HAZARDOUS GROUND GAS TOP TIPS

INTRODUCTION

This document outlines a series of top tips from SoBRA's sub-group on ground gases. These top tips are summary in nature and it is strongly recommended that the reader refers to the documents referenced for more detailed information on each aspect covered here.

The top tips are separated into:

1. The conceptual site model
2. The need for gas monitoring
3. Investigation design
4. Field work
5. Data quality assessment
6. Gas regime characterisation
7. Solutions, choice and detailed design
8. Prior to construction

1. TIPS ON THE CONCEPTUAL SITE MODEL

- Prior to starting gas monitoring, or any ground investigation, a desk study (collection of information) and development of a conceptual site model addressing hazardous ground gas (a gCSM) should be completed to inform a preliminary risk assessment.
- In most cases the gCSM should include a scaled cross section through the site (based on the available data at the time, so may only be approximate until exact ground levels and strata are known) showing geology, hydrogeology and, where appropriate, monitoring well response zones. Such a section should allow confirmation of the viability of potential migration pathways and the location of potential sources in relation to the proposed development, also allowing for any proposed changes in level.
- The gCSM should be used to design any subsequent ground investigation, especially the preliminary well response zone depths (which should be confirmed based on conditions actually encountered during drilling). The gCSM is not a static document and should be continually reassessed and developed during/after the ground investigation as further data becomes available.
- It is important that only realistic and credible contaminant linkages are considered in the gCSM. It is not acceptable to just state that there are potential linkages without consideration of topography, geology and the likely nature of the source and its gas generation potential. It is also important to assess the influence of known (or possible) foundation options that could enhance or inhibit linkages (e.g. stone columns).

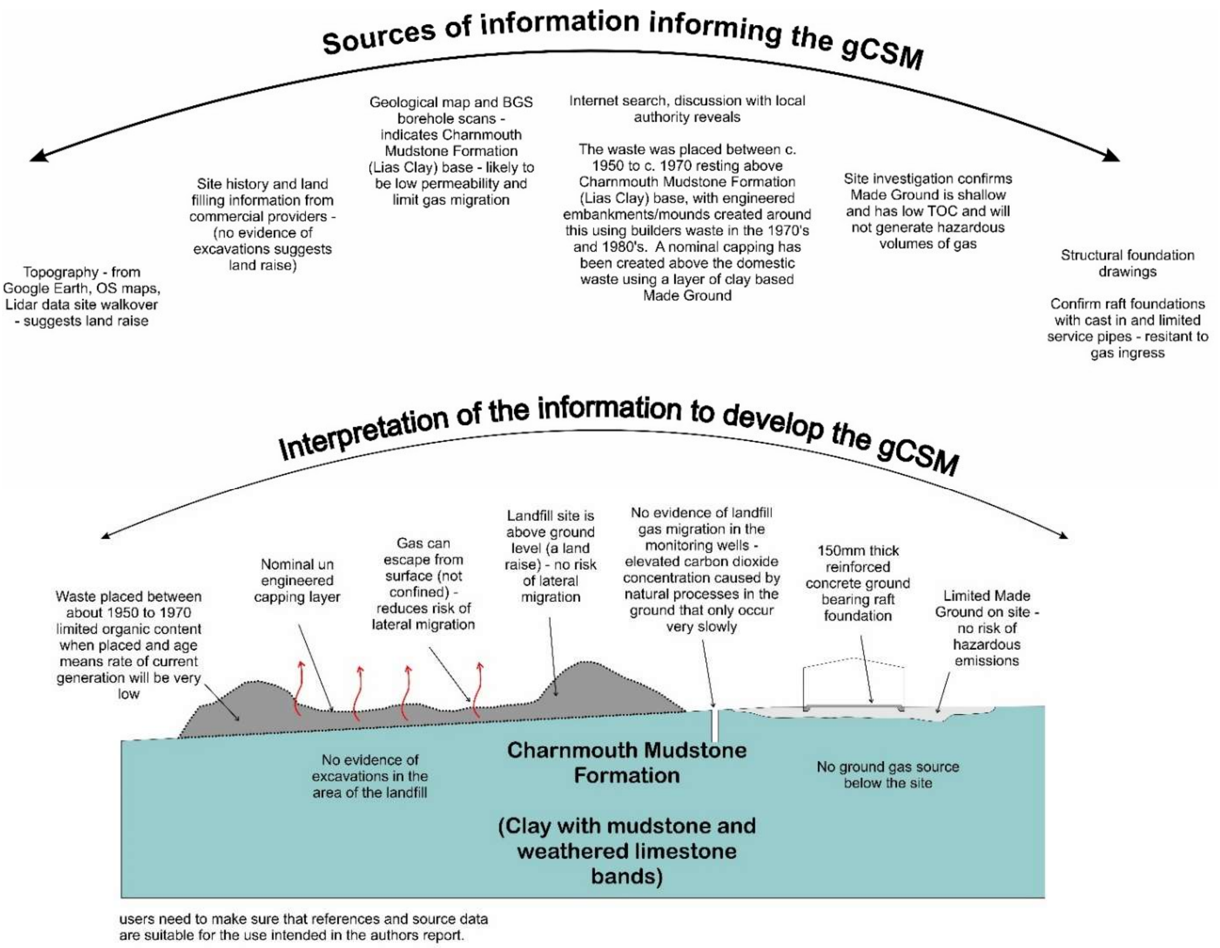
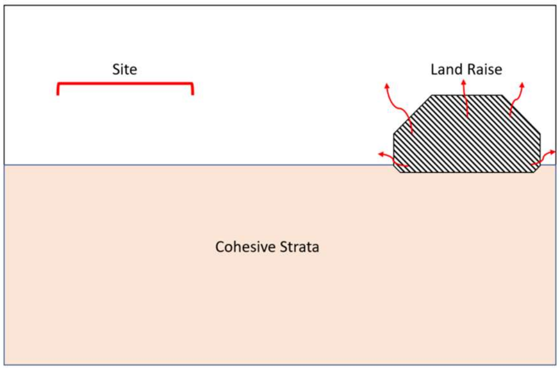


Figure 1. Desk study and the initial gCSM

2. TIPS ON NEED FOR GAS MONITORING

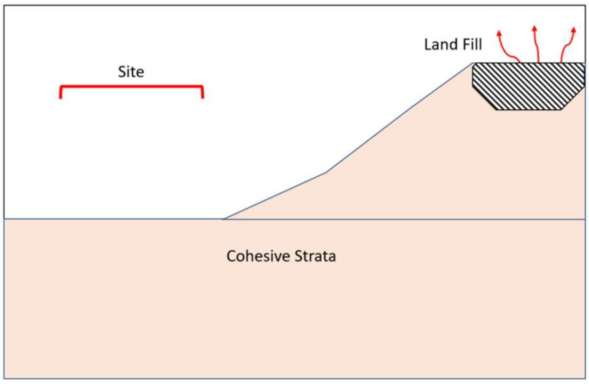
- A robust preliminary risk assessment and conceptual site model can sometimes be sufficient to adequately demonstrate the absence of ground gas risks. It is not necessary to monitor for ground gas where there is no credible source or pathway, or where ground gas risk is very low. The lines of evidence that can be used to assess whether gas monitoring in wells is necessary on a site will be included in the preliminary gCSM and include: site topography, history and ground investigation data, in particular;
    - Trial pit and borehole logs – provide details on composition and thickness of potential ground gas sources, allows for interpretation of migration pathways (e.g., cohesive strata, fractures in bedrock, or bedrock stratigraphy) and identification of source types unlikely to generate sufficient gas to sustain migration:
    - Observations – evidence from investigation logs and notes on presence of visual/olfactory evidence of contamination with potential to produce ground gases/vapours.
    - Total Organic Carbon (TOC) testing - can allow assessment of ground gas risk [Refs 1 and 2] and in ground gas risk assessment to assess whether Made Ground is the source of any identified gas.
    - Flux box testing or surface emissions surveys.
- The influence of the proposed development should also be considered, for example will the earthworks or basement excavation remove the potential source of ground gas? If after undertaking a preliminary risk assessment, producing a gCSM, and reviewing any available ground investigation data, gas monitoring is still proposed then it needs to be proportionate to the site and to the risk posed to end-users (see the decision matrix in Figure 6 of BS8576:2013 [Ref 3].

Scenario 1. Potential source is a land raise with no potential pathways connecting it to the site.



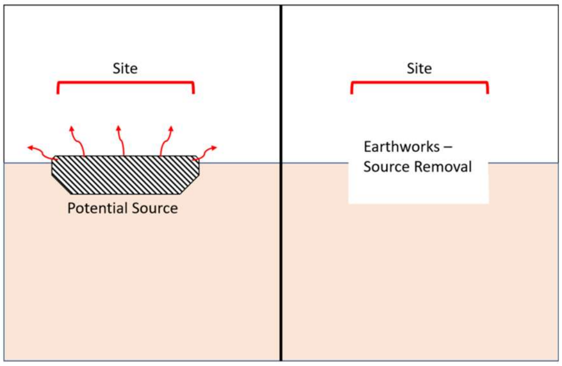
No credible pathway; no gas monitoring required.

Scenario 2. Potential source located at greater elevation than site. Pathways unlikely to exist.



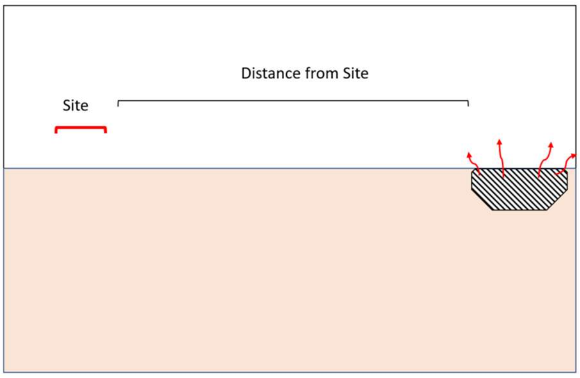
No credible pathway; no gas monitoring required.

Scenarion 3 Earthworks removes the source prior to construction.



No source; no gas monitoring necessary.

Scenario 4. Potential source located at distance (relevant distance depends on ground conditions)



No credible pathway; no gas monitoring required.

Figure 2. Simplified examples of conceptual site models where gas monitoring would be unlikely to be required

3. TIPS ON INVESTIGATION DESIGN

- The design of a ground investigation to collect data for gas risk assessment should be based on the gCSM. Multiple lines of evidence may require to be adopted in order to collect robust and sufficient data. It is important the monitoring well installations are installed as the designer intended. The well is a scientific instrument and needs to be installed correctly with adequate supervision by competent professionals who fully understand the rationale for the well design. The design of the ground investigation must include the number and spacing of monitoring wells which should reflect the gas hazard and sensitivity of the end use, for both on-site and off-site ground gas sources (Ref. 3). The well spacing and response zone design should be justified in the site investigation report.
- It is important to consider the monitoring well response zone within the framework of the gCSM, i.e., in regard of potential gas sources and migration pathways. The final decision on response zone depths should be made by appropriately qualified and experienced engineers, after drilling and based on the ground and groundwater conditions actually encountered in each borehole.
- Response zones should not cross different strata and should be wholly in the unsaturated zone wherever possible. Monitoring should not be specified to be carried out in groundwater sampling wells/wells that are not specifically designed to collect data for ground gas assessment. As part of the sampling and analysis plan, consideration should be given to the need to collect gas samples for laboratory analysis as an additional verification of the data.

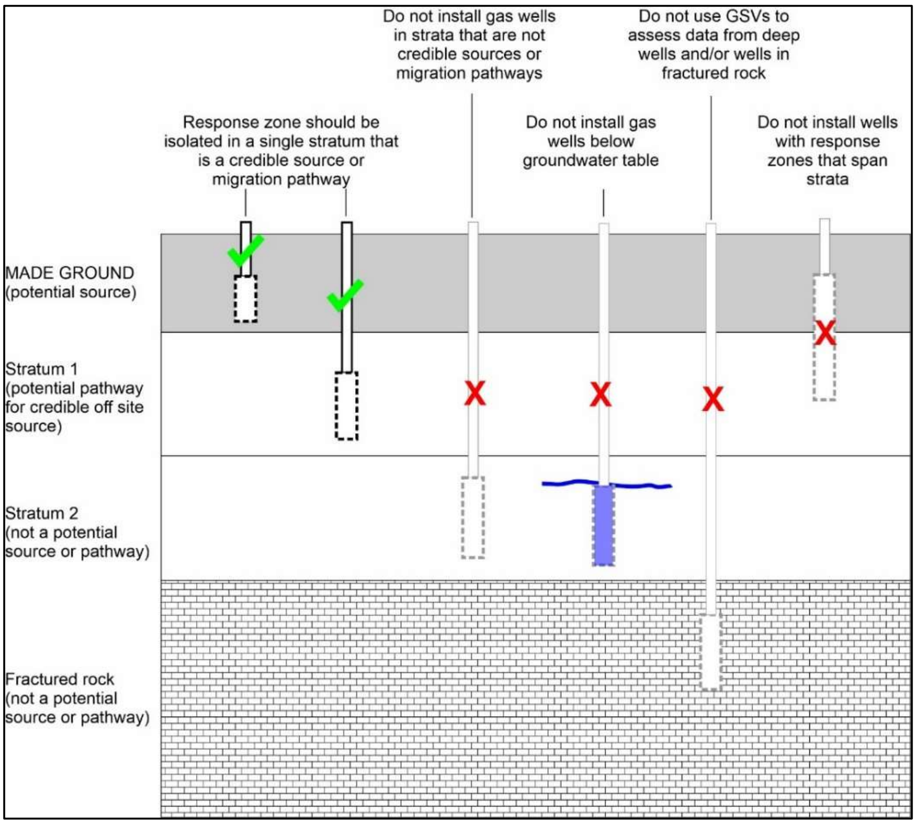


Figure 3. Design of monitoring installations

4. TIPS ON FIELDWORK [LOGGING, WELL INSTALLATION & MONITORING]

- Good soil and rock descriptions are vital to allow interpretation of the gas monitoring results and are an important line of evidence to be considered in any ground gas risk assessment. It is important to make an assessment of organic content to determine the potential of degradable material to generate gas [Refs 1,2 and 5].
- Once the ground conditions are known, following drilling, the final well design should be confirmed with the designer of the well.
- Dry bentonite pellets do not form an effective seal. Water must be added to allow the pellets to swell, compaction is then required to create a seal. For deeper seals liquid grout tremied from the base of the sealed section is more likely to form an effective seal.
- Gas monitoring should be carried out by well trained staff experienced in the use of each specific instrument. Instruments must be maintained in accordance with the manufacturer's specification. Before visiting site to carry out gas monitoring (or installing continuous monitors) the monitoring personnel should have a good understanding of the logs/well installation/depths for the boreholes being monitored. Flow rate and borehole pressure should be measured first prior to measurements of gas concentrations. Each well should be monitored for a sufficient period of time to allow steady state flow rates to be achieved and recorded (this can take ten minutes or more in some wells).
- Log and record all monitoring results and observations on the monitoring record – ambient gas concentrations, instrument details and instrument calibration checks, wind, ground condition, construction activities, nearby slopes, condition of well head and gas tap, highlight any variations in flow rates and influence of wind on flow rates, depth to water and to base of well (this is also required prior to and after continuous monitoring if the instrument does not record water levels). Instruments should be purged between readings / wells by running in clean air.

Gas Monitoring Results Sheet - Information at each monitoring well

Date and time ____________

Location ID ____________

Notes on condition of borehole and surrounding ground ____________

Height of well top above/below ground level ____________

Notes on activites in nearby area that could affect results (eg dewatering excavations) ____________

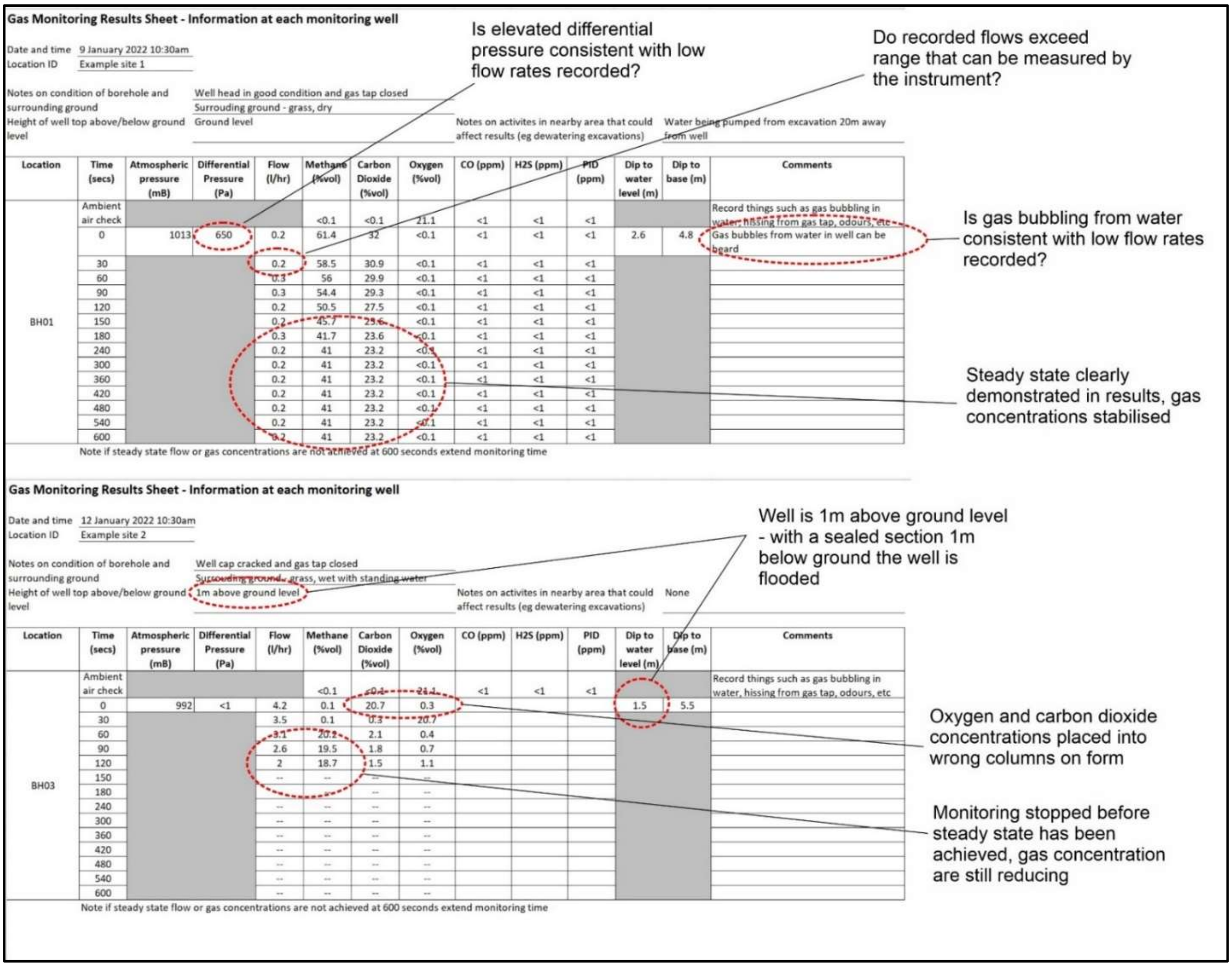
Location	Time (secs)	Atmospheric pressure (mB)	Differential Pressure (mB)	Flow (l/hr)	Methane (%vol)	Carbon Dioxide (%vol)	Oxygen (%vol)	CO (ppm)	H2S (ppm)	PID (ppm)	Dip to water level (m)	Dip to base (m)	Comments
BH01	Ambient air check												Record things such as gas bubbling in water, hissing from gas tap, odours, etc
	0												
	30												
	60												
	90												
	120												
	150												
	180												
	240												
	300												
	360												
	420												
	480												
	540												
	600												

Note if steady state flow or gas concentrations are not achieved at 600 seconds extend monitoring time

Figure 4. Gas monitoring results sheet

5. TIPS ON DATA QUALITY ASSESSMENT

- Data quality assessment is a vital step in the risk assessment process and BS8485: 2015+A1:2019 requires the data quality to be assessed when deriving a Gas Screening Value (GSV). When selecting concentrations and flow rates to generate a GSV (as per BS 8485: 2015 +A1:2019), ensure the values chosen are representative to avoid a disproportionately high gas hazard prediction. Selection of the chosen values used in the GSV must demonstrate that temporal variation is accounted for, and justification should also be given for the selection of peak or steady state values. The smaller the data set the more precautionary the approach must be. This process may mean that a plausible 'worst case' condition has been calculated.
- Check whether the response zones of the monitoring wells are flooded and if so, use extreme caution when assessing and/or using the data. The calculation of GSVs, as described in BS 8485 (Ref 2), is based on the assumption that the data are provided from response zones that are wholly or partly above groundwater level. Read all the comments made on the gas monitoring record (e.g. gas bubbling out of water, comments regarding the condition of the monitoring wells, etc) as a sanity check on results and to inform the subsequent assessment.
- Check the data against the gCSM for any unusual results (e.g., unexpected high or low flow rates or gas concentrations). Consider any possible cross sensitivity of instruments with other gases and the need for gas sampling and laboratory testing to confirm the results from field monitoring. Where hydrocarbon contamination is present (even at low concentrations) consider using a photoionization detector as part of the monitoring.
- Be aware that water vapour absorbs infrared which can affect the methane and carbon dioxide measurements on some instruments. Sufficient water vapour can overwhelm the moisture filters and is more likely on continuous monitoring devices (normally seen as a gradual drift up in the gas concentration but with no corresponding change in oxygen).



Gas Monitoring Results Sheet - Information at each monitoring well

Date and time: 9 January 2022 10:30am
Location ID: Example site 1

Notes on condition of borehole and surrounding ground: Well head in good condition and gas tap closed; Surrouding ground - grass, dry
Height of well top above/below ground level: Ground level
Notes on activites in nearby area that could affect results (eg dewatering excavations): Water being pumped from excavation 20m away from well

Location	Time (secs)	Atmospheric pressure (mB)	Differential Pressure (Pa)	Flow (l/hr)	Methane (%vol)	Carbon Dioxide (%vol)	Oxygen (%vol)	CO (ppm)	H2S (ppm)	PID (ppm)	Dip to water level (m)	Dip to base (m)	Comments
BH01	Ambient air check				<0.1	<0.1	21.1	<1	<1	<1			Record things such as gas bubbling in water, hissing from gas tap, odours, etc
	0	1013	650	0.2	61.4	32	<0.1	<1	<1	<1	2.6	4.8	Gas bubbles from water in well can be heard
	30			0.2	58.5	30.9	<0.1	<1	<1	<1			
	60			0.3	56	29.9	<0.1	<1	<1	<1			
	90			0.3	54.4	29.3	<0.1	<1	<1	<1			
	120			0.2	50.5	27.5	<0.1	<1	<1	<1			
	150			0.2	45.7	25.6	<0.1	<1	<1	<1			
	180			0.3	41.7	23.6	<0.1	<1	<1	<1			
	240			0.2	41	23.2	<0.1	<1	<1	<1			
	300			0.2	41	23.2	<0.1	<1	<1	<1			
	360			0.2	41	23.2	<0.1	<1	<1	<1			
	420			0.2	41	23.2	<0.1	<1	<1	<1			
	480			0.2	41	23.2	<0.1	<1	<1	<1			
	540			0.2	41	23.2	<0.1	<1	<1	<1			
	600			0.2	41	23.2	<0.1	<1	<1	<1			

Note if steady state flow or gas concentrations are not achieved at 600 seconds extend monitoring time

Gas Monitoring Results Sheet - Information at each monitoring well

Date and time: 12 January 2022 10:30am
Location ID: Example site 2

Notes on condition of borehole and surrounding ground: Well cap cracked and gas tap closed; Surrounding ground - grass, wet with standing water
Height of well top above/below ground level: 1m above ground level
Notes on activites in nearby area that could affect results (eg dewatering excavations): None

Location	Time (secs)	Atmospheric pressure (mB)	Differential Pressure (Pa)	Flow (l/hr)	Methane (%vol)	Carbon Dioxide (%vol)	Oxygen (%vol)	CO (ppm)	H2S (ppm)	PID (ppm)	Dip to water level (m)	Dip to base (m)	Comments
BH03	Ambient air check				<0.1	<0.1	21.1	<1	<1	<1			Record things such as gas bubbling in water, hissing from gas tap, odours, etc
	0	992	<1	4.2	0.1	20.7	0.3				1.5	5.5	
	30			3.5	0.1	0.3	20.7						
	60			3.1	20.2	2.1	0.4						
	90			2.6	19.5	1.8	0.7						
	120			2	18.7	1.5	1.1						
	150			--	--	--	--						
	180			--	--	--	--						
	240			--	--	--	--						
	300			--	--	--	--						
	360			--	--	--	--						
	420			--	--	--	--						
	480			--	--	--	--						
	540			--	--	--	--						
	600			--	--	--	--						

Note if steady state flow or gas concentrations are not achieved at 600 seconds extend monitoring time

Figure 5. Assessing monitoring data

6. TIPS ON GAS REGIME CHARACTERISATION

- Interpretation involves assessing what the results are indicating about the ground gas risk and drawing conclusions. A significant ground gas risk requires sufficient replenishment at the source to ensure sustained ground gas migration. Any assessment of the ground gas risk should therefore prioritise the assessment of ground gas generation rates, volumes and flow rates over the ground gas concentrations.
- The generation of a Gas Screening Value (GSV) is a screening approach comparable to using generic assessment criteria (GACs) for soil or groundwater contaminants). The GSV is defined (Ref 2) as the flow rate of hazardous gas representative of a site or zone, derived from assessment of borehole concentration and flow rate measurements, taking account of all other influencing factors, in accordance with a gCSM and must consider the nature of development (if any) e.g. sub-structure, foundations basement etc. which could affect the source and /or migration pathways Ref 9). The GSV is based on measured data but ultimately should be determined using professional judgement. [Note: Guidance should not be mixed and matched (e.g. BS8485 (Ref 2), CIRIA C665 (Ref 6) and NHBC (Ref 7). The screening approach has evolved and current good practice for determining GSVs is as set out in BS8485 (Ref2)].
- A gas source may be a hazard (capable of gas generation) but some do not pose a risk to a development due to other factors. For example, the stratum is fully saturated, or the source is present beneath a laterally persistent impermeable stratum, or unable to generate a sustained gas emission at surface. Where the gas source is alluvial clays, methane is unlikely to pose a risk to a development.
- Where more than one source is present a source specific assessment for each should be undertaken. The consistency of the results with the potential source should be considered. If Made Ground was identified in the preliminary risk assessment, site-specific information (descriptions and TOC results) should be used to determine whether the Made Ground is a credible source. Ternary plots (see Fig 6) are a valuable tool that can help distinguish gases from different sources (ref 8).
- Assessments should include a consideration of climate change (e.g. potential changes in contaminant behaviour / fate and transport due to increasing temperature, reduced migration potential due to groundwater rise).
- Negative flows should not automatically be discounted as erroneous or unexpected values. Although often caused by flooded wells they need to be appropriately discounted (Ref 2). Explain why they are occurring (e.g., changes in groundwater levels, lag in change of borehole pressure when atmospheric pressure changes).
- Increasing characterisation from CS1 to CS2 because of high gas concentrations is not mandatory. The risk assessor should decide whether it is appropriate or not based on gCSM. The advice to consider increasing the CS in this way is there as a sense check.
- Uncertainties in the risk assessment should be clearly acknowledged with their implications considered (Ref 2);
  - Is there sufficient data concerning the factors that affect gas migration and emission to assess the likely variability of the gas regime?
  - Was the frequency of monitoring sufficient to characterize the consistency or inconsistency of the gas regime over the monitoring period?
  - Was the period of monitoring long enough to monitor changes in ambient conditions that influence gas generation and migration?

- The data set should only be considered representative and comprehensive if it captures temporal variation. Consideration must be given to conditions during monitoring (e.g. waterlogged or frozen ground surfaces that could influence gas behaviour). Atmospheric pressure trends should be recorded. Monitoring during falling atmospheric pressure events is more important than low atmospheric pressure values.
- If the data set is temporally or spatially limited, peak or maximum steady state data can be combined from more than one monitoring standpipe location as a worst case check by multiplying the maximum gas concentration by the maximum steady state flow. If this worse case check indicates that a greater hazard could reasonably exist, then either this worst case should be adopted as the GSV, or further monitoring should take place to provide evidence that the worst case should not be used.
- To adopt the worst case as the GSV, the assessor should be confident that to do so is prudent and reasonable and does not result in unnecessarily conservative protection of the development. The basis for decisions should be set out clearly and justifications stated. [Note: a worst case check is not appropriate for continuous monitoring data available the worst case check is not appropriate (Ref 10). and should not be used (the continuous data should have been collected over worst case conditions).

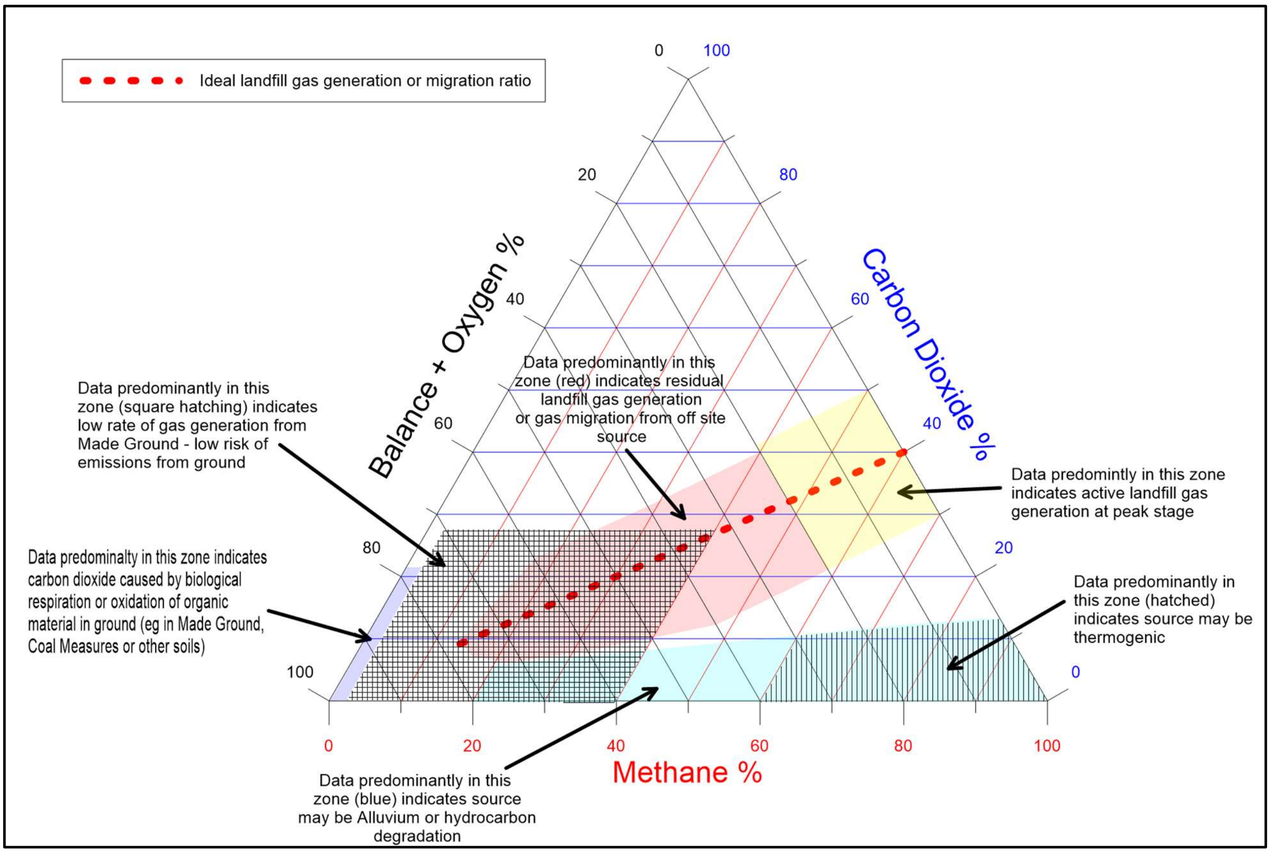


Figure 6a Ternary Plot

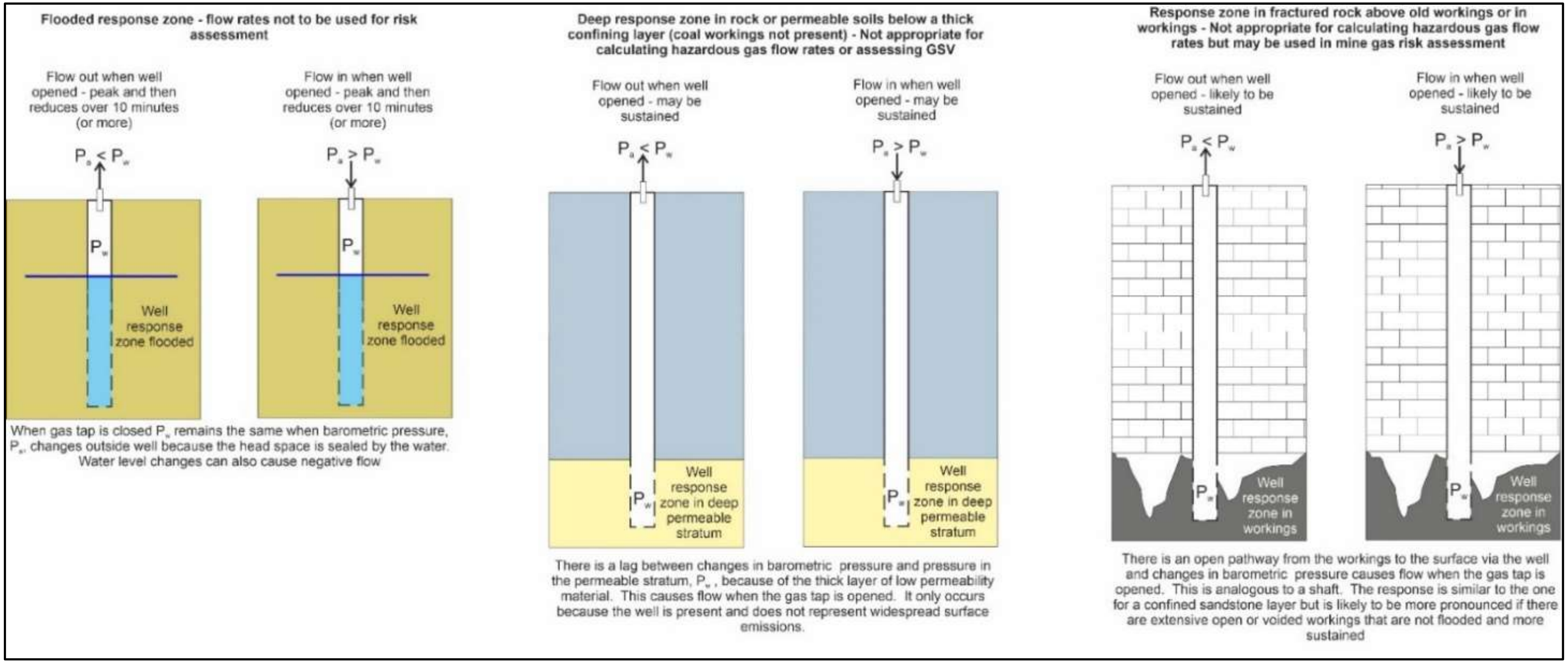


Figure 6b Consideration of response zones in gas characterisation

7. TIPS ON SOLUTIONS, CHOICE AND DETAILED DESIGN

- The requirements for gas protection design are explained in CIRIA C801 (Ref 11) with a screening level approach (the "points system") to determine the scope of gas protection required set out in BS8485 (Ref 2). Once the scope is determined a detailed design, including design drawings, and a design report is required.
- BS8485 (Ref 2) allows detailed quantitative risk assessment (DQRA) to be used as part of the gas protection design process. DQRA does not just involve collecting more gas monitoring data and should not use GSVs. It requires an assessment of gas generation, gas flows through ground, and flow into building through floor construction (Ref 4). The design of gas protection using DQRA will require input from qualified risk assessors (e.g., with SoBRA accreditation).
- Uncertainties in the risk assessment should be dealt with in the design of the gas protection measures. This uncertainty should be clearly acknowledged with the implications considered and justification provided as to why the gas protection measures are appropriate.
- Future changes that may affect the performance of the gas protection system should be considered in the protection design. These should be credible factors not just a shopping list of hypothetical events that are not relevant to a site. This is mainly concerned with how a building will be used and operated so may be different to the future changes considered at the risk assessment stage. Consideration should be given to the design life of materials, management or maintenance of the building and the material specifications.
- Consideration should also be given to the effect of buildings and other construction on the gas regime, risk and the implications for the gas protection design. For example, (i) larger width buildings can reduce oxygen ingress to the sub surface and if methane oxidation is occurring at the time of monitoring this can be reduced once the building is constructed (ii) gas may become trapped below large area buildings, (iii) basement excavation may remove the source of ground gas, and (iv) basement design and requirement for waterproofing may mitigate gas risk (Ref 12).

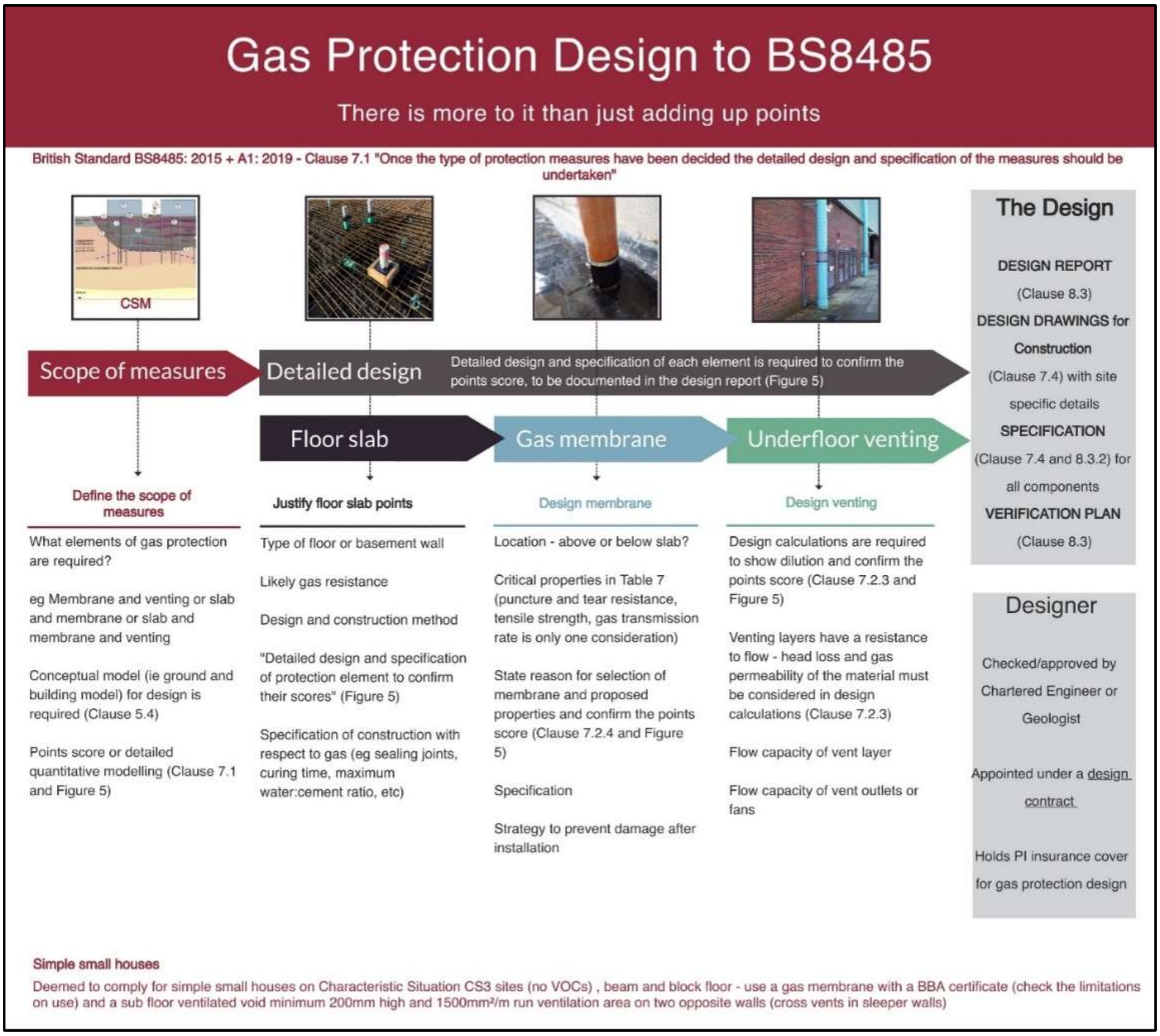


Figure 7 Gas protection design to BS8485 (reproduced from CIRIA C801 Hazardous Ground Gas – a site management guide, 2021)

8. TIPS PRIOR TO CONSTRUCTION

- Make sure that borehole positions are accurately recorded (coordinates should be on logs) and decommissioned appropriately (Ref 13 and 14) prior to site redevelopment / earthworks. Decommissioning advice should be included in the recommendations section of the ground gas risk assessment report and also the gas protection design report if appropriate (wells that are not decommissioned will have an impact on the performance of the gas protection measures).
- In some cases, the ground gas risk can be influenced by the development design (e.g., deep sewer trenches penetrating a clay layer and causing a preferential gas migration pathway, stone columns increasing gas migration risk, basement excavations removing the source of ground gas, etc). An example showing how the use of stone columns has increased the risk of gas migration towards the underside of the slab is shown in Figure 8.
- Where the risk of ground gas migration could be affected by the development design, the ground gas risk assessment report should have a statement requiring it to be reassessed once the development design is fixed. Where the source of gas is Made Ground below the footprint of a building and there are shallow utilities (such as gas, water and electricity) these are unlikely to provide a direct route that allows gas to migrate at greater rates to the building (the limiting factor is still migration from the ground to the service). In addition, the backfill used around those services is often no more permeable than the surrounding soil.

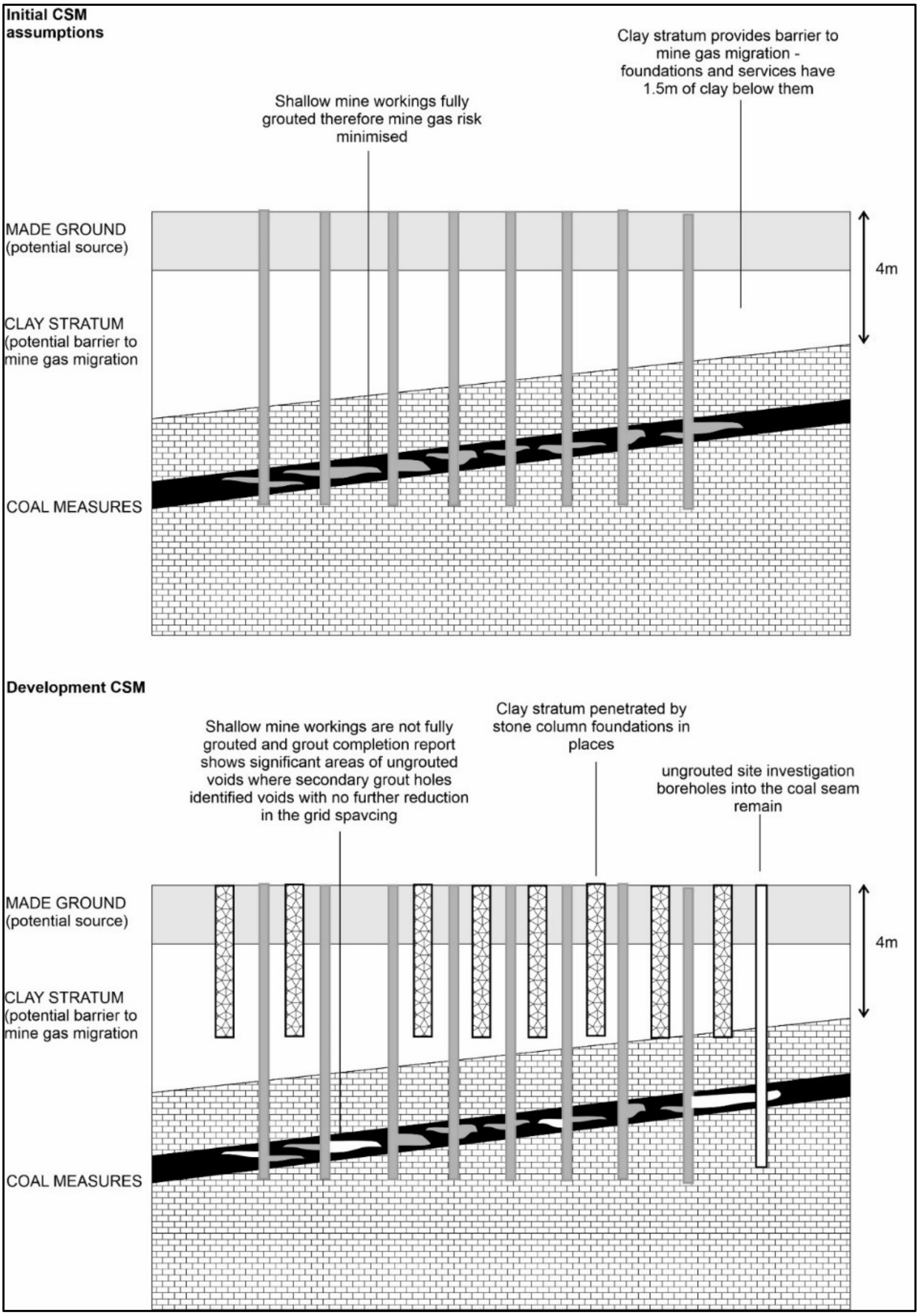


Figure 8. Consideration of development

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In addition to the preceding references the most up to date guidance on all aspects of hazardous ground gases is provided in the NHBC Foundation report, Hazardous Ground Gas – an essential guide for housebuilders, NF94, April 2023. This includes a full Bibliography of documents that provide useful information on ground gas, and is also included on the CL:AIRE Water and Land Library (WALL).

PUBLICATION

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ISBN: 978-1-9161111-4-1

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ACKNOWLEDGEMENTS

This document has been prepared the Ground Gas Sub-Group of SoBRA. The group would like to thank Hugh Mallett for his work on the final editing of the document. SoBRA also wishes to thank the Executive Committee for their steer, encouragement and review.