



SUPPLEMENTARY GROUND GAS RISK ASSESSMENT REPORT RICHARD STREET, ROCHDALE

TE1582-TE-00-XX-RP-GE-004-V03

09 JANUARY 2026

FINAL

Prepared for:

Willmott Dixon

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**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : i of ii
Engineer: Adrian Read
Date: 09/01/2026

CONTENTS

1.	INTRODUCTION	1
1.1.	Proposed Development	1
1.2.	Previous Reports	2
1.3.	Objectives	2
1.4.	Assumptions.....	3
2.	SITE DETAILS AND DESCRIPTION	4
3.	PREVIOUS THIRD-PARTY GROUND GAS RISK ASSESSMENT CONCLUSIONS	5
3.1.	Ground Gas Protection Measure Requirements.....	6
4.	SUPPLEMENTARY GROUND GAS RISK ASSESSMENT	8
4.1.	Introduction	8
4.2.	Conceptual Site Model Considerations.....	8
4.3.	Radon Gas	15
4.4.	Gas Monitoring Data Quality	15
4.5.	Ground Gas Monitoring Results.....	16
4.6.	Ground Gas Risk Assessment.....	18
5.	CONCLUSIONS AND RECOMMENDATIONS	30
5.1.	Conclusions	30
5.2.	Recommendations	31
6.	REGULATORY APPROVALS	32
7.	REFERENCES	33
8.	GLOSSARY OF TERMS.....	36

TABLES

Table 2.1 Current Site Overview.	4
Table 4.1 Scope of Monitoring Installations	12
Table 4.2 Summary of Ground Conditions During Tier Environmental Supplementary Monitoring Well Installations.....	13
Table 4.3 Ground Gas Monitoring Results Summary –7 No. Visits of Proposed Monitoring Programme of 7 No. Visits	17
Table 4.4 Summary of Borehole Hazardous Gas Flow Rates	22
Table 4.5 Initial Worst-Case GSV Calculation	25



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : ii of ii

Engineer: Adrian Read

Date: 09/01/2026

FIGURES

Figure 3.1 Extract From Curtins' Proposed Ground Gas Protection Measures Zoning Plan (Proposed Layout Has Been Superseded)	6
Figure 4.1 Spatial Grid System Employed at Site	11
Figure 4.2 Ternary Plot For All Data	26

APPENDICES

Appendix A - Drawings

Appendix B - Exploratory Hole Logs

Appendix C - Groundwater and Gas Monitoring Results & Calibration Certificate

Appendix D - Definitions of Terms Used in Qualitative and Quantitative Risk Assessments

Appendix E - Assessment Criteria Applied for Ground Gas



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 1 of 37
Engineer: Adrian Read
Date: 09/01/2026

1. INTRODUCTION

Tier Environmental was commissioned by Willmott Dixon to undertake a Supplementary Ground Gas Risk Assessment report for a development referred to as 'Neighbourhood', Richard Street, Rochdale, OL11 1DX (the "Site").

This report has been prepared following the commentary contained within the previously issued 'Remediation Strategy and Implementation Plan' prepared by Booth King Partnership Limited (report reference: FPE0422NRF, dated 20th September 2022):

*"A preliminary zoning for ground gas protection is provided in the Curtins Phase 2 Report based on the results of the ground gas monitoring. However, it is recommended that this is reviewed based on the earthworks proposals and final site/building layout **with further gas monitoring possibly required post earthworks to confirm and justify the zoning and or define it in relation to building footprints.**"*

*"A Moderate / Low risk rating is identified to site end users from ground gases arising (carbon dioxide) from Made Ground and natural organic rich soils on the site, characterised by CS-2 gas regime in the vicinity of WS07, WS09, WS11 and WS19 due to elevated concentrations of carbon dioxide. **Further monitoring and assessment to be undertaken upon completion of earthworks.**"*

*"Given the proposed strategy to remove potential identified sources of ground gas, namely organic rich soils and any putrescible material within the Made Ground, during the turnover of the upper portion of the ground, **additional gas monitoring may confirm a reduction in the gas protection measures.**"*

It is understood that the driver for such reassessment is, in part due to the following contained within the 'Remediation Strategy and Implementation Plan' (hereafter referred to as 'RSIP'):

"Any significant putrescible material from the Made Ground, again to reduce the potential for the generation of ground gas. It is assumed that such material will be removed anyway as part of the ground works for geotechnical reasons to meet the required specifications for material used within the development platform (similar to peat and organic rich soils)."

Consideration has also been made within this report to the following statement detailed in the RSIP:

"An assessment of the requirement for hydrocarbon vapour membranes should be made post groundworks if there have been any practical constraints to removal of hydrocarbon material from below the building footprints."

1.1. Proposed Development

It is understood the development will comprise:

- Apartment blocks of 7 No. storeys;
- Low rise residential housing (terraced) with private gardens; and,
- Associated parking, access roads, infrastructure and landscaping.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 2 of 37
Engineer: Adrian Read
Date: 09/01/2026

1.2. Previous Reports

The following previous pertinent reports have been prepared for the site:

- Delta Simons - A Phase 1 Environmental Assessment for Site 1, Rochdale Central Retail Park' (report reference: 18-0848.01, dated August 2018);
- Delta Simons - A Preliminary Geo-Environmental Risk Assessment for Site 2, Rochdale Central Retail Park (report reference: 18-0848.01, dated August 2018);
- Delta Simons - A Geo-Environmental Assessment for Site 2, Rochdale Central Retail Park (report reference: 18-0848.01, dated September 2018);
- Curtins - Neighbourhood, Rochdale, Phase 1 Preliminary Risk Assessment prepared for Willmott Dixon Construction Limited, (report reference: 075882-CUR-00-XX-RP-GE-001, Revision V01, dated 7th October 2020);
- Curtins - Neighbourhood, Rochdale, Phase 2 Ground Investigation prepared for Willmott Dixon Construction Limited, (report reference: 075882-CUR-00-XX-RP-GE-001, dated 23rd July 2021);
- Tier Environmental Ltd - Remediation Statement, Land at Richard Street, Rochdale prepared for Wilmott Dixon Construction Limited (report reference: TE1583-TE-00-XX-RP-GE-002-V02, dated 30th June 2021);
- LK Remediate - A Site Investigation for Rochdale 'Neighbourhood' (report reference: LKR221043, dated August 2022).
- Booth King Partnership Limited - Remediation Strategy and Implementation Plan, Residential Development, Neighbourhood, Rochdale (report reference: FPE0422NRF, dated 20th September 2022);
- LK Remediate - A Completion Report for Site Enabling Works at Neighbourhood, Rochdale (report reference: LKR221043_CR, dated 5th July 2023)
- Booth King Partnership Limited - A Remediation Strategy and Implementation Verification Report (Ref: ORRD-BKP-XX-XX-RP-C-00010, Version 1.1 dated September 2023)

Tier Environmental also produced the following package of information as part of the Materials management Plan (MMP) Declaration (Ref: 2022-10-31 09:19:12):

- 'A Site of Origin MMP Verification Plan for Richard Street, Rochdale' (Ref: TE1582-TE-00-XX-GE-CO-001-V01, dated 17th October 2022);
- 'A Supplementary Risk Assessment Letter Report for Neighbourhood, Richard Street, Rochdale' (Ref: TE1782-TE-00-XX-GE-RP-001-V02, dated 23rd October 2022);
- 'A Materials Management Plan for Former Central Retail Park, Rochdale' (Ref: TE1582-TE-00-XX-GE-MMP-001-V01, dated 25th October 2022); and,
- Interim Materials Management Verification Report For Neighbourhood (Richard Street), Rochdale (Ref: TE1582-TE-00-XX-GE-MMP-001-V01, dated 11th October 2023)

1.3. Objectives

The objectives of this report are:

- To briefly summarise the ground gas risk assessment conclusions of the most recent previous Ground Investigation Report iteration;
- To present additional ground gas data, associated additional risk assessment works;
- To include an assessment of different foundation solutions and potential impact on the outcome of the ground gas risk assessment; and,



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 3 of 37
Engineer: Adrian Read
Date: 09/01/2026

- To update the potential risks posed to the Site from hazardous ground gases and determine whether parts of the site may be 'zoned' with respect to the Characteristic Situation and therefore ground gas mitigation measure requirements.

1.4. Assumptions

The following assumptions are made in this report:

- It is assumed that ground levels will not change significantly from those described in this report or as shown on proposed development drawings. If this is not the case, then amendments to the recommendations made in this report may be required.
- The ground investigation works previously conducted were designed with due consideration of known or suspected constraints (including underground services and access constraints).
- Any references to observations of suspected asbestos-containing materials are for information only and should be verified by a suitably qualified asbestos specialist and/or confirmed by laboratory analysis.
- The use of the term 'Topsoil' within this report is based on a visual identification only and that these materials have not been classified in accordance with BS3882:2015.
- The use of the terms 'shallow' and 'deep' within this report (from a geotechnical perspective) assume *typically* between ground level to circa 3.00m below ground level (bgl) for 'shallow' and greater than 3.00m bgl regarded as 'deep';
- The comments and opinions presented in this report are based on the findings of the review of third party information, ground conditions encountered during intrusive investigation works performed by Tier Environmental and the results of tests carried out within one or more laboratories. There may be other conditions prevailing on the Site which have not been revealed by this investigation and which have not been taken into account by this report.
- Responsibility cannot be accepted for any conditions not revealed by this investigation. Any diagram or opinion on the possible configuration of the findings is conjectural and given for guidance only. Confirmation of intermediate ground conditions should be undertaken if deemed necessary.

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**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 4 of 37

Engineer: Adrian Read

Date: 09/01/2026

2. SITE DETAILS AND DESCRIPTION

Table 2.1 Current Site Overview.

Site name	Neighbourhood (Richard Street), Rochdale
Site address	Land between Richard Street, Oldham Road, Milnrow Road and Drake Street, Rochdale, OL11 1DU. A site location plan is included as Drawing No. TE1582-TE-00-XX-DR-GE-002-V01 within Appendix A.
National Grid Reference (NGR)	389962, 412973
Approximate site area	2.7ha
Site shape	The Site is irregular in shape
Current land use on the site	The Site is currently in development
Surrounding land uses	The Site is situated in an area of commercial/industrial land use.
General topography and ground levels	The Site is situated approx. 144m AOD in the west, gently sloping to 140m AOD in the east



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 5 of 37
Engineer: Adrian Read
Date: 09/01/2026

3. PREVIOUS THIRD-PARTY GROUND GAS RISK ASSESSMENT CONCLUSIONS

The following conclusions were made with respect to ground gas risk at the Site:

- The Delta Simons ground gas risk assessment was based on the results from 3 No. ground gas monitoring visits from a total of 10 No. gas monitoring wells conducted between 22nd August and 11th September 2018.
 - Individual Gas Screening Values (GSVs) were determined for each monitoring well based on the reported carbon dioxide and methane concentrations and the reported flow rates from the three monitoring visits.
 - Delta Simons determined that a Characteristic Situation 2 – Low Risk Scenario was applicable at 1 No. of the 10 No. monitoring wells on the basis of the gas screening values calculated, only, but that in 7 No. instances, the Characteristic Situation should be increased from CS1 to CS2 because of *“maximum carbon dioxide and methane concentration having exceeded 5% v/v and 1 %v/v respectively in addition to the existing uncertainty around the nature of potential further putrescible sources of ground gases from the backfilled canals”*.
 - The report recommended that *“Further ground gas monitoring is likely to be required to satisfy planning requirements”*.
- The Curtins ground gas risk assessment was based on the results from 6 No. ground gas monitoring visits from a total of 12 No. monitoring wells conducted between 13th April and 23rd June 2021. Barometric pressure recorded between 975 mb to 1016 mb. Barometric pressures <1000 mb were recorded on the second, third and fourth monitoring visits. Falling barometric pressure was recorded on the fourth and fifth monitoring visits.
 - Maximum peak carbon dioxide (CO₂) concentrations ranged between <0.1% v/v and 8.8% v/v throughout the monitoring period. The greatest maximum carbon dioxide concentrations were recorded in WS07, WS09, WS11, and WS19.
 - Methane concentrations were typically recorded below the limit in all monitoring wells throughout the monitoring period, with exception of WS07 on the second (0.2% v/v) and sixth (0.4% v/v) monitoring visits.
 - Maximum peak air flow rates ranging between <0.1 l/hr and -22.2 l/hr were recorded, while steady state air flow rates were always recorded below the limit of detection of the monitoring instrument (<0.1l/hr).
 - Curtins considered that the low rise housing is unlikely to be constructed in accordance with the ‘model house’ described in NHBC Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide Are Present. As such, for all low-rise housing, and the apartments, the ground gas risk assessment was undertaken with reference to BS8485 for all proposed structures on site.
 - The greatest calculated representative ‘borehole’ scenario Gas Screening Value (GSV) was 0.0088 l/hr for carbon dioxide in WS07 on the second monitoring visit. However, given elevated carbon dioxide concentrations (>5% v/v) were recorded in WS07, WS09, WS11 and WS19 during the monitoring program, it was recommended that CS-2 protection measures were installed in these areas. Curtins drawing ref. 075882-CUR-00-XX-RP-GE-013-P01 summarises the preliminary characteristic situation zoning for the site, considering pre-earthworks information. An extract from this drawing is provided in Figure 3.1 below.
 - Curtins recommended that *“further gas monitoring may be required post earthworks to justify the zoning and or define it in relation to building footprints”*.

Figure 3.1 Extract From Curtins' Proposed Ground Gas Protection Measures Zoning Plan (Proposed Layout Has Been Superseded)



3.1. Ground Gas Protection Measure Requirements

The RSIP determined that for where CS-2 protection measures are required, the following design of ground gas protection measures will be required (please note that the below is an extract from the Booth King Partnership Limited RSIP Report):

- *For ground bearing slabs the minimum gas protection score required from the soil gas protection measures will be accumulated by appropriately detailed reinforced concrete ground slabs and the provision of an appropriate gas resistant membrane to achieve scores 1.5 and 2.0 respectively; a total of 3.5.*

The typical scope of protective measures for a residential building set out in C665 are:

- *Reinforced concrete cast in situ floor slab (suspended, non-suspended or raft) with at least 1200g DPM and underfloor venting.*
- *Beam and block or pre-cast concrete and 2000g DPM / reinforced gas membrane and underfloor venting. All joints and penetrations sealed*



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 7 of 37

Engineer: Adrian Read

Date: 09/01/2026

The requirement for gas protection measures commensurate with Characteristic Situation 2, if needed, for the apartments and houses will be included on the foundation design drawings.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 8 of 37
Engineer: Adrian Read
Date: 09/01/2026

4. SUPPLEMENTARY GROUND GAS RISK ASSESSMENT

4.1. Introduction

The ground gas risk assessment has been undertaken in accordance with the following guidance:

- BS 8485:2015+A1:2019;
- CIRIA C665, 2007;
- Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide Are Present, NHBC, 2007 (note that this is being withdrawn on 1st July 2025);
- A Pragmatic Approach to Ground Gas Risk Assessment RB17. CL:AIRE, 2012; and,
- Ground Gas Monitoring and 'Worst-Case' Conditions TB17, CL:AIRE, 2018

The ground gas risk assessment has been conducted with full consideration of the viable sources, pathways and receptors included within the Curtins' Conceptual Site Model and also cognisant of the remedial works conducted to date as described in the Booth King Partnership Limited 'Remediation Strategy and Implementation Verification Report' (Ref: ORRD-BKP-XX-XX-RP-C-00010, Version 1.1 dated September 2023).

Ground gas monitoring was conducted in conjunction with groundwater monitoring; however, it should be noted that the gas monitoring was conducted first, prior to any groundwater monitoring works. The monitoring well locations and construction were designed with due consideration of the proposed development layout and conceptual site model.

4.2. Conceptual Site Model Considerations

Current and Surrounding Land Uses

Current Land Use

The enabling works to prepare the Neighbourhood site for the construction phase of the development was completed by LK Remediate between December 2022 and May 2023. The site was cleared of general waste and vegetation ahead of the works.

The focus of the works was the excavation and removal of hardstanding, foundations associated with former buildings and other relic structures together with surrounding soils and replacement with acceptable site-won materials engineered to provide a suitable development platform for the foundations and infrastructure of the new development. This process included the crushing of concrete from hardstanding, foundations and relic structures into suitable granular fill materials, as specified by the earthworks contract.

In accordance with the Remediation Strategy, as part of the site turnover, as soils were excavated, they were screened to identify and remove, where encountered, hydrocarbon contaminated soils from below building footprints and any significant ACM impacted material. Within the Remediation Strategy the site turnover had also been identified as an opportunity to remove sources of ground gas including putrescible material within the Made Ground and organic rich soils.

Several hotspots of potential contamination were identified through visual/olfactory evidence during the site turnover. Where this potential contamination was identified it was sampled and tested and an assessment made on its suitability for re-use. In all but two case material was deemed suitable for use below the cover layer within the area designated for public open space on the development plan.



SUPPLEMENTARY GROUND GAS RISK ASSESSMENT REPORT RICHARD STREET, ROCHDALE

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 9 of 37
Engineer: Adrian Read
Date: 09/01/2026

Surrounding Land Use

Land to the north comprises Oldham Road and A640 with small commercial and residential premises beyond. To the east is Central Retail Park, Oldham Road and small commercial and residential premises beyond. To the south of the site, Rochdale Masonic Buildings and Richard Street are present with residential dwellings beyond. Finally, to the west the A640 (Drake Street) and Metrolink tram line is present with small commercial and residential premises beyond.

Site History

The earliest mapping (1850) shows the site is predominantly occupied by canal basins and wharfs. The canal enters the site in the southeast, progressing into the southwest corner, with two basins orientated approximately NNE-SSW in centre-west and centre-east. The basins are connected to the main canal in the south. Warehouses are identified adjacent to the basins. Residential dwellings are at the north. By 1910, a Timber Yard is noted in the east, and nine cranes, servicing the canal and Timber Yard. By 1930, the dwellings in the north east are replaced by a Picture Theatre.

By the 1950s, the western canal basin was infilled, reducing in size by approximately half, and the central area of the site is noted to be a depot, as is the area of the Timber Yard. A garage is noted in the east. By 1977, both canal basins, and the canal in the south, have been infilled. A Timber Yard is noted in the north and the warehouse in the east was demolished.

There was significant redevelopment of the site in the 1980s associated with the construction of the Central Retail Park, comprising three commercial warehouses/retail units. A car park was located centrally within the site, with smaller retail units in the west. The retail units and residential dwellings have now been demolished sometime after 2006 mapping.

Ground Conditions

Geological Maps Information

Made Ground is not indicated to be present on BGS mapping, however it was anticipated (prior to conducting ground investigation) that Made Ground will be present within the infilled canal basins and infilled canal. Made ground associated with historic development may also be present on site.

Published mapping indicates the site is primarily underlain by Glaciofluvial Deposits (superficial deposits) comprising sand and gravel with some clay and silt.

The superficial deposits are underlain by the Pennine Lower Coal Measures Formation (sandstone, siltstone, mudstone, some coal). Shallow coal seams (<30m bgl) were not anticipated to be present beneath the site. One BGS recorded fault line is located approximately 60m south of the site. The site is located on the downthrow side of the southwest to northeast orientated fault.

The site is situated in a coal mining reporting area; however, it is not within a development high risk area. The nearest recorded mine entries are located approximately 1km west, and the nearest coal subcrop is approximately 133m west, dipping to the west. There are no BGS recorded mineral sites within 500m of the site. It should be noted that a Low risk was previously identified by third parties to the proposed development from coal mining legacy and no further action was deemed necessary. Tier Environmental has therefore **not** conducted a Coal Mine Gas Risk Assessment as part of this assessment as it is understood risks from coal mine gases have been previously considered as acceptably low so as to not be a driver for ground gas protection measures.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 10 of 37
Engineer: Adrian Read
Date: 09/01/2026

Ground Conditions Encountered – Pre Enabling Works

The ground conditions across the site prior to the Enabling Works commencing were established through the ground investigation works and comprised:

- Concrete, reinforced concrete (existing ground floor slabs) and tarmacadam, typically 0.05-0.22m thick and underlain by a sand and gravel yellow/grey sub-base.
- Made Ground typically 1.5 to 3.0m thick. The base of the Made Ground was encountered at 132.51-139.35m AOD. Made Ground was predominantly granular, described as slightly silty gravelly fine to coarse sand. Gravel was fine to coarse angular to rounded sandstone, mudstone, concrete, brick, slate, wood, ash, clinker, glass and rare coal, plastic and metal. Rare to occasional boulders of bricks, sandstone and mudstone. Made ground thought likely to be associated with the two canal basins was encountered in the centre-west and centre-east of the site.
- Superficial deposits comprising Alluvium generally in the western area of the site, with Peat / organic soils locally, underlain by interbedded cohesive clay and silt and granular sand and gravel Glaciofluvial deposits. Where progression through the Glaciofluvial Deposits was achieved, Glacial Till clay was encountered.
- Bedrock was not encountered, with the investigations completed to a maximum depth of 30.45mbgl (108.06m AOD).

Various concrete foundations and other below ground obstructions related to the site's former uses, including the former canal basin and retail park were found to be present across the site.

Groundwater was encountered between 1.20 and 2.70mbgl during the investigations, where it was encountered in the granular Made Ground. Perched groundwater was also encountered within alluvial deposits and peat deposits at the site. Groundwater was also encountered between 4.00 and 24.50m bgl in the granular Glaciofluvial Deposits.

Ground Conditions – Supplementary Ground Investigation

Section 4.3.4 of the Booth King Partnership Limited 'A Remediation Strategy and Implementation Verification Report' (Ref: ORRD-BKP-XX-XX-RP-C-00010, Version 1.1 dated September 2023) details the following pertinent works conducted during the site remediation works:

- There were 7 no. hotspots of black odorous material encountered during the site turnover. These were excavated and stockpiled in a 'Quarantine Area'. Material was sampled and tested to include the suite of contaminants set out in the Remediation Strategy. Based on the results it was concluded that the material was suitable to be retained on-site within the Public Open Space (POS) Areas (i.e. not beneath the proposed building footprints). The materials were placed within placed within the POS area at F1-G1 and B6 (see grid reference system employed on the Figure below).
- There was a pocket of black material containing potentially large amounts of asbestos containing material (ACM) encountered around Grid Squares D5 in Week 12 of the programme and then similar material was found and excavated from E4/E3 in Weeks 13 to 17. The residual treated material was placed at depth (around 3m below final formation levels) at Grid Square A6 at the south-western end of the POS area.
- An underground fuel tank was encountered towards the end of the works at Grid Square I4, towards the eastern perimeter of the site. LK state that this was excavated and taken off-site for recovery/disposal. No obvious hydrocarbon impacted soils were encountered around the tank. Samples of the made ground around the tanks were taken and tested to ensure the materials were not impacted and were suitable for re-use. Materials are indicated to have been used as fill in I5.
- Six timber boats buried within the former canal basins. The locations of these are shown as orange blocks on the figure below. The presence and form of these boats have been recorded as part of the Archaeological Works for the site and was outside the scope of the Remediation



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 11 of 37

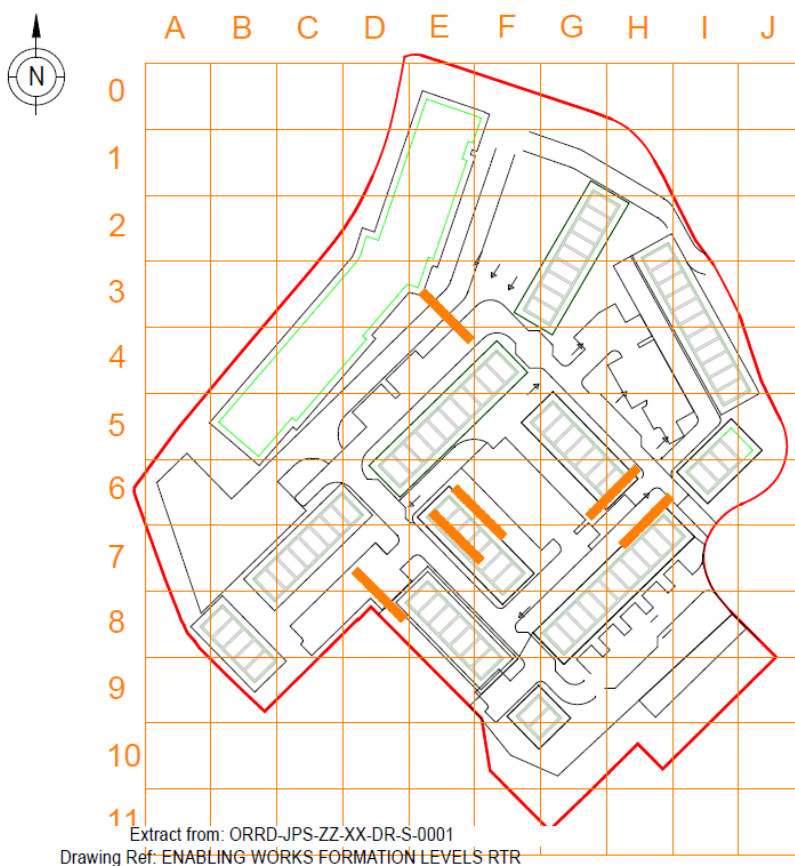
Engineer: Adrian Read

Date: 09/01/2026

Strategy. However, it is noted that these boats were excavated and removed and in the LK Report it states that two loads of timber from the old hoardings and boats were taken off-site for recycling/disposal. With respect to the Remediation Strategy, this complies with the requirement for the removal of significant potentially putrescible organic material from the site where it was encountered to reduce the potential for the generation of ground gas.

- Areas of stone setts/cobbles (possibly historic roadways) and flag stones were encountered during the works. Some of these were noted to have a strong coal tar like odour associated with them. As demonstrated by the list of 'Waste Material' in Table 1 of the LK Completion Report, where identified these were separated and removed off-site. Based on investigations carried out on-site during a meeting on 5th April 2023, the presence of PAHs in some of the test data for the aggregates was considered to be inclusion of occasional setts or cobbles within the stockpiles for crushing. This was concluded not to preclude the use of the recycled aggregate. Subsequent verification sampling of the aggregate used within roadways has not indicated levels of PAHs higher than recorded during the original site investigation.

Figure 4.1 Spatial Grid System Employed at Site



Tier Environmental conducted supplementary monitoring well installation at WS101 to WS109 as shown on Drawing No. TE1582-TE-00-XX-DR-GE-003-V01, included in Appendix A. The exploratory hole locations and proposed depths was stipulated in correspondence between Willmott Dixon and Booth King.

The design of the monitoring wells was cognisant of BS 8576:2013, which states *"Where practical and reasonable, the response zone for permanent gas monitoring wells should be located in an unsaturated zone. (Such a zone might exist below perched water tables and could form a migration pathway.) This is subject to intercepting all potential gas sources. For example, peat layers in alluvium might be below the groundwater table but*



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 12 of 37
Engineer: Adrian Read
Date: 09/01/2026

pockets of gas can be trapped within the peat. In this case, it would be desirable for the well to penetrate below the groundwater. If there is doubt, it is useful to install wells with response zones above and below the water table."

A summary of the ground conditions encountered is presented below in Table 4.2 and a summary of the monitoring well installs is provided in Table 4.1, below:

Table 4.1 Scope of Monitoring Installations

Exploratory Hole Location	Strata Targeted	Slotted Response Zone (m bgl)	Rationale
WS101	Made Ground / Alluvium / Glaciofluvial Deposits	1m to 4m bgl	Response zone targetting potential ground gas sources associated with Made Ground and organic clay with peat. Slight hydrocarbon odour noted.
WS102	Made Ground / Glaciofluvial Deposits	1m to 5m bgl	Response zone targetting potential ground gas sources associated with Made Ground and viable pathway offered by granular GFD. Very slight hydrocarbon odour noted.
WS103	Glaciofluvial Deposits	1m to 4m bgl	Potential viable pathway offered by granular GFD.
WS104	Made Ground / Alluvium / Glaciofluvial Deposits	1m to 4m bgl	Response zone targetting potential identified source sof dark grey colouration in Made Ground and black silt with frequent pockets of fine grained, black sand. Slight organic odour noted.
WS105	Glaciofluvial Deposits	1m to 4m bgl	Potential viable pathway offered by granular GFD.
WS106	Made Ground / Alluvium / Glaciofluvial Deposits	1m to 4m bgl	Response zones targetting potential identified sources of gases associated with Made Ground with organic odour, and black possible organic stained thin band of sand in natural deposits.
WS107	Made Ground / Alluvium	1m to 4m bgl	Response zones targetting potential identified sources of gases associated with Made Ground with rare rootlets and black, possibly organic stained sand and gravel sized pockets of black, possibly organic stained sand within the Alluvium.
WS108	Made Ground / Glaciofluvial Deposits	0.7m to 4m bgl	Response zone targetting viable pathway offered by Made Ground and granular GFD.
WS109	Made Ground / Alluvium / Glaciofluvial Deposits	1m to 4m bgl	Response zones targetting potential identified sources of gases associated with Made Ground with organic odour and Alluvium.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 13 of 37
Engineer: Adrian Read
Date: 09/01/2026

Table 4.2 Summary of Ground Conditions During Tier Environmental Supplementary Monitoring Well Installations

Monitoring Well Location	MG - sand			MG - Clay		Alluvium - Organic Clay / Silt		Alluvium - Sand with black/dark grey silt		Alluvium - Soft brown silt		GFD - Sand		GFD - Brown Silt	
	Depth (m bgl)		MG Anthropogenic Constituents	Depth (m bgl)		Comments	Depth (m bgl)		Comments	Depth (m bgl)		Comments	Depth (m bgl)		Depth (m bgl)
WS101	0.00	2.20	Concrete, brick, sandstone, mudstone, occasional coal and rare clinker.	2.20	2.40	Black with brick/possible burnt shale. Occasional metal strips. Slight hydrocarbon odour	2.40	3.80	Dark brown, organic clay with thin bands of peat with decaying plant debris and occasional pieces of bark/branches, Slight organic odour.	2.40	3.80		3.80	4.00	
WS102	0.00	1.90	Brick, concrete, sandstone and occasional coal	1.90	2.80	Gravel of sandstone, mudstone and rare coal. Very slight hydrocarbon odour between 2.10m bgl - 2.30m bgl.							2.80	4.70	4.70 5.00
WS103	0.00	0.75	Brick, concrete, sandstone, rare asphalt, rare rootlets near base of stratum.										0.75	5.00	
WS104	0.00	1.55	Concrete, brick, sandstone, mudstone and rare coal.	1.55	2.10	Dark grey with gravel of concrete, sandstone and mudstone.	2.10	2.80	Soft to firm, black SILT with frequent pockets of fine grained, black sand. Slight organic odour.	2.80	3.40		3.40	5.00	
WS105	0.00	0.60	Sandstone, concrete and brick										0.60	5.00	
WS106	0.00	2.00	Concrete and occasional brick. From 1.10m to 1.40m - pockets of dark grey silt with locally slightly, organic odour.							2.65	5.00	Black, possible organic stained thin band of sand between 2.70m bgl and 2.71m bgl. No discernible odour. Brown silt between 3.00 and 3.20m bgl and fine black flecks of possible organic fragments between 3.20 to 3.60m bgl.	2.00	2.65	
WS107	0.00	2.10	Concrete, brick, sandstone and rare rootlets at around 0.90m bgl and 1.00m bgl.							2.10	5.00	Occasional black, possibly organic staining of sand around gravel at 3.00m bgl and 3.20m bgl. Occasional gravel sized pockets of black, possibly organic stained sand between 4.30 and 5.00m. Between 3.45m and 3.70m bgl - Soft, brown, damp, slightly sandy SILT.			
WS108	0.00	1.40	Concrete, brick, sandstone, rare coal and cobble of asphalt	1.40	2.70	Sandstone, concrete and occasional brick. Rare cobble of sandstone between 1.50m bgl to 1.60m bgl.							2.70	5.00	
WS109	0.00	1.65	Concrete and occasional sandstone. Brick and sandstone. Occasional lenses of black clay with slight organic odour from 0.90m bgl.	1.65	1.95	Soft, black, sandy clayey, silty CLAY. Cobble of sandstone at 1.75m bgl. Cobble of brick at 1.85m bgl. Band of black, sandy, fine to medium, angular GRAVEL of coal with occasional brick fragments from 1.85m to 1.95m bgl.				1.95	3.95	Greyish brown with frequent thinly interbedded silt. Band of soft, greyish brown, wet, sandy SILT between 3.30m to 3.95m bgl.	3.95	5.00	



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 14 of 37
Engineer: Adrian Read
Date: 09/01/2026

Sources

Landfills

One BGS recorded landfill site is within 500m, located 466m east of the site. Research conducted by Curtins indicates the site accepts household waste only. Two historical landfill sites are located within 500m. The closest is 273m southeast, Rochdale Timber Company, which accepted inert, industrial and commercial waste between 1987 and 1989. The second is 454m east which accepted inert, industrial, commercial and household waste between 1922 and 1985.

No active licenced waste management facilities are located within 500m. The closest was 322m southeast, managing end of life vehicles until 2019.

One area of infilled land (water) is located on site. This is associated with the infill of the canal which began in the 1930s. Historic mapping indicates the infill of the canal basins on site was completed by the 1970s. According to the Envirocheck Report (included in Curtins reporting) infilling of basins associated with the canal occurred to the south east of the site between 1851 and 1956. One area of infilled land (water) is also located 245m north of the site, dated in 1956.

One area of infilled land (non-water) has been identified within 250m of the site. This was the infilling of a pit/quarry etc. 198m northeast in 1989. There is potential for ground gas generation within the canal infill deposits directly beneath the site, sourced from the degradation of organic matter within the infill materials. The composition of the infill materials is unknown at this stage. There is also potential for ground gas migration from infilled land to the southeast, north and nearby active and historic landfill sites.

Made Ground

No TOC samples have been obtained from the Made Ground as part of this supplementary investigation; however, previous investigation work by Curtins reported the following with respect to Soil Organic Matter (which have been converted to Total Organic Carbon (TOC) by multiplying by 0.58):

“Soil organic matter (SOM) values for the Made Ground soils in the area of the ‘Residential without home grown produce’ end use ranged from 0.2% to 15%, with a calculated geometric mean of 2.25%”. Converted to TOC: this produced a range from 0.116% to 8.7% and a geometric mean of 1.305%.

In accordance with British Standard BS8576, Made Ground with total organic carbon (TOC) up to 6% “(e.g. dock silt. No food or other easily degradable waste)” has a low (to very low) gas generation potential. In addition, it is worth noting that the CIEH Local Authority Guide to Ground Gas (2008) indicates a very low generation potential, very low risk for development and negligible risk of lateral migration from “Made-up ground with low degradable organic content (e.g. up to five percent organic material such as pieces of wood, pieces of paper, rags, etc. with a high proportion of ash. No food or other easily degradable waste)”.

Alluvium

BS8485:2015+A1:2019 states “Methane (which is flammable and an asphyxiant) and carbon dioxide (which is toxic and an asphyxiant) can originate from a range of sources including... peat and organic matter within alluvial deposits”.

CL:AIRE Research Bulletin RB17 states that “Alluvial soils and buried peat can quite often give high concentrations of methane and carbon dioxide in monitoring wells, often methane concentrations can reach up to 90%. This is because the gas has been generated historically and is trapped in the pores due to limited transport (at low diffusion rates)”.

The CIEH Local Authority Guide to Ground Gas (2008) states that for the bands of Alluvium with ostensibly low degradable organic content that these represent a very low generation potential, very low risk for development and negligible risk of lateral migration and that for natural soil strata with a



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 15 of 37
Engineer: Adrian Read
Date: 09/01/2026

high degradable organic content e.g. peat *“(note: gas in peat is historically generated and is trapped or adsorbed in the soil so the actual current generation rate is very low)”* that these deposits represent very low to low generation potential, low risk for development and negligible risk of lateral migration.

Groundwater Conditions

Variable groundwater depths have been previously reported by Curtins (depths varying between 1.57m and 11.46m bgl, likely to be representative of a number of shallow perched groundwater bodies.

The results from Tier Environmental gas monitoring visits determined that no groundwater was detected from any well during the first 2 No. gas monitoring visits (23rd and 27th August 2024) and only one well recorded groundwater (WS102) during the third visit. Groundwater levels were thereafter found to vary in the wells from between 1.12m bgl and 4.17m bgl; however, it is noted that the groundwater measured in several of the wells represented nothing more than potential build-up of infiltrated water following rainfall events (collecting within the base of the well) rather than being truly representative of a shallow groundwater body and it does not appear that where wells have become flooded over the duration of the gas monitoring that they have caused elevated flow rates.

Therefore, Tier Environmental is satisfied that the wells installed sufficient met the requirements of BS 8576:2013, which states *“Where practical and reasonable, the response zone for permanent gas monitoring wells should be located in an unsaturated zone. (Such a zone might exist below perched water tables and could form a migration pathway.) This is subject to intercepting all potential gas sources. For example, peat layers in alluvium might be below the groundwater table but pockets of gas can be trapped within the peat. In this case, it would be desirable for the well to penetrate below the groundwater. If there is doubt, it is useful to install wells with response zones above and below the water table.”*

4.3. Radon Gas

The site lies within an area where between 1% and 3% of properties are above the radon Action Level. On this basis no radon protection measures are required.

In addition to the above, basements represent areas that are more at risk because the walls are in contact with the ground as well as the floor. This, coupled with reduced natural ventilation below ground level, increases the risk of elevated radon levels. All basements are therefore considered under BR 211 to be at increased risk of elevated levels of radon regardless of geographic location.

Currently, no basements or converted cellars / basements are proposed for the development and therefore no additional consideration of potential increased risk needs to be made; however, this should be revisited in the event that the proposals change to include for a basement.

4.4. Gas Monitoring Data Quality

In total 7 No. rounds of ground gas monitoring have been undertaken. Two visits were conducted on 23rd and 27th August 2024, with the second visit being conducted to confirm the background atmospheric gas readings which were recorded as background atmospheric readings of methane - 0.2% v/v and carbon dioxide – 0.1% v/v. Two Geotech GA5000s were taken to site on the second visit to confirm that the gas readings (both atmospheric and within the monitoring wells) were consistent between the two units and it was confirmed on site that indeed they were, and consistent with the results from the first visit. It has not been possible to determine with certainty as to the reason for these elevated background readings, which were recorded at various positions across the site (up wind and downwind). Nevertheless, it was deemed important to conduct a sense-check that these were unlikely to be associated with a single instrument error.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 16 of 37

Engineer: Adrian Read

Date: 09/01/2026

The calibration certificate for the Geotech GA5000 unit used on site for the reported gas monitoring results in Appendix C, is also provided in Appendix C.

The locations for the monitoring wells were provided by Booth King on behalf of Willmott Dixon and were considered adequate to assess the current ground gas regime, post-enabling and remediation works, in order to potentially inform any zoning of the site with respect to ground gas protection measures. The wells were all located beneath proposed building footprint areas.

Flow rates and gas concentrations were allowed to fully stabilise during the monitoring.

4.5. Ground Gas Monitoring Results

The full ground gas monitoring results from the installations are presented in Appendix C and summarised below.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 17 of 37
Engineer: Adrian Read
Date: 09/01/2026

Table 4.3 Ground Gas Monitoring Results Summary –7 No. Visits of Proposed Monitoring Programme of 7 No. Visits

Strata targeted by response zone	Monitoring well reference	Maximum peak CH ₄ (%v/v)	Maximum steady state CH ₄ (%v/v)	Maximum peak CO ₂ (%v/v)	Maximum steady state CO ₂ (%v/v)	Lowest O ₂ recorded (%v/v)	Maximum peak gas flow rate (l/h)	Maximum steady state gas flow (l/h)
Made Ground / Alluvium / Glaciofluvial Deposits	WS101	6.0	5.9	14.6	14.0	0.2	5.5	<0.1
Made Ground / Glaciofluvial Deposits	WS102	4.4	4.4	15.4	15.4	0.1	<0.1	<0.1
Glaciofluvial Deposits	WS104	2.4	2.4	2.0	1.1	1.2	0.1	0.1
Made Ground / Alluvium / Glaciofluvial Deposits	WS103	0.7	0.2	5.5	5.5	0.4	<0.1	<0.1
Glaciofluvial Deposits	WS105	0.9	0.1	5.3	0.3	0.6	1.0	<0.1
Made Ground / Alluvium / Glaciofluvial Deposits	WS106	0.5	0.5	5.3	5.3	0.4	<0.1	<0.1
Made Ground / Alluvium	WS107	0.2	0.2	13.2	13.1	0.3	<0.1	<0.1
Made Ground / Glaciofluvial Deposits	WS108	0.3	0.3	11.6	0.3	0.2	<0.1	<0.1
Made Ground / Alluvium / Glaciofluvial Deposits	WS109	0.2	0.2	8.7	0.2	6.9	<0.1	<0.1

Bold = maximum value reported across all visits.

For information: gas analyser instrument limits of detection are as follows: Methane 0.1% v/v, Carbon Dioxide 0.1% v/v, Oxygen 0.1% v/v, Hydrogen Sulphide 1ppm, Carbon Monoxide 1ppm and flow rate 0.1 l/hr.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 18 of 37
Engineer: Adrian Read
Date: 09/01/2026

4.6. Ground Gas Risk Assessment

It is considered that the 7 No. gas monitoring visits that have been conducted between 23rd August and 3rd October 2024 by Tier Environmental, alongside the previous 3 No. ground gas monitoring visits conducted between 22nd August and 11th September 2018 by Delta Simons and the 6 No. ground gas monitoring visits conducted between 13th April and 23rd June 2021 by Curtins represents a robust data set for both pre- and post-earthworks.

Indeed, it is considered that the total number of monitoring visits (16 No.) and the period of monitoring (cumulatively 132 days = approximately 4.34 months) over a 6 year period significantly exceeds the minimum requirements for a Low, or even a Moderate generation potential and high sensitivity development.

The total atmospheric pressure range of the ground gas monitoring data included in this report was between 968 mbar and 1014 mbar. This range covers low (<1000 mbar) and moderate (1000 mbar to 1015mbar) atmospheric pressures. Monitoring events included periods of rising and falling pressure trends.

The pressure graphs information is from the *nearest* available weather station (relative to the site) and therefore indicative of *regional* pressure trends. The below does not represent direct atmospheric pressure conditions on the site.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

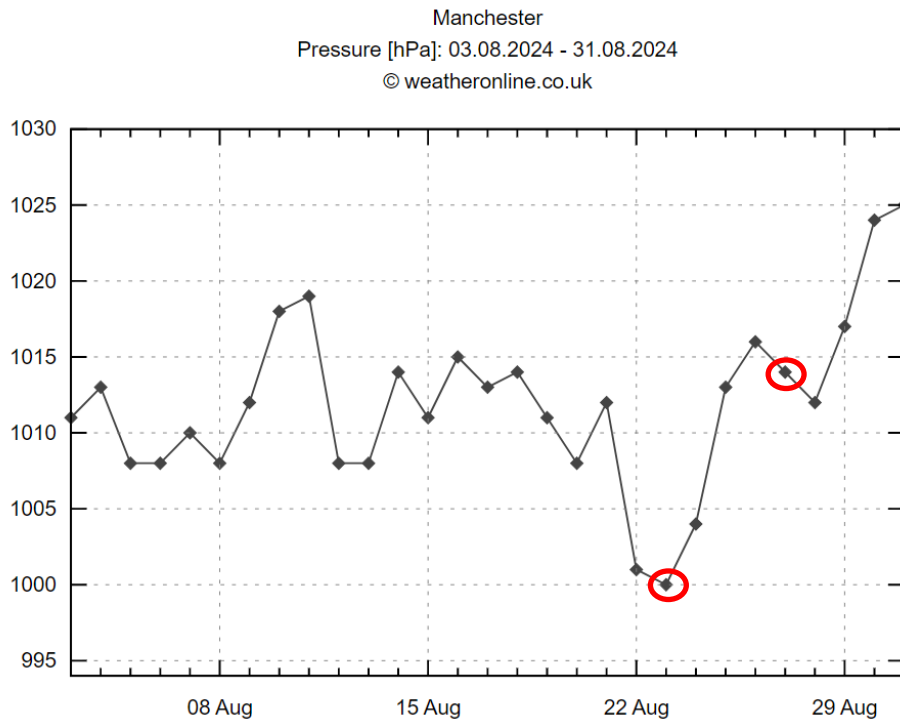
Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 19 of 37

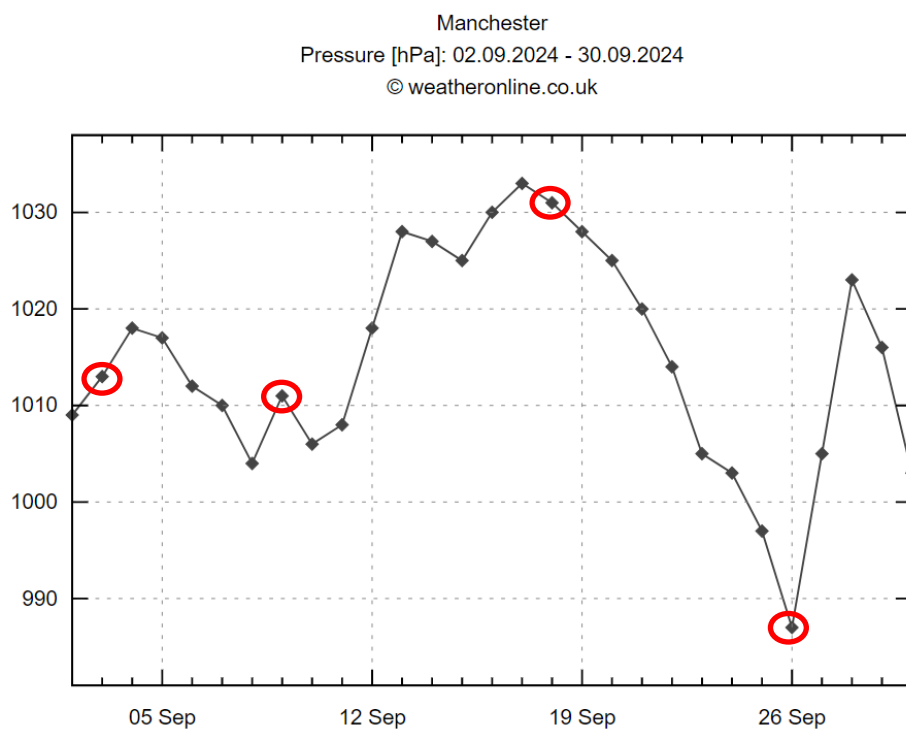
Engineer: Adrian Read

Date: 09/01/2026

Visits 1 & 2– 23/08 & 27/08/2024



Visits 3 to 6 – 03/09, 09/09, 18/09 and 26/09/2024



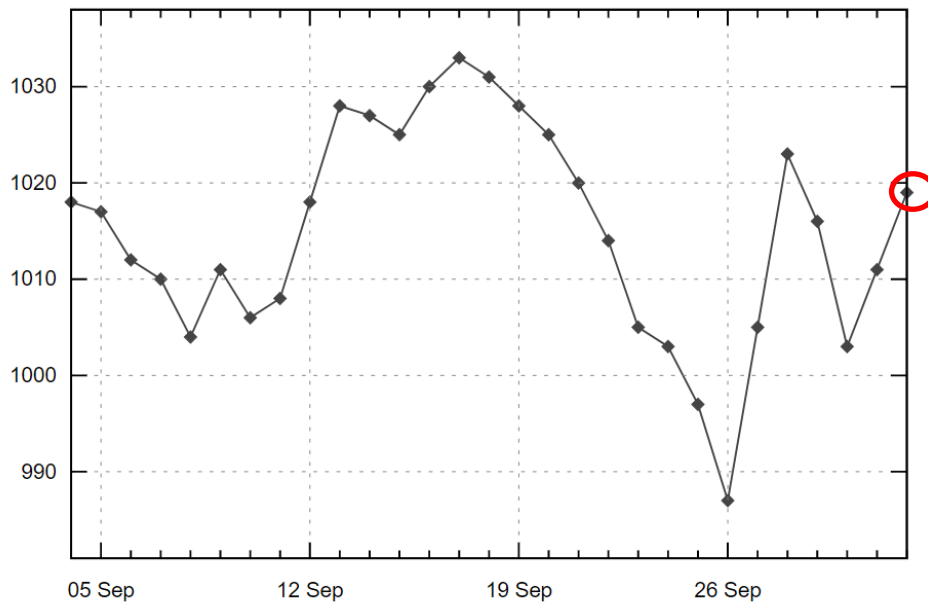


**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 20 of 37
Engineer: Adrian Read
Date: 09/01/2026

Visit 7 –03/10/2024

Manchester
Pressure [hPa]: 04.09.2024 - 02.10.2024
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Consideration of Groundwater Effects

An assessment has been made to determine whether groundwater levels beneath the site lie at a shallow depth at, or above, the plain section of the monitoring well or within cohesive strata. In those instances where shallow groundwater is located within the plain section of the monitoring well pipe or within cohesive strata this can result in 'groundwater pumping' or a 'piston effect' where the measured peak (and in some cases steady) flow rates reported at these monitoring well locations are significantly (and artificially) influenced by the pressures formed in the void above the groundwater in the plain section of the pipe or within the pipework installed within cohesive strata, as opposed to being truly representative of the ground gas flow rates. In such instances, this scenario can create 'artificial' negative and /or relatively high peak positive readings depending on whether the groundwater levels have increased or decreased in between monitoring events or since installation of the monitoring wells.

The results of the ground gas monitoring within this report have indicates that there have been no instances of artificial groundwater pumping.

The results of the ground gas monitoring have been assessed in accordance with the criteria specified for this site, which were derived as described in Appendix E.

Gas Risk Assessment

Methodology

In accordance with Section 6.3.1 in BS 8485:2015 +A1:2019, the development of the GSV for the site or the zone follows a process in which:

- 1) borehole hazardous gas flow rates are calculated for each borehole standpipe for each monitoring event and included in a database;
- 2) the reliability of the measured gas flow rates and concentrations is assessed taking into account borehole construction, etc;
- 3) decisions are made as to whether to use peak gas flow rates or steady-state rates in each calculation;



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 21 of 37
Engineer: Adrian Read
Date: 09/01/2026

- 4) decisions are made about how to deal with any temporal or spatial shortages in the data;
- 5) a decision is made about whether the site might be zoned or not; and
- 6) judgements are made about what GSV to use for design purposes taking all relevant information into account.

Subsequently to the above, the calculated borehole hazardous gas flow rates are considered to determine a Gas Screening Value (GSV) either for the site as a whole, or for site zones, if applicable.

Additionally, CIRIA C665 indicates that in the event that the reported methane concentrations are 'typically' >1% v/v and/or the reported carbon dioxide concentrations are 'typically' >5% then consideration should be made to increase the determination of the site to a Characteristic Situation 2 – Low Risk scenario.

Consideration of Peak Gas Flow Rates

In accordance with BS 8485:2015 +A1:2019 it may be appropriate to robustly discount *“peak instantaneous flows and negative flows that have been judged to be unrepresentative of a possible worst case”*. In addition, it is stated that *“peak flow measurements might result in a disproportionately high gas hazard prediction, and assignment of an over-precautionary CS”*.

Tier Environmental has conducted a review of the peak flow rates reported at the site. A maximum peak gas flow rate of 5.5 l/hr was reported at WS101 on the 7th gas monitoring visit; however, no similar results were recorded from the same well during the monitoring period and the next highest recorded peak gas flow rate reported elsewhere on site was 1.0 l/h, recorded at WS105 during the 6th visit. It was also noted that a steady flow rate of <0.1 l/hr was reported from both of these well on those visits and that the steady flow rate was reached rapidly. The 6th and 7th visit was conducted after a period of heavy rainfall in the region and so it is more likely, given the robust nature of the monitoring data that these instantaneous peak flow rates are not resultant of the ground gases at the site and may be confidently discounted in the calculation of the borehole hazardous gas flow rates.

Consideration of Peak Ground Gas Concentrations

An assessment has been made as to whether peak flow rates or steady flow rates should be applied for the purposes of calculating the borehole hazardous gas flow rates. Overall, based on the conceptual site model understanding of the site and with due consideration of the flow rates and reported TOC concentrations, it is not considered that there is evidence of significant gas generation from the Made Ground. Whilst there was olfactory evidence of hydrocarbon contamination within the Made Ground reported at WS101 and WS102 anaerobic degradation of these will produce only small volumes of methane at a very low rates.

Similarly, for organic rich alluvium / peat, the peak concentrations and flow rates are not representative of sustained gas flow that would cause elevated emissions from the ground.

On this basis, it is considered appropriate to discount peak gas concentrations from the borehole hazardous gas flow rate calculations.

Borehole Hazardous Gas Flow Rates

Calculated borehole hazardous gas flow rates have been determined and are presented in Table 4.4, below.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 22 of 37

Engineer: Adrian Read

Date: 09/01/2026

Table 4.4 Summary of Borehole Hazardous Gas Flow Rates

Visit No.	Visit date	Monitoring Point	Flow Data	Gas Concentrations				Borehole Hazardous Gas Flow Rates (l/hr)		Characteristic Situation Using Steady-State Gas Concentrations	Does Steady CH4 Exceed 1%?	Does Steady CO2 Exceed 5%?
			Flow rate (l/hr)	Methane (%v/v)		Carbon dioxide (%v/v)						
				CH4		CO2						
			Steady	Peak	Steady	Peak	Steady	CH4 Qhg (Steady)	CO2 Qhg (Steady)			
Visit 1	23/08/2024	WS101	ND	5.6	5.6	ND	ND	0.0056	0.0001	CS1	YES	No
Visit 2	27/08/2024	WS101	ND	5.7	5.7	ND	ND	0.0057	0.0001	CS1	YES	No
Visit 3	03/09/2024	WS101	ND	ND	ND	1.3	1.3	0.0001	0.0013	CS1	No	No
Visit 4	09/09/2024	WS101	ND	5.9	5.9	4.7	0.1	0.0059	0.0001	CS1	YES	No
Visit 5	18/09/2024	WS101	ND	6.0	1.3	14.6	0.1	0.0013	0.0001	CS1	YES	No
Visit 6	26/09/2024	WS101	ND	0.2	ND	14.0	14.0	0.0001	0.014	CS1	No	YES
Visit 7	03/10/2024	WS101	ND	3.7	2.1	0.3	0.1	0.0021	0.0001	CS1	YES	No
Visit 1	23/08/2024	WS102	ND	ND	ND	4.7	4.7	0.0001	0.0047	CS1	No	No
Visit 2	27/08/2024	WS102	ND	0.1	0.1	2.9	2.9	0.0001	0.0029	CS1	No	No
Visit 3	03/09/2024	WS102	ND	4.4	4.4	0.1	0.1	0.0044	0.0001	CS1	YES	No
Visit 4	09/09/2024	WS102	ND	ND	ND	5.1	5.1	0.0001	0.0051	CS1	No	YES
Visit 5	18/09/2024	WS102	ND	0.2	0.1	15.4	15.4	0.0001	0.0154	CS1	No	YES
Visit 6	26/09/2024	WS102	ND	ND	ND	15.1	15.1	0.0001	0.0151	CS1	No	YES
Visit 7	03/10/2024	WS102	ND	0.2	0.1	1.9	1.9	0.0001	0.0019	CS1	No	No
Visit 1	23/08/2024	WS103	ND	0.2	0.2	ND	ND	0.0002	0.0001	CS1	No	No
Visit 2	27/08/2024	WS103	ND	0.1	0.1	5.1	5.1	0.0001	0.0051	CS1	No	YES
Visit 3	03/09/2024	WS103	ND	ND	ND	3.3	3.3	0.0001	0.0033	CS1	No	No
Visit 4	09/09/2024	WS103	ND	0.2	ND	3.8	3.8	0.0001	0.0038	CS1	No	No
Visit 5	18/09/2024	WS103	ND	0.7	ND	5.5	5.5	0.0001	0.0055	CS1	No	YES
Visit 6	26/09/2024	WS103	ND	ND	ND	5.5	5.5	0.0001	0.0055	CS1	No	YES
Visit 7	03/10/2024	WS103	ND	ND	ND	4.0	4.0	0.0001	0.004	CS1	No	No
Visit 1	23/08/2024	WS104	ND	0.7	0.7	ND	ND	0.0007	0.0001	CS1	No	No
Visit 2	27/08/2024	WS104	0.1	0.6	0.6	ND	ND	0.0006	0.0001	CS1	No	No
Visit 3	03/09/2024	WS104	ND	0.1	0.1	0.1	0.1	0.0001	0.0001	CS1	No	No
Visit 4	09/09/2024	WS104	0.1	0.5	0.4	0.3	ND	0.0004	0.0001	CS1	No	No



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 23 of 37

Engineer: Adrian Read

Date: 09/01/2026

Visit No.	Visit date	Monitoring Point	Flow Data	Gas Concentrations				Borehole Hazardous Gas Flow Rates (l/hr)		Characteristic Situation Using Steady-State Gas Concentrations	Does Steady CH4 Exceed 1%?	Does Steady CO2 Exceed 5%?
			Flow rate (l/hr)	Methane (%v/v)		Carbon dioxide (%v/v)						
				CH4		CO2						
			Steady	Peak	Steady	Peak	Steady	CH4 Qhg (Steady)	CO2 Qhg (Steady)			
Visit 5	18/09/2024	WS104	ND	1.1	0.7	0.9	ND	0.0007	0.0001	CS1	No	No
Visit 6	26/09/2024	WS104	ND	0.2	0.2	2.0	1.1	0.0002	0.0011	CS1	No	No
Visit 7	03/10/2024	WS104	ND	2.4	2.4	1.7	0.1	0.0024	0.0001	CS1	YES	No
Visit 1	23/08/2024	WS105	ND	ND	ND	0.1	0.1	0.0001	0.0001	CS1	No	No
Visit 2	27/08/2024	WS105	ND	0.1	0.1	0.3	0.3	0.0001	0.0003	CS1	No	No
Visit 3	03/09/2024	WS105	ND	ND	ND	0.3	0.3	0.0001	0.0003	CS1	No	No
Visit 4	09/09/2024	WS105	ND	0.9	ND	0.2	0.2	0.0001	0.0002	CS1	No	No
Visit 5	18/09/2024	WS105	ND	ND	ND	5.3	ND	0.0001	0.0001	CS1	No	No
Visit 6	26/09/2024	WS105	ND	0.2	ND	ND	ND	0.0001	0.0001	CS1	No	No
Visit 7	03/10/2024	WS105	ND	ND	ND	2.6	0.2	0.0001	0.0002	CS1	No	No
Visit 1	23/08/2024	WS106	ND	0.2	0.2	ND	ND	0.0002	0.0001	CS1	No	No
Visit 2	27/08/2024	WS106	ND	0.1	0.1	2.7	2.7	0.0001	0.0027	CS1	No	No
Visit 3	03/09/2024	WS106	ND	ND	ND	2.4	2.4	0.0001	0.0024	CS1	No	No
Visit 4	09/09/2024	WS106	ND	ND	ND	3.5	3.2	0.0001	0.0032	CS1	No	No
Visit 5	18/09/2024	WS106	ND	0.3	0.2	5.3	5.3	0.0002	0.0053	CS1	No	YES
Visit 6	26/09/2024	WS106	ND	ND	ND	2.6	2.6	0.0001	0.0026	CS1	No	No
Visit 7	03/10/2024	WS106	ND	0.5	0.5	3.6	2.6	0.0005	0.0026	CS1	No	No
Visit 1	23/08/2024	WS107	ND	0.2	0.2	ND	ND	0.0002	0.0001	CS1	No	No
Visit 2	27/08/2024	WS107	ND	0.1	0.1	11.9	11.9	0.0001	0.0119	CS1	No	YES
Visit 3	03/09/2024	WS107	ND	ND	ND	1.2	1.2	0.0001	0.0012	CS1	No	No
Visit 4	09/09/2024	WS107	ND	ND	ND	12.2	12.2	0.0001	0.0122	CS1	No	YES
Visit 5	18/09/2024	WS107	ND	ND	ND	11.1	11.1	0.0001	0.0111	CS1	No	YES
Visit 6	26/09/2024	WS107	ND	ND	ND	13.2	13.1	0.0001	0.0131	CS1	No	YES
Visit 7	03/10/2024	WS107	ND	ND	ND	8.4	8.4	0.0001	0.0084	CS1	No	YES
Visit 1	23/08/2024	WS108	ND	0.3	0.3	ND	ND	0.0003	0.0001	CS1	No	No
Visit 2	27/08/2024	WS108	ND	0.1	0.1	0.1	0.1	0.0001	0.0001	CS1	No	No



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 24 of 37
Engineer: Adrian Read
Date: 09/01/2026

Visit No.	Visit date	Monitoring Point	Flow Data	Gas Concentrations				Borehole Hazardous Gas Flow Rates (l/hr)		Characteristic Situation Using Steady-State Gas Concentrations	Does Steady CH4 Exceed 1%?	Does Steady CO2 Exceed 5%?
			Flow rate (l/hr)	Methane (%v/v)		Carbon dioxide (%v/v)						
				CH4		CO2						
			Steady	Peak	Steady	Peak	Steady	CH4 Qhg (Steady)	CO2 Qhg (Steady)			
Visit 3	03/09/2024	WS108	ND	ND	ND	0.1	0.1	0.0001	0.0001	CS1	No	No
Visit 4	09/09/2024	WS108	ND	ND	ND	10.4	0.1	0.0001	0.0001	CS1	No	No
Visit 5	18/09/2024	WS108	ND	ND	ND	9.9	0.1	0.0001	0.0001	CS1	No	No
Visit 6	26/09/2024	WS108	ND	ND	ND	11.6	0.3	0.0001	0.0003	CS1	No	No
Visit 7	03/10/2024	WS108	ND	ND	ND	7.8	0.1	0.0001	0.0001	CS1	No	No
Visit 1	23/08/2024	WS109	ND	0.2	0.2	0.1	0.1	0.0002	0.0001	CS1	No	No
Visit 2	27/08/2024	WS109	ND	0.2	0.2	0.1	0.1	0.0002	0.0001	CS1	No	No
Visit 3	03/09/2024	WS109	ND	ND	ND	0.1	0.1	0.0001	0.0001	CS1	No	No
Visit 4	09/09/2024	WS109	ND	ND	ND	0.1	0.1	0.0001	0.0001	CS1	No	No
Visit 5	18/09/2024	WS109	ND	ND	ND	0.9	ND	0.0001	0.0001	CS1	No	No
Visit 6	26/09/2024	WS109	ND	ND	ND	0.3	ND	0.0001	0.0001	CS1	No	No
Visit 7	03/10/2024	WS109	ND	ND	ND	8.7	0.2	0.0001	0.0002	CS1	No	No



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 25 of 37
Engineer: Adrian Read
Date: 09/01/2026

The hazardous gas flow rate for methane and carbon dioxide from all the wells in the site is shown in Table 4.4. This shows that across the whole site in both Made Ground, Alluvium and Glaciofluvial Deposits the Borehole Hazardous Gas Flow Rates are below the limit for Characteristic Situation CS1.

‘Worst-Case’ GSV Check Calculation – Carbon Dioxide and Methane

In accordance with BS8485, Tier Environmental has conducted a ‘worst-case’ check by calculating the Gas Screening Value (GSV) for the site:

“Irrespective of the apparent comprehensiveness of the dataset, the plausible worst case condition should be calculated for each hazardous gas by multiplying the maximum recorded flow in any standpipe in that strata (and zone) with the maximum gas concentration in any other standpipe in that strata (and zone), but discounting any peak instantaneous flows and negative flows that have been judged to be unrepresentative of a possible worst case.”

Therefore, the following process has been followed:

- the maximum reported methane or carbon dioxide concentration (whichever is highest) from any monitoring well and during any ground gas monitoring visit; and,
- the remaining maximum peak positive flow rate (after any negative flow rates or ‘artificially’ high flow rates have been discounted as described above) from any monitoring well and during any ground gas monitoring visit.

Table 4.5 Initial Worst-Case GSV Calculation

Ground Gas	Maximum Reported Peak Concentration (% v/v)		Selected Concentration used in GSV Calculation (% v/v)		Maximum Appropriately Selected Gas Flow Rate (l/hr)		'Worst case' GSV (l/hr)
Methane (CH ₄)	6.0	⌈	15.4	x	0.1	=	0.0154
Carbon dioxide (CO ₂)	15.4						

Historically, CIRIA C665 provides two separate methods to ‘characterise’ a site that firstly requires the assessor to distinguish between two fundamental development ‘situations’:

- Situation A** - Any development other than Situation B (e.g. factories, shops, commercial, warehouses, schools, cinemas, sports centres, stadiums, high rise housing, housing with basements, etc) for which the **Modified Wilson and Card ‘Characteristic Situation’ classification system** is applied; and,
- Situation B** - Low rise building with minimum ventilated under floor void (min 150mm) for which the **NHBC Traffic light classification system** is applied.

In this instance, as the site is due to be developed as a combination of terraced housing (81 No. dwellings) and a 5/6 storey building containing 142 No. apartments (Use Class C3) with ground floor commercial use (Use Class E), it shall be regarded as a Situation A scenario for the purposes of the ground gas risk assessment. This is also consistent with the Curtins report which states “...[the anticipated] construction type does not conform with the requirements of the ‘model house’ used within NHBC Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide Are Present. As such, assessment of ground gas risk to site end users in the low rise housing has been undertaken with reference to BS



SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 26 of 37

Engineer: Adrian Read

Date: 09/01/2026

8485:2015+A1:2019". In addition, it should be noted that the Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide Are Present, NHBC, 2007 has being withdrawn from 1st July 2025 which includes the withdrawing of the NHBC Traffic Light system.

Table 4.5 demonstrates that the site is placed in a Characteristic Situation 1 – Very Low Risk scenario on the basis of the **'worst case'** GSV alone.

Carbon Dioxide and Methane Concentrations

Both the calculated hazardous ground gas flow rates and worst-case GSV checks have indicated that the site should be classed as a Characteristic Situation 1 – Very Low Risk, however, CIRIA C665 (and BS8485) indicates that in the event that the reported methane concentrations are 'typically' >1% v/v and/or the reported carbon dioxide concentrations are 'typically' >5% then *consideration* should be made to increase the determination of the site to a Characteristic Situation 2 – Low Risk scenario.

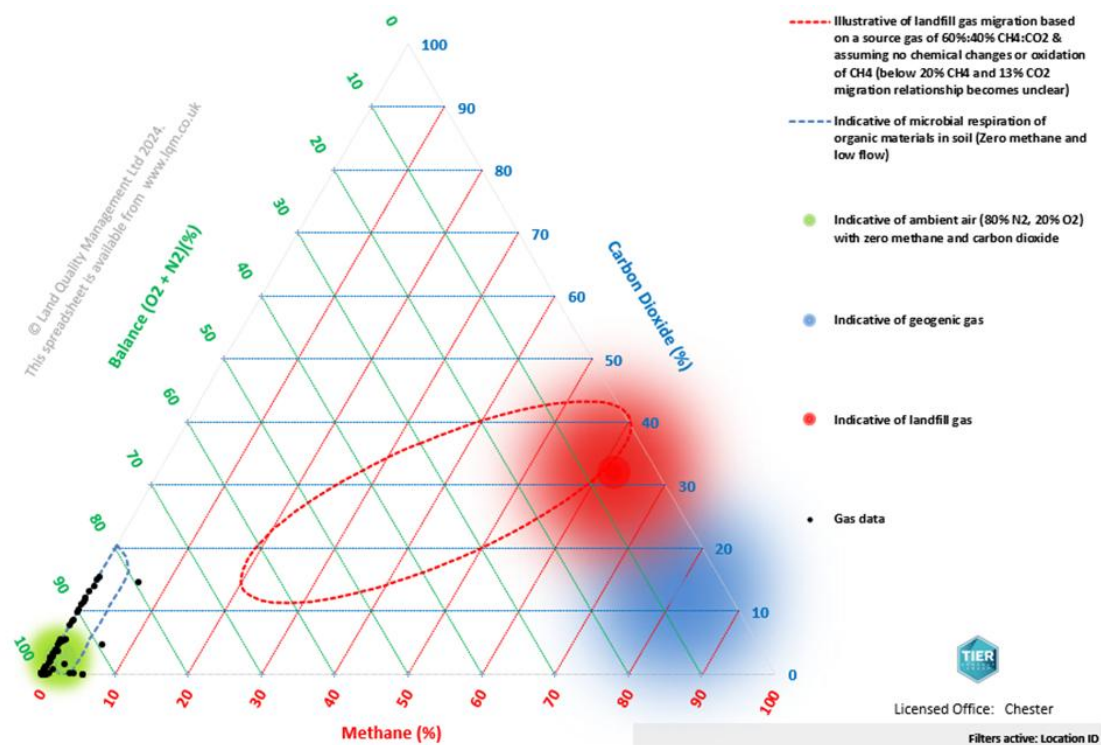
Ternary Plot

A ternary plot has been produced for the reported gas concentrations shown in the figure below. From this it can be determined that the gas source generation on site is predominantly from microbial respiration of organic materials within the natural superficial and Made Ground.

Two data points which fall outside of this are representative of gas generated from Made Ground, which Tier Environmental consider falls within an area on the plot of anticipated very low rate of gas production.

The rate of gas generation via the respiration process in the natural soils and Made Ground is very low (i.e. a low risk or very low risk source in accordance with BS8576: 2013), therefore it is considered that is not required to increase from Characteristic Situation CS1 to CS2 on the basis of this ternary plot information.

Figure 4.2 Ternary Plot For All Data





**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 27 of 37
Engineer: Adrian Read
Date: 09/01/2026

A maximum steady methane concentration of 5.9% v/v and a maximum steady carbon dioxide concentration of 15.4% v/v have been reported at the site during the recent monitoring works. Tier Environmental has considered that, conceptually, the measured carbon dioxide and methane are not resultant from significant sources of ground gases (e.g. such as from landfills or coal mine gases) and this is reflected in the very low gas generation potential evidenced by the consistently low steady gas flow rates and the evidence provided in the above ternary plot information.

On this basis, it is not considered that that the site should be increased to a CS2 scenario on the basis of this information so far within the risk assessment.

Carbon Monoxide and Hydrogen Sulphide

There is no current UK risk assessment guidance available for carbon monoxide and hydrogen sulphide derived from ground gases.

A maximum peak carbon monoxide concentration of 14 ppm has been reported which is below the workplace long term exposure limit (30ppm) and the workplace short term exposure limit (200ppm) published by the Health and Safety Executive (EH40/2005 Workplace Exposure Limits) but exceeds the WHO long term (24 hours) indoor exposure guideline value (5.68 ppm). Natural soils produce carbon monoxide as a result of chemical oxidation of small quantities of organic matter. It is regularly detected in natural soils and unless there is an external source such as a landfill it does not pose a risk to development. The production of carbon monoxide is transient and is likely dependent on rainfall.

A maximum peak hydrogen sulphide concentration of 1 ppm has been reported which is below the workplace long term exposure limit (5ppm) and the workplace short term exposure limit (10ppm) published by the Health and Safety Executive (EH40/2005 Workplace Exposure Limits).

Consideration of Foundation Types and Floor Slab Design

Tier Environmental has considered the proposed foundation types within the ground gas risk assessment. It should be noted that the apartment block, which is having precautionary ground gas protection measures installed, is being piled whereas the foundation solution for remaining residential blocks is finalised to comprise Rigid Inclusion (aka Controlled Modulus Columns) and this risk assessment has included consideration of the effects that differing foundation solutions may have on the development.

BS 8485 states that deeper foundations can influence or change ground gas pathways and gas generation rates. This might be due to the creation or alteration of flow paths for existing ground gases or be the result of the introduction of oxygen at depth (e.g. in peaty soils) promoting the generation of ground gas. The guidance states that the foundations adopted for a building can influence the generation of gas and/or the pathways through which the gas might move and thus impact on the gas protection measures required. This could be a result of changing the permeability of the underlying strata, possible changes to the groundwater regime and the creation of preferential pathways due to the proposed foundation solution.

The guidance also states that assumptions made during initial gas risk assessments, including gas flow rates, are re-evaluated during the design of the foundations for the building.

Tier Environmental considers that notwithstanding the foundation solution, via multiple lines of evidence provided above, and consideration of the CSM, to determine that the site be regarded as a Characteristic Situation 1 – Very Low risk scenario, for which no ground gas protection measures would be required. However, in line with BS8485: *“The designation of GSV should be made after consideration of the available monitoring data and all other relevant aspects of an adequate conceptual site model and **with knowledge of the development’s sub-structure and foundation arrangement.**”*



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 28 of 37
Engineer: Adrian Read
Date: 09/01/2026

Floor Slab design

With regards to the inherent design of the floor slab, it is understood that the terraced houses will have a suspended beam and block floor slab construction, which does not achieve any point score as a structural barrier (point score of '0' points) in accordance with Table 5 in BS 8485. It is current proposed that there will be a 200mm clear ventilated void (with periscopic vents) that may contribute a point score of at least 1.5 points (assuming a worst-case of 'good ventilation') in accordance with Table 6 in BS 8485. In accordance with BS 8485, any gas protection system should consist of at least two different elements; for example, a barrier element with either a membrane or a ventilation or dilution element (or both). The elements work independently and collaboratively, and a single element should not be used because there would be no redundancy to allow for defects in the component.

Nevertheless, the inherent floor slab design and ventilation do provide some contribution towards gas protection and is relevant within the CSM considerations.

Foundation Solution

Tier Environmental has been informed that the final selected foundation solution for the site is a Rigid Inclusions (aka Controlled Modulus Columns (CMCs)) solution. RI / CMCs are cast-in-situ, cementitious, intrinsically low-permeability inclusions that do not adversely change the diffuse flow mechanisms baked into the risk assessment or introduce preferential pathways that would otherwise act as 'chimneys' for gas to migrate through.

Assuming robust QA/QC is in place, Tier Environmental considers that a RI / CMC foundation solution do not automatically trigger an uplift in CS, particularly when compared with the obvious change in flow mechanisms triggered by alternative ground improvement techniques such as Vibro Stone Columns. As such, **the Characteristic Situation 1 – Very Low Risk designation determined for the site may remain, unaffected for the proposed Rigid Inclusions / CMC solution.**

Considerations of Regulators and Warranty Providers

It is understood from Willmott Dixon that the warranties for the developments will be NHBC backed and there will also be a requirement for the developments to be Local Authority Cuiling Control compliant. The ultimate client is Rochdale Borough Council.

Tier Environmental presently understands considers that there are no requirements to install ground gas protection measures (commensurate with a Characteristic Situation 2 – Low Risk Scenario) irrespective of ground gas assessment discussion above, driven by requirements from one, or more, of the third party organisations above.

Finally, it should be note that the site lies within an area where between 1% and 3% of properties are above the radon Action Level. On this basis no radon protection measures are required and Tier Environmental understands that Local Authority Building Control have **not** insisted on conservative implementation of radon protection measures for this site.

Considerations for Construction and Maintenance Workers

During engineering and construction activities, the ground gas data indicate that the following aspects are to be considered during the preparation of relevant site H&S plans, method statements and related documents, and appropriate working methods adopted:

- **Carbon dioxide concentrations in ground gas:** The measured CO₂ concentrations in ground gas reported are elevated relative to background levels and could present an asphyxiation risk in excavations and other confined spaces. The Health & Safety Executive has published information defining safe occupational exposure levels for CO₂ and the latest guidance must be consulted to determine whether the ground gas regime necessitates specific precautions during site works.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 29 of 37

Engineer: Adrian Read

Date: 09/01/2026

- **Methane concentrations in ground gas:** The measured methane concentrations in ground gas reported are elevated relative to background levels and could give rise to explosive mixtures in confined spaces. Safe working methods should be adopted to mitigate this risk.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 30 of 37
Engineer: Adrian Read
Date: 09/01/2026

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Tier Environmental was commissioned by Willmott Dixon to undertake a Supplementary Ground Gas Risk Assessment Report of Richard Street, Rochdale.

- The spatial distribution of the monitoring wells was provided by Booth King on behalf of Willmott Dixon;
- It is understood that gas protection measures are to be installed within the apartment block in the northwest of the site as there is insufficient time for any adjustments to be made to the pre-existing design proposals. As such, this investigation has focussed on reassessment of the remaining proposed residential properties across the site, following remediation works conducted in parallel with earthworks across the site.
- Previous ground gas monitoring has been conducted at the site - before remediation and enabling works had been undertaken – by Delta Simons in 2018 and Curtins in June 2021;
 - No representative Gas Screening Values determined by either Curtins or Delta Simons exceeded the threshold for Characteristic Situation 2 with the exception of a single well monitored by Delta Simons;
 - Generally, the recorded steady gas flow rates have been reported by Delta Simons and Curtins as below the limit of detection of the instrument, with the exception of a single reported steady flow rate of 2.7 l/hr (from CP202) reported during the third visit (of three) by Delta Simons; however, it was noted that this well was flooded and appeared to have been installed primarily for groundwater monitoring purposes and that no similar sustained flow rates were reported from the well during the other two visits.
 - The maximum steady methane concentration reported by Delta Simons was 19.2% v/v (reported in the flooded well at CP202) and all other wells reported <0.1% v/v. The maximum steady carbon dioxide concentration reported was 10.1% v/v. Curtins reported that steady methane concentrations were typically recorded below the limit in all monitoring wells throughout the monitoring period, with exception of WS07 on the second (0.2% v/v) and sixth (0.4% v/v) monitoring visits. The maximum steady carbon dioxide concentration of 8.8% v/v was reported by Curtins during their monitoring works.
 - Delta Simons considered that because carbon dioxide concentrations have been reported (>5% v/v) and methane concentrations (>1% v/v) that the site should be concluded as having a “provisional CS2 classification”, but recommended that further gas monitoring was undertaken;
 - Curtins determined that preliminary zoning of the site with respect to CS2 designations was appropriate in the northwestern and eastern areas due to “elevated carbon dioxide concentrations (>5% v/v) [that] were recorded in WS07, WS09, WS11 and WS19”;
- Tier Environmental has considered the conceptual site model for the site (including the proposed foundation and floor slab design), following remediation and earthworks and conducted 7 No. additional supplementary ground gas monitoring visits from wells installed within the Made Ground, Alluvium and Glaciofluvial Deposits beneath the site.
 - Remediation works conducted in parallel with site-wide earthworks included the removal of potentially putrescible materials (including black odorous material and six timber boats) from beneath the building footprints and removal of hydrocarbon impacts from beneath building footprints;
 - Borehole hazardous gas flow rates have been calculated in accordance with BS8485;
 - Justification has been provided for not including instantaneous peak flow rates or peak gas concentrations within these calculations;
 - The results of the calculated borehole hazardous gas flow rates determined that in each case, they are below the CS2 threshold;



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 31 of 37
Engineer: Adrian Read
Date: 09/01/2026

- A worst-case check, conducted using the maximum reported methane or carbon dioxide concentration (whichever is highest) from any monitoring well and during any ground gas monitoring visit and the highest representative flow rate has also determined that the calculated worst-case GSV is below the CS2 threshold;
- Due consideration has been made, with respect to the nature of the Made Ground materials, that the low TOC concentrations in these materials (<1.35% average) represent a low to very low gas generation potential. Anaerobic degradation some localised residual slight hydrocarbon odours will produce only small volumes of methane at a very low rates;
- Due consideration has also been made to the alluvium materials and localised peat - peak concentrations and flow rates are not representative of sustained gas flow that would cause elevated emissions from the ground;
- Tier Environmental has also taken due consideration of the extensive available ground gas monitoring data available for the site in being able to conclude that whilst methane concentrations and carbon dioxide concentrations have been reported above 1% v/v and 5% v/v, respectively, this does not mean that the site should automatically be increased to a CS2 scenario. CIRIA C665 states only that you should “consider” increasing to CS2, rather than it being an automatic requirement to do so;
- Further consideration of this has been made via assessment of ternary plots for the data which demonstrate that the sources of the gases are either Alluvium of Made Ground and with a very low risk of emissions from the ground, based on the reported flow rates;
- As such, it is not considered that there is sufficient evidence to warrant increasing the ground gas characteristic value to a Characteristic Situation 2 – Low Risk scenario, and that **a Characteristic Situation 1 – Very Low Risk scenario is appropriate for the site.**
- Further consideration of the proposed foundation solution for the terraced housing plots has been undertaken. Tier Environmental has been informed that the final selected foundation solution for the site is a Rigid Inclusions (aka Controlled Modulus Columns (CMCs)) solution. RI / CMCs are cast-in-situ, cementitious, intrinsically low-permeability inclusions that do not adversely change the diffuse flow mechanisms baked into the risk assessment or introduce preferential pathways that would otherwise act as ‘chimneys’ for gas to migrate through. **As such, the Characteristic Situation 1 – Very Low Risk designation determined for the site may remain, unaffected for the proposed Rigid Inclusions / CMC solution.**
- The inherent current floor slab design, despite the sub-slab ventilation, would **not** be currently sufficient to form a gas protection system that meets the requirements of BS 8485, commensurate with a Characteristic Situation 2 – Low Risk scenario. Nevertheless, the sub-slab ventilation **will** contribute to reducing the risks from ground gases *further* and provides *additional* confidence in the conclusions above.
- Finally, currently understood that the ultimate client (Rochdale Borough Council), the warranty provider (NHBC) or Local Authority Building Control are **not** stipulating any requirements that ground gas protection measures (commensurate with a CS2 scenario) are implemented at the site.

The Conceptual Site Model is provided as Drawing No. TE1582-TE-00-XX-DR-GE-004-V01, presented in Appendix A.

5.2. Recommendations

The above conclusions have been reached based on detailed consideration of the site and the reported ground gas results and should be submitted to the Local Authority for review and approval.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 32 of 37

Engineer: Adrian Read

Date: 09/01/2026

6. REGULATORY APPROVALS

The conclusions and recommendations presented above are considered reasonable based on the findings of the site investigation. However, these cannot be guaranteed to gain regulatory approval and, therefore, the report should be passed to the appropriate regulatory authorities and/or other organisations for their comment and approval prior to undertaking any works on site.

It is recommended that conditions placed on any planning permission are discharged prior to commencement of site works.



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 33 of 37
Engineer: Adrian Read
Date: 09/01/2026

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**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 34 of 37
Engineer: Adrian Read
Date: 09/01/2026

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**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 35 of 37
Engineer: Adrian Read
Date: 09/01/2026

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**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03
Page No : 36 of 37
Engineer: Adrian Read
Date: 09/01/2026

8. GLOSSARY OF TERMS

ACEC	Aggressive Chemical Environment for Concrete (classification)
aOD	Above Ordnance Datum
bgl	Below ground level
BGS	British Geological Survey
BRE	Building Research Establishment
CBR	California Bearing Ratio (test)
COMAH	Control of Major Accident Hazards (regulations)
Designated location	Site (and the ecosystem on that site) protected under national or international legislation. A potential ecological receptor to be considered as part of the assessment of land contamination. Example designated locations include SSSIs (q.v.), SACs (q.v.), national nature reserves, Ramsar sites and bird special protection areas.
DQA	Data Quality Assessment
DQO	Data Quality Objective
DQRA	Detailed Quantitative Risk Assessment
DWS	Drinking Water Standard
EQS	Environmental Quality Standard
GAC	Generic Assessment Criterion
GQA	General Quality Assessment (Environment Agency)
GSV	Gas Screening Value
HCV	Health Criteria Value
IPPC	Integrated Pollution Prevention and Control (regulations)
K _{ow}	Octanol-water partition coefficient
LEL	Lower Explosive Limit
LL	Liquid Limit
LoD	Limit of Detection (analytical)
LoQ	Limit of Quantification (analytical)
Mean Value Test	Statistical test (described in the CIEH Guidance) to estimate the mean value of a normally distributed population of data at a given level of confidence. Normally for contaminated land assessment, the 95th percentile (referred to as the 95%UCL or US95) is applied as a reasonable but conservative estimate of the mean concentration for comparison with the relevant assessment criteria.
Maximum Value Test	Statistical test (described in the CIEH Guidance) to identify whether an elevated concentration within a normally distributed data set forms part of the underlying population from which it has been sampled or whether it is an outlier (such as a localised area of contamination) that merits further consideration.
MC	Moisture Content
NGR	National Grid Reference
NIHHS	Notification of Installations Handling Hazardous Substances (regulations)
OS	Ordnance Survey
PI	Plasticity Index
PID	Photoionisation Detector
PL	Plastic Limit
ppm	Parts per million
ppmv	Parts per million by volume
QA	Quality Assurance
QC	Quality Control
SAC	Special Area of Conservation
SOM	Soil Organic Matter



**SUPPLEMENTARY GROUND GAS RISK
ASSESSMENT REPORT RICHARD STREET,
ROCHDALE**

Report No : TE1582-TE-00-XX-RP-GE-004-V03

Page No : 37 of 37

Engineer: Adrian Read

Date: 09/01/2026

SPT	Standard Penetration Test
SPZ	Source Protection Zone
SSAC	Site-Specific Assessment Criterion
SSSI	Site of Special Scientific Interest
SVOC	Semi-Volatile Organic Compound
TEF	Toxicity Equivalent Factor
TPH	Total Petroleum Hydrocarbons
TWA	Time Weighted Average
US95	95 th percentile estimate of the true mean value of a data population (also known as 95%UCL).
VOC	Volatile Organic Compound

APPENDIX A - DRAWINGS

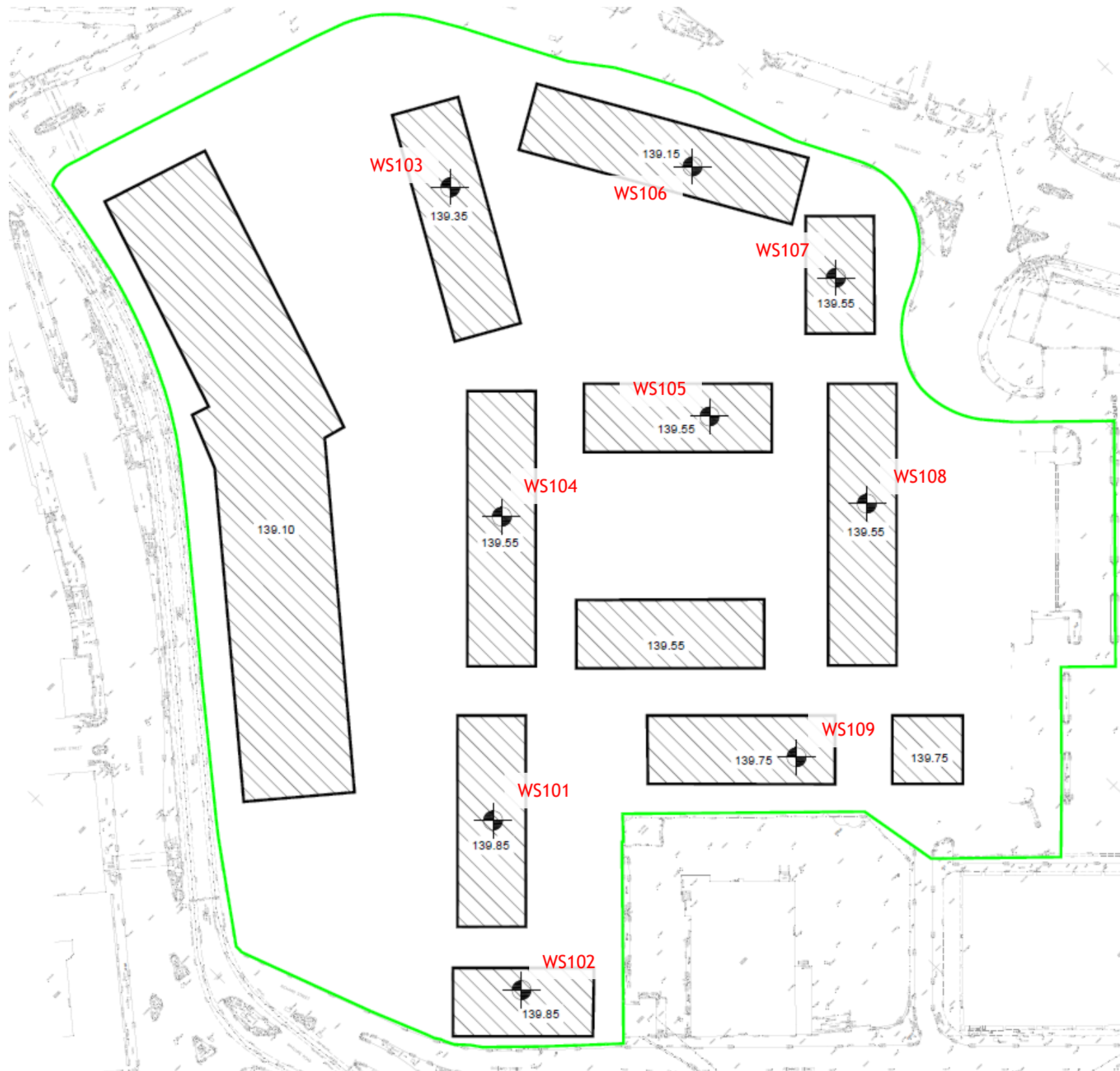
Reproduced from the Ordnance Survey map with the permission of The Controller of Her Majesty's Stationary Office, © Crown Copyright. All rights reserved.



Supplementary Gas Risk Assessment Monitoring Well Location Plan

Contract Number	TE1582
Contract	Neighbourhood, Rochdale
Client	Willmott Dixon

WS10x  Tier Environmental window sample and installed gas monitoring well (12th August 2024)



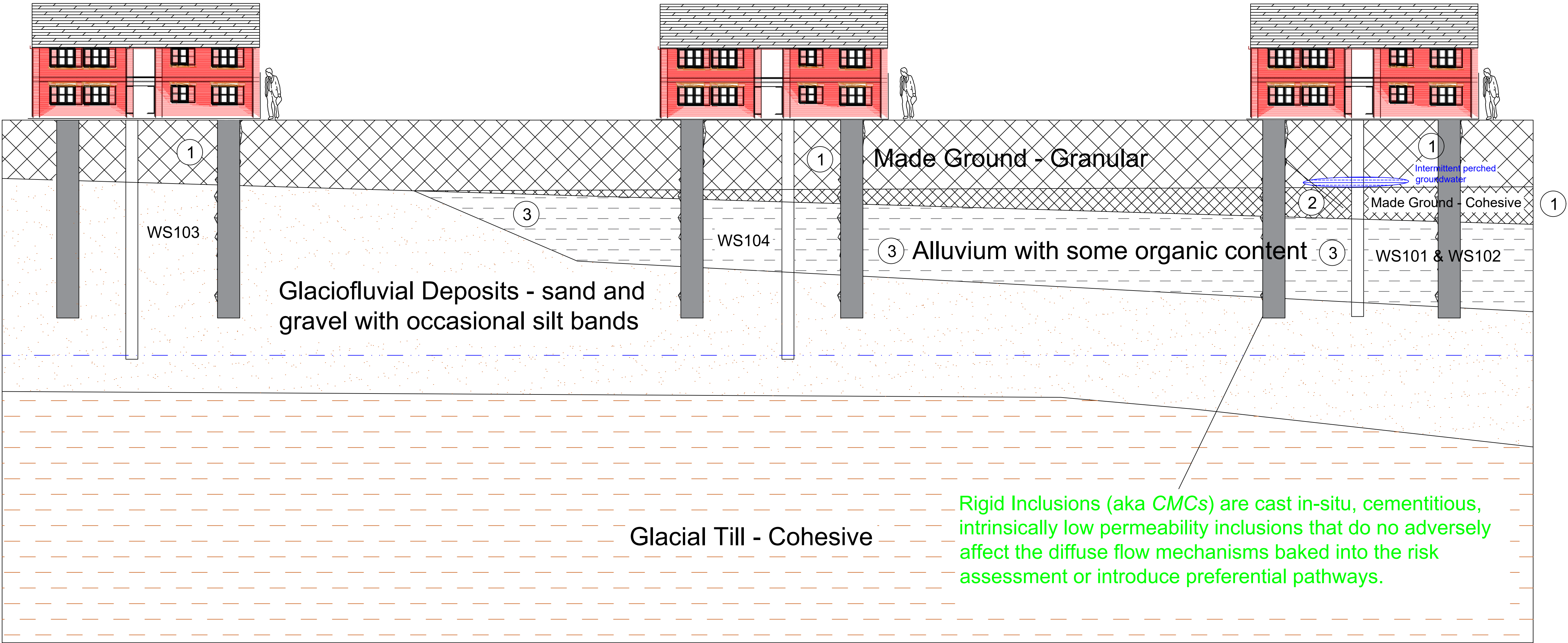
Scale	NTS	
Drawn by	AGR	Approved SL
Drawing Number	TE1582-TE-00-XX-DR-GE-003-V01	

Northeast

Site Boundary

Southwest

Proposed low rise terraced housing



- 1 Made Ground - Low to very low gas generation
- 2 Slight hydrocarbon odours - very low gas generation
- 3 Alluvium including plant debris and natural organic materials - very low gas generation

DO NOT SCALE



NOTES

This drawing is purely schematic and is a representation of the ground conditions and process, based upon information derived from the third party reports, desk study, third party site investigations, and the ground conditions encountered during Tier Environmental's supplementary gas monitoring well installation.

This model should be revised, following the availability of any future supplementary information to ensure its relevance to actual conditions (if necessary).

P2	09/01/2026	AR	FINALISED WITH FOUNDATION SOLUTION	SL	SL
P1	11/10/2024	AR	ISSUED FOR INFORMATION	SL	SL
REV	DATE	BY	DESCRIPTION	CHK	APD

DRAWING STATUS: FINAL



Tier Environmental Ltd.
Unit 5 Office Village
Sandpiper Court
Chester Business Park
Chester | CH4 9QZ

t: 01925 818 388

CLIENT:

WILLMOTT DIXON

PROJECT:

NEIGHBOURHOOD, ROCHDALE

TITLE:

GROUND GAS CONCEPTUAL SITE MODEL

SCALE	SIZE	CHECKED	APPROVED
NTS		SL	SL
CAD FILE		DESIGN/DRAWN	DATE
-		AR	09/01/2026
PROJECT No:	DRAWING No:	REV:	
TE1582	TE1582-TE-00-XX-DR-GE-004-V02	p2	

APPENDIX B - EXPLORATORY HOLE LOGS





Borehole Log

Borehole No.

WS102

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 389896.00 - 412907.00

Hole Type
WS

Location: Rochdale

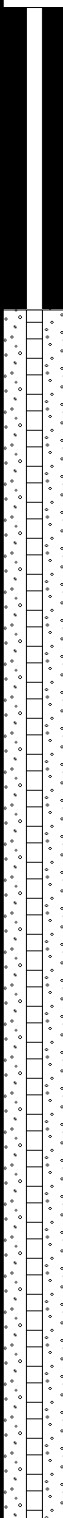
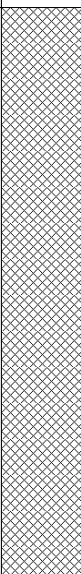
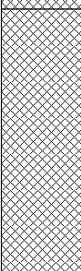
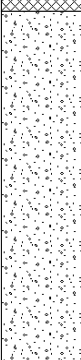
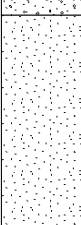
Level:

Scale
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Client: Willmott Dixon Construction

Dates: 12/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
								MADE GROUND: Greyish brown, clayey, gravelly SAND. Gravel is fine to coarse, angular to subrounded of brick, concrete, sandstone and occasional coal. Compacted, difficult to hand dig. MADE GROUND	1
					1.90			POSSIBLE MADE GROUND: Soft, dark brownish grey, becoming friable, very sandy, slightly gravelly CLAY. Gravel is fine to coarse, angular of sandstone, mudstone and rare coal. Very slight hydrocarbon odour between 2.10m bgl - 2.30m bgl. POSSIBLE MADE GROUND	2
					2.80			Orangish brown, gravelly, fine to medium, grained SAND. Gravel is fine to coarse, subrounded to rounded of sandstone. GLACIOFLUVIAL DEPOSITS	3
					4.00			Orangish brown, fine grained SAND. Wet from 4.30m bgl. GLACIOFLUVIAL DEPOSITS	4
					4.70			Soft to firm, brown SILT. GLACIOFLUVIAL DEPOSITS	5
					5.00	End of borehole at 5.00 m			

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as wet material between 4.30m bgl to 5.00m bgl 3) Very slight hydrocarbon odour between 2.10m bgl - 2.30m bgl. No visual contamination. 4) Terminated at target depth. 5) Collapse of borehole between 4.50m bgl and 5.00m bgl.





Borehole Log

Borehole No.

WS103

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 389996.00 - 413030.00

Hole Type
WS

Location: Rochdale

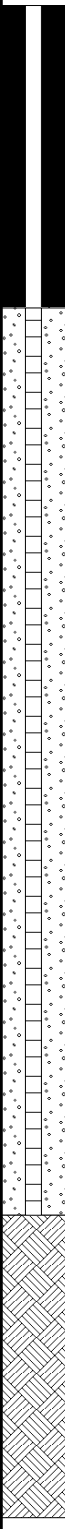
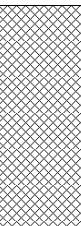
Level:

Scale
1:25

Client: Willmott Dixon Construction

Dates: 12/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					0.75			MADE GROUND: Greyish brown, slightly clayey, gravelly SAND. Gravel is fine to coarse, angular to subrounded of brick, concrete, sandstone, rare asphalt, rare rootlets near base of stratum. MADE GROUND	
								Orangish brown, fine grained SAND. GLACIOFLUVIAL DEPOSITS <i>Slightly silty between 1.00m bgl and 1.65m bgl and 2.20m bgl and 2.45m bgl.</i>	1
					2.70			Firm, orangish brown, slightly silty, slightly sandy CLAY. GLACIOFLUVIAL DEPOSITS	2
					2.95			Orangish brown, fine grained SAND GLACIOFLUVIAL DEPOSITS	3
					3.50			Brown, damp, fine to medium, grained SAND becoming mottled dark brown at 3.80m bgl with very fine possible black organic fragments. GLACIOFLUVIAL DEPOSITS	4
					4.25			Greyish brown, damp, fine to medium, grained SAND. GLACIOFLUVIAL DEPOSITS	5
					5.00			End of borehole at 5.00 m	

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as damp material between 4.25m bgl and 5.00m bgl. 3) Black, very fine possible organic fragments between 3.80m bgl and 4.25m bgl. 4) Terminated at target depth. 5) Collapse of borehole at 4.50m bgl.





Borehole Log

Borehole No.

WS104

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 389957.00 - 412982.00

Hole Type
WS

Location: Rochdale

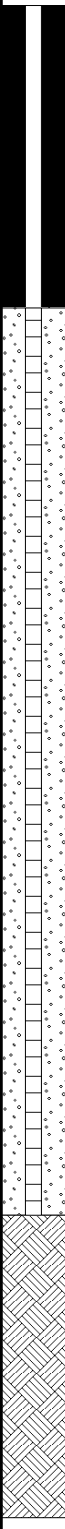
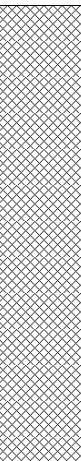
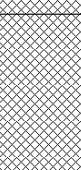
Level:

Scale
1:25

Client: Willmott Dixon Construction

Dates: 12/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					1.55			MADE GROUND: Greyish brown, slightly clayey, gravelly SAND. Gravel is fine to coarse, angular to subrounded of concrete, brick, sandstone, mudstone and rare coal. Compacted, difficult to hand dig through. MADE GROUND	1
					2.10			MADE GROUND: Dark grey, sandy, gravelly CLAY. Gravel is fine to coarse, angular to subangular of concrete, sandstone and mudstone. MADE GROUND	2
					2.80			Soft to firm, black SILT with frequent pockets of fine grained, black sand. Slight organic odour. ALLUVIUM	
					3.40			Greyish brown, fine, grained SAND with occasional pockets of black/dark grey silt. ALLUVIUM	3
					4.60			Brown, fine to medium, grained SAND. Becoming damp from 3.90m bgl. GLACIOFLUVIAL DEPOSITS	4
					5.00			Brown, silty, fine, grained SAND. GLACIOFLUVIAL DEPOSITS	5
End of borehole at 5.00 m									

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as wet material at 3.90m bgl. 3) Black material with organic odour between 2.10m bgl and 2.80m bgl. Pockets of black silt between 2.80m bgl and 3.40m bgl. 4) Terminated at target depth. 5) Collapse of borehole between 4.00m bgl and 5.00m bgl.





Borehole Log

Borehole No.

WS105

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 389990.00 - 412970.00

Hole Type
WS

Location: Rochdale

Level:

Scale
1:25

Client: Willmott Dixon Construction

Dates: 12/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					0.60			MADE GROUND: Greyish brown, clayey, gravelly SAND. Gravel is fine to coarse, angular to subangular of sandstone, concrete and brick. Compacted, difficult to hand dig through. MADE GROUND	1
					1.10			Orangish brown, silty, slightly gravelly SAND. Gravel is medium, subangular of sandstone. GLACIOFLUVIAL DEPOSITS	
					1.70			Soft to firm, orangish brown, sandy, silty CLAY. GLACIOFLUVIAL DEPOSITS	
					1.90			Brown, sandy, gravelly CLAY. Gravel is fine to medium, subangular to subrounded of sandstone. GLACIOFLUVIAL DEPOSITS	2
					2.50			Brown, slightly silty, slightly clayey, slightly gravelly SAND. Gravel is medium to coarse, subangular to subrounded of sandstone. GLACIOFLUVIAL DEPOSITS	
								Orangish brown, fine, grained SAND. GLACIOFLUVIAL DEPOSITS <i>Occasional dark brown and black, thin lenses of sand between 2.60m bgl and 2.70m bgl.</i>	3
									4
					5.00			End of borehole at 5.00 m	5

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as wet material between 4.00m bgl and 4.20m bgl. 3) Terminated at target depth. 5) Collapse of borehole between 4.00m bgl and 5.00m bgl due to wet sand. 6) No visual or olfactory evidence of contamination.





Borehole Log

Borehole No.

WS106

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 390029.00 - 413000.00

Hole Type
WS

Location: Rochdale

Level:

Scale
1:25

Client: Willmott Dixon Construction

Dates: 13/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					0.35			MADE GROUND: Greyish brown, gravelly, fine, grained SAND. Gravel is fine to coarse, subangular to subrounded of concrete and occasional brick. Compacted, difficult to hand dig through. MADE GROUND POSSIBLE MADE GROUND: Brown, slightly gravelly, fine, grained SAND. Gravel is medium to coarse, angular to subangular of sandstone, rare brick. POSSIBLE MADE GROUND	1
					1.10			POSSIBLE MADE GROUND: Brown, fine, grained SAND with occasional pockets of dark grey silt with locally slightly, organic odour. POSSIBLE MADE GROUND	
					1.40			POSSIBLE MADE GROUND: Greyish brown, gravelly SAND. Gravel is medium to coarse, angular to subangular of sandstone and rare pieces of geotextile at 1.50m bgl with concrete gravel. POSSIBLE MADE GROUND	
					2.00			Soft brown SILT. ALLUVIUM	2
					2.25			Orangish brown, slightly silty, fine grained SAND. ALLUVIUM	
					2.40			Soft, brown, sandy SILT. ALLUVIUM	
					2.65			Orangish brown, fine, grained SAND. ALLUVIUM <i>Black, possible organic stained thin band of sand between 2.70m bgl and 2.71m bgl. No discernable odour.</i>	
					3.00			Soft, damp, brown, sandy SILT ALLUVIUM	3
					3.20			Orangish brown, slightly gravelly, fine grained SAND. Gravel is fine to medium, subrounded of sandstone with occasional fine black flecks of possible organic fragments between 3.20m bgl and 3.60m bgl and 4.40m bgl and 4.50m bgl. Damp between 4.00m bgl and 4.10m bgl. ALLUVIUM	4
					5.00			End of borehole at 5.00 m	5

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as damp material between 3.00m bgl and 3.20m bgl. 3) Locally dark grey pockets of silt with a slight organic odour between 1.10m bgl and 1.40m bgl. Thin band (possibly organic) stained sand between 2.70m bgl and 2.71m bgl, no discernable odour, and occasional fine black flecks of possible organic material between 3.20m bgl and 3.60m bgl and 4.40m bgl and 4.50m bgl. 4) Terminated at target depth. 5) Collapse of borehole between 4.00m bgl and 5.00m bgl.





Borehole Log

Borehole No.

WS107

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 390035.00 - 412961.00

Hole Type
WS

Location: Rochdale

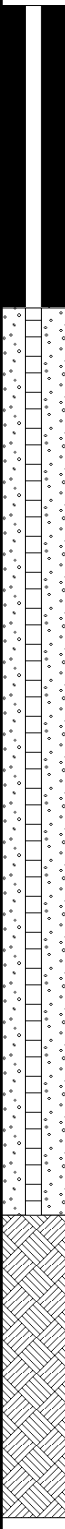
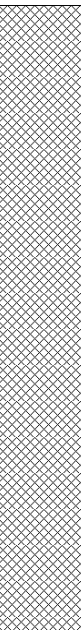
Level:

Scale
1:25

Client: Willmott Dixon Construction

Dates: 13/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
								MADE GROUND: Greyish brown, gravelly SAND. Gravel is fine to coarse, angular to subangular of concrete, brick, sandstone and rare rootlets at around 0.90m bgl and 1.00m bgl. Compacted, difficult to hand dig through. MADE GROUND	1
					2.10			<i>No recovery between 1.00m bgl and 1.60m bgl.</i>	2
					3.00			Yellow, orangish brown, fine, grained SAND with rare medium, angular gravel of sandstone. ALLUVIUM	3
					3.45			Brown, gravelly, fine, grained SAND. Gravel is fine to coarse, subangular to subrounded of sandstone. Occasional black, possibly organic staining of sand around gravel at 3.00m bgl and 3.20m bgl. ALLUVIUM	
					3.70			Soft, brown, damp, slightly sandy SILT. ALLUVIUM	
					4.30			Brown, fine, grained SAND with thin (typically 0.01m) bands of silt from 4.00m bgl. ALLUVIUM	4
					5.00			Greyish brown, fine to medium, grained SAND with occasional gravel sized pockets of black, possibly organic stained sand. ALLUVIUM	5

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as wet material between 3.45m bgl and 3.70m bgl. 3) Occasional black organic staining of sand between 3.00m bgl and 3.20m bgl and 4.30m bgl and 5.00m bgl. 4) Terminated at required depth. 5) Collapse of sand between 4.00m bgl and 5.00m bgl.





Borehole Log

Borehole No.

WS108

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 389998.00 - 412922.00

Hole Type
WS

Location: Rochdale

Level:

Scale
1:25

Client: Willmott Dixon Construction

Dates: 13/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					1.25			MADE GROUND: Greyish brown, slightly clayey, gravelly SAND. Gravel is fine to coarse, angular to subangular of concrete, brick, sandstone, rare coal and cobble of asphalt. Compacted, difficult to hand dig through. MADE GROUND	1
					1.40			MADE GROUND: Yellowish brown, fine, grained reworked SAND. MADE GROUND	
								MADE GROUND: Soft to firm, greyish brown, sandy, gravelly CLAY. Gravel is fine to coarse, angular of sandstone, concrete and occasional brick. Rare cobble of sandstone between 1.50m bgl to 1.60m bgl. MADE GROUND	2
					2.70			Orangish brown, fine, grained SAND. Damp from 3.10mbgl. GLACIOFLUVIAL DEPOSITS	3
					3.85			Greyish brown, wet, silty, fine grained SAND, GLACIOFLUVIAL DEPOSITS	4
					5.00			End of borehole at 5.00 m	5

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as damp material from 3.10m bgl, wet material encountered from 3.85m bgl. 3) No visual/olfactory evidence of contamination. 4) Terminated at target depth. 5) Collapse due to wet material from 3.65m bgl.





Borehole Log

Borehole No.

WS109

Sheet 1 of 1

Project Name: Richard Street

Project No.
TE1582

Co-ords: 389959.00 - 412907.00

Hole Type
WS

Location: Rochdale

Level:

Scale
1:25

Client: Willmott Dixon Construction

Dates: 13/08/2024 -

Logged By
SE

Well	Water Strikes	Samples and In Situ Testing			Depth (m)	Level (m)	Legend	Stratum Description	
		Depth (m)	Type	Results					
					0.55			MADE GROUND: Greyish brown, gravelly SAND. Gravel is fine to coarse, angular to subangular of concrete and occasional sandstone. Compacted, difficult to hand dig through. MADE GROUND	1
								MADE GROUND: Dark greyish brown, slightly clayey, slightly gravelly SAND. Gravel is fine to medium, angular to subangular of brick and sandstone. Occasional lenses of black clay with slight organic odour from 0.90m bgl. MADE GROUND	
					1.65			MADE GROUND: Soft, black, sandy clayey SILT / silty sandy CLAY. Cobble of sandstone at 1.75m bgl. Cobble of brick at 1.85m bgl. MADE GROUND	2
					1.85				
					1.95				
					2.40			MADE GROUND: Black, sandy, fine to medium, angular GRAVEL of coal with occasional brick fragments. MADE GROUND Greyish brown, slightly gravelly, fine grained SAND. Gravel is fine to medium, subrounded to rounded of sandstone. ALLUVIUM Greyish brown, fine, grained SAND with frequent thinly interbedded silt. ALLUVIUM	3
					3.30			Soft, greyish brown, wet, sandy SILT. ALLUVIUM	
					3.95			Brown, fine, grained SAND. GLACIOFLUVIAL DEPOSITS	4
					5.00				
								End of borehole at 5.00 m	5

Remarks

1) Hand dug pit to 1.20m bgl. 2) Groundwater encountered as wet material between 3.30m bgl and 3.95m bgl. 3) Occasional lenses of black clay with slight organic odour between 0.90m bgl and 1.75m bgl. Black material with slight organic odour between 1.65m bgl 1.85m bgl. 4) Terminated at target depth. 5) Cased to 2.00m. 6) Collapse of wet material from 4.00m bgl.



**APPENDIX C - GROUNDWATER AND GAS MONITORING RESULTS & CALIBRATION
CERTIFICATE**

Job No:	TE1582		
Visit No:	1	of	7
Operator:	HB		
Project Manager:	Adrian Read		

O_2	21.2
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☐ Frozen[illegible]

Job No:	TE1582		
Visit No:	2	of	7
Operator:	HB		
Project Manager:	Adrian Read		

O ₂	21.1
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☐ Frozen[illegible]

Job No:	TE1582		
Visit No:	3	of	7
Operator:	HB		
Project Manager:	Adrian Read		

O ₂	21.3
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☐ Frozen[illegible]

Job No:	TE1582		
Visit No:	4	of	7
Operator:	LH		
Project Manager:	Adrian Read		

O ₂	20.9
----------------	------

	Snow	☐	Frozen
	Strong		
X	Overcast		
	Heavy		
990	After		
X	Rising		

[illegible]

Job No:	TE1582		
Visit No:	5	of	7
Operator:	LH		
Project Manager:	Adrian Read		

O ₂	20.9
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☐ Frozen[illegible]

TIER
CONSULT
GROUP

Job No:	TE1582		
Visit No:	6	of	7
Operator:	LH		
Project Manager:	Adrian Read		

O ₂	20.9
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☐ Frozen[illegible]

Job No:	TE1582		
Visit No:	7	of	7
Operator:	LH		
Project Manager:	Adrian Read		

O ₂	20.9
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	Snow
	Strong
	Overcast
	Heavy
1003	After
X	Rising

☐ Frozen[illegible]

CERTIFICATION OF CALIBRATION



Date Of Calibration: 09-Aug-2024

No. 66916

Certificate Number: G508641_9/36190

Issued by: QED Environmental Systems Inc.

Customer: TIER ENVIRONMENTAL LTD
UNIT 5 VILLAGE OFFICE CHESTER BUSINESS PARK CHESTER, CHESHIRE CH4 9QZ
GB

Description:

Model: GA5000

Serial Number: G508641

Accredited Results:

Methane (CH4)		
Certified Gas (%)	Instrument Reading (%)	Uncertainty (%)
5.0	5.0	0.42
15.1	15.1	0.66
60.0	59.9	1.03

Carbon Dioxide (CO2)		
Certified Gas (%)	Instrument Reading (%)	Uncertainty (%)
5.0	5.0	0.43
15.0	15.0	0.71
39.9	40.0	1.19

Oxygen (O2)		
Certified Gas (%)	Instrument Reading (%)	Uncertainty (%)
20.9	21.0	0.25

Gas cylinders are traceable and details can be provided if requested.

CH4, CO2 readings recorded at: 34.6 °C/94.2 °F

O2 readings recorded at: 26.0 °C/78.8 °F

Barometric Pressure: 0979 mbar/28.90 "Hg

Method of Test: The analyzer is calibrated in a temperature controlled chamber using reference gases. All analyzers are calibrated in accordance with our procedure ISP-17 using high purity grade gas.

Instrument has passed calibration as the measurement result is within the specification limit. The specification limit takes into account the measurement uncertainty.

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor of $k=2$, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with NIST requirements.

The calibration results published in this certificate were obtained using equipment capable of producing results that are traceable through NIST to the International System of Units (SI). Certification only applies to results shown. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

CERTIFICATION OF CALIBRATION



Date Of Calibration: 09-Aug-2024

No. 66916

Certificate Number: G508641_9/36190

Issued by: QED Environmental Systems Inc.

Non Accredited results:

Pressure Transducers (inches of water column)					
Transducer	Certified (Low)	Reading (Low)	Certified (High)	Reading (High)	Accuracy
Relative	0"	0"	40"	40.7"	2.0"

Barometer (mbar)	
Reference	Instrument Reading
0979 mbar / 28.90 "Hg	0979 mbar / 28.90 "Hg

Additional Gas Cells		
Gas	Certified Gas (ppm)	Instrument Reading (ppm)
CO	500	500
H ₂ S	256	256

As received gas check readings:

Methane (CH ₄)	
Certified Gas (%)	Instrument Reading (%)
5.0	5.0
15.1	14.9
60.0	60.4

Carbon Dioxide (CO ₂)	
Certified Gas (%)	Instrument Reading (%)
5.0	5.6
15.0	16.9
39.9	44.4

Oxygen (O ₂)	
Certified Gas (%)	Instrument Reading (%)
20.9	20.5

As received Gas readings recorded at: 34.6 °C/94.2 °F

As received Barometric Pressure recorded at: 26.0 °C/78.8 °F

As received gas check readings are only recorded if the instrument is received in a working condition.
Where the instrument is received damaged no reading can be taken.

Date of Issue : 12 Aug 2024

Approved By Signatory

Linda Ostrowski
Laboratory Inspection

The calibration results published in this certificate were obtained using equipment capable of producing results that are traceable through NIST to the International System of Units (SI). Certification only applies to results shown. This certificate may not be reproduced other than in full, except with the prior written approval of the issuing laboratory.

Calibration Instance: 118 IGC Instance: 118

Page 2 of 2 | LP015LNANIST-1.1

APPENDIX D - DEFINITIONS OF TERMS USED IN QUALITATIVE AND QUANTITATIVE RISK ASSESSMENTS

CIRIA C552 Terminology

For the qualitative and quantitative assessment of risks posed by potential pollutant linkages have been undertaken using the risk matrix adapted from CIRIA C552 and outlined in the table below.

	Category	Definition
Potential severity	Severe	Acute (short term) risk to human health, Major pollution of sensitive controlled waters, ecosystems or habitat. Catastrophic damage to buildings or property or crops.
	Medium	Chronic (Medium / long term) risk to human health Pollution of sensitive controlled waters, ecosystems or species, Significant damage to crops, buildings or structures
	Mild	Easily preventable permanent health effects on humans. Pollution of non-sensitive controlled waters. Minor damage to buildings or structures.
	Minor	Easily preventable non-permanent health effects on humans, or no effects. Minor, low level and localised contamination of on-site soil. Easily repairable damage to buildings or structures.
Probability of risk	High Likelihood	Pollutant linkage may be present, and the risk is almost certain to occur , or there is evidence of harm already occurring.
	Likely	Pollutant linkage may be present, and it is probable that the risk will occur over the long term.
	Low Likelihood	Pollutant linkages may be present and there is a possibility of the risk occurring, although there is no certainty that it will do so.
	Unlikely	Pollutant linkage may be present but the circumstances under which harm would occur are improbable.

		Potential Severity			
		Severe	Medium	Mild	Minor
Probability of risk	High Likelihood	Very high risk	High risk	Moderate risk	Moderate / low risk
	Likely	High risk	Moderate risk	Moderate / low risk	Low risk
	Low Likelihood	Moderate risk	Moderate / low risk	Low risk	Very low risk
	Unlikely	Moderate / low risk	Low risk	very low risk	Very low risk

APPENDIX E - ASSESSMENT CRITERIA APPLIED FOR GROUND GAS

Ground Gas Monitoring Methodology

Monitoring for the following is generally performed as part of ground gas assessment:

- Methane (CH₄): an odourless, flammable gas. Mixtures of methane with air containing between 5 and 15% v/v methane are explosive.
- Carbon dioxide (CO₂): an asphyxiant at elevated concentrations. Denser than air, it can accumulate in excavations, and within low points inside buildings
- Oxygen (O₂): important in the assessment of the potential formation of explosive mixtures with methane. Monitoring normally measures both methane and oxygen concentrations in ground gas to derive an indication of the risk of explosive mixture formation, expressed as a percentage of the Lower Explosive Limit (LEL). Low concentrations of oxygen in ground gas can also exacerbate the risk of CO₂ asphyxiation.
- Hydrogen sulphide (H₂S): odorous and toxic, capable of forming flammable mixtures with air.

In addition, depending on the Conceptual Site Model, monitoring may also include for measurements of Volatile Organic Compounds (VOCs); present as chemical contaminants of soil and sometimes also biologically produced in low concentrations.

Assessment of methane (CH₄) and carbon dioxide (CO₂)

Methane and carbon dioxide can arise from natural geological sources, mine workings, rotting organic matter (peat, landfilled materials, etc.) and/or contaminant biodegradation. Assessment of ground gas composition and flows is therefore an essential part of site assessment. The need to adequately address potential risks from ground gas on development sites is therefore required under the planning regime.

In order to appropriately assess the site risks, the Construction Industry Research and Information Association (CIRIA) and others have issued several guidance documents on landfill and ground gas that are intended to provide advice on how to investigate and deal with gas contaminated ground with respect to development. These are:

- Report 149: 'Protecting Development from Methane' (CIRIA, 1995a)
- Report 150: 'Methane Investigation Strategies' (CIRIA, 1995b)
- Report 151: 'Interpreting Measurement of Gas in the Ground' (CIRIA, 1995c)
- Report 152: 'Risk Assessment for Methane and Other Gases from the Ground' (CIRIA, 1995d)

More recent guidance has been published to update the documents detailed above to collaborate and promote industry 'good practice'. These are:

- CIRIA Report 665: 'Assessing risks posed by hazardous ground gases to buildings (CIRIA, 2008)
- NHBC: 'Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present' (NHBC, 2007)
- BS8485:2015+A1:2019: Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings (BSI Group, 2019)
- BS8576:2013: Guidance on investigations for ground gas. Permanent gases and Volatile Organic Compounds (VOCs) (BSI Group, 2013)
- SoBRA Report Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater (Feb 2017)
- CL:AIRE Technical Bulletin TB17 Ground Gas Monitoring and 'Worst Case' Conditions (CL:AIRE Aug 2018)

The earlier CIRIA 149 approach is now considered to be too conservative. A more realistic measure of the risk posed by methane and CO₂ in ground gas can be established by determining an appropriate Gas Screening Value (GSV), using the methods described in the NHBC and CIRIA 659 documents. These values are based upon earlier work undertaken by Wilson and Card (1999).

GSVs are calculated by multiplying the borehole flow rate (l/hr) by the percentage (% v/v) concentration in the gas stream of the specific component, i.e.:

$$\text{GSV} = (\text{Concentration} / 100) \times \text{Flow rate.}$$

A risk-based methodology for deriving GSVs is defined for two situations (designated A and B), which are adequate for the great majority of site cases (as per CIRIA 665 Section 8.3):

- **Situation A:** Any development other than Situation B, e.g. factories, shops, commercial, warehouses, schools, cinemas, sports centres, stadiums, high rise housing, housing with basements, etc
- **Situation B:** Low rise building with minimum ventilated under floor void (min 150 mm)

Under Situation A, classification of the scope of protection required is determined from the site GSV, summarised in Table 1. For Situation B, GSVs derived are used in a 'Traffic Light' classification (summarised in Table 2) which determines the required level and scope of protection measures. Tables 1 and 2 are summaries only: the details provided in the body text, footnotes and appendices of the above-referenced documents should be read in conjunction with the results to determine the appropriate level of protection.

For conservatism, Tier Environmental **initially** uses the maximum concentration and gas flow rate of methane detected in any borehole during all of the monitoring visits in deriving recommendations on appropriate protection measures. This represents the worst-case risk of forming an explosive mixtures. For carbon dioxide, steady state concentrations and flow data are applied, as these determine the development of an asphyxiating mixture. All values are selected whether or not they occurred in the same borehole or during the same monitoring event.

Exceedances of the maximum concentrations used in a Tier 1 Gas Risk Assessment can be tolerated, when the conceptual site model indicates that it is safe to do so. However, appropriately derived GSV values must never be exceeded - where site-specific circumstances permit the derivation of alternative GSVs according to the defined conceptual model, then the appropriate GSV values should be applied.

Table 1. GSV Categories Defined for Situation A (Summarised from CIRIA Report 665).

Risk classification	GSV (CH ₄ or CO ₂ ; l/hr)	Additional factors	Characteristic Situation
Very low	<0.07	Typically methane <=1% and/or CO ₂ <=5%, otherwise consider increase to Low Risk.	1
Low	<0.7	Typically borehole ground gas flow rate <=70 l/hr; otherwise consider increase to Moderate Risk.	2
Moderate	<3.5	---	3
Moderate to high	<15	QRA required to evaluate scope of remediation measures.	4
High	<70	---	5
Very high	>70	---	6

Table 2. GSV Categories Defined for Situation B (Summarised from NHBC, 2007).

Methane		CO ₂		"Traffic light" classification
Typical max. conc. (% v/v)	GSV (l/hr)	Typical max. conc. (% v/v)	GSV (l/hr)	
				Green
1	0.13	5	0.78	Amber 1
5	0.63	10	1.60	
				Amber 2
20	1.60	30	3.10	Red

Assessment of hydrogen sulphide (H₂S)

H₂S is toxic and highly odorous ("rotten eggs") gas. It is often a minor component within mine gases, in ground gas within or overlying strata rich in pyrites or other sulphide-rich ores, and in most natural gas fields.

H₂S can be generated biologically in significant concentrations by the decomposition by sulphate-reducing bacteria of natural or anthropogenic organic matter under oxygen-free conditions. Its potential generation will be greater in environments containing elevated sulphate concentrations (including sea water). H₂S is therefore common within the gas arising from estuarine and marine sediments, pond sediment, stagnant water bodies, bogs and marshlands and landfilled waste, for example.

It must be noted that H₂S normally occurs together with other potentially hazardous ground gases. The measures adopted for protection against these will prove equally protective against H₂S.

There are no standards by which H₂S concentrations in ground gas can be assessed directly. Therefore, the significance of measured H₂S concentrations in ground gas must be evaluated on a case-by-case basis, taking into account the measured concentrations of other components and the specific conceptual site and exposure models. To assist in this process, the following standards and guidance may be applied.

General protection of land users

There are no UK air quality standards for general exposure to H₂S. The World Health Organisation has derived ambient air quality standards (WHO, 2000) for this gas, which may be used to inform risk assessment and decision-making:

The 24 hour average exposure guideline value for ambient air: 0.15 mg/m³ (0.1 ppmv, approx.; this was derived by the application of a 100x safety factor to the LOAEL for long-term exposure).

This is significantly above the odour threshold, which is typically around 0.01 mg/m³. To avoid substantial nuisance odour complaints, WHO (2000) recommends that the 30 minute average H₂S concentration in ambient air should not exceed: 0.007 mg/m³ (0.005 ppmv, approx.).

Occupational exposures

For occupational exposure, the HSE (2005) limits for H₂S are applicable:

- 8 hour time weighted average occupational exposure limit: 5 ppmv (7 mg/m³).
- Short-term exposure limit (15 minute reference period): 10 ppmv (14 mg/m³).

VOC Data Collection, Sampling and Assessment

BS8576 Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs).

Volatile organic compounds (VOCs) include, for example, halogenated hydrocarbons such as trichloroethene, non-halogenated hydrocarbons such as benzene, and organosulfur compounds such as thiols (mercaptans). They can occur as a component of ground gas originating from historically contaminated ground, spills and leaks from industry, commercial or residential properties (e.g. from pipelines, storage facilities, and at the point of use or dispensing), land-filled wastes and from naturally occurring sources.

The migration of VOCs in ground gas can be via three primary mechanisms:

- diffusive flow (movement of constituent along a concentration gradient);
- advective flow (movement of constituent due to motion of a transporting fluid);
- dispersion (transport resulting from local variations in fluid flow, e.g. due to friction effects in the matrix).

The choice of sampling and monitoring techniques should be based upon the conceptual model and be designed to achieve the objectives of the investigation, bearing in mind the requirements of any subsequent analytical procedures and the need to provide relevant data of sufficient quantity and quality. Consideration should also be given to the nature of ground under investigation, as well as the nature and distribution of contamination, the geology and the hydrogeology. Every effort should be made to avoid cross-contamination and at no point should underlying aquifers be put at risk.

Where the response zone extends below the water table, gas present in the groundwater will tend to produce an equilibrium concentration in the well headspace. This applies to both permanent gases and VOCs but can be particularly misleading in the latter case. Testing for dissolved gases in groundwater is useful to help interpret monitoring results in such a situation. Similarly, any VOCs in a floating non-aqueous hydrocarbon layer will produce an equilibrium concentration in the well headspace.

The monitoring period and frequency of monitoring for VOCs in ground gases should be developed on a site-specific basis from the conceptual site model and investigation data quality objectives.

Ground gas samples can be collected from the unsaturated zone adjacent to, or above, the known or suspected source of VOCs in ground gas through installation of a ground gas monitoring point in the unsaturated zone (see 10.2), and from a near-surface location beneath hardstanding or a floor or foundation slab through installation of a near- or sub-slab monitoring point (see 10.3). For monitoring of VOCs in ground gas the monitoring well should be installed into unsaturated ground to allow sampling for VOCs to take place. The borehole should not be progressed below the groundwater table or the surface of any floating non-aqueous layer. The borehole should be progressed to the target sampling depth within the unsaturated zone. Full details can be found in BS8576 Section 10.2 onwards.

Assessment of VOC concentrations have been made for limited number of VOCs by SoBRA with the Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater in Feb 2017.

The assessment of VOC concentrations is not covered by above-referenced reports. These data can be used to inform the human health risk assessment for site occupants but should not be relied upon to assess human health risk due to uncertainties in the ground gas flow regime, variability in the (generally low) contaminant concentrations measured and inaccuracies in the concentrations measured by PID instruments.

Data on the VOC concentration in ground gas can also help inform potential occupational exposure risks to construction and similar workers. For this purpose, the measured values can be compared to the relevant occupational exposure limit (OEL) for the contaminant(s) of concern, as given in HSE (2005). In cases of doubt as to the identity of the organic contaminants within the ground gas or when these are present as a complex mixture, then the 8 hour time-weighted average (TWA) exposure limit for benzene (1 ppmv) will be applied for screening purposes. This is a reasonably conservative approach since the OEL for benzene is lower than that for the great majority of organic contaminants commonly encountered in soil and groundwater at contaminated sites