Greater Manchester Public Protection Partnership (GMPPP) BRIEFING NOTE BN01/2008

DEVELOPMENT ON LAND POTENTIALLY AFFECTED BY HAZARDOUS GROUND GAS

John Naylor (Chair of Gas sub-group) – Bury MBC
Dave Bateson – Bolton MBC
Danny Hope – Rochdale MBC (now with Scott Wilson)
Dr Peter Morris – University of Manchester
Dr Mark Todman – Urban Vision Partnership

March 2008

Forward

This guidance document has been produced in an attempt to improve the service delivery and technical consistency between member authorities of the Greater Manchester Public Protection Partnership (GMPPP). The GMPPP consists of the ten Greater Manchester authorities, Manchester CC, Salford CC, Bury MBC, Trafford MBC, Tameside MBC, Oldham MBC, Bolton MBC, Rochdale MBC, Stockport MBC, Wigan MBC, plus Blackburn with Darwin BC and Warrington BC.

Aim

This Briefing Note has been written to assist the GMPPP Local Authorities when considering development on land potentially affected by ground gas contamination. It brings together the key points of CIRIA Report C665, CIEH Ground Gas Handbook, NHBC 2007 Guidance and BS 8485 and offers recommendations where appropriate.

Contents

Appendices

This Briefing Note is intended to serve as an informative document to be read in conjunction with the guidance documents named above. It is not intended to replace the above guidance notes. There is no substitute for reading and understanding the guidance.

It must be noted that legislation, guidance and practical methods may be subject to change.

The authors have taken all reasonable precautions to ensure that the information contained within this reference document is accurate at the time of publication. However, GMPPP, its officers, its servants or its agents cannot assume legal responsibility for any loss or damage caused to person, land or property for person(s) relying on this information.

1. Introduction

Recently, there has been a wealth of new guidance regarding hazardous ground gases, their assessment and remediation. In response to the new guidance, GMPPP has produced this Briefing Note in order to promote best practice and maintain a consistent approach to the regulation of ground gas issues across Greater Manchester.

Background to the new guidance notes considered in this document

CIRIA C665

Originally produced by CIRIA in 2006 as C659. It provides an update of the guidance released by CIRIA in the 1990s. It attempts to consolidate good practice and promote consistency in investigation, data collection, monitoring and risk assessment.

NHBC

Written by RSK Group PLC for NHBC and intended as internal guidance. It covers ground gas, principally methane, carbon dioxide and a few trace gases, but does not include radon. The focus of the guidance is on ground gas and not gas from landfill sites.

Draft CIEH Handbook

Currently being prepared by *Wilson et al* on behalf of the Chartered Institute of Environmental Health. It is aimed at regulators and others who need to complete, manage or review ground gas assessments and design appropriate protection measures.

BS 8485:2007 Code of Practice

Prepared by the British Standards Institute to allow designers to judge the adequacy of site investigation data and identify possible construction solutions for new developments. It considers methane and carbon dioxide only.

2. Preliminary Risk Assessment

CIRIA C665 chapter 3
NHBC 2007 guidance chapter 7 & 8
CIEH handbook chapter 6
BS 8485 section 4 & 5

All the guidance notes provide information for performing a preliminary risk assessment (PRA) and all specifically refer to the CLR11 framework with the exception of the CIEH handbook.

The main objective of the PRA is to develop an initial conceptual model (ICM) involving the likely gas sources on or near the site and the likely migration pathways and receptors.

In order to construct the ICM a desk study is first carried out usually accompanied with a site walk over. Table 3.1 (CIRIA) (pg27) provides a useful table of desk study information and both Table 1 (CIEH) (pg16 & 17) and Table 3.2 (CIRIA) (pg29), provide useful guides to gas sources and their risk potential.

Table 8.1 in the NHBC document provides a classification of risk for assistance in developing the conceptual model based on the source, information available, migration potential and development. This provides a rule of thumb for subsequent protection and risk strategy but should never replace a complete risk assessment.

The initial conceptual model should include:

- *Expected ground conditions below and adjacent to a site*
- *All potential sources of ground gas*
- *All potential migration pathways*
- *All potential receptors*
- *Robust justification*

A PRA will inform further site investigation, which will then in turn revise and augment the conceptual model. Figure 1 in BS 8485 provides a useful decision making flow chart for the process of developing the conceptual model.

Where the PRA clearly shows and justifies there are no pollution linkages, or where they are shown to be extremely unlikely and low risk, it is possible to exit the ground gas assessment at this stage.

3. Strategies, Methods & Scope of Investigation

CIRIA C665 chapter 4
NHBC 2007 guidance chapter 10
CIEH handbook chapter 5
BS8485 section 5

The CIRIA, NHBC and CIEH documents generally concentrate on methods for investigation and monitoring of the bulk gases. CIRIA C665 and the NHBC guidance provide a good discussion of the key elements. The CIEH Handbook discusses the soil properties such as structure and permeability and how these should be considered within an investigation.

BS 8485 briefly touches on the requirements for site investigation and poses a series of questions that should be answered. It also stresses the need for an appropriate investigation strategy based on good desk study information, the findings of the preliminary risk assessment and the importance of data evaluation.

Appendix B within the NHBC guidance provides an example flow chart for a typical ground gas investigation for low rise housing with a sub-floor void, which includes the traffic light system (TLS).

The NHBC flow chart is generally in line with CLR11 although refinement is needed to fit with current practice. The chart refers to the requirement for gas protection measures if significant risk exists. The use of the term "significant" is inappropriate and does not fit with the other gas risk assessment methodologies. This flow chart has been modified and is included as Appendix A.

The multitude of investigation methods is best covered within CIRIA C665. Full consideration of different aspects is covered from Health & Safety, to site circumstances, to cost. All of which have a bearing on the choice of options to be used in a particular investigation. An extensive comparison of available techniques listing their advantages, disadvantages and when to use them is within CIRIA C665 Table 4.1 (pg35-37).

All guidance documents discuss the inappropriateness of some techniques in ground gas assessment. The authors of the NHBC Guidance recommend that: "[the use of] standpipes in trial pits [to collect data for use in risk assessment] should be avoided at all costs".

We agree that standpipes in trial pits are not an acceptable methods for investigation of ground gas. This type of monitoring well does not produce representative results due to extensive ground disturbance and poor quality of installation. In addition, spike tests are not suitable for gathering data for use in a risk assessment.

Both CIRIA and CIEH include good discussions on the number and location of monitoring installations required. Table 4 of the CIEH handbook considers the gas hazard and sensitivity of development to give an initial borehole spacing. This table is repeated within Table 4.2 (pg39) of CIRIA C665.

For off-site sources, a different approach is taken which primarily considers geology and sets the spacing of monitoring wells accordingly. This is presented in Table 4.3 (pg40) of CIRIA C665.

CIRIA 665 Section 4.3 suggests gas investigations should have three wells as a minimum, no matter how small the site.

We welcome this inclusion, which will benefit most intrusive ground gas investigations. However, we suggest that less than three monitoring well locations may be appropriate in low risk circumstances for very small developments (e.g. single dwelling development or a small extension to existing dwelling) where the conceptual model indicates it is safe to do so.

The key elements are to ensure that the monitoring well has a response zone set in the appropriate place, is adequately sealed above and below this response zone, that the correct stone has been used for the filter pack (i.e. non-calcareous or reactive to ground conditions) and that an air tight cap and valve are fitted.

Typical standpipes are available in three sizes (19mm, 25mm and 50mm internal diameter). All publications consider whether there is any real difference between the results obtained from each diameter. The NHBC guidance concludes that differences in results due to well diameter will largely be masked by other variables in the ground gas regime. They recommend that 50mm standpipes are used so that they can be directly related to the TLS assessment.

The NHBC guidance also discusses the use of nested standpipes to record different response zones in the same borehole. The NHBC authors recommend that the preferred option is to drill separate boreholes in close proximity to the different horizons.

We are of the opinion that it is possible to nest standpipes; however, great care should be taken when doing this to ensure an adequate seal is achieved between the response zones. This is a specialist skill and should be undertaken by suitably experienced contractor or consultant. Where 50 mm standpipes are used, we would recommend a maximum of 2 standpipes in a 200 mm (8 inch) borehole.

CIRIA C665 section 4.4.2 gives a good definition of a response zone: “the response zone refers to the perforated length of standpipe which allows the gas in the unsaturated zone to enter the standpipe and collect in the upper unperforated length of the pipe” and goes on to describe the basic principles.

Poor practice is often characterised by one depth of response zone across the site, regardless of the underlying site conditions or type of source present. Each response zone should be designed on a location-by-location basis. A common error is to conclude that there is no gas below a site when the wells have either not been installed deeply enough or the response zones not set to intercept the pathway or source.

Figure 4.2 and Table 4.4 (pg 43) within CIRIA C665 give examples of ground conditions and suitable response zones. Figure 10.3 (pg 40) of the NHBC guidance provides a good schematic cross section for a borehole monitoring installation, however, please note that the filter pack should consist of single sized non-calcareous gravel.

4. Monitoring & Sampling

CIRIA C665 chapter 5 & 6
NHBC 2007 guidance chapter 10
CIEH handbook chapter 5
BS 8485 section 5

All the guidance documents (with the exception of BS 8485) cover monitoring methodologies. The CIRIA guidance concentrates on an overview approach, highlights the various methods available, provides a general monitoring procedure for bulk gas monitoring and reviews other more specialist methods. The CIEH handbook takes a closer look at the reasons why and where monitoring should be carried out and provides insight into the processes occurring in the ground. The NHBC guidance fits between the two and gives a good overview within a lengthy chapter.

For the most part, the three guidance publications (other than BS 8485) generally do not offer conflicting advice. The main exceptions to this are with the NHBC guidance, which is discussed below.

The CIEH and CIRIA publications specifically cover the amount of monitoring that should be carried out for standard land uses for bulk gases and are consistent with each other.

Table 5 in the CIEH Handbook and Table 5.5a & b in CIRIA 665 provide the typical frequency and period of monitoring required. There is, however, provision for ‘professional judgement’ in the guidance documents, which allows scope for less monitoring to be carried out if the consultant can demonstrate that worst case conditions have been recorded.

Although professional judgement is required, in this situation it leaves opportunity for inappropriate monitoring and insufficient gas protection designs. The regulator needs to be confident that worst case conditions have been identified and understood on a site by site basis.

The NHBC guidance (section 10.1.6) has not differentiated the amount of monitoring needed, other than to state a minimum of 6 visits over a three-month period, which may need to be significantly longer to enable the worst case temporal conditions to be defined.

We recommend that the CIRIA or the CIEH handbook are referred to for determining monitoring periods.

Monitoring & Sampling Methodologies

There is a large range of equipment available to monitor all types of ground gases and vapours. Table 5.1 in CIRIA C665 (pg 46-49) lists the most commonly used with advantages, disadvantages and when to use.

We identified that parts of the information regarding some of the instruments was either misleading or did not contain enough information. In particular, further detailed information for the use and understanding of the Photo Ionisation Detector (PID) should be sought.

Standard monitoring for bulk gases

Standard monitoring procedures and data collection have been clearly written into the CIRIA C665 guidance and also in Appendix A of the CIEH Handbook. Table 5.2 (pg52) and Example 5.1 (pg 53) in CIRIA C665 provide a good methodology for carrying out typical bulk gas monitoring such as methane, carbon dioxide and oxygen.

It has been identified that some editing to this table would be beneficial. Included in Appendix B is Example 5.1 in CIRIA C665, with additional notes.

It is vitally important to record flow rate before monitoring gas concentration for single valve monitoring wells. This is to ensure that the flow from the monitoring well will not be affected during the pumping of gas for concentration analysis.

The CIRIA, CIEH and NHBC guidance notes consider that following installation it will take a period of time for the monitoring well to be in equilibrium with the ground gas regime. This will vary due to a number of factors with the main two being gas generation and the permeability of the material in which the monitoring well is located. The NHBC recommends a period of 1 week to reach equilibrium.

Any results obtained prior to equilibrium should not be used for risk assessment purposes. These results can, however, provide an indication of the recovery of ground gas conditions following installation. A borehole may take longer than one week to reach equilibrium and this should be considered when reviewing the monitoring results.

A pro-forma for recording gas monitoring is included in Appendix A3 of CIRIA C665 (pg132-133) and in Appendix C of the NHBC guidance, which also considers time elapse monitoring of a single monitoring point. The CIRIA, CIEH and NHBC guidance cover several methods for more specialist monitoring.

Specialist Monitoring & Analysis

We recommend that the practitioner refers to the relevant sections in the guidance documents for further information on a site by site basis.

We advise caution regarding the 'Internal gas survey' described in Section 5.3.4 of CIRIA C665. We are of the opinion that the steps contained within Example 5.2 could put operators at risk from potentially explosive or hazardous environments and should not be used in cases of emergency where a hazardous environment is suspected. Only fully trained and equipped personnel should respond to these emergencies and we recommend that the fire brigade or Transco are contacted in the first instance.

Identification of the source gas

It is not uncommon to find that there are several different potential sources of ground gas. Identification of the predominant gas source will help select the correct driving mechanism for risk assessment and design of remediation measures. This is clearly displayed in Figure 6.1 of CIRIA C665 (pg 69).

Quality assurance

It is important that all sampling and analysis is carried out appropriately and properly accredited where available. Detailed records of gas monitoring and sampling should be presented within reports.

Calibration certificates and service records relating to monitoring equipment used should be provided with any monitoring results.

Remember that it is the recorded site data and lab analysis that will feature in the risk assessment for the site. If this is inaccurate, then the risk assessment will not characterise the site properly and ultimately could leave a site being under protected.

5. Interpretation of Results

CIRIA C665 chapter 7
NHBC 2007 guidance chapter 10
CIEH handbook chapter 6
BS 8485 section 6

All guidance documents recognise that interpretation of results can be very complex and that good quality data is required to characterise the ground gas regime. There is unanimous recognition that every attempt should be made to characterise the worst case conditions onsite and the need for sufficient and representative data.

The NHBC handbook reminds the reader that monitoring data will be indicative of conditions at a particular time and location, and that longer monitoring periods or more detailed records may be required when dealing with complex ground gas regimes. The most useful advice on the interpretation of results is available in the CIEH handbook section 6.3 and CIRIA C665 section 7.

The CIRIA guidance considers each of the parameters of the collected data individually. This guidance document provides a useful discussion of the parameters of collected data and the implications for the refinement of the conceptual model. There is a very useful set of questions in CIRIA 665 section 7.3, which will help practitioners with the refinement of the contaminant-pathway-receptor model. The CIEH handbook also focuses on the conceptual model in some detail, before leading directly into the semi-quantitative aspect of the risk assessment processes.

The CIRIA guidance considers the need for additional site investigation data in line with recommendations in CLR11. Further investigation may be required when collected data is not sufficient to adequately characterise the site in a reliable and confident manner. The need for further data will depend on the result of the revised conceptual model and the approach chosen for risk assessment.

It may be the case that further monitoring of existing monitoring wells will be sufficient to significantly improve confidence in the data. This may negate the need for further intrusive site investigation in some cases.

The CIEH handbook discusses data manipulation, including the calculation of the mean and standard deviation. These parameters will determine the statistical significance of the maximum results and the presence of outliers.

Furthermore, the CIEH handbook suggests considering the relationship between borehole flow, atmospheric pressure and groundwater levels. The relationship can be identified by correlating these parameters.

The CIEH handbook recommends the use of line graphs to consider temporal trends. However, this represents an attempt to interpolate the information between the monitoring periods, when the reality could be very different. In order for this method to be accurate there would need to be a thorough understanding of the gas regime of the site.

Continuous / high frequency monitoring would elucidate the temporal ground gas regime and remove the need to interpolate information between monitoring events and, therefore, could be considered as an alternative.

6. Risk Assessment

CIRIA C665 chapter 8
NHBC 2007 guidance chapter 11 & 14
CIEH handbook chapter 6
BS 8485 section 6

There is a reminder in the introduction to chapter 8 in the CIRIA document that any qualitative or quantitative risk assessment can only be based on adequate and reliable monitoring data. If data is inadequate or unreliable, additional investigation and / or monitoring may be needed before proceeding with the risk assessment.

The CIRIA, CIEH and NHBC guidance documents go into detail regarding the background to adopting a risk based approach. The CIRIA document considers the implications of the nature of the source and provides a brief summary.

The purpose of risk assessment is to aid judgement and help make informed decisions that are legal, justified, understandable and transparent.

There is a *pro forma* provided in Appendix A5 (pg134) of the CIRIA guidance, which can be referred to in order to confirm that the necessary steps involved in risk assessment and gas protection design have been undertaken.

We recommend that, at this stage, you do not get distracted by the NHBC reference to Fault Tree Analysis and Event Tree Analysis. These will rarely be required, except on the most difficult and sensitive of sites where exceptional circumstances apply. For example, Part 2A sites may require these more detailed methods to prove significant possibility of significant harm (SPOSH).

Generic Risk Assessment

A common parameter in all four guidance documents is the gas screening value (GSV), although in the British Standard it is referred to as hazardous gas flow rate. The gas screening value is a result of multiplying borehole gas concentration (% v/v) by borehole flow rate (l/h). For example:

Maximum methane and/or carbon dioxide concentration of 12% v/v
Worst case flow rate of 2.0 l/h

GSV *= 12/100 x 2.0 =* ***0.24 l/h***

The GSV is an important and simple calculation, which is used to evaluate the risk at a particular site. However, there are some subtle differences between the CIRIA, CIEH, NHBC and BS documents regarding GSVs . The CIEH, CIRIA and BS guidance suggest that consideration should be given to initial calculation of the GSV which is based on the highest gas concentration and the highest borehole flow rate from across the site as a whole. The recommendation is then to refine the data analysis and risk assessment (e.g. looking at each borehole GSV separately), based on information from the conceptual model and the intrusive investigation. The NHBC guidance does not consider the need for an initial conservative screen and recommends moving straight to the calculation of the GSV for each borehole separately.

Furthermore, in contrast to the CIEH handbook and CIRIA publication, the NHBC guidance recommends separate methodologies for calculating the methane and carbon dioxide GSV.

NHBC guidance for methane GSV: Initial flow rate and initial concentration recorded at each monitoring well. It is argued that this represents the worst case scenario of a build up of potentially explosive gas, which could occur at any time.

NHBC guidance for carbon dioxide GSV: Steady state flow rates and steady state concentrations. It is argued that although the build up of carbon dioxide results in death, this happens over a period of time and, as such, could be more easily mitigated.

All documents are in agreement that [however derived] the worst case GSV should be used to characterise the site in the risk assessment.

We consider that any of these methods for calculating the GSV is acceptable. It may be a useful initial screen to take the worst case site wide conditions, in line with CIRIA and CIEH guidance. However, it should be recognised that site conditions may not be homogenous and, in such circumstances, the NHBC guidance is a more refined method of deriving a GSV. With enough monitoring locations, it is also possible to zone a site with different GSVs.

It should be noted that the GSV is not an absolute threshold value. Therefore, it may be acceptable to exceed the GSV in some circumstances, if the conceptual model suggests it is safe to do so. It may also be the case that detailed consideration of the parameters (i.e. concentration / flow rate) can lead to a consideration of increasing the characteristic situation.

Several example GSV calculations and resulting situations are presented in Box 8.1 (pg 88) of CIRIA 665. It is important to note that some of the examples recognise the need to consider the flow rate and concentration independently of the GSV and whether these parameters affect the characterisation of the site.

Calculating a GSV is never enough on its own. As with any risk assessment process, it is important to consider the implications of all available data.

Using Gas Screening Values

The CIRIA, CIEH and NHBC guidance documents present two systems for determining the level of risk based on the GSV. The use of these systems are determined by the proposed end use.

When the proposed end use is low rise residential considered to be a non-flat / apartment development consisting of one to three storeys in height with a clear ventilated sub floor void, the NHBC propose the Traffic Light System (TLS). Whilst the TLS is discussed in most of the documents (notably not the BS), it is covered most comprehensively in Chapter 14 of the NHBC guidance document. In addition, there are further details in Appendix A7 (pg 167) of the CIRIA report, which provides information on the dimensions of a model low rise development for use with the TLS.

There may be some confusion with the CIRIA 665 guidance as to what assessment should be used when you have low rise housing without a sub-floor void as required by the TLS. The wording of the guidance could be seen as misleading as to what is 'traditional low rise housing with gardens'. The main consideration for foundation construction is the geotechnical properties of the ground. It will therefore be necessary to allow for a wide range of different foundation types, some of which do not have a sub-floor void. In these circumstances we would consider it appropriate to revert to the modified Wilson & Card (1999) method, with an increase in verification requirements.

The TLS includes Typical Maximum Concentrations (TMC), used for initial screening purposes, and risk based GSV for consideration where TMC are exceeded. It is noted that practitioners must carefully evaluate the soil gas regime before proceeding with a design where the TMC is exceeded. However, in certain circumstances, when the conceptual model indicates that it is safe, TMC can be exceeded without an increase in the classification. A useful discussion and example of classifications are presented in section 14.1.1 in the NHBC guidance.

In order to provide a simple assessment, the GSV limits for the TLS have been derived based on one air change per day in the sub floor void and, therefore, design must meet the minimum ventilation requirements.

It should be noted that there are some minor inconsistencies between the NHBC document, CIRIA and the CIEH guide regarding the GSV for the TLS.

The Amber 2 / Red methane GSV and Amber 1 / Amber 2 carbon dioxide GSV is reported as 1.60 l/h in the NHBC guide and 1.56 l/h in CIRIA / CIEH documents.

The Amber 2 / Red carbon dioxide GSV is 3.10 l/h in the NHBC guide and 3.13 l/h in CIRIA / CIEH.

These details probably relate to rounding to one decimal place and then deciding to report to two decimal places at a later date. These differences should be regarded as irrelevant.

For all other developments, CIRIA 665 present a modified Wilson and Card approach. This is discussed in detail in Chapter 8, section 8.3.1 (pg 87) and table 8.5 (pg 88) in the CIRIA guidance.

The NHBC guidance makes it clear that the original Wilson and Card (1999) and CIRIA 149 approaches are out of date and, therefore, should no longer be used.

The modified Wilson and Card approach outlined in CIRIA could be used to identify sites that are unlikely to pose SPOSH, but should not be used to determine sites as contaminated land under the Part 2A statutory definition. In order to determine sites as contaminated land, due to ground gas contamination, there needs to be a more detailed quantitative risk assessment.

Detailed Quantitative Risk Assessment

This topic is barely covered by the new guidance and is typically beyond their scope. The CIEH Handbook provides the most detail including:

- Entry of gas into a building
- Estimating the probability of membrane damage
- Failure of sub-floor ventilation
- Justification of parameters and sensitivity analysis
- Limitations and considerations of Fault Tree Analysis.

It will more commonly be used for the trace components of ground gas or for specific hazardous gases or vapours identified at a site. CIRIA 665 recommends that human health assessment tools such as RBCA are the best equipped to deal with these gases.

CIRIA are currently writing a new publication that concentrates on the assessment and management of volatile organic compound vapours and other trace gases from contaminated ground on brownfield sites.

DQRA will rarely be used for bulk gas assessments and will primarily be used as a tool for use in Part2A assessments, particularly when trying to ascertain SPOSH .

Fault tree analysis is a typical example. Although this analysis appears simple, the input parameters need to be fully understood and fully justified with sensitivity analysis. This should only be carried out by suitably experienced professionals.

We recommend that you seek specialist professional advice in carrying out these types of assessments.

7. Remediation Options

CIRIA C665 chapter 9
NHBC 2007 guidance chapter 11, 12 & 14, appendices D & E
CIEH handbook chapter 7 & 9
BS 8485 section 7

This chapter assesses the proposed new scoring systems (BS, CIRIA and CIEH) for protection measure design and highlights inconsistencies between the guidance documents. This represents a considerable change of approach to remediation options presented in earlier guidance. The new approach provides flexibility in the design of mitigation measures, through combining different elements of protection based on a scoring system.

Due to the limitations within the guidance documents and the scope of this document, we are not able to provide a detailed review of all available ground gas mitigation measures.

Levels of protection

Levels of protection refer to the required integrity, type and number of mitigation measures. The British Standard introduces a scoring system for mitigation measures, which is useful in determining appropriate measures. A slightly different scoring system is also presented in the CIEH handbook.

There are differences between the British Standard and the modified Wilson and Card (1999) table in the CIRIA / CIEH / NHBC documents (which all use the same source information).

The differences relate to recommended levels of protection and their associated scores. There are several key points:

1. *We would question whether the active measures recommended in the British Standard for residential dwellings on characteristic situation 4 or above sites are acceptable on any type of non-managed residential dwelling. We would advise that this is to be avoided for all non-managed housing due to lack of control over maintenance, future development and unwitting impairment.*
2. *Note that membrane installation without independent validation is allocated a protection score of only 0.5*
3. *The British Standard and the modified Wilson and Card (1999) approaches to levels of protection do not match. We believe that the British Standard presents the most comprehensive information. However either approach would be valid.*

Types of protection measures

The CIRIA, CIEH and NHBC guidance documents give an overview of the established passive and active systems of gas protection. The CIEH document includes more detailed discussion on component parts and includes reference to `virtual curtain` systems.

Due to the range and scope of protection measures, we recommend that you refer to the source documents for detailed information. Design of protection measures should be consistent with recommendations in BRE 414 (2001) and the Partners in Technology report (1997).

If exceptional protection measures are required, we recommend that you seek specialist professional advice.

There is inconsistency between the CIRIA, CIEH and NHBC guidance documents regarding the minimum specification of membrane to be incorporated into gas protection systems. CIRIA C665 Table 8.6 (pg90) includes a minimum 1200g (300mu) damp proof membrane in the typical scope of protection measures, whilst the proposal in the text above the table is for a minimum thickness of unreinforced 2000g (500mu) for low risk sites. The NHBC guidance in Appendix D recommends a minimum standard of 1200g (with reference to BRE 212 (1991)). The CIEH handbook recommends that a 2000g membrane should be the minimum required where methane is present.

A 1200g unreinforced membrane is unlikely to survive the construction phase intact, we would advise that 2000g should be minimum standard for unreinforced membranes in gas protection systems. Reinforced membranes should be to a minimum standard of 1200g.

The membrane specification should be appropriate for the particular application and adhere to the manufacturers recommendations. Verification of correct installation is paramount.

8. Verification of Remediation

CIRIA C665 chapter 9
NHBC 2007 guidance chapter 12, chapter 14, appendix E
CIEH handbook chapter 7,8 & 9
BS 8485 section 7

All the guidance documents, with the exception of BS 8485, express concern regarding the installation of membranes and examples are cited illustrating cases of defective construction. There are many references to the 'watchpoints' in BRE 414 and, consequently, the importance of construction quality assurance (CQA) and verification of the installation of membranes is emphasised. The CIRIA and CIEH documents make general comments on the need for CQA and verification of the installation of gas protection measures. The NHBC document is specific on the circumstances in which CQA and verification is required. Both the CIEH and BS 8485 documents relate the degree of CQA and verification to proportionate levels of protection.

The CIRIA guidance states that passive systems are a "single installation which should be quality assured and verified by a third party". It is indicated that the lesser degree of verification carried out, the greater is the risk (Table A5.3). Increased confidence in the installation is provided by use of skilled installers, installation under CQA procedures and post-construction independent inspection. The CIRIA guidance does not differentiate between the gas regimes in relation to the need for CQA and verification.

CQA relates to measures aimed at the prevention of defects during construction. These can include training, onsite procedures and checks and use of skilled installers.

Verification relates to the post construction detection of defects and can include inspection and testing.

The CIEH guidance (section 9) reiterates the importance of inspections and validation of membranes and recommends that this should be carried out immediately before concreting of floors or covering over. Whether CQA and/or verification is carried out, and by whom, is reflected in Table 17 by a score for the protective measures. BS 8485 repeats the scores for CQA and verification (Table 4); however, the scoring systems are slightly different (see 7. Remediation Options above).

The NHBC guidance recommends that the installation of certified gas proof measures may be required on certain sites. It is clarified that 'certain sites' refers to Amber 2 classifications where membranes should always be fitted by a specialist contactor and should be fully certified (Table 14.2). For Amber 2 classifications it is recommended that integrity testing is carried out on the membrane by certified professionals and guidance is given on the most effective integrity test (Appendix E3). There is no specific reference to verification for Amber 1 classifications.

There is no nationally recognised certification scheme for installers of gas protection measures. Certain membrane manufacturers do have a list of approved installers of their product. Similarly there is no formal guidance on verification procedures for the installation of gas protection measures. We would recommend that developers are required to submit proposals for CQA and verification of protection measures for approval and preferably specified in planning conditions.

Note that all the guidance documents view CQA and verification as being applicable to membrane installation only. We would question this approach, as a sub-floor void is often the primary means of protection, the constructed depth of the void being particularly critical to ventilation performance. Correct construction of all other components (e.g. granular blankets and vents) is essential to ensure the desired performance of the overall protection system.

We believe that installation of all gas protection systems should be subject to a degree of CQA and/or verification. With respect to membrane installation this should be reflected in the score for levels of protection as indicated in Table 4 of BS 8485.

We further believe that installation of all components of protection systems (in addition to the membrane) should be subject to verification.

For passive systems, CQA and/or verification should therefore include, where applicable:

- *Membrane*
- *Void or void former*
- *Granular blanket*
- *Collection pipes*
- *Telescopic and straight through vents*
- *Air bricks*
- *Cavity tray*
- *DPC*

An example of a simple verification pro forma sheet for use on site is shown in Appendix C.

The above information should be supplemented in the completion report where necessary with:

- *Photographic evidence*
- *Membrane specification*
- *Integrity testing*
- *Construction details (plans)*

This is not an exhaustive list and will depend on the site circumstances.

Active systems require specialist design and construction and, therefore, verification should be tailored to the specific application.

9. Post Development Monitoring

CIRIA C665 chapter 10
NHBC 2007 guidance chapter 13
CIEH handbook chapter 8
BS 8485 section 7

All the guidance documents (with the exception of BS 8485) address the issue of post development gas monitoring. There is a significant contrast between approaches between the documents.

The CIRIA guidance addresses the issue in depth and makes recommendations for gas monitoring over a period following groundworks/foundation completion. Both the CIRIA and CIEH guidance make reference to monitoring of the constructed sub-floor void. The NHBC guidance argues against post development monitoring, this is discussed below.

Under the CIRIA guidance it is accepted that post construction monitoring of a new development is both undesirable and impractical once homes are ready for sale and occupation. However, under section 10.6 (pg 113), it is recommended that normally a programme of post construction gas monitoring is carried out, to `confirm that the soil gas regime remains within the design parameters of the protective measures`. It is suggested that for a site with a well defined gas regime and falling into the Amber category, a monitoring period of 3-6 months following completion of the groundworks/foundation construction is likely to be appropriate. This may need to be extended to one year where the gas regime is less well defined and/or falls into the red category. The monitoring should be carried out using exploratory techniques (e.g. gas monitoring wells) and monitoring methodologies as described in Chapters 4-6.

If the gas regime is well defined due to sufficient and appropriate pre-development monitoring, and the specifics of the development are taken into account in the risk assessment, we would question the need for a further period of 3-6 months soil/gas monitoring (post groundworks/foundation construction). Furthermore, construction of new wells or maintenance of existing wells could be impractical during this phase of construction.

In addition the CIRIA guidance states that the effectiveness of sub-floor venting can be demonstrated by post construction independent validation of sub-floor gas concentrations and suggests that continuous monitoring from a number of detection points is the most reliable method (Notes to Table A5.3). The CIEH guidance also suggests that gas monitoring can be undertaken in the sub-floor voids on completion of the foundation slab to give added confidence in the performance of passive systems.

The NHBC document acknowledges that post development monitoring is a requisite of CLR 11. However, it is considered that it is almost impossible to carry out post installation verification of the installed measures due to the presence of homeowners. Therefore, it is emphasised that any alterations in the gas regime as a result of the development are taken into account in the design of the protection measures. It is for this reason that the NHBC document is opposed to post development monitoring.

The NHBC stance on post development monitoring is understandable, although monitoring of the sub-floor void could be carried out immediately after completion of the slab, which is normally many months prior to occupation.

Monitoring of the sub-floor void after completion of the foundation slab could be useful to demonstrate that the dilution objectives have been met. Although, it should not be required in normal practice.

Our view is that the design of the gas protection measures should be robust enough to handle any increases in gas flows and concentrations (worst case conditions) as a result of development.

Post development monitoring should be limited to exceptional circumstances:

- *High risk sites where quantitative evidence show that target levels will not be exceeded in the sub-floor void, however, the conceptual model has identified a risk which has yet to be realised or quantified. In such circumstances the design of structures should be such that contingency measures can be incorporated if necessary*
- *The investigation and risk assessment have been inadequate and remain unapproved*
- *The installed protection measures have not been approved and, therefore, are thought to be inadequate*

The methodology of the monitoring to be adopted (monitoring wells or sub-floor void) will relate to the objectives and risk management strategy. Results and interpretation of post construction monitoring should be included in the completion report.

10. Bibliography

1. Boyle, R & Witherington, P (2007) *Guidance on Evaluation of Development Proposals on Sites where Methane and Carbon Dioxide are Present*, NHBC.

2. BS 5925 (1991) Code of Practice for Ventilation Principles and Designing for Natural Ventilation.

3. BS8485 (2007) Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments

4. Building Research Establishment 212 (1991) Construction of New Buildings on Gas-Contaminated Land.

5. Building Research Establishment 414 (2001) Protective Measures for Housing and Gas Contaminated Land.

6. Department of the Environment, Transport and the Regions (1997) *Passive venting of Soil Gases Beneath Buildings – Volume 1*.

7. Department of the Environment, Transport and the Regions/Partners in Technology (1997) Passive Venting of Soil Gases Beneath Buildings – Research Report.

8. Environment Agency (2004) *Guidance on the Assessment of Risks from Landfill Sites*.

9. Environment Agency (2004) *Model Procedures for the Management of Land Contamination CLR11*.

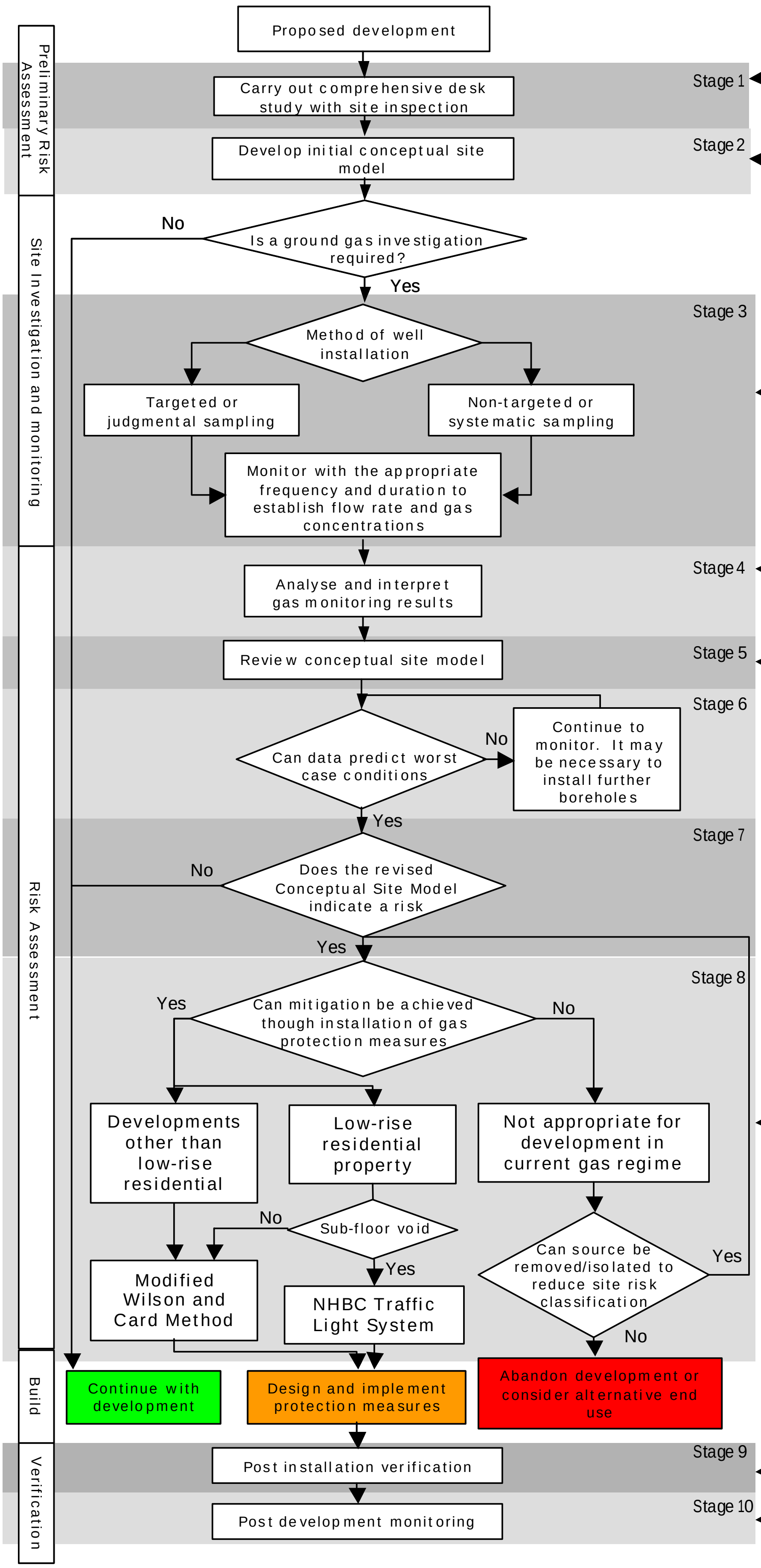
10. Wilson, S and Haines, S (2005) *Site Investigation and Monitoring for Ground Gas Assessment – Back to Basics*, Land Contamination & Reclamation, 13 (3).

11. Wilson, S; Card, G & Haines, S (2007) *Ground Gas Handbook for Designers and Regulators*, in progress.

12. Wilson, S; Oliver, S; Mallet, H; Hutchings, H & Card, G (2006) *Assessing Risks Posed by Hazardous Ground Gases to Buildings*, CIRIA Report C665.

APPENDICES

Appendix A: Ground Gas Investigation Flow Chart



Useful list of desk study information in Table 3.1 CIRIA. Guides to gas sources and their risk potential Table 1 CIEH, Table 3.2 CIRIA and Table 8.1 NHBC. There is a desk study checklist Table 1 in BS. Briefing note Ch. 2.

The initial conceptual site model (CSM) should include ground conditions below a site, all potential sources, pathways and receptors of ground gases. All potential s-p-r should be indicated. See Ch. 8 NHBC, CIEH pg 51, Ch. 3 CIRIA. Briefing note Ch. 2.

Well distribution varies according to site conditions. Where there are no target areas, use a grid pattern according to Table 4.2 CIRIA & Table 4 CIEH. If target areas are identified, bias the locations towards them, see 4.3 CIRIA, CIEH pg 39. For off site source see Table 4.3 CIRIA & Table 5 CIEH. A minimum of 3 wells are recommended, however we suggest that less can be used for very small, low risk developments e.g., single dwelling when CSM indicates it is safe to do so.
For the frequency and duration of monitoring consult Table 5 CIEH Handbook & Table 5.5 CIRIA. The aim of this is to collect data for the risk assessment and must demonstrate worst case conditions have been identified and understood. Briefing note Ch. 3/4.

Good quality data is required to characterise the ground gas regime, temporal resolution and environmental conditions should be considered. Longer monitoring periods or more detailed records may be required when dealing with complex ground gas regimes. Also further investigation may be required when collected data is not sufficient to adequately characterise the site in a reliable and confident manner. It may be possible that extra monitoring at existing boreholes will be sufficient to improve the significance of the data rather than further intrusive SI. See 6.3, CIEH, 51-54, 7, Ch. 7 CIRIA, useful flow-chart pg 71. Briefing note Ch. 5.

The CSM should be refined as information is gathered, see CIRIA section 7.3 and Ch. 8 NHBC. Briefing note Ch. 2/5.

The guidance documents present two risk assessment systems. When the proposed end use is low rise residential considered to be a non-flat / apartment development consisting of one to three storeys in height with a clear ventilated sub floor void, the NHBC propose the Traffic Light System (TLS) see Ch. 14 NHBC. Appendix 7, CIRIA provides information on the dimensions of a model low rise development for use with the TLS. For all other developments use the modified Wilson and Card approach, see 8.3.1 CIRIA. Briefing note Ch. 6/7.

Gas screening values (GSV) are used in the risk assessment, see 6.5 CIEH, 8.3.1 CIRIA, 6.2 BS and 11.10.3 NHBC. Any method can be used. Remember the GSV is not a threshold value and consideration needs to be applied to both its parameters in the risk assessment, see box 8.1 CIRIA and section 14.1.1 NHBC. Briefing note Ch. 6.

All protection measures should be subject to CQA/ verification. Installation of all components should be subject to verification. See Ch. 9 CIRIA, Ch. 9 CIEH, BS 8485 table 4, Ch. 14 NHBC. Briefing note Ch. 8.

Adequate risk assessment should negate the need for post development monitoring (PDM). The gas protection measures should be able to mitigate worst case conditions, therefore PDM is limited to exceptional circumstances. Ch. 10 CIRIA. Briefing note Ch. 9.

Appendix B: Example of typical gas monitoring round – modified from CIRIA C665

EXAMPLE 1: Example of typical gas monitoring round – modified from CIRIA C665
1. Record daily (and if appropriate hourly) atmospheric pressure readings during period before the monitoring visit.
2. Gas check and calibrate the instruments before the monitoring visit.
3. Before beginning the monitoring round, turn on the monitoring equipment, attach tubing and run through clean air to purge the equipment. Zero all gases such as methane, carbon dioxide and hydrogen sulphide, carbon monoxide and normalise oxygen to 20.9 %v/v. This needs to be done well away from any sources of soil gases and/or vapours such as vehicles and monitoring locations. Also record weather conditions, atmospheric pressure and ground conditions at the site. This information is important as it may influence the interpretation of the gas results.
4. Keep the monitoring equipment switched on between boreholes to prevent having to zero the instrument each time it is switched on. Purge any residual gas from the equipment between monitoring points.
5. First measure the gas flow and pressure. Switch on the flow meter, attach the inlet tube to the gas tap and open. Record the pressure and flow readings on the gas monitoring pro forma, making sure "positive" or "negative" is recorded. Be careful to shield the flow meter outlet pipe from any breeze which could affect the reading, particularly at low flow rates.
6. Close the gas tap and remove the gas flow meter tubing. This prevents further loss of gas from the monitoring point.
7. Attach the gas concentration monitoring equipment tubing to the gas tap and open. Switch on the pump and record the peak and steady reading for methane (% v/v), methane (% LEL), carbon dioxide (% v/v) and steady reading for oxygen (% v/v). It is also good practice to record the time taken to reach the steady reading. Also record concentrations of any other gases and other functions where available on the instrument such as atmospheric pressure, borehole pressure and balance etc.
8. If the gas readings have not reached a steady value after 3 minutes, record the concentrations and the direction and rate of change in concentration (that is steadily increasing/rapidly decreasing). Where the concentrations are decreasing always record the peak concentration (expect oxygen). If very high readings are recorded on the monitoring equipment it is worth monitoring the well for a longer period (up to 10 minutes) to determine if the

concentrations are related to build up of gas in the well (for example from a pocket of methane within a layer of alluvium) or are being constantly replenished by methane or carbon dioxide from the soil. The readings over time should be recorded on a separate individual monitoring well sheet similar to the example in Appendix C page C5 of the NHBC Guidance. *Note: The Monitoring equipment is liable to suck up water from the boreholes which is why a hydrophobic filter is fitted to the inlet pipe. Watch the clear plastic tubing (attached to the tap) carefully and if this should happen, quickly detach the tubing from the inlet and switch off the pump. Record the gas concentrations and make a note that water was sucked up. Remove any remaining water from the tubing. Check the filter and if wet, replace with a dry filter.*
9. Once data is recorded remove the tubing from the gas tap and close the tap. Purge the monitoring equipment in clean air (away from the borehole/and other sources of gas) until the methane and carbon dioxide concentrations return to zero and the oxygen is reading atmospheric concentrations.
10. Record the water level and well depth using a dip meter, usually obtained by removing the gas tap or cover from the borehole. Water level and well depth readings are usually recorded from the top of the borehole or from ground level or both (be consistent and note to where depth relates). After obtaining a reading, record on the pro forma and replace the gas tap or cover ensuring that the tap is closed and cover locked. *Note: Other readings and samples can be taken at this point such as water temperature, water sampling, water conductivity etc.*
11. Make a note of any defects to the boreholes and perform maintenance if appropriate.
12. Repeat for all boreholes and record an atmospheric pressure reading once all monitoring has ceased and record on pro forma. Note any trend in atmospheric pressure in the lead up to and during the monitoring visit.
Note: The steps listed in Example 1 is an example only and does not represent generic advice

Appendix C: Example gas protection measure verification form

Simple Example Pro Forma Sheet for Verification of Installation of Gas Protection Measures

Job No	
Site Name	
Plot No	
Foundation Type	

Vented Void					
Component	**Specification (or N/A)**	**Inspected by**	**Date**	**Pass/Fail**	**Comments**
Open void					
Void former					
Granular blanket					
Gas drains					
Periscope vents					
Str through vents					
Air bricks					

Membrane					
Component	**Specification**	**Inspected by**	**Date**	**Pass/Fail**	**Comments**
Membrane					
Joints					
Service entries					
DPC					
Cavity tray					

This Pro Forma can be modified to suit each individual building by adding/removing protection measure elements.
It is for example only and the listed compenents are by no means exhaustive.
Add explanatory guidance notes as appropriate