GEOLOGICAL
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DATA ACQUISITION
CONSULTANCY

Gas Monitoring Addendum Report

LOCATION	Land at Mill Street, Frizington CA26 3SL
ISSUE DATE	November 2022
FOR	Laurie Crayson
CLIENT REF.	
OUR REF.	G22250

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1. Final Gas Monitoring Results

Six (6) gas monitoring visits to three monitoring installations at the above site were carried out by Geoinvestigate as part of the phase 2 site investigation (G22250).

A summary of the results of gas monitoring in the boreholes at the site is presented in Table 1 below.

Table 1: Summary of Gas Monitoring Data

Job Number	G22250
Client	Laurie Crayson
Site	Land at Mill Street, Frizington CA26 3SL

	CH_4 (%)	CO_2 (%)	O_2 (%)
Mininum	0	0.2	12.2
Maximum	0	5.9	20.3

Borehole	Number of Visits	CH_4 (%)		CO_2 (%)		O_2 (%)		Flow Rate (l/hr)	H_2S (ppm)	CO (ppm)	Atmospheric Pressure (mb)
		Min.	Max.	Min.	Max.	Min.	Max.				
BH1	6	0	0	4.9	5.9	12.4	14	<0.1	0	0	994
BH2	6	0	0	0.2	5.2	14.1	20.3	<0.1	0	0	to
BH3	6	0	0	2.6	5.4	12.2	17.6	<0.1	0	0	1011

The monitoring has returned the following:

- Atmospheric pressures of between 994mb and 1011mb.
- Levels of O_2 between 12.2% and 20.3%.
- Levels of CO_2 between 0.2% and 5.9%.
- CH_4 content below detectable limits at all locations on each monitoring occasion.
- H_2S and CO content below detectable limits at all locations on each monitoring occasion.
- Gas flow rates below detectable limits (<0.01lt/hr) at all locations on each monitoring occasion.
- On the second visit, BH3 was waterlogged with water head at 1.5m bgl. The well was dry on all other visits.
- All other wells were dry on each monitoring visit.

This addendum report will review the potential risk to the site based on the above gas results and ground conditions encountered by the site investigation works. This information will be used in association with CL:AIRE Research Bulletin 17 to provide a comprehensive overview of the gas risk and associated classification for the site, and to provide comment regarding any implications when considering the specific nature of the proposed development.

2. Review of sources and ground conditions encountered

2.1 Review of Sources

The findings of the Phase 1 desk study and Phase 2 intrusive site investigations suggested that the most likely source of hazardous gas at the site would be the presence of a treated mine shaft towards the southern margin of the property at grid reference 303082, 517438.

The extract of the 1:50,000 Solid & Drift geological map (BGS Sheet 28 – Wolverhampton) indicates the site is underlain by Whitehaven Sandstone of unknown thickness. The map suggests that drift/soil cover is largely absent, bedrock lying at or near surface at this locality perhaps below thin soil cover.

The area is obviously within a coal and ferrous mining area but is not within close proximity (100m) to landfills, cemeteries or other gas generating historical activity. No peat or alluvial soils are shown close to the site.

2.2 Review of Coal Mining Risk Assessment

A Coal Mining Risk Assessment (CMRA) has been carried out by Geoinvestigate Limited (Ref: G22250(a) July 2022), which concluded that although there was no risk to the site from very shallow or shallow coal seams that may contain coal mine-workings, owing to the proximity of a treated/capped coal mine shaft to the development the client has been advised to carry out longer term monitoring. This was recommended to be undertaken in line with the shallow geo-environmental and geotechnical investigation at the site.

2.3 Review of ground conditions encountered

The borehole positions were chosen to give an indication of the ground conditions generally throughout the site, both in terms of geotechnical appraisal and assessment of soil contamination. The soils encountered in the boreholes are considered to be broadly representative of soils throughout the site. The hand excavated trial pit positions were chosen to target external areas surrounding the proposed dwelling.

2.3.1 Windowless Sample Boreholes

The ground conditions were relatively uniform across the site and comprised a thin layer of made ground (topsoil) underlain by cohesive deposits with mudstone bedrock coming in at the base of each borehole.

The made ground comprised of dark brown very sandy gravelly clay topsoil containing sandstone and coal fragments to depths between 0.10m (BH2) and 0.40m (BH1).

The natural ground comprised an upper layer of firm to stiff reddish brown and grey very sandy slightly gravelly clay containing sandstone and mudstone fragments to depths between 1.90m (BH1) and 2.50m (BH3). Beneath the upper clay was weathered mudstone bedrock, which was present to the base of each borehole.

No ground water was recorded during the works.

Gas wells were installed in BH1, BH2 and BH3.

2.3.2 Hand Excavated Trial Pits

TPA to TPC encountered similar conditions to the boreholes. Made ground (topsoil) was encountered from ground level to the base of each trial pit at a depth of 0.30m bgl. The made ground consisted of dark brown very sandy gravelly clay with fragments of sandstone and coal.

The trial pits remained stable and dry on completion.

3. CL:AIRE Research Bulletin 17

A research bulletin posted by Contaminated Land – Applications in Real Environments (CL:AIRE) has reviewed the process of gas monitoring and risk assessment and presents potential scope to classify sites without the need for lengthy and costly gas monitoring exercises, including for example scope for some sites to be considered low risk and therefore require no or only limited gas monitoring and/or protection measures.

It includes consideration to the fact that many new developments will include features which offer a good level of ground gas protection regardless of whatever gas risk might exist associated with a site's setting, i.e. features intrinsic to the proposed construction design which are not specifically intended to offer ground gas protection but do so regardless as an incidental consequence of their use. This includes, for example, sites in radon risk areas which will include radon protection measures, or developments which will feature airtight construction; both of which are likely to provide good protection against ground gas ingress. Where a site may have no obvious apparent gas sources, assumptions can also be made about protection measures or small volumes of ground gas present in soil pores.

Assumptions are also made for sites that have less need for monitoring including sites with high carbonate natural soils, organic soils with potential methane content that may be slow to be released (e.g. peat and alluvium), made ground with low organic content, and mine workings flooded or abandoned in the early 20th century.

The report does make mention that monitoring will still normally be required for sites featuring made ground deposits of considerable depth and/or in excess of 6% Total Organic Carbon and sites where shallow mine workings exist or where the site is within 20m of a shaft or adit. The research bulletin provides a table to indicate the likelihood for gas monitoring and/or protection measures to be required for any given site based on common scenarios.

The current study site matches the seventh scenario set out in Table A1 below but, rather than assume a classification of CS3, monitoring has been undertaken to determine the actual level of risk at the site.

Table A1 of CL:AIRE RB17: Application of approach to common scenarios

Scenario and source of ground gas	Gas monitoring	Gas protection
Natural soils with no Made Ground e.g. London Clay, Mercia Mudstone, Lias Clay, Chalk, Gault Clay or Glacial Till.	✗	✗
Natural soils with no Made Ground. In an area where radon protection is required.	✗	✓ Gas/radon measures required
Natural soils with low organic content. Less than 1m of Made ground that comprises general infill and car park construction materials e.g. Made ground over London Clay, Mercia Mudstone, Lias, Clay, Chalk, Gault Clay or Glacial Till.	✗	✗
Natural soils with high organic content. Less than 1m of Made ground that comprises general infill and car park construction materials e.g. Alluvium, Peat over natural soils such as London Clay, Mercia Mudstone, Lias, Clay, Chalk, Gault Clay or Glacial Till.	✗	✓ CS3 Gas measures required
Natural Soils with low organic content and 1m to 5m of Made Ground (average <3m) that compromises general infill and car park construction materials. TOC is less than 6% e.g. Made Ground over London Clay, Mercia Mudstone, Lias Clay, Chalk , Gault Clay or Glacial Till.	✗	? Determine gas protection using TOC of Made Ground and Table 2
Old landfill with 6m of older refuse material. Identified as old on historical maps.	✓ Determine TOC content and use gas generation modelling to assist with the interpretation of results	? To be determined from gas monitoring data
Old Mine workings that were abandoned before the early 20th century.	? To be determined based on preliminary conceptual model using desk study data	?
Glacial drift deposits over Coal Measures strata with no former mine workings.	✗	✗

4. Gas Risk Conclusions

Table 1: Summary of Gas Monitoring Data

Job Number	G22250
Client	Laurie Crayson
Site	Land at Mill Street, Frizington CA26 3SL

	CH_4 (%)	CO_2 (%)	O_2 (%)
Mininum	0	0.2	12.2
Maximum	0	5.9	20.3

Borehole	Number of Visits	CH_4 (%)		CO_2 (%)		O_2 (%)		Flow Rate (l/hr)	H_2S (ppm)	CO (ppm)	Atmospheric Pressure (mb)
		Min.	Max.	Min.	Max.	Min.	Max.				
BH1	6	0	0	4.9	5.9	12.4	14	<0.1	0	0	994
BH2	6	0	0	0.2	5.2	14.1	20.3	<0.1	0	0	to
BH3	6	0	0	2.6	5.4	12.2	17.6	<0.1	0	0	1011

The ground gas monitoring results have returned levels of CO_2 in excess of the upper threshold limits for Characteristic Situation 1 (CS1) classification*. As such, the returned CO_2 levels necessitate that the site classification be raised to CS2 / Amber 1 designation, meaning that ground gas protection measures (in line with CS2 / Amber 1 classification) will be required in the proposed structure(s). With a maximum GSV of just 0.0590l/hr, there is no reason to increase the classification further. A slightly depleted oxygen content has also been recorded.

*Modified Wilson and Card Classification, CIRIA C665.

Historical weather records* have been consulted to gain an indication of atmospheric pressure trends. These appear to have been rising on the second and sixth monitoring visits, falling on the third and fifth visits, and roughly constant on the day of the first and fourth visit. No correlation between the elevated CO_2 and atmospheric pressure trends is apparent with the elevated CO_2 levels being returned on days of both rising and falling pressure. *At https://www.worldweatheronline.com/v2/historical-weather.aspx?q=ca26

Therefore, on the basis of the monitoring data, the site is concluded to fall into "Characteristic Situation 2" (CS2) of the Modified Wilson and Card classification or "Amber 1" of the NHBC Traffic Light System for low rise housing with a ventilated under-floor void (min 150mm) (CIRIA C665.) meaning that **ground gas protection measures will be required in the proposed structure(s)**.

With regard to Radon Gas risk, the site lies in a radon affected area where <1% of the properties are above the action level. Therefore, accordingly, no radon protection measures are required based on current guidelines.

Additional Information

Reference to Tables 2 and 3 (appendix 3 of this report), and BS 8485: 2015 guidance, suggests that the proposed development might be classified as a Type "A" building, and with a site classification of CS2 would therefore require a mitigation point score of 3.5 to ensure that the property is mitigated correctly (Table 3).

To achieve the 3.5 score a combination of options should be selected from Tables presented in Appendix 3 of this report. It is advised to choose remediation options from at least two of the tables. Two possible solutions for gas protection features are as follows (list not exhaustive):

- A passively ventilated, clear sub-floor void (1.5-2.5 points) coupled with a fully sealed gas membrane across the whole building footprint(s) (2 points). (Total: 3.5-4.5 points).
- A well-reinforced, monolithic concrete raft foundation (1.5 points) coupled with a fully sealed gas membrane across the whole building footprint(s) (2 points). (Total: 3.5 points).

Please note that these tables are illustrative and further information can be found in BRE 414 and BS8485:2015.

END OF REPORT

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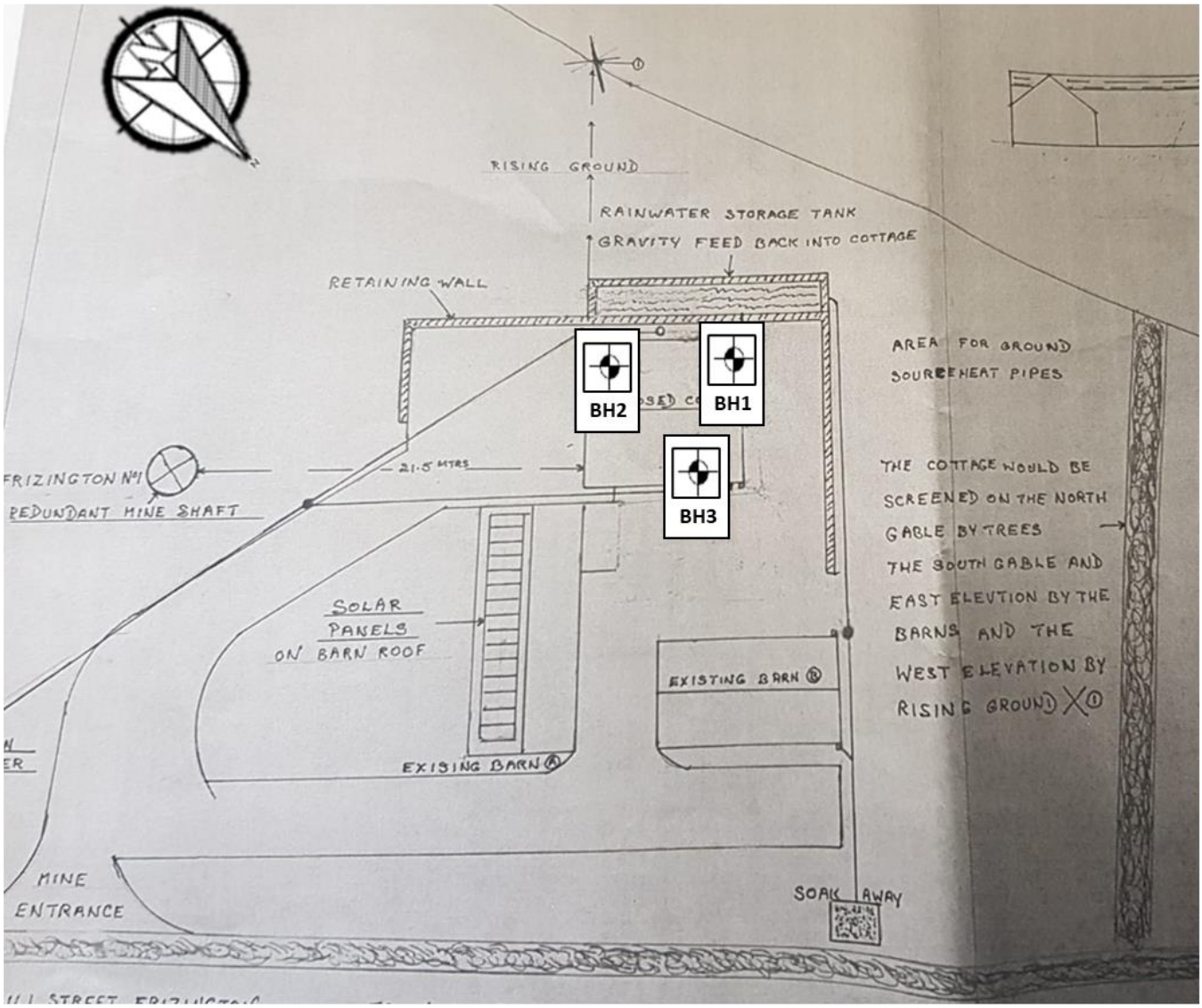
APPENDIX 1

SITE PLAN

GEOINVESTIGATE Ltd.

OUR REF: G22250	YOUR REF:	SITE PLAN (NOT TO SCALE)
DATE: 25/07/2022	LOCATION: Land at Mill Street, Frizington CA26 3SL	



Key

BH1 Window Sample Borehole Location

APPENDIX 2

COMPLETE GAS MONITORING RESULTS

Job Number	G22250
Client	Laurie Crayson
Site	Land at Mill Street, Frizington CA26 3SL
Instrument	GFM 406 + 410

Key	
WL	Water Logged
BDL	Below Detectable Levels
NB	No Bung
WD/I	Well destroyed / inaccessible

Monitoring Personal	AW	Date	06/07/2022	Weather	Rain/Cloudy	Temperature	14	Starting Pressure		1011 (Constant)		
Monitoring Point	Well condition	Flow range (l/hr)	Atmospheric Pressure (mb)	Methane % (v/v)	Methane % LEL	Carbon dioxide % (v/v)	Oxygen % (v/v)	Water Level (mbgl)	Depth of Well (m)	Volume of gas in well (m^3)	Hydrogen Suphide (ppm)	Carbon Monoxide (ppm)
BH1		0	1011	0.0	0	5.4	12.6				0	0
BH2		0	1011	0.0	0	5.1	12.0				0	0
BH3		0	1011	0.0	0	2.6	17.5				0	0

Monitoring Personal	BG	Date	05/08/2022	Weather	Light Rain	Temperature	20	Starting Pressure		996 (Rising)		
Monitoring Point	Well condition	Flow range (l/hr)	Atmospheric Pressure (mb)	Methane % (v/v)	Methane % LEL	Carbon dioxide % (v/v)	Oxygen % (v/v)	Water Level (mbgl)	Depth of Well (m)	Volume of gas in well (m^3)	Hydrogen Suphide (ppm)	Carbon Monoxide (ppm)
BH1		0	996	0.0	0	5.6	13.4				0	0
BH2		0	996	0.0	0	4.7	14.7				0	0
BH3	WL	0	996	0.0	0	3.0	17.6	1.5			0	0

Monitoring Personal	AW	Date	12/08/2022	Weather	Sunny	Temperature	19	Starting Pressure		1010 (Falling)		
Monitoring Point	Well condition	Flow range (l/hr)	Atmospheric Pressure (mb)	Methane % (v/v)	Methane % LEL	Carbon dioxide % (v/v)	Oxygen % (v/v)	Water Level (mbgl)	Depth of Well (m)	Volume of gas in well (m^3)	Hydrogen Suphide (ppm)	Carbon Monoxide (ppm)
BH1		0	1010	0.0	0	4.9	14.0				0	0
BH2		0	1010	0.0	0	3.7	15.6				0	0
BH3		0	1010	0.0	0	4.0	13.8				0	0

Monitoring Personal	AW	Date	23/08/2022	Weather	Rain	Temperature	17	Starting Pressure	995 (Constant)			
Monitoring Point	Well condition	Flow range (l/hr)	Atmospheric Pressure (mb)	Methane % (v/v)	Methane % LEL	Carbon dioxide % (v/v)	Oxygen % (v/v)	Water Level (mbgl)	Depth of Well (m)	Volume of gas in well (m^3)	Hydrogen Suphide (ppm)	Carbon Monoxide (ppm)
BH1		0	995	0.0	0	5.9	12.4				0	0
BH2		0	995	0.0	0	5.2	14.1				0	0
BH3		0	995	0.0	0	4.2	15.7				0	0

Monitoring Personal	AW	Date	27/10/2022	Weather	Cloudy	Temperature	14	Starting Pressure	994 (Fallling)			
Monitoring Point	Well condition	Flow range (l/hr)	Atmospheric Pressure (mb)	Methane % (v/v)	Methane % LEL	Carbon dioxide % (v/v)	Oxygen % (v/v)	Water Level (mbgl)	Depth of Well (m)	Volume of gas in well (m^3)	Hydrogen Suphide (ppm)	Carbon Monoxide (ppm)
BH1		0	994	0.0	0	5.7	13.1				0	0
BH2		0	994	0.0	0	2.4	17.2				0	0
BH3		0	994	0.0	0	5.4	12.2				0	0

Monitoring Personal	AW	Date	11/11/2022	Weather	Strong Wind	Temperature	13	Starting Pressure	1000 (Rising)			
Monitoring Point	Well condition	Flow range (l/hr)	Atmospheric Pressure (mb)	Methane % (v/v)	Methane % LEL	Carbon dioxide % (v/v)	Oxygen % (v/v)	Water Level (mbgl)	Depth of Well (m)	Volume of gas in well (m^3)	Hydrogen Suphide (ppm)	Carbon Monoxide (ppm)
BH1		0	1000	0.0	0	5.3	14.0				0	0
BH2		0	1000	0.0	0	0.2	20.3				0	0
BH3		0	1000	0.0	0	4.9	12.5				0	0

APPENDIX 3

ADDITIONAL NOTES ON GAS CLASSIFICATION AND MITIGATION OPTIONS

New guidance published in BS 8485: 2015 has indicated a new system of design and implementation of gas protection measures. The new guidance works to identify the risk to a site using the sensitivity of the receptors and the risk associated with potential sources of hazardous ground gas. The most applicable building type for this site is inferred to be Type A as shown in table 3 below.

Table 2: Building types for site classification as per BS 8485:2015

	High Risk		Medium Risk	Low Risk
	Type A Building	**Type B Building**	**Type C Building**	**Type D Building**
Ownership	Private	Private or commercial/public, possible multiple	Commercial/public	Commercial/public
Control (change of use, structural alterations, ventilation)	None	Some but not all	Full	Full
Room sizes	Small	Small/medium	Small to large	Large industrial/retail park style

Building type highlighted blue considered most applicable to current study site.

Using the building types listed in Table 2 above, BS 8485:2015 has incorporated a scoring system dependent on building type and the characteristic situation of the site in order to select the appropriate measures for hazardous gas protection. This provides a Gas protection Score (assigned using Table 3 below).

Once the required gas protection score has been determined, various potential protective measures can be considered for inclusion in the proposed structures, each of which have their own gas protection score. These measures can be combined and their gas protection scores summed to match or exceed the required gas protection score determined by Table 3. These measures include structural barriers, ventilation measures and gas resistant membranes which are graded separately within the points system. In order to ensure sufficient measures are in place; one measure is normally selected from each category (see tables for gas protection).

Table 3: Gas Protection Scoring by CS Level and Building Type

Characteristic Situation	Minimum gas protection score (points)			
	High Risk		Medium Risk	Low Risk
	Type A Building	Type B Building	Type C Building	Type D Building
CS1	0	0	0	0
CS2	3.5	3.5	2.5	1.5
CS3	4.5	4	3	2.5
CS4	6.5	5.5	4.5	3.5
CS5		6.5	5.5	4.5
CS6			7.5	6.5

Table A: Gas Protection Scores – Ventilation Protection Measures

Protection element/system	Score	Comments
(a) Pressure relief pathway (usually formed of low fines gravel or with a thin geocomposite blanket or strips terminating in a gravel trench external to the building)	0.5	Whenever possible a pressure relief pathway (as a minimum) should be installed in all gas protection measures systems. If the layer has a low permeability and/or is not terminated in a venting trench (or similar), then the score is zero.
(b) Passive sub floor dispersal layer: Very good performance: Good performance: Media used to provide the dispersal layer are: • Clear void • Polystyrene void former blanket • Geocomposite void former blanket • No-fines gravel layer with gas drains • No-fines gravel layer	 2.5 1.5	Performance criteria for methane and carbon dioxide are shown in Figure B.6 and Figure B.7, respectively. The ventilation effectiveness of different media depends on a number of different factors including the transmissivity of the medium, the width of the building, the side ventilation spacing and type and the thickness of the layer. The selected score should be assigned taking into account the recommendations in Annex B. Passive ventilation should be designed to meet at least "good performance", see Annex B
(c) Active dispersal layer, usually comprising fans with active abstraction (suction) from a subfloor dilution layer, with roof level vents. The dilution layer may comprise a clear void or be formed of geocomposite or polystyrene void formers	1.5 to 2.5	This system relies on continued serviceability of the pumps, therefore alarm and response systems should be in place. There should be robust management systems in place to ensure the continued maintenance of the system, including pumps and vents. Active ventilation should always be designed to meet at least "good performance", as described in Annex B.
(d) Active positive pressurization by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket	1.5 to 2.5	This system relies on continued operation of the pumps, therefore alarm and response systems should be in place. The score assigned should be based on the efficient "coverage" of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet at least "good performance".
(e) Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park)	4	Assumes that the car park is vented to deal with car exhaust fumes, designed to *Buildings Regulations 2000*, *Approved Document F* [9].

Table B: Gas Protection Scores – Structural Barriers

Floor and substructure design (see Annex A)	Score[A]
Precast suspended segmental subfloor (i.e. beam and block)	0
Cast in situ ground-bearing floor slab (with only nominal mesh reinforcement)	0.5
Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations 1 or 1.5	1 or 1.5[B]
Basement floor and walls conforming to BS 8102:2009, Grade 2 waterproofing [C]	2
Basement floor and walls conforming to BS 8102:2009, Grade 3 waterproofing [C)]	2.5

A) The scores are conditional on breaches of floor slabs, etc., being effectively sealed.
B) To achieve a score of 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in (see **A.2.2.2**).
C) The score is conditional on the waterproofing not being based on the use of a geosynthetic clay liner waterproofing product (see **C.3**, Note 4).

Table C: Gas Protection Score – Gas Resistant Membranes

Protection element/system	Score	Comments
Gas resistant membrane meeting all of the following criteria: • sufficiently impervious to the gases with a methane gas transmission rate <40.0 ml/day/m2/atm (average) for sheet and joints (tested in accordance with BS ISO 15105-1 manometric method); • sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • sufficiently strong to withstand in-service stresses (e.g. settlement if placed below a floor slab); • sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc); • capable, after installation, of providing a complete barrier to the entry of the relevant gas; and verified in accordance with CIRIA C735 [N1]	2	The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and integrity of joints. For example, a minimum 0.4 mm thickness (equivalent to 370 g/m2 for polyethelene) reinforced membrane (virgin polymer) meets the performance criteria in Table 7 (see **C.3**). If a membrane is installed that does not meet all the criteria in column 1 then the score is zero.

Table D: Gas protection measures for low-rise housing development based upon NHBC Traffic Light system

Traffic Light Classification	Protection measures required
Green	Negligible gas regime identified and gas protection measures are not considered necessary.
Amber 1	Low to intermediate gas regime identified, which requires low – level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into buildings. Gas protection measures should be prescribed as per BRE Report 414. Ventilation of sub – floor void should facilitate a minimum of one complete volume change per 24 hours.
Amber 2	Intermediate to high gas regime identified, which requires high – level gas protection measures, comprising a membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into buildings. Gas protection measures should be prescribed as per BRE Report 414. Gas membranes should always be fitted by a specialist contractor. As with Amber 1, Ventilation of sub – floor void should facilitate a minimum of one complete volume change per 24 hours. Certification that these measures have been installed correctly should be provided.
Red	High gas regime identified. It is considered that standard residential housing would not be normally acceptable without a further gas risk assessment and/or possible remedial mitigation measures to reduce and/or remove the source of gas.

*Table is for illustration only; please see BRE 414 for more information on designing appropriate measures. (BRE 414 - Protective measures for housing on gas-contaminated land)