

HEXA

Twycross Zoo

Ground Gas Risk Assessment

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**Engineering
opportunity.**



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Matt Lomas C.WEM C.Env C.Sci Director		25/03/ 2025

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1.0 Introduction

1.1 Appointment

Henry Brothers Construction Ltd have instructed Hexa to undertake a Ground Gas Risk Assessment for the proposed redevelopment works at Twycross Zoo.

This risk assessment is intended to present a comprehensive appraisal of the site setting and historical & factual data pertaining to the subject site, to derive a suitable ground gas risk assessment.

The ground gas risk assessment has the following objectives:

- a) Review the appropriate British Standards and other relevant guidance used to derive the ground investigation and subsequent assessment of the site with respect to ground gas risk.
- b) Review the ground gas conceptual site model (CSM), derived in accordance with appropriate current British Standards and guidance.
- c) Summarise the factual information obtained through intrusive investigation and subsequent monitoring of ground gas monitoring wells.
- d) Provide a consolidated assessment of ground gas risk based on the available data sources with the assessment undertaken in accordance with current British Standards.

1.2 Previous Reporting

Hexa have been provided with existing non-intrusive and intrusive Ground Investigation Reports relating to the development specifically:

- Clancy Consulting, Phase 1 Preliminary Risk Assessment NSCC Project, Twycross Zoo October 2023 10/2197/001 Rev. 01.
- Clancy Consulting, Phase 2 Site Investigation Report NSCC Project, Twycross Zoo October 2024 10/2197/002 Rev. 02.

1.3 Limitations

This document has been prepared based on factual information provided to Hexa by the client which has been accepted in good faith. Hexa cannot be held responsible for inaccuracies in the information provided.

2.0 Regulatory Framework

The following current British Standards have formed the basis of the approach to, and undertaking of, the ground gas risk assessment at the site:

1. BS8485:2015+A1:2019 - Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings
2. BS8576:2013 - Guidance on Investigations for Ground Gas - Permanent Gases and Volatile Organic Compounds (VOCs).

The above British Standards refer to additional guidance documents which include CIRIA C665 *Assessing risks posed by hazardous ground* (2007).

Reference is made to the framework provided in the British Standard throughout this report and, where deemed appropriate, supplemented by the current guidance listed below;

- CIRIA C665 *Assessing Risks Posed by Hazardous Ground* (2007).
- CL: AIRE RB17 A Pragmatic Approach to Ground Gas Risk Assessment, 2012
- CL: AIRE TB17 Ground Gas Monitoring and 'Worst-Case' Conditions, 2018
- Ambisense and EPG, Ltd Using ternary plots for interpretation of ground gas monitoring results. Ground Gas Information Sheet No. 1, 2018
- Ground Engineering Technical paper: Risk and reliability in gas protection design – 20 years on: Part 1 and Part 2, 2019
- CL:AIRE, Good practice for risk assessment for coal mine gas emissions, 2021
- NHBC, NF94 Hazardous ground gas - an essential guide for housebuilders, 2023

3.0 Current Site Setting and Preliminary Ground Gas Source Assessment

3.1 General

The following section aims to highlight the geological and anthropogenic features on, or within influencing distance of, the site which are considered to represent relevant potential ground gas sources.

The magnitude of the generation potential of each of the identified sources has been determined using the framework outlined in Clause 8.7 of BS8576:2013, Figure 6. This generation potential will be used to justify the requirement for, amount and duration of monitoring undertaken (discussed further in Section 4).

3.2 Site Setting

Twycross Zoo, working with Hinckley & Bosworth Borough Council are looking to deliver three new buildings on the wider zoo site, with associated landscape works. The three buildings are:

- NSCC Building
- Residential Building
- Orangutan Building

A two storey National Science and Conservation Centre building (NSCC) will be located in the southern part of the site, comprising a campus building, incorporating Zoo facilities, laboratory spaces, research offices, a 206-person lecture hall/auditorium and other associated external works.

A further two storey residential building sited close to the NSCC building will provide short stay accommodation for researchers.

The orangutan building is located in the North segment of the development site, including both internal and external habitats, animal dens, and enrichment equipment/spaces. The internal habitat is to comprise a three-storey framed building set into a sloped landscape. The building will also accommodate zookeeper back-of-house spaces and a visitor centre.

Several ancillary structures and buildings are also proposed for the surrounding site including lodges, substation, refuse store, viewing shelters and a babirusa house.

The site is bordered to the north and east by land and buildings associated with the Zoo. To the south, the site is bound by a hedgerow, beyond which lie agricultural fields. To the west, the site is bound by Orton Hill, beyond which lie further agricultural fields and some associated agricultural buildings, sheds or other structures.

The site generally slopes from north to south. Reference should be made to the sitewide topographical survey for local levels.

The zoo can be seen in Figure 3.1 (plan) with the proposed development to the southwest of the existing zoo, highlighted in red.



Figure 3.1 Site location plan from satellite

3.3 On-site Ground Gas Source Appraisal

The Clancy Phase 1 (October 2023) report identified potential Made Ground as the only viable source of potential of ground bourne gas.

The following section provides a holistic review of potential ground gas sources to further refine/confirm the ground gas conceptual site model incorporating the desk based and ground investigation information.

3.3.1.1 Historical Sources

The historical maps provided in Phase 1 report have been reviewed with specific focus on potential gas generation sources.

Figure 3.2 below provides a selection of historical maps covering the area of the proposed development.

Review of the maps does not highlight any likely sources of high-potential ground gas generation sources such as areas of quarrying or large ponds which may have been infilled.

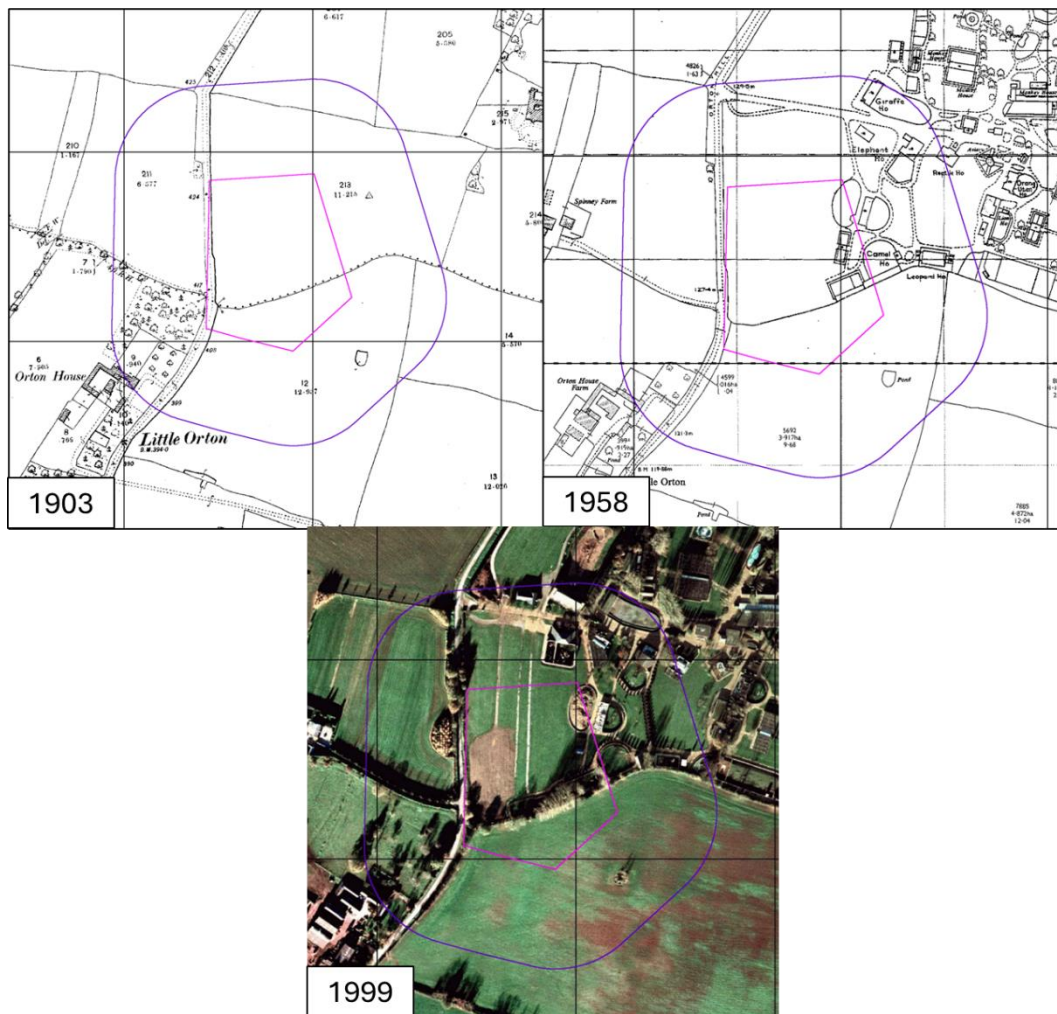


Figure 3.2 – Historical OS Maps with approximate proposed building outline

3.3.1.2 Environmental Sources

There are no recorded landfill or waste management sites located within the site boundary.

There are no known or listed potential areas of infilled land located within the site boundary.

There are no Integrated Pollution Prevention and Control, or Local Authority Pollution Prevention and Control permits recorded within the site boundary.

3.3.1.3 Ground Conditions

Made Ground

Prior to the wider development of Twycross Zoo the site has a limited development history and the geological maps indicate that extensive Made Ground deposits are unlikely to be present.

The Clancy 2024 Phase 2 ground investigation comprised the advancement of 15 No. exploratory holes across two phases of investigation.

Investigations comprised:

- Four Rotary Cored boreholes,
- Nine Windowless Sampler boreholes,
- Two Trial Pits.

Made Ground was generally encountered at a limited thickness with an average thickness of 0.5m with a maximum depth of 1.4m recorded in the north of the investigation area.

Typically the Made Ground was encountered as a single unit described as a reddish grey/ brown clayey, gravelly sand with gravel comprising comprised fine to coarse, angular to subrounded limestone, chert and mudstone. In terms of description there was limited variation of note between areas of thin (<0.5m) Made Ground and the where Made Ground was recorded to be thicker.

Total Organic Carbon (TOC) derived from the organic matter has not been tested as part of the ground investigations however no evidence of organic rich deposits, household type waste or other putrescible materials were noted in the revealed Made Ground in any location advanced.

As outlined within NF94 NHBC Guidance for hazardous ground gas published in April 2023, Made Ground soils are not considered a credible source of ground gas, unless substantial proportions of putrescible material (i.e vegetation, food waste, paper, cardboard, wood etc.) is present.

Physical descriptions and laboratory testing, indicate this not to be the case.

Geological Sources

Published Geology (BGS 1:50,000 Sheet 155) indicates the site is underlain by superficial deposits comprising Glaciofluvial (sands and Gravel) and Thrussington Member (Glacial Till clays). Bedrock is indicated to comprise mudstone of the Gunthorpe Member.

Ground investigation broadly confirmed the anticipated published geological sequence. Underlying the Made Ground red-brown sand and gravels with variable clay content was encountered. These strata are interpreted as Glaciofluvial Deposits, encountered at depths ranging from approximately 1.00m to 4.20m below ground level (bgl). Beneath the Glaciofluvial Deposits, a layer of soft to firm, grey, red, and brown mottled sandy, gravelly clay, silty sand, or gravel was identified, which is considered representative of the Thrussington Member, extending to depths between approximately 4.45m and 7.00m bgl. Underlying this, weathered red mudstone was encountered, attributed to the Gunthorpe Member, continuing to a maximum proven depth of approximately 15.00m bgl.

No organic material was noted within the superficial soils and as noted in NF94 guidance, in absence of any biodegradable material, superficial soils are not considered a credible source of ground gas generation.

The site is not located within an area affected by coal mining being located outside of the coal field. In the absence of coal mining related sources the bedrock geology is not considered a credible source of ground gas.

When considering the gas generation potential of the above sources, reference has been made to Clause 8.7 in BS8576:2013, Figure 3.3 as extracted below:

Very low	- Natural carbonate soil and strata, e.g. chalk and limestone. - Natural soil strata with a low degradable organic content, e.g. alluvium, peat. - In-filled pond less than 15 m diameter, in-filled before 1930s to 1940s. - Made ground with low degradable organic content (e.g. up to 5% organic material such as pieces of wood, pieces of paper, rags, etc. with a high proportion of ash and no food or other easily degradable waste). - Mine workings shallow or shaft (where there is clear evidence that they are flooded). (Gas in coal is historically generated and is trapped or adsorbed so the actual current generation rate is very low but it accumulates in workings and large volumes can be emitted very quickly.) - Inert landfill sites. (Lack of regulation in the past means that most sites are never entirely inert – they can include timber, plasterboard and even domestic refuse and consequently care is needed when assessing such sites. They might require a higher risk classification.)
Low	- Natural soil strata with a high degradable organic content (DOC). - Made ground with total organic carbon (TOC) up to 6% (e.g. dock silt. No food or other easily degradable waste). - Foundry sand (includes phenolic binders, rags and wood that decay, albeit at low rates). - Landfill 1945 to mid 1960s (see also "moderate"). Higher TOCs might not always indicate high degradability. For example, coke breeze can contain up to 51% TOC but only 4% DOC. In this case, the assessor should estimate what proportion of the TOC is degradable.
Moderate	- Sewage sludge. - Mine workings – unflooded, more than 50 years since last worked (gas is liberated from coal when mine workings are excavated; this continues for up to about 50 years). - Landfill 1945 to mid 1960s (this could also be "low" or, if disturbed, "high").
High	- Landfill mid 1960s to early 1990s. - Mine workings – unflooded – less than 50 years since last worked.
Very high	- Municipal landfill sites. - Landfill early 1990s onwards.

Figure 3.3 – Risk ratings from BS8576:2013 Figure 6.

Based on the identified thickness and organic content it is determined that the Made Ground on site has a **very low** gassing potential.

Natural geology are similarly assessed to have a **very low** gassing potential.

Radon

UK Radon mapping places the site in a low risk radon setting with <1% of homes above the action level. As such radon protection measures are not required in new dwellings or extension.

3.4 Off-Site Source Appraisal

No significant off-site sources have been identified based on review of historical information available.

There are no recorded landfill or waste management sites located within 500m of the site.

There are no known or listed potential areas of infilled land within 500m of the site.

There are no Integrated Pollution Prevention and Control, or Local Authority Pollution Prevention and Control permits recorded within 500m of the site.

3.5 Pathway Assessment

In accordance with Clause 5.2 of BS8485:2015+A1:2019 *'All potential pathways should be identified, which includes natural geological pathways, services, underground structures, and mine workings. Pathways that are not credible should be discounted.'*

Given the revealed ground profile it is considered that ground gas migration to site would be through the more granular units in the shallow Made Ground or the Glaciofluvial deposits.

The likelihood of gas migrating significant distance through these deposits from an unknown source (as no direct source has been identified) is considered very low. This is due to the likelihood that any ground gas would migrate preferentially through these shallow deposits vertically discharging to atmosphere.

This is further indicated by the results of infiltration testing undertaken at depths of between 1.0 and 2.0m in the two trial pits which recorded low permeabilities of between 6×10^{-7} m/s and 9×10^{-7} m/s.

No preferential pathways have been identified to date and the local geology does not provide an obvious preferential pathway for gas to migrate from off site.

4.0 Ground Investigation and Monitoring Data

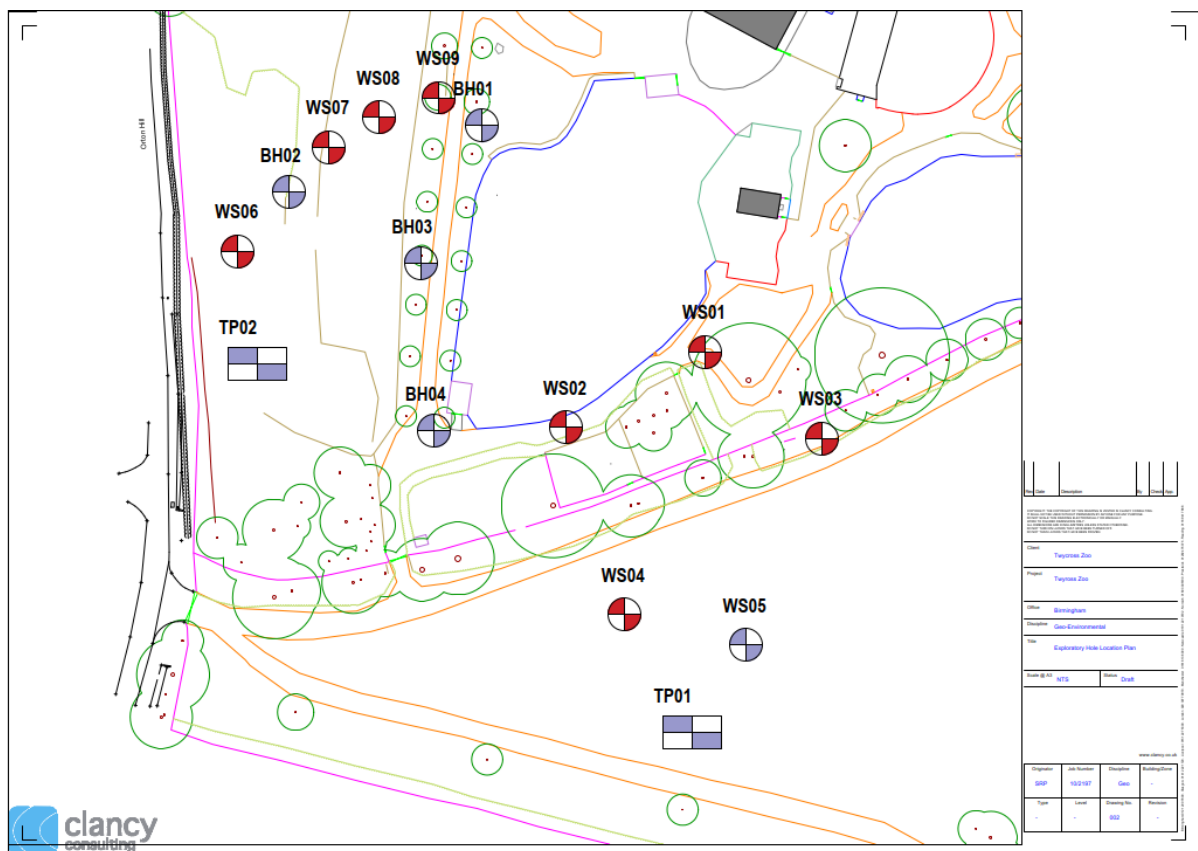
4.1 Ground Investigation Information

As part of the Clancy ground investigations, six monitoring wells were installed and monitored for bulk gases. A total of seven rounds of monitoring have been undertaken, however not all locations were monitored on all occasions.

A summary of the monitoring wells is provided in Table 4.1.

Table 4.1 – Monitoring Well Summary

Reference	Response Zone (m bgl)	Strata Screened	No. of times monitored
BH01	5.00 to 15.00	Thrussington and Gunthorpe Members	5
BH02	5.00 to 15.00	Thrussington and Gunthorpe Members	6
BH04	5.00 to 15.00	Gunthorpe Member	5
WS01	0.50 to 1.50	Made Ground and Glaciofluvial	1
WS04	2.00 to 3.70	Thrussington Member	1
WS07	1.50 to 3.50	Thrussington Member	1



The length of screen in the deeper boreholes is larger than would typically be recommended for gas monitoring. Data collected from BH01, BH02 and BH04 should be considered with caution, as they are unlikely to be representative of the gas regime from any individual lithological unit.

The shallow wells (<5m depth) are noted to predominantly be installed within the natural soils with the exception of WS01 which spans Made Ground and Glaciofluvial deposits. It is recommended that gas monitoring wells are constructed to specifically target either gas sources or pathways and the spanning of multiple strata is to be avoided unless the conceptual site model indicates that it is required. However in this case as no credible source of gas has been identified on or within influencing distance of the site the monitoring well construction is unlikely to be detrimental to the overall risk assessment.

Groundwater was recorded in all of the wells on subsequent monitoring. Groundwater levels in BH03 were consistently above the screened section of the pipe. Similarly in the one monitoring round undertaken on the shallow wells WS01 and WS04 recorded groundwater above the slotted pipe. In WS07 monitored water level was noted at 1.57m depth with the screened section starting at 1.50m.

It should however be noted that even in slotted sections of pipe, around the threads where the pipe is connected the pipe is typically plain (i.e. free of slots) for c 0.2m length.

Based on the above it is anticipated that the BH04, WS01, WS04 and WS07 are 'flooded'.

4.2 Monitoring Data

4.2.1 Frequency of Monitoring and Factual Data Summary

The appropriate monitoring and frequency should be determined by the CSM following the framework defined in BS8576:2013. As detailed in Section 3.0 using the framework defined BS8576:2013 Figure 6, the overall gas generation potential **on the site** is '**Very Low**'. This is based on a conservative worst-case scenario and considers the highest source generation potential.

BS8576 Figure 6 also provides further guidance on monitoring frequencies for Very Low gas generation potential sites extracted below in Figure 4.1.

Figure 6 Decision matrix for initial monitoring

	Generation potential of source				
Gas monitoring requirements	Very low	Low	Moderate	High	Very high
Gas monitoring might not be necessary					
Gas monitoring over a period of 2 months with up to weekly measurements					
Gas monitoring over a period of 2 months up to 6 months with up to fortnightly readings					
Gas monitoring over a period of 6 months up to 12 months with up to fortnightly readings. Use high frequency monitoring where appropriate					

NOTE The darker the section on the matrix, the more likely it is that monitoring is needed.

Figure 4.1 – Figure 6 BS8576

Based on the requirements defined in the appropriate standards, the worst-case requirement would be readings taken over a two month period, up to weekly readings measurements.

However there is scope within the Standard to undertake no monitoring given the very low ground-gas source potential identified within the conceptual site model.

Table 5.5a and Table 5.5b within CIRIA guidance C665 (Assessing Risk Posed by Hazardous Ground Gasses to Buildings), as shown in Figure 4.2, outline the 'idealised/typical' frequencies and periods. As highlighted in Section 5 of CIRIA guidance C665, *'that during longer periods of monitoring, once the temporal pattern of gas emission is established, monitoring frequency can be decreased unless specific threshold concentrations are detected'*. As such the framework outlined within Table 5.5a and Table 5.5b should be considered as guidance only when compared to that detailed in the current Standard BS8576.

Given the conceptual site model established for the site it is assessed that the monitoring frequency and number is adequate to assess the ground gas regime.

TB17 notes that the monitoring of 'worst case' atmospheric pressure conditions is relevant only when there is likely to be a reservoir of gas beneath or within influencing distance of the site. The conceptual site model indicates that the likelihood of a reservoir of gas being present at the site is extremely low. As such the pressure ranges including low and falling pressure events are considered to be suitably representative.

4.3 Gas Data Summary

4.3.1 Flow

Flows were recorded during the Clancy investigation however it is not clear whether the values reported are peak or steady rate. Peak flows should be considered in gas assessment with caution.

Positive flow rates (above equipment detection limits) have been noted during the majority of monitoring rounds, typically within BH02. The highest flow recorded is 9l/hr. Positive flow of 2.2l/hr was noted in WS01 on the one occasion monitored. Negative flows were also recorded, once in BH02 (-7l/hr) and WS07 (-2.6l/hr).

Typically recorded positive gas flows are caused by advection or pressure driven flow caused by the generation of gas in a landfill for example. There is no evidence of a landfill on or in close proximity to the site. Alternatively positive flows can be recorded where specific preferential pathways exist such as mine entry or faulting. As noted previously no records of any preferential pathways exist on the site.

RB17 highlights several scenarios where artificial flows can be recorded within monitoring installations as highlighted below in Figure 4.3.

The most common mechanism for artificial flow recordings is caused by changes in groundwater within the well and this is most likely to be the cause of the positive flow recorded in WS01 and likely the cause of negative flow in WS07.

Groundwater measured in BH02 was noted below the screened section, however, could still be the cause as the surrounding ground has low permeability (effectively causing a sealed environment). However given the spanning of multiple strata by the wells it is likely that the elevated peak pressures are caused by a lag between ground pore pressure and atmospheric pressure causing differential pressures. This is supported by the changes in flow noted including the switch in this location from positive to negative flow. If the flow were caused by the movement of gases from source of gas generation it would not be expected that altering positive and negative flows would be recorded.

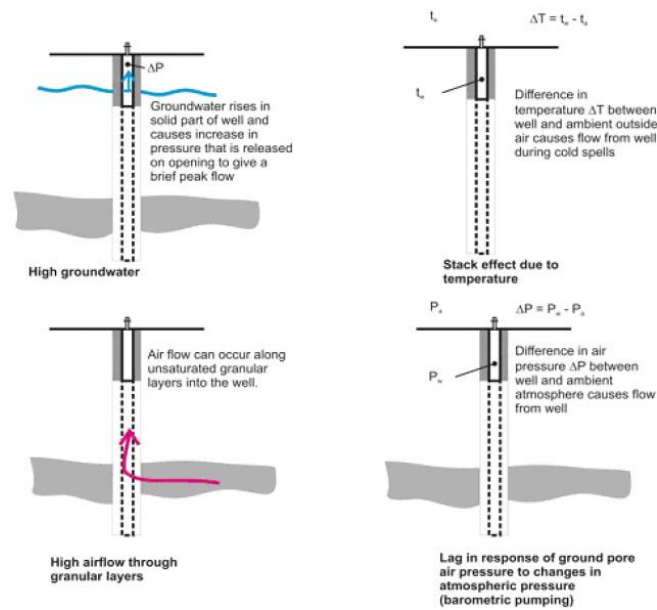


Figure 4.3: Excerpt from RB17

4.3.1 Methane

Methane was recorded at or below detection limits of the analysers used in all wells on all visits.

4.3.1 Carbon Dioxide

Carbon dioxide was recorded above method detection in all shallow boreholes on each monitoring round undertaken. Review of the concentrations recorded on a well by well basis shows that concentrations are broadly steady with variation within the same order of magnitude.

5.0 Gas Screening Value and Characteristic Situation Assessment

5.1 Gas Screening Values

The definition of a gas screening value (GSV) in BS8485:2015+A1:2019 is provided below for clarity in Figure 5.1:

3.4 gas screening value (GSV)

flow rate of a specific hazardous gas representative of a site or zone, derived from assessment of borehole concentration and flow rate measurements and taking account of all other influencing factors, in accordance with a conceptual site model

NOTE 1 This definition is different from the definition of GSV in CIRIA C665 [6].

NOTE 2 GSV is based on measured data but ultimately derived using professional judgement.

Figure 5.1: Excerpt from BS8485:2015+A1:2019

Clause 6.2.1.1 in BS8485:2015+A1:2019 dictates that GSVs should be derived from the CSM and monitoring data collected from gas monitoring standpipes installed in the ground.

As such the data cannot be viewed in isolation and must be considered against the CSM.

As detailed in Section 4, the flows recorded are considered to be reflective of artificial conditions caused within the well and the use of these values within a GSV calculation should only be undertaken where there are supplementary lines of evidence which would support their use.

As detailed in Section 3 there are no viable identifiable sources of gas generation noted on or within influencing distance of the site, nor are there any preferential pathways identified.

It is therefore considered unsuitable to use GSVs as a mechanism to assess the gas risk of the site.

5.2 Elevated Carbon Dioxide

Levels of carbon dioxide in the shallow wells are recorded >5% meaning an increase from CS1 to CS2 should be considered in accordance with BS8485.

However, the screened deposits are not assessed to be a credible ground gas generation source being predominantly natural superficial soils or Made Ground with overall low organic content.

As detailed in CL:AIRE Research Bulletin 17 'A Pragmatic Approach to Ground Gas Risk Assessment' (2012), '*Gas concentration in the ground (or monitoring well) should not be confused with volume of gas present. The two are very different and a small volume of gas can give rise to a high concentration in a monitoring well.*' Gas trapped within pore spaces in the soil can readily collect in monitoring wells installed in the ground providing this over estimation of

total gas concentration. Similarly microbial action (respiration) can occur within monitoring wells producing elevated gases, typically Carbon Dioxide and associated reduction in oxygen.

As noted in Ambisense and EPG 2018 there are situations where carbon dioxide could pose a risk and elevated concentrations require careful consideration. The situation listed in this guidance:

- Landfill gas migration through open fractured rock or other highly permeable pathway;
- Old open coal mine workings that have a free connection to the ground surface;
- High flow of acidic mine water in open working or fractured rock with an open pathway to the surface;
- Volcanic activity causing emission of gas from the ground.

The source of bulk gases within monitoring wells can be assessed using ternary plots.

Recorded concentrations within wells at the site have been plotted and are shown in Figure 5.2.

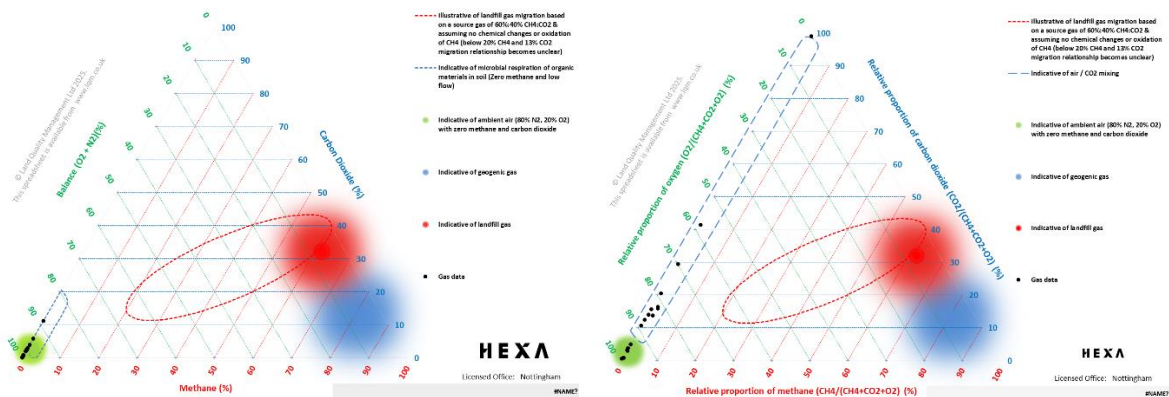


Figure 5.2: Relationship between Carbon dioxide, methane, and balance of gas + oxygen.

This charts illustrate that there is no indication of landfill ground gas or other sources of bulk gas with the likely source of concentrations generated via microbial respiration or the oxidation of small amounts of organic matter in the soils.

6.0 Conclusions

A detailed review of the Conceptual Site Model (CSM) has been undertaken for the site with reference to the appropriate British Standards and supplemented by recognised guidance.

This CSM has been tested through intrusive investigation and monitoring undertaken in broad alignment with current British Standards as detailed in this report.

In reference to CIRIA C665 and NHBC N94 ground gas guidance, no viable ground gas generation sources have been identified in near surface soils on or within influencing distance of the site.

No viable pathways are identified which could allow migration from off site sources or sources at depth beneath the site.

A critical analysis of the monitoring data supports the CSM. While some monitoring wells were sampled on only one occasion, confidence in the CSM remains robust, particularly regarding the absence of viable gas sources. This limitation is not considered to undermine the overall conclusions of the assessment.

Elevated carbon dioxide is assessed to be representative of gas trapped in pore spaces and or microbial respiration which is a commonly recognised occurrence in ground gas monitoring and not representative of a ground gas risk.

Based on the review of all available data, there are sufficient lines of evidence to characterize the site as **Very Low Risk** (Characteristic Situation 1). As such:

- **No further ground gas risk assessment** is deemed necessary for the proposed development.
- **No ground gas protection measures** are required in the construction of the proposed development.

The UK Radon mapping current at the time of writing place the site **not within a Radon Affected Area**. Radon protection measures are therefore not required to be installed within the structure.