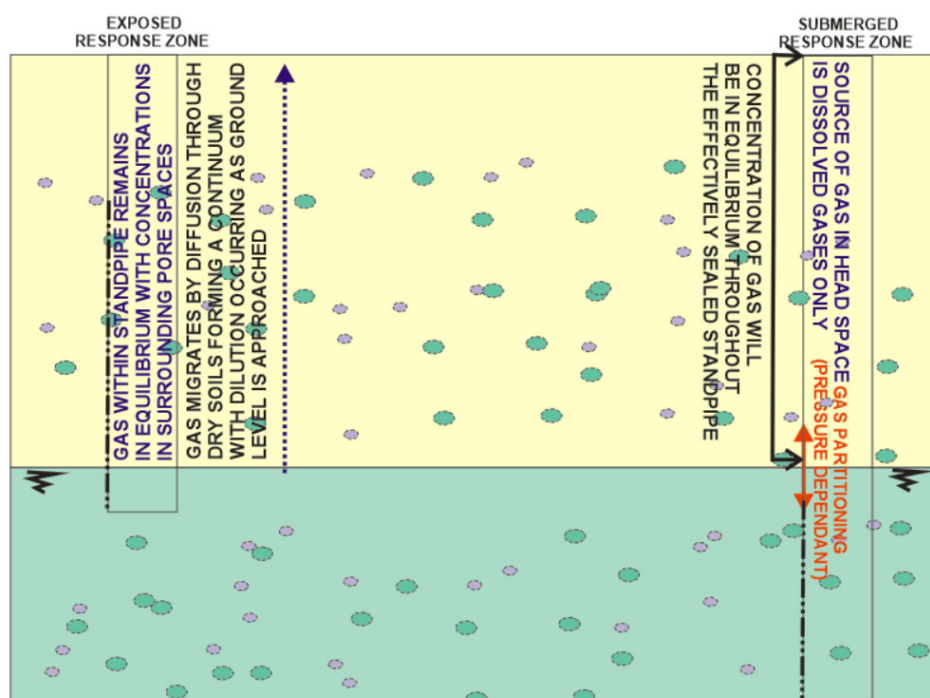


Figure 8: Headspace gas behaviour in submerged and exposed response zones

The location of standpipes where the response zone was fully submerged on all monitoring events is illustrated in Figure 9 below.

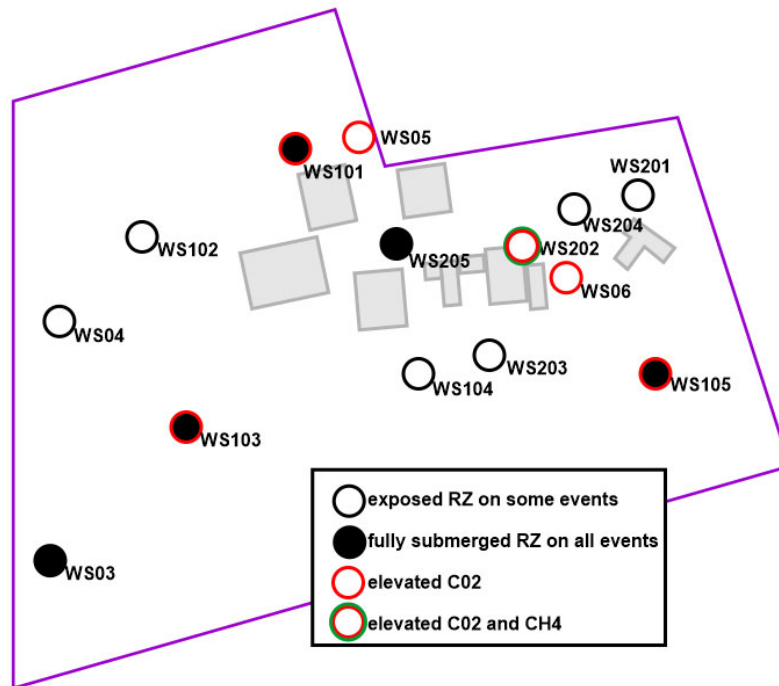


Figure 9: Submerged response zones

It can be seen that, of the six standpipes where elevated concentrations of carbon dioxide were recorded, three had continuously submerged response zones, including WS101 where the most consistently elevated concentrations were noted. These results demonstrate that there is a relatively high concentration of carbon dioxide dissolved within the perched groundwater, which is partitioning within the confined headspace. This is (over the wider area) considered to be due to the long-term use of the farm for animal husbandry and does not represent a risk to the proposed development.

A single positive flow rate (0.5l/hr) was recorded in WS3. The response zone of WS3 was fully submerged on each monitoring event, demonstrating that the variable (positive/neutral/negative) recorded flow rates were a direct result of changes in groundwater level generating positive or negative pressure within the confined headspace.

7.2 WS5

WS5 was the only non-submerged standpipe where positive flow rates were recorded during the extended monitoring program. Recorded flow within WS5 ranged from -0.3l/hr to +0.4l/hr, demonstrating that the positive flow was not a result of pressure-driven (advective) migration which would have resulted in continuously positive recordings. Moderately elevated concentrations of carbon dioxide were recorded within WS5, but once again not consistently. It is also notable that recorded groundwater levels were highly variable, ranging from 1.20mBGL to 2.36mBGL. There is no obvious relationship between recorded groundwater levels and either flow rate or concentration, however in the absence of continuous monitoring it is impossible to be clear on this.

7.3 WS202 and WS6

The location of WS202 was selected to target an above ground diesel storage tank. A diesel odour was recorded within soils to a depth of 3.5m, and soil analysis from samples taken from 0.1mBGL and 1.0mBGL identified low concentrations of hydrocarbon contamination, although a deeper (3.7mBGL) sample recorded no hydrocarbon concentrations above the lower level of detection. A sample of groundwater taken from WS202 also identified the presence of low concentrations of hydrocarbons.

DETAILED QUANTITATIVE GAS RISK ASSESSMENT

Natural soils in this location were recorded as sandy clay (low permeability) to a depth of 2.2m, overlying clay (very low permeability). It was identified by the farmer that the existing plastic self-bunded tank replaced a single skinned steel tank which had been in place since the 1950s. There is no record of a major contaminative event, however over this extended period, long term minor spillage and leakage will have impacted the underlying soils and groundwater. Given the impermeable nature of the natural soils, lateral and vertical migration will have been restricted, resulting in a localised zone of contamination.

The gas monitoring results recorded in WS202 identified marginally elevated methane (maximum 4.6%) and carbon dioxide (maximum 5.9%) combined with flow rates of $<0.1\text{l/hr}$. Results recorded in the nearest adjacent standpipe, WS6, recorded $<0.1\%$ methane with moderately elevated carbon dioxide (maximum 9.3%) combined with flow rates of -0.4l/hr to $<0.1\text{l/hr}$. These results support the conclusions drawn above, as illustrated below in Figure 10.

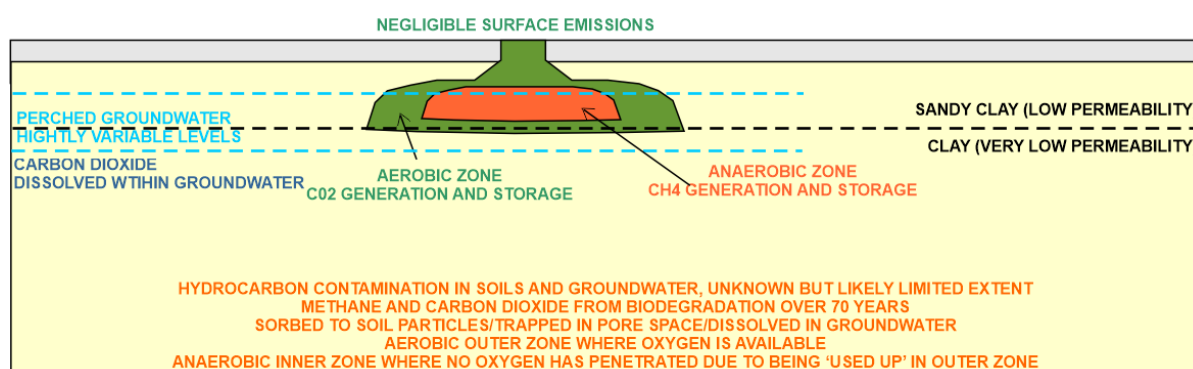


Figure 10: Illustration of hydrocarbon contamination restricted by low permeability soils

7.4 Discussion

The site has a lengthy history of agricultural use, with no records of any previous usage that may result in potential bulk gas generation. Site investigation has identified a shallow layer of Made Ground across the site (maximum thickness 0.4m) over the Wittering Formation in the form of clay with varied sand/silt content (associated low to very low permeability). Groundwater is perched, highly variable and reactive to precipitation.

Soil analysis has identified relatively high total organic carbon within made ground and shallow natural soils, indicative of the long-term use of the site for animal husbandry with the resultant migration of manure-related products into the soils with precipitation. This is insufficient to represent a potential source of bulk gas generation, however the long-term biodegradation of this material will have resulted in carbon dioxide being present within soils and groundwater. Due to the limited source material and extended time period of deposition, the migration mechanism will be by diffusive flow only with no pressurized (advective flow). A combination of effects may result in this being released into standpipe headspaces however this does not represent a risk to the proposed development.

The more recent targeted site investigation undertaken by GESL identified minor hydrocarbon contamination in soils and groundwater immediately adjacent to an above ground diesel storage tank. Gas monitoring recorded marginally elevated concentrations of methane and carbon dioxide, but no measurable flow rate. This is indicative of a long-term (over 70 years) slow-release contaminative event, which combined with low/very low permeability soils has resulted in a localised area of impacted soils with a central anaerobic zone. No methane was recorded in the adjacent WS6.



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

All gas monitoring results produced an HGFR indicative of characteristic situation 1 (CS1) conditions, however localised concentrations of carbon dioxide (a number of standpipes) and methane (WS202 only) indicated that further consideration should be given to potentially designating the site as CS2. The lines of evidence presented above demonstrate that:

- No advective flow is occurring;
- The occurrence of methane is limited to an area of localised hydrocarbon contamination;
- No potential source of bulk gas generation is present on the site.

Based on the above, it can be concluded that the site meets Characteristic Situation 1 conditions.



8.0 CONCLUSIONS AND RECOMMENDATIONS

Historic maps indicate that the Site is located within an extensive area of long term agricultural use. No records of historic or current usage are available that suggest a source of bulk gas generation is likely to be located on or in the vicinity of the site.

A total of three site investigations have identified a maximum thickness of 0.4m Made Ground overlying the Wittering Formation (Clay with variable silt/sand/gravel content) over the London Clay Formation (Clay). The Made Ground descriptions identified topsoil (with rootlets) with rare anthropogenic inclusions in the form of ash, clinker, brick fragments and mortar. No descriptions are indicative of a potential source of bulk gas generation.

Total organic carbon (TOC) analysis of samples taken from the Made Ground across the Site identified concentrations indicative of inert waste, incapable of generating sufficient gas to represent a risk to any proposed development.

Localised hydrocarbon contamination was identified in soils and groundwater in the direct vicinity of an above ground diesel storage tank. No organic contamination was identified at concentrations capable of bulk gas generation. No unusual materials were recorded that might be indicative of localised landfilling or waste disposal.

As such it can be concluded that:

- No potential source of bulk gas generation is present on the Site; and
- The presence of localised hydrocarbon contamination, and the long-term use of the site for livestock farming will have resulted in gas 'stored' within soil pores, sorbed to soil particles and dissolved in groundwater. This does not represent a risk to the proposed development.

Gas monitoring identified limited elevated concentrations of carbon dioxide and methane, combined with negligible and sometimes negative flow rates. This indicates that the site should be classified as Characteristic Situation 1 and does not require gas protection measures to be incorporated within the proposed development.

As such it can be concluded that:

- No bulk gases are present across the Site; and
- No advective flow is occurring.

Based on all the lines of evidence presented above, it is considered in relation to the proposed development, that the site should be considered a Characteristic Situation 1 classification, with no requirement for gas protection measures.

It is recommended that, following demolition of the existing buildings and removal of floor slabs, additional localised investigation is undertaken in the vicinity of the above ground diesel storage tank.



9.0 DISCOVERY STRATEGY

Whilst the site has been the subject of at least two phases of intrusive investigation, it remains possible that unexpected ground and/or groundwater conditions may be encountered during the process of construction.

Should previously undiscovered contamination or unforeseen ground conditions be encountered during construction by the ground workers, this must be reported to the Site Manager immediately in order that the Consultant is notified.

Where deemed necessary, the Consultant shall attend the site to inspect the discovery and provide recommendations on the further actions required, if any. Where necessary the regulatory authority shall be informed. Post any additional investigation or laboratory testing the results and any proposed remedial measures shall be reported to the regulatory authority or other appropriate organisation for consent, before proceeding or implementing the remedial measures.

A copy of the discovery strategy must be lodged on site, and provisions made to ensure that all workers are made aware of their responsibility to observe, report, and act on any potentially suspicious, abnormal, unforeseen or contaminated ground and/or groundwater conditions they may encounter.

Depending on the type, nature and extent of any such 'discovery', it may be necessary to halt works in that location until such time as the assessment has been completed. This shall be reviewed on a 'discovery' specific basis and in conjunction with consultation with the client, other technical personnel and/or regulatory/approval organisations.

As a general guide, where such unexpected conditions are encountered the following approach is required as a minimum:

- All discoveries must be reported to the Site Manager immediately and works at that location are to halt until further notice;
- The Site Manager must report any such discoveries to the Client and the Consultant;
- Following notification from the Site Manager, the Consultant shall discuss the discovery with the Local Authority and/or other relevant parties and if considered necessary, arrange to meet on site to view the discovery;
- The Consultant shall attend the site to record the location, extent and nature of the discovery and implement an appropriate sampling and analysis regime, taking due account of the type and nature of the discovery, known and probable land uses in that area of the site;
- Where remedial action is required, regulatory consultation and approval will be sought;
- A record will be produced by the Consultant and held on site (with copies held by the Consultant, Client and Local Authority/other relevant organisation), detailing the discovery, assessment works undertaken, findings thereof, confirmation either of no action required or detailing the remedial action taken and validation thereof.

The process is summarised overleaf:



DETAILED QUANTITATIVE GAS RISK ASSESSMENT

