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5.02 ENVIRONMENTAL STATEMENT APPENDIX 17.3 DETAILED QUANTITATIVE RISK ASSESSMENT - HUMAN HEALTH

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1 INTRODUCTION

1.1.1 This Detailed Quantitative Risk Assessment (DQRA) has been undertaken by Luton Rising (a trading name for London Luton Airport Limited) (the applicant) to support the application for a Development Consent Order (DCO) for the expansion of the airport, the Proposed Development.

1.1.1 The aim of this risk assessment report is to build on the findings of the Preliminary Risk Assessment (PRA) (Ref. 1) (**Appendix 17.1**) and Generic Quantitative Risk Assessment (GQRA) (Ref. 2) (**Appendix 17.2**) of the Environmental Statement (ES) **[TR020001/APP/5.02]**. It presents a detailed quantitative risk assessment relating to human health and ground gas for Area A which is a former landfill (see **Figure 1** for location) within the Main Application Site. In other areas of the Main Application Site no further assessment with respect to potential contamination.is required at this time. It is intended for this report to be read in conjunction with the PRA (Ref. 1) and GQRA (Ref. 2).

1.1.2 The Proposed Development builds on the current operational airport with the construction of a new passenger terminal and additional aircraft stands on land owned by the applicant located to the northeast of the runway. This will take the overall passenger capacity from 18 million passengers per annum (mppa) to 32 mppa. In addition to the above and to support the initial increase in demand, the existing infrastructure and supporting facilities will be improved in line with the phased growth in capacity of the airport. The Proposed Development and associated earthworks are described in **Chapter 4** of the ES **[TR020001/APP/5.01]**.

1.1.3 This report meets the requirements of a quantitative risk assessment as defined by the Environment Agency's Land contamination risk management (LCRM)[1] guidance (Ref. 3).

1.2 Information sources

1.2.1 Several ground investigations and other reports are available for the site and surrounding area. These were reviewed in detail in the PRA (Ref. 1) (**Appendix 17.1**) of the ES **[TR020001/APP/5.02]**. Results of the most recent ground investigation completed on site in 2018 are presented in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**. Data from these reports have been used in preparing this assessment.

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[1] LCRM was published in 2020 (last updated April 2021) and replaced "CLR11 Model Procedures for the Management of Contaminated Land" (2004).

2 HUMAN HEALTH DETAILED QUANTITATIVE RISK ASSESSMENT

2.1 Identified Potential Contaminant Linkages (PCLs) requiring further assessment

2.1.1 The PRA (Ref. 1) (**Appendix 17.1**) and GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** established that further assessment was required with respect to the risks presented by Area A, former landfill, see **Figure 1**.

2.1.2 The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** undertook an assessment of the risks in Area A to human health from contaminants in the soil and groundwater, as well as the risks from asbestos fibres and ground gases. The GQRA (Ref. 2) indicated that no further detailed assessment was required for the following PCLs:

a. Chronic risks to human health from contaminants in the landfill;

b. Acute risks to human health from contaminants in the landfill; and

c. Risks to human health from inhalation of vapours from volatile contaminants in groundwater.

2.1.3 However, the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** concluded that given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required, particularly in landscape areas to prevent direct contact with the waste i.e. a cover system.

2.1.4 The following PCLs were identified as requiring further detailed risk assessment:

a. Inhalation of soil derived vapours;

b. Risks to human health from inhalation of asbestos fibres in soils; and

c. Risks from ground gases.

2.1.5 A summary of the PCLs requiring further DQRA are presented in **Table 2.1** and **Figure 1** of this document. **Table 2.2** below includes the PCLs which were assessed in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** as not requiring further detailed assessment, but measures were required to be included in the Outline Remediation Strategy (ORS) (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. It has been indicated within **Table 2.1** and **Table 2.2** below whether the PCLs apply either:

a. During excavation, remediation and construction phase; or

b. Future use of Proposed Development

2.1.6 The PCLs have been classified as follows, consistent with the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**:

	Confirmed relevant pollutant linkage (RPL) requires inclusion in ORS.
	PCL requires further consideration through DQRA.
	Impact is possible but can be mitigated by design and/or managed under an alternative regime such as permitted operation or occupational safety. Measure should be included in the ORS.
	Impact ruled out no further assessment required.

Table 2.1: CSM for Human Health Receptors requiring further DQRA.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
On-site						
1	DEV	Ground gases from former landfill e.g. methane	Migration into future buildings and aviation apron resulting in build-up of gases	Users of future development – public/airport operatives/Green Horizons Park users (formerly New Century Park) - risk of explosion	Very High	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated that the Characteristic Situation (CS) is 2 to 3. However further DQRA is required to understand the gassing conditions.
2	DEV		Migration off-site	Adjacent site users (e.g. residential housing and other buildings on Luton Airport, WVP Community Centre/ pavilion)- - risk of explosion	Moderate	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated little evidence of off-site migration of gases. Further DQRA is required to understand the gassing conditions.
11	CON	Waste in former landfill	Inhalation of vapours	Construction workers	Low	There are no generic assessment criteria for assessing soil gas vapour concentrations. Therefore, PCLs associated with soil gas vapours require further DQRA.
12	DEV			Future maintenance workers	Low	

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
13	DEV			Users of future development – public/airport operatives/Green Horizons Park users	Low	There are no generic assessment criteria for assessing soil gas vapour concentrations. Therefore, PCLs associated with soil gas vapours require further DQRA.
14	DEV		Inhalation of airborne contaminants/ dust/ asbestos fibres and microorganisms	Users of future development – public/airport operatives/Green Horizons Park users	Low	Further assessment is required to establish the mitigation measures with respect to asbestos fibres, considered with DQRA.
15	CON			Adjacent site users (e.g. residential housing, Luton Airport visitors and operatives, users of WVP)	High	Further assessment is required to establish the mitigation measures with respect to asbestos fibres, considered with DQRA.
16	CON			Construction workers	Moderate	Further assessment is required to establish the mitigation measures with respect to asbestos fibres, considered with DQRA.
31	CON	Contaminants in Made Ground (car	Inhalation of soil derived dusts/asbestos fibres	Construction workers	Moderate	Further assessment is required to establish the mitigation measures with respect to asbestos fibres, considered with DQRA.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
32	DEV	park, capping material)		Future maintenance workers	Moderate/ Low	Further assessment is required to establish the mitigation measures with respect to asbestos fibres, considered with DQRA.
33	DEV			Users of future development – public/ airport workers/users of Green Horizons Park	Low	Further assessment is required to establish the mitigation measures with respect to asbestos fibres, considered with DQRA.
34	CON			Adjacent site users (e.g. residential housing, Luton Airport, WVP)	Moderate/ Low	Further assessment is required to establish the mitigation measures with respect to asbestos fibres, considered with DQRA.
35	CON		Inhalation of vapours	Construction worker	Low	There are no generic assessment criteria for assessing soil gas vapour concentrations. Therefore, PCLs associated with soil gas vapours require further DQRA.
36	DEV			Future maintenance workers	Low	
37	DEV			Users of future development – public/ airport workers/users of Green Horizons Park	Moderate/ Low	There are no generic assessment criteria for assessing soil gas vapour concentrations. Therefore, PCLs associated with soil gas vapours require further DQRA.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
38	DEV			Adjacent site users (e.g. residential housing, Luton Airport, WVP Buildings)	Low	There are no generic assessment criteria for assessing soil gas vapour concentrations. Therefore, PCLs associated with soil gas vapours require further DQRA.
KEY: CON- PCL during excavation, remediation and construction phase DEV- PCL associated with future use of Proposed Development						

Table 2.2: PCLs which do not require further assessment but required consideration in the ORS (Ref. 4) (**Appendix 17.5** of the ES **[TR020001/APP/5.02]**).

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
On-site						
2	CON	Ground gases from former landfill e.g. methane	Migration off-site through preferential pathways	Adjacent site users (e.g. residential housing and other buildings on Luton Airport,	Moderate	Mitigation measures will be required to treat existing pathways e.g. Thames Valley Drain (TVD) (also referred to as the Thames Water overflow pipe).

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
				WVP Community Centre/ pavilion)		
3	DEV	Volatile radionuclides occupying buildings overlying radioactive land contamination	Migration into future buildings and build-up of gases	Users of future development – public/airport operatives/ New Century Park users	Low	The recent GI included testing for radionuclides, which indicated levels observed were consistent with background levels (see **Section 10.1.2** of the GQRA (Ref. 2), **Appendix 17.2** of the ES **[TR020001/APP/5.02]**). No further risk assessment of the radionuclide risks is required. However, a watching brief will be required during excavation works and procedures in place to ensure any suspected radionuclide containing material encountered is appropriately managed.
4	DEV		Migration off-site through preferential pathways	Adjacent site users (e.g. residential housing and other buildings on Luton Airport, WVP Community Centre/ pavilion)	Low	
5	CON	Waste in former landfill	Direct contact e.g. dermal contact, soil ingestion	Construction workers	Low	Based on the results of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02],** no special precautions, above and beyond best practice, are considered necessary during construction works to control potential acute risks. Appropriate measures should be undertaken during construction to

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
						ensure the site is secure and dusts are controlled. Any risks to construction workers can be reduced by adoption of appropriate site management protocols and PPE.
6	DEV			Future maintenance workers	Low/ Moderate	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated there was very few exceedances and the risk to maintenance workers of the Proposed Development is low. Maintenance workers may be exposed to areas of landfill waste during future excavation. This can be reduced by placing of services in a clean cover system.
7	DEV	Waste in former landfill		Users of future development – public/airport operatives/Green Horizons Park users	Low	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated there was very few exceedances and the risk to future users Proposed Development is low. The future development will comprise buildings & hardstanding, therefore there is unlikely to be any contact with landfilled wastes. However, given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required, particularly in landscape areas to prevent direct contact with the waste.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
8	CON		Direct or indirect contact with radionuclides – incurring radiation dose by indirect dose received from ingestion of radium (or other alpha emitting contaminated material) or direct risk from contact with beta emitters such as Carbon-14 or Caesium-137	Construction workers	Low/ Moderate	The recent GI included testing for radionuclides, which indicated levels observed were consistent with background levels (see **Section 10.1.3** GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**). However, given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required. Maintenance workers may be exposed to areas of landfill waste during future excavation. This can be reduced by placing of services in a clean cover system.
9	DEV			Future maintenance workers	Low	The recent GI included testing for radionuclides, which indicated levels observed were consistent with background levels (see **Section 10.1.3 in GQRA** (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]).** However, given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required. Maintenance workers may be exposed to areas of landfill waste during future excavation. This can be reduced by placing of services in a clean cover system.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
10	DEV			Users of future development – public/airport operatives/Green Horizons Park users	Low	The recent GI included testing for radionuclides, which indicated levels observed were consistent with background levels (see **Section 10.1.3** in GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**). However, given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required, particularly in landscape areas to prevent direct contact with the waste.
20	CON	Leachate in former landfill[2]	Direct contact e.g. dermal contact	Construction workers	Moderate/ Low	Construction workers may be exposed to landfill leachate during future excavation works. The GI undertaken indicates there is likely to be limited leachate present. Any excavation work would adopt appropriate site management protocols and PPE.
21	DEV			Future maintenance workers	Moderate/ Low	The GI undertaken indicates there is likely to be limited leachate present. Maintenance workers may be exposed to areas of landfill waste during future excavation. This can be reduced by placing of services in a clean cover system.

[2] The source of the leachate in assumed to be the landfill waste material

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
22	DEV			Users of future development – public/airport operatives/Green Horizons Park users	Low	The GI undertaken indicates there is likely to be limited leachate present. The future development will be buildings and hardstanding and is likely to include an engineered cover layer and leachate control system, therefore there is limited potential for contact with any leachate in the landfill.
28	CON	Contaminants in Made Ground (car park, capping material)	Direct contact e.g. dermal contact, soil ingestion	Construction workers	Moderate/ Low	Based on the results of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**, no special precautions, above and beyond best practice, are considered necessary during construction works to control potential acute risks. Appropriate measures should be undertaken during construction to ensure the site is secure and dusts are controlled. Any risks to construction worker can be reduced by adoption of appropriate site management protocols and PPE.
29	DEV	Contaminants in Made Ground (car		Future maintenance workers	Moderate/ Low	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated there was very few exceedances and the risk to maintenance workers of the new airport development is low. Maintenance workers may be exposed to areas of Made Ground during future excavation. This can be reduced by placing of services in a clean

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
		park, capping material)				cover system and adoption of appropriate site management protocols and PPE.
30	DEV			Users of future development – public/ airport workers/users of Green Horizons Park	Low	The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** indicated there was very few exceedances and the risk to future users of the Proposed Development is low. The future development will comprise buildings & hardstanding, therefore there is unlikely to be any contact Made Ground. However, given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required, particularly in landscape areas to prevent direct contact with the Made Ground.
KEY: CON- PCL during excavation, remediation and construction phase DEV- PCL associated with future use of Proposed Development						

3 ASBESTOS IN SOILS

3.1 Background

3.1.1 The term 'asbestos' relates to several fibrous minerals regulated under UK law (see **Section 3.3** of this document) that are known to cause serious health effects (including mesothelioma and lung cancer) when inhaled.

3.1.2 Asbestos containing material (ACMs)[3] were widely used in the construction and manufacturing industry (see **Table 3.1** of this document). Three main types of asbestos were commonly used:

a. Crocidolite (commonly known as blue asbestos);

b. Amosite (commonly known as brown asbestos); and

c. Chrysotile (commonly known as white asbestos).

3.1.3 The use of blue and brown (crocidolite and amosite) asbestos has been banned since 1985 and white asbestos (chrysotile) has been banned since 1999. Asbestos may be present in a building if it was built or refurbished prior to 2000. All types of asbestos are classed as carcinogens, although it is generally accepted that chrysotile presents less of a risk to health than the other forms.

3.1.4 Historical waste management and demolition practice has resulted in asbestos-containing materials (ACMs) being potentially present in the soil or Made Ground at any brownfield site.

3.1.5 Asbestos containing soils (ACS) may occur in a number of different forms:

a. Large and easily recognisable fragments of ACM with the asbestos fibre contained in the original construction material to varying degrees. Some ACMs are more friable than others and more easily release the fibres when disturbed (see **Section 3.1.6** below). ACM fragments may degrade with time to release fibres, or release fibres into the air when disturbed;

b. Very small fragments of ACM not easily identifiable to the eye or only identifiable by microscopic inspection, where the fibres are still bound to varying degrees, within the ACM matrix; and

c. Loose fibres in the soil or Made Ground, usually only identifiable by microscope in a laboratory.

3.1.6 The risk of harm to human health from asbestos principally relates to the inhalation of airborne fibres. The risk increases with cumulative exposure which is a function of the airborne asbestos concentrations and the duration of exposure. The release of fibres from soil into the air can occur during physical disturbance (e.g. construction, remediation or earthworks) or during site use after development, during maintenance for instance. Increased airborne fibre release is anticipated with ACM that is degraded or disaggregated and friable with less bonding within the material matrix. Friable ACMs, such as asbestos insulating

[3] Any discrete fragment of material that contains asbestos above trace levels (see definition of trace later in section)

board (AIB) and lagging, release fibres much more easily than bound materials, such as asbestos cement.

Table 3.1: Common historical asbestos uses (Ref. 5).

Asbestos	Common Uses
Chrysotile	Loose insulation, thermal insulation, insulating boards, paper, ropes and yarns, cloth, gaskets and washers, resins, drive belts, cemented sheets/tiles and textured coatings.
Amosite	Thermal insulation, insulating boards, cloth and cemented sheets/tiles.
Crocidolite	Loose insulation, sprayed coating, thermal insulation, insulating boards, ropes and yarns, cloth, gaskets and washers and cemented sheets/tiles.

3.2 Results from GQRA

3.2.1 As discussed in **Section 10.3** of GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**, most of the asbestos fibre concentrations were reported by the laboratory as below <0.001% w/w, with concentrations of fibres in soil samples ranging from <0.001% to 6.93% w/w.

3.2.2 No asbestos caches or 'cells' of asbestos waste were identified. Results indicated asbestos fibres and ACMs were dispersed throughout the landfill mass at various depths.

3.2.3 Asbestos was detected in all eras of waste (see **Table 8.2** of GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**), indicating its extensive use in products throughout the period of filling at the landfill. The highest fibre content in soils was detected in the 1960-1970s waste.

3.2.4 Asbestos was detected in all waste types but was most frequent and at the highest fibre concentrations in the industrial and commercial waste types (36% of samples analysed for asbestos within these waste type contained fibres) (see **Table 8.3** of GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**.

3.2.5 The GQRA noted that the nature of the asbestos encountered in the former scrapyard appeared to be different from that encountered within the landfill i.e. no visible bundles of fibres were noted in the landfill during the GI.

3.2.6 Given the detection of some high concentrations of fibres and the nature and extent of earthworks proposed, the initial assessment identified the requirement for a detailed assessment to inform potential mitigation measures required during earthworks and construction, when the risk of release of fibres is greatest.

3.2.7 The previous assessment confirmed that risk of harm to futures users of the development from asbestos fibres i.e. public, airport operatives, maintenance worker, is very low. The development is predominately hardstanding and measures will be incorporated into the design to prevent future contact with landfill materials i.e. a cover system. However, this assessment does include consideration of the specific requirements for the cover system and any future occasional maintenance works.

3.3 Assessment approach

Guidance

3.3.2 The UK guidance with regards to asbestos primarily relates to occupational health and safety legislation. A significant body of guidance and approved codes of practice (ACoP) has been published by the Health and Safety Executive (HSE). However most of these do not directly relate to asbestos in soils.

3.3.3 In recent years several detailed guidance documents have been produced to control risks to site operatives during site investigation and remediation works on sites with ACMs. Guidance on meeting health and safety legislation is the primary aim of these documents:

a. CIRIA C765 (2017) ‘Asbestos in made ground good practice site guide’ (Ref. 5).
b. Joint Industry Working Group (JIWG) (2016) CAR-SOILTM. Control of Asbestos Regulations 2012. ‘Interpretation for Managing and working with Asbestos in Soil and Construction and Demolition Materials’ (Ref. 6).
c. JIWG (2016) ‘Decision support tool for the categorisation of work activities involving asbestos in soil and construction and demolition materials’ (Ref. 7).
d. Construction Industry Publications Ltd. (2014) ‘Construction Health and Safety Manual C5: Asbestos (including June 2018 amendments) (Ref. 8).
e. AGS (2013) ‘Site Investigation Asbestos Risk Assessment, For the protection of Site Investigation and Geotechnical Laboratory Personnel’ (Ref. 9).

3.3.4 The only current UK guidance which covers exposure to asbestos in soils and non-construction related exposure for end users is CIRIA (2014) ‘Asbestos in soil and made ground: a guide to understanding and managing risks’ C733 (Ref.10). It includes guidance on qualitative and quantitative assessment of risk.

3.3.5 The Control of Asbestos Regulations (CAR) 2012 (Ref. 11) requires actions to ensure the protection of workers and general public from asbestos exposures resulting from work activities. Specifically, Regulation 16 of the Control of Asbestos Regulations 2012 (CAR) (Ref. 11) imposes a duty on every employer to “*prevent or, where this is not reasonably practicable, reduce to the lowest level reasonably practicable the spread of asbestos from any place where work under his control is carried out*”. This also applies to work with asbestos in soil.

3.3.6 Where work involves (or is likely to involve) contact with asbestos (including asbestos in soil), then CAR (2012) requires a risk assessment. All staff likely to encounter asbestos at work require appropriate information, instruction and training to comply with CAR (2012) (Ref. 11).

3.3.7 Depending on the conditions and type of work and the outcome of the occupational risk assessment the work may be deemed either licensed work (LW), notifiable non-licensed work (NNLW) or non-licensed work (NLW). LW and NNLW are notifiable in advance to the Health and Safety Executive (HSE).

3.3.8 Sites meeting certain conditions i.e. isolated or 'trace[4]' asbestos fibres or isolated or random pieces of ACMs might fall outside of the scope of the Regulations, though this will be dependent on what is considered '*reasonably practicable[5]*' in each case, assuming that a suitable and sufficient investigation and assessment of the site has been undertaken.

3.3.9 There are no published generic assessment criteria for asbestos in soils in the UK. The methodology used to assess the risk of harm to human health during earthworks and construction is outlined below.

Methodology

3.3.10 The results have been assessed using multiple lines of evidence as to the potential significance during and after construction based on the latest guidance in CARSOIL™ (Ref. 6) and CIRIA C733 (Ref. 10).

3.3.11 A preliminary assessment of the licensing status of the earthworks has been undertaken using the JIWG Decision Support Tool (DST). The JIWG DST is a two-stage assessment which allows the input of real or assumed data. Stage one of the DST considers hazard factors while stage two considers exposure factors. The DST identifies the licensing status and associated level of control measures to be implemented.

3.3.12 **Table 3.2** below sets out a summary of the likely activities at each stage of the Proposed Development (as described in **Section 2.4** in GQRA (Ref. 2), (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** which may interact with the landfill material, and as such ACMs, and the potential receptors.

3.3.13 Only the earthworks activities have been considered in JIWG DST at this stage, as these activities are considered to represent the worst-case exposure scenario with regards to potential exposure to ACMs. Future risk assessments are likely to be required for the other activities detailed in **Table 3.2** below**.** The contractor for these works should consider the potential licensing status prior to undertaking the works.

3.3.14 The DST assessment is based on data obtained from the ground investigation and assumptions on the approach to the earthworks. An initial step in the assessment is the detailed consideration of the type, frequency of ACMs encountered, which is detailed in **Section 3.4** below. The DST assessment is detailed in **Section 3.6** of this document, extracting from the DST assessment provided in **Appendix A.**

[4] CAR-SOIL defines 'trace' as soil and construction and demolition materials where no fragments of ACMs are isolated and fewer than three fibres are identified during the detailed and extended identification and gravimetric analysis procedures combined (see Section 3.4.14), the mass concentration of asbestos fibre is likely to be many orders of magnitude below the 0.0001% w/w Limit of Detection.
[5] Reasonably practicable is defined in Watch Point 4 of CAR-SOIL

Table 3.2: Description of activities at different stages of the development which may have potential interaction with ACMs in landfill material.

Stage of works	Activity	Nature of work	Receptors potentially exposed
Enabling/ preparatory works	Segregation trials	Excavation of large trial pits to undertake trials to inform best configuration of equipment to be used during earthworks	Workers
	Ground investigation	Installation of monitoring wells	Workers
	Localised shallow excavations using excavator	Installation of boundary gas protection. Locate and treat old utilities (where required)	Workers
Earthworks	Extensive excavation	Large scale excavation of landfill material	Construction workers
	Complex sorting of landfill materials	Segregation of landfill materials	Construction workers
	Ground improvement	Compaction of existing and treated materials where required to improve geotechnical properties	Construction workers
Construction	Piling	Piling through landfill for foundations leading to arisings	Construction workers
Operation of development	Future maintenance operations	For example, installation of underground utilities, erection of fencing, landscaping activities	Maintenance works

3.4 Asbestos characterisation

3.4.1 In assessing the risks it is necessary to consider the characteristics of asbestos present from both visual identification of suspected ACM and laboratory testing.

3.4.2 The GQRA indicated that the characteristics of the asbestos encountered in the former scrapyard area was likely to be different from the rest of the landfill area. Therefore, these areas have been assessed separately below.

Visual identification during GI

Former landfill

3.4.3 The confirmation of ACM type by visual identification of small fragments of degraded ACMs in the ground on-site is not straightforward, particularly on a former landfill site. This is because degradation and coating by the host material disguises them to the extent that they become very difficult, if not near impossible to spot. In addition, as many ACMs present within the landfill have been in the ground for many years, they are not readily or 'clearly' identifiable due to weathering, degradation and mixing with soil and other, similar materials.

3.4.4 Significant effort was made during the ground investigation to identify ACMs. This included the following:

a. Suitable qualified and trained site investigation contractor staff competent in CAR 2012 and identification of ACMs; and
b. Use of forensic waste analysis in an on-site laboratory which further provide an opportunity to identify ACMs.

3.4.5 **Table 3.3** below summarises the suspected ACMs identified during the fieldwork both from forensic and conventional logging. The era and waste type of the material from the ground model (see **Section 8**, GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**) for details of the ground model) is also presented. Where a soil sample was also taken in the location of visually identified ACM and analysed for asbestos fibre content the result is presented in **Table 3.3** below. The results of the soil analysis are discussed in **Section 3.4.16** below.

Table 3.3: Identified suspected ACMs in the Former Landfill.

Exploratory hole	Depth (mbgl)	Suspected ACM	Soil sample analysed (see Table 3.10)	Waste Era	Waste Type[6]
BH206	4.5-6.0	Cement slab	N	1970-1980	Construction / Recent Domestic
BH206	6.0-7.0	Cement slab	Y	1970-1980	Construction
BH210	6.5-8.1	Small fibrous sheet	Y	1947-1955	Old Domestic / Construction
BH210	8.65	Tile	N	Pre 1947	Old Domestic
BH212	6.0-7.0	Possible fibrous ACM	Y	1970-1980	Recent Domestic / Construction
BH216	6.3-6.8	Tile	N	Pre 1947 – 1955	Old Domestic
BH216	8.3-8.5	Tile	N	Pre 1947	Old Domestic
BH217	7.7-8.4	Insulation type material	N	1947-1955	Commercial
BH217	13.2	Tile	Y	Pre 1947	Construction
BH218	12.7-13.5	Cemented tile	N	1955-1960	Industrial

[6] Description and definition of waste types provided in Table 8.1 of the GQRA

Exploratory hole	Depth (mbgl)	Suspected ACM	Soil sample analysed (see Table 3.10)	Waste Era	Waste Type[6]
BH219	6.0-7.5	Tile	N	1970-1980	Commercial
BH221	3.5-4.5	Cemented tile	Y	1955-1960	Industrial
BH221	4.0-4.2	Tile	N	1955-1960	Industrial
BH222	4.0-4.4	Tile	N	1960-1970	Industrial
BH223	5.6-6.0	Fabric sheet	N	1960-1970	Industrial
BH224	1.5-3.5	Tile	N	1960-1970	Construction / Industrial
BH228	7.0-7.5	Tile	N	1960-1970	Old Domestic
GW205A	3.0-4.5	Fabric sheet	N	1970-1980	Recent Domestic / Industrial
LW201	9.0-10.5	Cement slab	N	1970-1980	Recent Domestic
LW202	4.5-6.0	Heat resistant sheeting	N	1970-1980	Construction
LW202	6.6-7.5	Tile	N	1970-1980	Construction
LW204	10.5-11.2	Cement tile	N	1955-1960	Industrial
PFWS61	1.5	Tile	Y	1970-1980	Construction
PFWS61	3.0	Tile	N	1970-1980	Construction
TP208	1.6	Corrugated tile	Y	1970-1980	Construction
TP208	2.9	Fibrous board fragment	Y	1970-1980	Recent Domestic
TP213	2.0	Possible ACM fragment	N	1970-1980	Construction
TP217	2.5-2.6	Tile	Y	1970-1980	Industrial
TP219	1.6	Fragment of possible ACM (60 x 80mm)	Y	1970-1980	Recent Domestic
TP220	1.5-1.6	Cement tile	N	1970-1980	Recent Domestic
TP224	3.5	Pipe insulation	Y	1970-1980	Recent Domestic
TP225	4.5	Fibrous material	Y	1970-1980	Commercial
TP236	3.6	Pipe fragment	Y	1970-1980	Commercial

Exploratory hole	Depth (mbgl)	Suspected ACM	Soil sample analysed (see Table 3.10)	Waste Era	Waste Type[6]
TP241	4.5	Tile	N	1970-1980	Industrial
TP242	3.5	Cement tile	N	1970-1980	Industrial
TP244	3.4-3.5	Tile	Y	1960-1970	Construction
TP244	2.9	Tile	N	1960-1970	Construction
TP247	4.1-4.2	Sheet	Y	1960-1970	Commercial
TP251	4.0-4.2	Sheet	Y	1960-1970	Industrial
TP256	4.4-4.5	Tile	Y	1970-1980	Industrial
TP263	3.5	Tile	Y	1960-1970	Commercial
TP267	5.6	Tile	N	1970-1980	Commercial
TP268A	1.5	Sheet	Y	1970-1980	Construction
TP268A	5.5	Cement	Y	1970-1980	Recent Domestic
WS205A	0.5	Tile	N	1970-1980	Construction
WS224	1.85	Tile	Y	1970-1980	Construction

3.4.6 Photographs of observations of some of the suspected ACMs which were able to be identified are shown in **Image 3.1** below.

Image 3.1: Selected photographs of suspected ACMs within the former landfill.

BH206 – Cemented slab possible asbestos

GW205A – Fabric sheet possible asbestos

LW202 – Sheeting possibly containing asbestos.

TP208 - Fragment of fibrous board

	
TP224 - Pipe insulation possibly containing asbestos	TP247 – Possible sheeting in spoil pile
	
TPH 251 - Possible asbestos sheeting	TPH256 - Possible asbestos pipe
	
TP244 – Sheet potentially containing asbestos	TP251 – Sheet potentially containing asbestos
	
TP 268A - Cement possibly containing asbestos.	TP 275 – Tile possibly containing asbestos

3.4.7 ACMs were visually identified in 36 of the 185 exploratory locations (19%). The visual observations suggest that the ACMs were observed in most waste types.

No visual observations of ACMs were noted within the cover material (both chalky and non-chalky). The number of observations of ACMs in different waste types is shown in **Table 3.4** below. Visually observed ACMs were commonly encountered in old domestic and commercial types, 26% and 64% respectively.

Table 3.4: Percentage of locations within different waste types where ACMs were visually identified.

Waste Type	Number of locations where ACMs were visually identified	Number of locations where waste type was encountered	Percentage with visually identified ACMs
Construction	17	97	18%
Old domestic	5	19	26%
Industrial	13	55	24%
Non-chalky cover	0	66	0%
Chalky cover	0	32	0%
Recent domestic	9	44	20%
Commercial	7	11	64%

3.4.8 The visual observations of ACMs were mainly detected in the 1970-1980 era waste. However, this is likely to be because of greater frequency of exploratory locations within this era waste i.e. most trial pits only penetrated this era. When the data is normalised, and the visual observations are compared to the number of locations within the era of waste, asbestos is most commonly detected in the pre-1947 waste (asbestos was visually observed in 50% of locations in this era of waste). The percentage of locations within the different eras of waste where ACMs were visually identified are shown in **Table 3.5** below.

Table 3.5: Percentage of locations within the different eras of waste where ACMs were visually identified.

Waste Era	Number of locations where ACMs were visually identified	Number of locations where waste type was encountered	Percentage with visually identified ACMs
Pre -1947	4	8	50%
1947-1955	3	11	27%
1955-1960	4	25	16%
1960-1970	9	49	18%

Waste Era	Number of locations where ACMs were visually identified	Number of locations where waste type was encountered	Percentage with visually identified ACMs
1970-1980	27	249	11%

3.4.9 The suspected ACMs visually identified mainly consisted degraded and weathered[7] fragments of floor tiles, cement or sheets. Only four observations of potential fibrous debris were noted. None of the fibrous material was positively identified as AIB or lagging which releases fibres more easily. Due to the nature of the landfill the degradation and coating by the host material may have hindered its ability to be observed. In addition, laboratory identification was not conducted on the fragments to confirm the type of ACM. The requirements for future confirmatory testing are discussed in **Section 3.6** below.

Former scrapyard

3.4.10 **Table 3.6** below summarises the potential ACMs identified during the fieldwork within the former scrapyard. Where a soil sample was taken to confirm asbestos fibre content, the results are presented in **Table 3.11** with the results of the soil analysis discussed in **Section 3.4.20**, both of which are in this document.

Table 3.6: Visually Identified ACMs in the former Scrapyard.

Exploratory hole	Depth (mbgl)	Suspected ACM	Soil sample analysed (see Table 5)
BH103	1.0	Textile fragments noted possible asbestos	Y
TP102	0.9	Pockets of bluish white crystalline material	Y
			Y
TP104	0.3	Blueish grey fibres	Y
TP104A	2.6	Cement board and blueish grey fibres	Y
TP105	1.3	Fragments of possible asbestos material	Y
TP107	0.9	Fragments of possible asbestos material	Y

3.4.11 Photographs of observations of some of the potential ACMs which were able to be identified are shown in **Image 3.2** below.

[7] Descriptions taken from CAR-SOIL Watch Point 10. Weathered (slight degradation in ACM; material still retains its basic integrity) and degraded (significant degradation in ACM; material has lost its basic integrity) .

Image 3.2: Selected photographs of potential ACMs within the former scrapyard.

	
TP104- Cement board possibly containing asbestos	TP104- Bundles of loose fibres found at base of trial pit
	
TP105- Fragments of possible asbestos material	TP105- Fragments of possible asbestos material

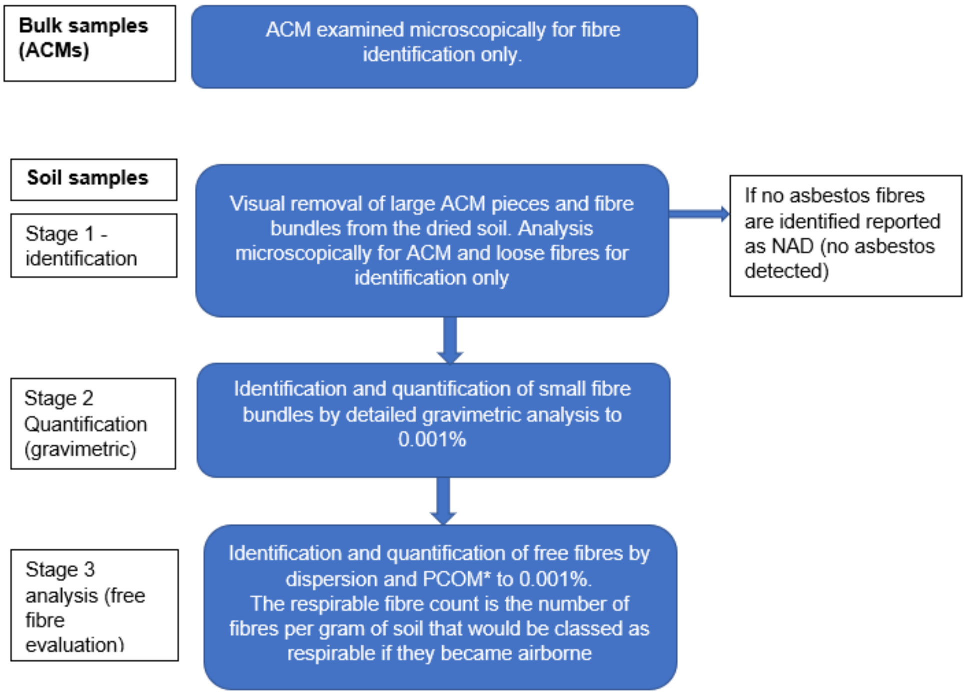
3.4.12 Out of the 17 exploratory locations undertaken visual observations of ACMs were made in six of the locations (35%). The visual observations of asbestos were all located within the bund material surrounding the area of the current Tidy Tip (formally called the Eaton Green Civic Amenity Site) (see **Image 3.2** above). This bund material comprised of reworked natural soils, demolition rubble, glass, metal, plastic and other waste. Historical maps and previous reports suggest the bunds were formed when the scrapyard was cleared and levelled to form the Tidy Tip site (Ref. 12).

3.4.13 The suspected ACM visually identified mainly consisted of fibrous debris. Identification of fragments of ACMs which were sampled and sent for laboratory analysis is presented in **Table 3.7** below.

Asbestos laboratory analysis

3.4.14 Quantification analysis was undertaken on all samples where asbestos was identified as present by the screening test. In addition, quantification of free fibres was undertaken on samples from the former landfill. Representative samples were recovered at regular depths and in different waste types throughout the profile of the former landfill.

3.4.15 All asbestos screen testing, bulk identification and asbestos quantification was undertaken by a UKAS accredited laboratory in accordance with HSG248 (Ref. 13). The process undertaken by the laboratory for analysing the soil samples is shown below:



* Phase Contrast Optical Microscopy (PCOM)

Former landfill

3.4.16 Within the area of the former landfill, 355 soil samples were taken from the exploratory holes and screened for asbestos. Asbestos was identified in 73 of the soil samples (21%). The results indicated fibres of chrysotile, amosite and crocidolite were present in the soils.

3.4.17 The results indicated only two samples identified ACMs present within the soil sample (<1% of the overall samples tested) from the stage 1 visual identification. The ACMs identified were:

a. Soil containing material typical of AIB (BH217 at 10.9 mbgl); and

b. Debris typical of asbestos cement in soil (BH227 1.8 mbgl).

3.4.18 In 26 of the samples the asbestos fibres were detected above quantification limit (0.001% w/w), these results are shown in **Table 3.8** below. Phase Contrast Optical Microscopy (PCOM) analysis was undertaken on all these samples which indicated that only eight had a respirable fibre count above quantification limit.

3.4.19 The results indicated that asbestos fibres were detected in all waste types including cover materials as shown in **Table 3.7** below. Fibres above quantification limit were most frequently detected in commercial (36%) and industrial (36%) waste types, with industrial waste types having the highest recorded concentration of fibres. The lowest percentage was in the chalky cover materials (4%) based on only one result out of 26 samples.

Table 3.7: Percentage of locations within different waste types where asbestos fibres were detected.

Waste Type	No of samples	No. with asbestos fibres detected	% of detections in waste type	Min (%w/w)	Max (%w/w)
Chalky Cover	26	1	4%	0.0534	0.0534
Commercial	11	4	36%	<0.001	<0.001
Construction	112	22	20%	<0.001	0.112
Industrial	53	19	36%	<0.001	6.93
Non-Chalky Cover	63	8	13%	<0.001	1.08
Old Domestic	17	4	24%	<0.001	0.963
Recent Domestic	50	12	24%	<0.001	0.225

Table 3.8: Summary of asbestos in soils laboratory results above quantification limit (0.001% w/w).

Exploratory hole	Era	Waste types	Visual identified ACMs during GI	Depth (m bgl)	ACMs identified	Fibre identification	Gravimetric quantification % w/w	PCOM % w/w	Total asbestos % w/w
BBH210	n/a	Made ground	No	2.7		Amosite	0.0209	0.0018	0.0227
BH202A	1970-1980	Construction	No	8.3		Chrysotile / Amosite	0.0041	<0.001	0.0041
BH208	1970-1980	Industrial	No	7.5		Amosite	0.0027	<0.001	0.0034
BH216	1955-1960	Construction	No	1.6		Chrysotile	0.001	<0.001	0.001
BH217	1960-1970	Old domestic	No	5.1	Loose fibres in soil	Chrysotile	0.0143	0.0053	0.0196
BH217	pre-1947	Industrial	No	10.9	Soil containing material typical of AIB	Chrysotile / Amosite	0.0037	<0.001	0.0037
BH217	pre-1947	Non-chalky cover	Yes	13.2		Chrysotile	0.0154	<0.001	0.0154
BH219	1970-1980	Recent domestic	No	16.0		Amosite	0.0012	<0.001	0.0012
BH221	1955-1960	Industrial	Yes	3.8		Chrysotile / Amosite	0.0834	0.0022	0.0856
BH227	1960-1970	Non-chalky cover	No	1.8	Debris typical of asbestos cement in soil	Chrysotile	1.08	<0.001	1.08

Exploratory hole	Era	Waste types	Visual identified ACMs during GI	Depth (m bgl)	ACMs identified	Fibre identification	Gravimetric quantification % w/w	PCOM % w/w	Total asbestos % w/w
BH232	pre-1947	Old domestic	No	5.8		Amosite	0.961	0.0012	0.963
GW204	1970-1980	Chalky cover	No	0.5		Chrysotile / Amosite	0.0523	0.0011	0.0534
GW206	1960-1970	Construction	No	3.7	Loose fibres in soil.	Chrysotile	0.0026	<0.001	0.0026
LW203	1970-1980	Industrial	No	10.0		Chrysotile	0.953	<0.001	0.953
TP203 (PFTP14)	1970-1980	Industrial	No	2.8		Amosite	0.001	<0.001	0.001
TP207	1970-1980	Recent domestic	No	3.6		Amosite	0.0087	0.0011	0.0098
TP212	1970-1980	Industrial	No	4.0		Chrysotile / Amosite	0.0066	<0.001	0.0068
TP214	1970-1980	Construction	No	1.5		Chrysotile	0.0014	<0.001	0.0014
TP219	1970-1980	Construction	Yes	1.5		Chrysotile	0.0014	<0.001	0.0014
TP221	1970-1980	Recent domestic	No	3.5		Crocidolite / Chrysotile	0.224	<0.001	0.225
TP222	1970-1980	Construction	No	1.0		Amosite	0.0029	<0.001	0.0037
TP229	1970-1980	Recent domestic	No	4.5		Chrysotile	0.009	<0.001	0.009
TP232	1970-1980	Industrial	No	2.3		Chrysotile / Amosite	0.0273	0.0239	0.0512
TP256	1960-1970	Industrial	Yes	4.4		Chrysotile / Amosite	6.92	0.002	6.93

Exploratory hole	Era	Waste types	Visual identified ACMs during GI	Depth (m bgl)	ACMs identified	Fibre identification	Gravimetric quantification % w/w	PCOM % w/w	Total asbestos % w/w
TP264	1970-1980	Industrial	No	2.0		Chrysotile	0.001	<0.001	0.001
WS213	1960-1970	Construction	No	1.0	Loose fibres in soil	Chrysotile	0.11	0.0024	0.112

Scrapyard

3.4.20 In the area of the former scrapyard 26 samples were taken from the exploratory holes and screened for asbestos. Asbestos was identified in eight of the soil samples. The results are presented in **Table 3.9** below.

3.4.21 All eight samples where asbestos was identified were confirmed as either ACM or ACS (31% of the overall samples tested) from the stage 1 visual identification (see **Table 3.9** below).

3.4.22 The gravimetric analysis indicated that fibres were identified in two samples above quantification limit.

Table 3.9: Asbestos identified in soil samples from former scrapyard area.

Exploratory hole	ACMs visual identified during GI	Depth (m bgl)	Bulk/ Soil sample	ACMs identified	Fibre identification	Gravimetric quantification % w/w
TP105	Yes- Fragments of possible asbestos material	1.3	Soil	Fibre bundles	Chrysotile	0.001
TP104	Yes- Blueish grey fibres	0.3	Soil	Fibre bundles	Amosite	<0.001
TP104A	Yes- Cement board and blueish grey fibres	2.6	Bulk	Cement board	Chrysotile/ crocidolite	-
TP102	Yes- Pockets of bluish white crystalline material	0.9	Soil	Fibre bundles	Amosite and chrysotile	0.377 Cement ACM also identified
TP107	Yes- Fragments of possible asbestos material	0.9	Soil	Fibre bundles	Amosite	<0.001
TP104B	No	2.6	Bulk	Insulation	NAD	-
TP101	No	1.1	Soil	Small bundles of fibres	Chrysotile	<0.001
BH103	Yes- Textile fragments noted possible asbestos	1.0	Soil	Small bundles of fibres	Amosite	<0.001

3.5 Summary of characterisation

Former landfill

3.5.1 The characterisation of asbestos in the former landfill indicated the following:

ACM type

3.5.2 The suspected ACMs visually identified consisted of predominately asbestos cement products including tiles, slabs or sheets. Only four observations of potential fibrous debris were noted. None of the fibrous material was positively identified as AIB or lagging which releases fibres more easily. Due to the degradation and coating by the host material, the potential to visually identify this type of ACM may be hindered. In addition, laboratory identification was not conducted on the fragments to confirm the type of ACM.

3.5.3 The soil samples analysed encountered one location (out of 355 tests) where soil containing material, typical of AIB, was noted. Visual observations of fibrous ACMs were not recorded at this location (BH217) during the GI. The soil results suggest there may be AIB material present within the landfill but the data suggests that this is not frequent. No 'clearly identifiable original form' AIB was noted from the visual observations during the GI. Clearly identifiable original form is defined in Watch Point 6 of CAR-SOIL™ (Ref. 6) and is taken to mean that it is possible for a trained and competent person to identify the type of material presumed to be ACM from its appearance in-situ on site. This is considered significant as work with clearly identifiable original form AIB would be licensed work under the regulations. Based on the visual and laboratory records it is unlikely that significant amounts of clearly identifiable original form AIB or other high risk materials is present. Even detailed ground investigations such as this only sample a relatively small proportion of soils and there is a potential for other unexpected ACM to be encountered during earthworks.

Friability and degree of bonding by matrix

3.5.4 The visual identification of ACMs suggest mainly non-friable types of ACMs are present i.e. cement sheets and tiles. No observations were made of fibre bundles.

3.5.5 Of the visible ACMs identified, 21 of these had the associated soil matrix sampled and analysed (see **Table 3.3** above). Asbestos fibres above limit of quantification were identified in four of these samples. These results were mostly very low or below the limit of quantification (Ref. 8), except for one location (TP256, 4.0- 4.5mbgl with a fibre concentration of 6.93% v/v).

3.5.6 One location included soil containing material typical of AIB. This was identified during the laboratory analysis. The fibre concentration associated with this sample was very low.

3.5.7 For the purposes of defining the state of degradation the descriptions within Watch Point 10 of CAR-SOIL™ (Ref. 6) have been used, which are:

a. Intact (very good condition ACM/ACM fragments);
b. Weathered (slight degradation in ACM; material still retains its basic integrity;

[8] Descriptions of very low, low, moderate and large are taken from Watch Point 12 in CAR-SOIL

c. Degraded (significant degradation in ACM; material has lost its basic integrity); and
d. Disaggregated (dominated by loose fibrous material; extreme degradation in ACM and/or free asbestos fibres/fibre bundles).

3.5.8 The visually identified ACMs and associated samples of the soil matrix suggest there is little evidence of disaggregation of the ACM in its current state. However, fibres were identified in numerous samples at low concentrations, so the assessment will need to consider that some disaggregation has occurred. The assessment also considers potential changes resulting from the earthwork activities proposed at site.

Distribution of visible asbestos

3.5.9 No gross visual asbestos contamination was identified during the GI. ACMs were visually identified during the GI within 36 of the 185 exploratory locations (19%). The degree of distribution of asbestos contamination within the landfill is therefore considered to be sporadic/random occurrences of visible ACMs (Ref. 9). The soil samples analysed supported this finding with only two samples identifying ACMs present within the soil sample (<1% of the overall samples tested).

3.5.10 Visually observed ACMs were proportionally more frequent in old domestic and commercial types, 26% and 64% respectively. No visual ACMs were identified in cover material (chalky or non-chalky).

3.5.11 The laboratory analysis indicated asbestos fibres were detected in all waste types, they were most frequently reported in commercial (36%) and industrial (36%) waste types. However, it is noted that the within the commercial waste types none of the fibres were above the quantification limit.

Amount of asbestos fibre in ACM/fibre type as % of host material

3.5.12 Asbestos was detected in 73 of 355 (21 %) representative soil samples taken from the different eras of waste. Chrysotile, amosite and crocidolite asbestos types were reported.

3.5.13 Where asbestos was detected in the soils under microscopic analysis, it was typically identified at very low concentrations (Ref. 10) or below limit of quantification. A summary of the asbestos in soils laboratory analysis is presented in **Table 3.10** below. The results indicated very few large or moderate quantities identified (approximately 2% of the samples analysed), the majority (77%) were very low or below limit of quantification.

3.5.14 PCOM analysis was undertaken which indicated eight had respirable fibre count above quantification limit.

[9] Description of degree of distribution of asbestos contamination taken from Watch Point 13 CAR SOIL
[10] Descriptions of very low, low, moderate and large are taken from Watch Point 12 in CAR-SOIL

3.5.15 The characterisation of the asbestos within the landfill area has been used within the assessment to determine the hazard and exposure ranking. The assessment is detailed in **Section 3.6** below.

Table 3.10: Summary of asbestos in soils laboratory results in former landfill area.

Asbestos Detected	Minimum concentration %w/w	Maximum concentration %w/w	No of samples and asbestos quantity
73/355	0.001	6.93%	6 Large
			3 Moderate
			3 Low
			11 Very Low
			45 Below LoQ
Note: Descriptions of quantities taken from Watch Point 12 CAR-SOIL: Large quantities: >0.1% w/w Moderate quantities: >0.05 to <0.1% w/w Low quantities: >0.01 to <0.05% w/w Very Low quantities: >0.001 to <0.01% w/w Below limit of quantification (LoQ): <0.001% w/w			

Former scrapyard

3.5.16 The characterisation of the asbestos in the former scrapyard indicated the following:

ACM type

a. The visually identified ACM mainly consisted of several different types of material including; textile fragments, fibrous debris, cement board, unidentifiable fragments of possible asbestos; and
b. The laboratory analysis did not identify any of the fibrous material as AIB. The ACMs identified were cement board, fibre bundles and insultation.

Friability and degree of bonding by matrix The ACM visually identified fibrous disaggregated asbestos debris and cement board.

3.5.17 Where the ACM was visually identified there was also some instances of the matrix surrounding the fibrous debris containing loose fibres.

Location TP102 was recorded as blueish white crystalline material and the laboratory results identified cement ACM as well as fibre bundles. This suggests that this material may be degraded asbestos cement.

The visually identified ACMs and laboratory analysis suggest that the ACMs are considered disaggregated consistent with the definition in Watch Point 10 of CAR-SOILTM (Ref. 6).

Distribution of visible asbestos

3.5.18 The abundance of ACMs across the 17 exploratory locations is described in **Section 3.4.12** above. The degree of distribution of asbestos contamination across the wider area of scrapyard is 'moderate' occurrences of visible ACMs (Ref. 11).

Amount of asbestos fibre in ACM/fibre type as % of host material

3.5.19 Asbestos was detected in seven of 26 (27 %) of the soil samples tested for the presence of asbestos. Chrysotile, amosite and crocidolite asbestos types were reported. Table 3.11 presents a summary of asbestos results reported.

3.5.20 Where asbestos fibres were detected under microscopic analysis, it was typically identified as very low or below quantification concentrations. High concentration quantities were detected in one sample; TP102 (0.9 mbgl) at 0.377 % v/v.

3.5.21 The characterisation of the asbestos within the former scrapyard area has been used within the assessment to determine the hazard and exposure ranking. The assessment is detailed in **Section 3.6** below.

Table 3.11: Summary of asbestos in soils laboratory results for the former scrapyard area.

Asbestos Detected	Min. conc. %w/w	Max conc. %w/w	No of samples and asbestos quantity
7*/26	0.001	0.377%	1 Large
			0 Moderate
			0 Low
			1 Very Low
			4 Below LoQ
Note: Descriptions of quantities taken from Watch Point 12 CAR-SOIL: Large quantities: >0.1% w/w Moderate quantities: >0.05 to <0.1% w/w Low quantities: >0.01 to <0.05% w/w Very Low quantities: >0.001 to <0.01% w/w Below limit of quantification (LoQ): <0.001% w/w * one sample had no quantification analysis undertaken			

3.6 Assessment results

3.6.1 Construction works have the highest potential to physically disturb any ACMs and ACS, therefore resulting in an increased risk of fibre release. The activities being undertaken at site are described in **Table 3.2**. The hazard and exposure ranking for the earthworks involving the excavation of landfill material has been assessed to determine the provisional licensing status for the works using CAR-SOIL™ (Ref. 6) guidance and JIWG (Ref. 7) DST as described in **Section 3.3.8**

[11] Description of degree of distribution of asbestos contamination taken from Watch Point 13 CAR SOIL

of this document. This is considered to represent the worst-case exposure scenario with regards to potential exposure to ACMs at the site.

3.6.2 Sensitivity analysis has been undertaken to assess a range of different scenarios based on the different types of ACMs encountered in the landfill and a range of potential exposure factors. These scenarios are presented in **Appendix A** of this document.

Provisional licensing status

Former Landfill

3.6.3 The visual observations made during the site work and laboratory analysis parameters have been inputted into the JIWG decision support tool to assess the preliminary licensing status for any future excavation works. The most common scenario with respect to ACMs present within the landfill, along with justification for the parameters is presented in **Table 3.12** below.

Table 3.12: Stage 1 and 2 of the JIWG (Ref. 7) decision support tool for the area of the former landfill.

Stage	Factors selected	Justification
Stage 1 Hazard Factors		
ACM Type	Bonded ACMs i.e. cement, vinyl	Visual observations suggest the ACMs encountered within the landfill are mainly cement products such as sheets, tiles and slabs.
Extent of degradation of ACM	Weather (slight degradation in ACM; material retains its basic integrity)	The visual and laboratory results suggest that the ACMs identified are largely intact, with little disaggregation of the bonded ACM. Therefore, the degradation state has assumed to be weathered.
Friability and degree of bonding	Non-friable ACM or ACM with fibres firmly linked in a matrix	Based on visual observations which suggests mainly non-friable types of ACMs present i.e. cement sheets, tiles.
Distribution of visible ACM	Moderate/frequent occurrences of visible contamination by ACMS	Visual observations and laboratory results suggest sporadic/random occurrences of ACMs. However, to allow for difficulties in identification of the ACMs in the host material an assumption of moderate/frequent occurrences has been assumed to provide a cautious assessment.
Quantity of asbestos	Large quantities >0.1% wt/wt	Soil analysis presented in **Table 3.8** above, indicated that most of the concentration were below limit of quantification or very low quantities (77% of the total tests). However, it is noted that where the highest concentrations were encountered these were

Stage	Factors selected	Justification
		associated with visible observations of cement ACMs. Therefore, to provide a cautious assessment, large quantities has been assumed.
Hazard ranking		***Low***
Stage 2 Exposure Factors		
Anticipated airborne fibre concentration	<0.01 f/ml	In accordance with JIWG guidance (Ref. 7), significant visible quantities of bound ACMs need to be present to give rise to exposure above 0.01 f/ml. Significant visible ACMs are not present, so the anticipated airborne fibre concentration is assumed to be <0.01 f/ml. Based on anticipated airborne fibre concentration the exposure is considered sporadic and low intensity exposure (SALI).However airborne fibre concentration monitoring will be required during works to confirm concentrations.
Anticipated duration of exposure to asbestos	>2 hours in a 7-day period, up to 10 hours in a full day (e.g. full time occupational exposure)	Earthworks is considered to be full time occupational exposure.
Activity type	Sampling, manual or mechanical (significant deterioration expected)	Earthworks will involve excavation of landfill material using an excavator, this process could lead to deterioration of the ACMs e.g. broken up/dispersion on excavation. Working methods to be confirmed by the remediation contractors. It will be a requirement of the works to reduce deterioration of the asbestos during remediation to as low as reasonably practicable.
Primary host material	Made Ground	Material is former landfill therefore Made Ground has been selected to represent material.
Respirable fibre index for ACM	Very low	Anticipated respirable fibre index based on visual and laboratory data. To be corroborated by the remediation contractors. It will be a requirement of the remediation works to reduce deterioration of the asbestos during remediation to as low as reasonably practicable.
Exposure ranking		***Medium***
Combined hazard and exposure ranking		***Medium***

Stage	Factors selected	Justification
Stage 3- Risk Assessment outputs		
Probable licensing status		Non-Licensed Work
RPE		EN140 with P3 filter half mask
Dust suppression		Localised mechanical dust suppression
Hygiene/Decontamination		Localised and enhanced personal decontamination facilities

3.6.4 The JIWG (Ref. 7) assessment indicated the overall hazard and exposure ranking was medium and anticipated to be non-licensed works (NLW). The sensitivity analysis indicated that even assuming the worst-case scenario of clearly identifiable insultation or lagging with a high respirable fibre index the work would be still be considered non-licensed work.

3.6.5 The sensitivity analysis indicated that for the works to be considered licensed the anticipated fibre concentration would need to exceed the control limit of 0.6 f/cm^3 in air measured over a ten-minute period. Experience of other sites indicates this limit has not been exceeded even on sites with very frequent/gross contamination with friable forms of ACM where reasonable precautions and methodologies are applied. Therefore, it is considered unlikely that the earthworks on the landfill will meet the conditions for licensed work. However, it is recommended airborne fibre concentration monitoring is undertaken during works to confirm concentrations. The JIWG (Ref. 7) tool also indicates it is unlikely that work would be notifiable non-licensed work (NNLW), although this will require review as the works progress based on the observations and findings.

Former scrapyard

3.6.6 The visual observations made during the site work and laboratory analysis parameters have been inputted into the JIWG (Ref. 7) decision support tool to assess the preliminary licensing status for any future excavation works. The most common scenario with respect to ACMs present within the scrapyard, along with justification for the parameters is presented below in **Table 3.13.**

Table 3.13: Stage 1 and 2 of the JIWG (Ref. 7) decision support tool for the former scrapyard area.

Stage	Factors selected	Justification
Stage 1 Hazard Factors		
ACM Type	Free dispersed fibres/fibre bundles	Visual identification and laboratory analysis suggest ACMs are mainly fibre bundles.

Stage	Factors selected	Justification
Extent of degradation of ACM	Disaggregated (dominated by loose fibrous material; extreme degradation in ACM and/or free asbestos fibres/fibre bundles	Based on mainly loose fibrous being encountered suggesting material is disaggregated. Visual and laboratory evidence suggested there is degraded cement ACM present.
Friability and degree of bonding	Friable ACM or ACM with fibres not linked in any matrix (free dispersed fibres/fibre bundles)	Loose fibrous material encountered in visual and laboratory analysis.
Distribution of visible ACM	Moderate/frequent occurrences of visible contamination by ACMS	The degree of distribution of asbestos contamination across the wider area of scrapyard is considered to be 'moderate' occurrences of visible ACMs. The bund areas had more frequent observations of ACMs.
Quantity of asbestos	Low quantities >0.01 to <0.05 % w/w	Soil analysis presented in **Table 3.8** above indicated that most of the concentration were below limit of quantification or very low quantities. However, in order to provide a cautious preliminary assessment 'low quantity' has been assumed.
Hazard ranking		***Medium***
Stage 2 Exposure Factors		
Anticipated airborne fibre concentration	<0.01 f/ml	Significant visible quantities of ACMs need to be present to give rise to exposure above 0.01 f/ml. Significant visible ACMs are not present, so the anticipated airborne fibre concentration is assumed to be <0.01 f/ml. Based on anticipated airborne fibre concentration the exposure is considered sporadic and low intensity exposure (SALI).
Anticipated duration of exposure to asbestos	>2 hours in a 7-day period, up to 10 hours in a full day (e.g. full time occupational exposure	Earthworks is considered to be full time occupational exposure.
Activity type	Sampling, manual or mechanical (significant deterioration expected)	Earthworks will involve excavation of landfill material using an excavator, this process could lead to deterioration of the ACMs e.g. broken up/dispersion on excavation. Working methods to be confirmed by the remediation

Stage	Factors selected	Justification
		contractors. It will be a requirement of the works to exposure to asbestos fibres during remediation to 'as low as reasonably practicable' (ALARP).
Primary host material	Made Ground	Material is mainly former landfill material within the bunds, therefore Made Ground has been selected to represent material.
Respirable fibre index for ACM	Low	Anticipated respirable fibre index based on visual and laboratory data. To be corroborated by the remediation contractors. It will be a requirement of the remediation works to reduce deterioration of the asbestos during remediation to as low as reasonably practicable.
Exposure ranking		***Medium***
Combined hazard and exposure ranking		***Medium***
Stage 3- Risk Assessment outputs		
Probable licensing status		Non-Licensed Work
RPE		EN140 with P3 filter half mask
Dust suppression		Localised mechanical dust suppression
Hygiene/Decontamination		Localised and enhanced personal decontamination facilities

3.6.7 The JIWG (Ref. 7) assessment indicated the overall hazard and exposure ranking was medium. The full assessment is provided in Error! Reference source not found. Therefore, the potential licensing status for groundworks, including ground excavation is anticipated as non-licensable works (NLW).

3.6.8 The sensitivity analysis indicated that even assuming the worst-case scenario of loose fibrous asbestos debris with a high respirable fibre index the work would be still be considered non-licensed work. As detailed above in **Section 3.6.5** the work would only be considered as licensed if the control limit of 0.6 f/cm^3 in air measured over a ten-minute period was exceeded. As discussed above this is considered unlikely to occur but it is recommended airborne fibre concentration monitoring is undertaken during works to confirm concentrations.

3.7 Controls required during earthworks and construction

3.7.1 The GI provided sufficient information to provide a preliminary characterisation of the condition of asbestos present within the landfill and scrapyard area to inform this assessment. Concentration of asbestos have been identified above trace (see **Section 3.3.8** below for definition of trace) levels within the site. As such all excavation in the former landfill and scrapyard would be classed as 'work with asbestos' based on the regulations and should be carried out under a specialist asbestos brief. The assessment indicated that the preliminary anticipated licensing status for the earthworks to be excavated and remodel the landfill is Non-Licensed Work.

3.7.2 It may be prudent to assume some works may be Notifiable Non-Licensed Work (NNLW) so that this is planned as a contingency should certain conditions prevail. This in turn may limit the potential for delay due to the requirements for advance notifications and the associated procedures and assessments required.

3.7.3 Specific advanced remediation of the landfill and scrapyard area is not anticipated to be required at this stage. The relatively small proportion of asbestos in soils indicates that the most efficient method of managing the asbestos would be via excavation with relevant controls in place (dust control, protective measures, control of materials and stockpiles) under a specialist watching brief and removal and management of visible ACMs, further details are provided in the section below.

3.7.4 Enhanced measures should be taken during works to limit fibre release, such as personal protective equipment (PPE), dust control including proactive dampening down and good materials and stockpile management.

3.7.5 The ground conditions in the areas of the landfill and scrapyard are heterogenous in nature and as such there is a potential for localised higher frequency asbestos which was not encountered by the ground investigation. A strategy for managing unexpected ACM finds has been developed as part of a ORS for the works (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

3.7.6 The level of deterioration of asbestos during the excavation activities and the respirable fibre index should be considered further by the specialist contractor in their planning of the works. These factors will depend on the selected method of works and be based on the contractors established procedures for undertaking the asbestos excavation and segregation. The remediation methodology should seek to limit / reduce to as low as reasonably practicable the intensity and the potential for the asbestos to deteriorate during the works.

3.7.7 The excavation of the landfill material should be carried out by appropriately trained, experienced and qualified personnel who have significant experience of working with asbestos in soils. Relevant documentation and notifications will be necessary to adequately plan works in accordance with CAR 2012 (Ref. 11).

Monitoring

3.7.8 Airborne fibre concentration monitoring will be required during works to confirm no exposure. This would be both monitoring in the area of excavation as well as boundary monitoring for asbestos fibres. The necessary controls may require to be altered based on the findings of the monitoring.

3.7.9 In addition, other enhanced measures as described above in **Section 3.7.4,** such as dampening down and dust suppression measures will be required to prevent airborne asbestos fibres. The monitoring and management measures are detailed further in the ORS (Ref. 4) (**Appendix 17.5** of the ES **[TR020001/APP/5.02]**).

Watching Brief and Management of Asbestos in Soils

3.7.10 The contractor should provide appropriate specialist supervision for the duration of the earthworks. This will include continuous inspection of excavations and stockpiles for visible ACMs.

3.7.11 Visual ACMs were most common in the commercial waste type and therefore the ORS considers measures for increased vigilance when encountering this waste type (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

3.7.12 Following identification of visible ACMs in soil, potential treatment or processing should be considered to facilitate re-use onsite or to provide a cost-effective solution for offsite disposal at suitably licensed facilities. The complete removal of ACM and fibres is not required, and may not be possible, but reasonable efforts to segregate significant amounts of larger visually identifiable ACM may be beneficial.

3.7.13 Full details of management of ACMs in relation to the processing of the excavated landfill material is considered in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

3.7.14 In the compound area appropriate containment and collection of water runoff will be required to prevent dispersion of asbestos fibres mobilised by water in the drainage system.

3.7.15 Careful consideration of the phasing would be necessary to ensure a continuous movement of soil excavation, processing and stockpiling.

3.7.16 The ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]** also identifies the measures for managing asbestos related risks during excavation for foundation (piles and pile caps) which will occur post earthworks. Further risk assessment may be required to inform these activities.

Cover system

3.7.17 On completion of the earthworks a marker layer such as a brightly coloured geotextile or layer of crush concrete, will be placed on the final finished surface to separate any residual asbestos contaminated soils within the landfill/scrap yard material from the overlying cover system. This is discussed further below**.**

Verification

3.7.18 A verification report should be prepared on completion of the works. The contractor should provide ‘as built’ records of the ground conditions on completion of the enabling works. This will include details of material movement and placement, and areas where asbestos material was removed or covered onsite including details of the marker layer and no dig barriers. The verification report describes the works undertaken, site controls, notification and provide evidence that the works have been completed in accordance with the approved ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

Post Construction- Future Users

3.7.19 Most of the former landfill will remain in-situ and will not be excavated. Reprofiling of the surface of the former landfill will be required to ensure correct development levels. Therefore, residual asbestos will remain within the landfill. If this material is left undisturbed in the ground it does not result in a potential risk to future users post construction, providing it is appropriately managed. Measures for management of the residual asbestos is detailed below.

3.7.20 The landfill material which is excavated in order to achieve the correct formation levels will be subject to the measures described in the section above to remove visible ACMs. In practice, it is not possible to remove all asbestos from the soils and therefore low-level fibres and fragments of ACM may remain in the material to be reused. A cover system to prevent future contact with any residual asbestos contaminated soils will mitigate the potential risks, providing it is adequately maintained.

3.7.21 The cover system should incorporate an appropriate marker layer and/ or a no dig crushed concrete layer to prevent accidental excavation during future maintenance works in areas of soft landscaping, or around services, to manage and demark the boundary between clean cover system soils and landfill material.

3.7.22 The processed landfill material may be reused within the scheme below marker layers. The position of the marker layers and depth of cover above them should be recorded for maintenance records.

3.7.23 The cover system locally may need to be deeper/thicker to incorporate ‘clean’ service corridors and tree pits to protect future maintenance workers from exposure to residual asbestos which may be present. The design of the cover system is considered further in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

4 GROUND GAS RISK ASSESSMENT

4.1 Summary of GQRA

4.1.1 The GQRA (Ref. 2) of the ground gas risks (**Section 11** of GQRA (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**) identified the following:

a. The gas spot monitoring results for the area of the former landfill were considered to be Characteristic Situation (CS) 2 with a few CS3 readings. The CS3 readings recorded were as a result of negative flow rates, which were considered to be a positive flow rate for the purposes of the initial assessment. Negative flow rates indicate that the gas pressures within the ground are below that of atmospheric pressure and can occur due rapid changes in atmospheric pressure. The effect of atmospheric pressure on the gas regime is more accurately measured with continuous gas monitoring (Ref. 12);

b. Outside of the landfill, generally the levels of gas recorded are low, with the exception of BWS203, BWS211, BWS214, BBH209, BBH210 and LF-BH05G, which are all located adjacent to the landfill boundary (see **Image 4.1**). LF-BH05G and BBH210 are located within an area which has a significant thickness of Made Ground associated with soils stored in London Luton Airport Operator contractors' compound. Flow rates from all the holes were low. Analysis of the monitoring data indicates that the area outside the landfill is CS2, which is considered low risk; and

c. In general, the gas monitoring results suggest that the landfill is past the peak of its capacity for gas generation and in its current state there is no evidence of significant off-site migration of landfill gases. This is consistent with the understanding of the landfill age and waste types as discussed in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**.

4.1.2 The GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** recommended further detailed assessment be undertaken to assess the ground gas conditions at the former landfill and specifically to understand the following:

a. Provide a robust detailed assessment of the current ground gas regime and understand relevant environmental correlations that have a direct effect on the landfill as a potential gas source;

b. Understand the potential future gassing potential of the waste in the landfill; and

c. Based on the current and future potential gas risks determine the required gas protection for future buildings on site and any measures required to prevent lateral migration of gases.

[12] Gas monitoring results were assessed using the classification system presented within CIRIA C665 (Ref. 25). The classification system uses gas concentrations and recorded flow rates for methane and carbon dioxide to determine a gas screening value (GSV). The GSV is used to determine the Characteristic Situation (CS) for the site, which is a qualitative method of defining risk to a proposed development constructed on gassing ground. Characteristic Situation (CS) 3 is considered to moderate risk and a typical of a gas source being generated from old landfill, inert waste, or flooded mineworkings.

4.2 Assessment methodology

4.2.1 The gas risk assessment presented in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** considered the data obtained from the gas spot monitoring only. The gas risk assessment DQRA considers the spot monitoring results in more detail and also the results obtained from the continuous gas monitoring completed on site.

4.2.2 Continuous ground gas monitoring was undertaken on five selected monitoring installations (BH202, BH206, BH208, BH224 and BWS202) as shown in **Figure 3** of this document. Four of the wells (BH202, BH206, BH208 and BH224) are located within the landfill waste and were selected to provide a spatial distribution across the landfill area which would target different waste types and eras encountered during the ground investigation. BWS202 is located within natural strata to the north of the landfill boundary and was selected to provide data on potential gas migration off-site.

4.2.3 Data obtained from continuous ground gas monitoring can provide a much greater understanding of ground gas behaviour. Correlations between variation in gas concentration and/or borehole flow and changes in atmospheric pressure, borehole pressure, temperature and groundwater fluctuations all provide information on the ground gas regime of a site.

4.2.4 In order to provide a more detailed understanding of the existing ground gas regime the lines of evidence approach set out in CL:AIRE Technical Bulletin 18 (Ref. 14) has been considered to assess the continuous monitoring data obtained on site. The methods used to assess the data are described below:

a. Consideration of barometric pressure: The barometric data was reviewed to assess if the data had been collected over a sufficient number of relevant barometric pressure variations to allow prediction of “worst-case” conditions. A fall in barometric pressure is an important ground-gas driver and specifically the rate and duration of the fall are considered important, with “worst-case” conditions considered to be a situation where a very large pressure fall occurs over a short period of time. A review of the changes in barometric pressure recorded during the continuous gas monitoring period identified that data was collected during three pressure falls that could be considered to represent “worst-case” conditions and therefore it is considered that the data is adequate to define the ground-gas regime of the site. The assessment was undertaken using the methodology described in CL:AIRE Technical Bulletin 17 (Ref. 15) and is presented in **Appendix B** in this document;

b. Environmental correlations: Relationships between ground gas concentrations, gas flow rates and changes in atmospheric pressure have been assessed. On some sites fluctuations in groundwater level can have an impact on the gas regime, however this has not been considered on this site due to the groundwater within the chalk being at significant depth beneath the landfill;

c. Concentration duration: Concentration duration analysis converts the total monitoring period for each well into percentage time and sorts all recorded ground gas concentrations from highest to lowest. The plots enable observations to be made about the proportion of the monitoring period spent at each gas concentration and can provide information to characterise the position of a monitoring well in relation to a ground gas source (Ref. 15). Close to the source, the gas will be consistently present in the monitoring well and at a distance from the source gas concentrations will fluctuate as ground gases interchange with atmospheric air conditions;

d. Ternary plots: The percentage compositions of ground gases obtained from site monitoring data (methane, carbon dioxide, oxygen and nitrogen) recorded during the continuous monitoring have been plotted on a ternary plot. The plots allow trends in gas composition to be identified and can aid with the identification of the potential source of ground gas (Ref. 16). This information can help to further characterise the ground gas regime of a site and differentiate between potential sources of ground gas;

e. Purge and recovery tests: On completion of the continuous gas monitoring a series of purge and recovery tests were completed in the five monitoring wells. The tests involve the pumping of inert nitrogen gas into the installation to displace other gases that may be present and then monitoring the rate of recovery of gases within the well to provide information on the gas flux within the response zone; and

f. Gas screening values: Real-time gas screening values (GSVs) were calculated for each installation to help define the Characteristic Situation (CS) for the site. This has been done by taking each value of methane and carbon dioxide concentration recorded and calculating the GSV based on the flow rate recorded at the corresponding point in time. Once GSVs for methane and carbon dioxide have been calculated, the highest GSV has been used to define the CS for each installation. The gas screening values were calculated using the methodology previously outlined in **Section 11** of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]** .

Quantitative assessment

4.2.5 Quantitative assessment of the ground gas regime has been undertaken using the modelling package GasSim 2.5. The modelling has been used to estimate the residual gas generation potential of the landfill and predict the long-term gassing potential. Further description of the methodology used is described in **Section 4.4.**

4.3 Results

Spot monitoring further assessment

4.3.2 The ability of a landfill to produce gas will depend on the decomposition status of the waste and the age of the landfill. Therefore, it is important to understand the components of waste which are degradable and the extent of degradation.

4.3.3 The spot monitoring data results are presented in the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**. The results from wells installed within the landfill waste generally recorded concentrations of methane between 40 to 60% which is typical of landfill gas. In order to understand whether there is any relationship between the waste type and gassing potential a comparison has been made to the maximum methane, carbon dioxide and flow rates with waste type. The results are shown in **Table 4.1** below**.**

4.3.4 The following observations are noted from **Table 4.1** below:

a. Construction and industrial waste types appear to be the most likely to produce landfill gases. However, it is noted that construction waste was the most encountered waste type within the landfill as a whole, so therefore there is a bias towards it being present in standpipes recording higher methane;

b. Overall the gas flow rates recorded were low in all waste types indicating there was no significant volume of gas being generated;

c. Some boreholes (WS211, WS216, WS218, WS221, WS223, WS225) contained no degradable materials but recorded moderate to high levels of methane and/or carbon dioxide. However, these were generally within close proximity of boreholes which contained a high percentage of degradable materials;

d. Visual and olfactory observations identified hydrocarbon odours and oily sheens in BH223, BH231 and WS224. Furthermore, groundwater (all three boreholes) and soil (WS224) testing showed high concentrations of hydrocarbons in these boreholes. These three boreholes are all noted to have recorded some of the highest concentrations of methane. This is because gas monitors cannot distinguish between hydrocarbon contamination and methane gases, therefore the methane concentrations in these locations may not reflect the true gassing potential of the material;

e. Overall there appears to be no definitive pattern between the production of carbon dioxide and methane and waste type. Examination of the borehole logs suggested higher percentages of landfill gases was more linked to boreholes which contained greater percentages of wood, newsprint, mixed paper, corrugated and/or textiles tended to produce a higher percentage of landfill gases. The GQRA (Ref. 2) (**Appendix 17.2** of the ES **[TR020001/APP/5.02]**) presented an assessment of the degree of degradation of samples by era of landfill waste (shown in **Image 4.1** below). This suggests that the older pre-1960s waste is predominantly moderately or highly degraded. In the younger wastes (1970s onwards) there is still a reasonably high component of undegraded waste with much less highly degraded waste;

f. Based on this assessment it is therefore considered younger wastes within the landfill will have the greatest potential for degradation and the generation of landfill gas; and

g. Outside of the landfill waste ground gas concentrations were generally low and indicated that there was no significant migration of landfill gas beyond the landfill boundary.

Image 4.1: Observations of the degree of degradation of samples by era of landfill waste.

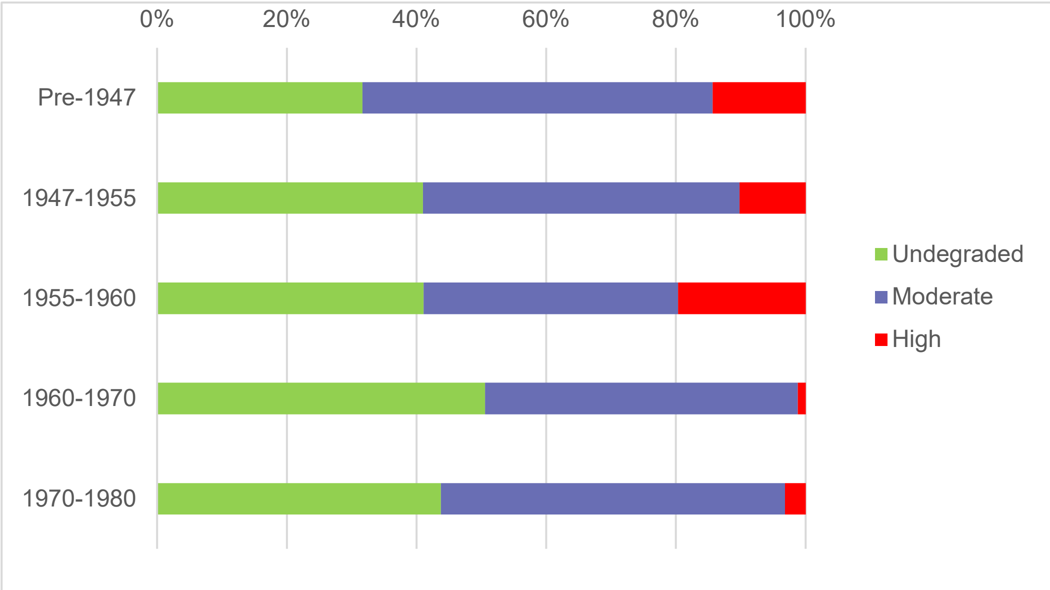


Table 4.1: A comparison of the maximum methane, carbon dioxide and flow rates compared to waste types present in the response zone.

Borehole Reference	Max. Flow Rate (l/hr)	Max. Methane (%)	Max. Carbon Dioxide (%)	Waste type present in response zone						
				Chalky cover material	Non-chalky cover material	Commercial	Old Domestic	Recent Domestic	Industrial	Construction
BH201	0.1	32.2	25.5	✓	✓				✓	✓
BH203	0.1	45.7	21.2	✓				✓	✓	✓
BH204	0.32	50.7	20.5				✓			✓
BH205A	0.1	57.7	32.2					✓		✓
BH207	0.1	74	25.2			✓			✓	✓
BH209	0.1	68.9	47.6	✓				✓	✓	✓
BH210	0.6	64.2	12.5	✓	✓		✓			✓
BH212A	0.1	37.4	29.6	✓	✓	✓		✓	✓	✓
BH213	0.1	59	24.7					✓	✓	✓
BH214	0.1	41.6	33.4	✓			✓		✓	✓
BH216	0.7	57.4	16.8				✓			✓
BH217	0.9	62.6	12.3	✓	✓	✓	✓		✓	✓
BH218	0.1	68	28.6	✓	✓				✓	✓
BH219	0.1	26.6	22.4	✓	✓	✓		✓	✓	✓
BH220	0.1	56.4	27.6	✓	✓		✓		✓	✓
BH221	0.1	29.3	18.7		✓				✓	✓
BH222	0.1	73.4	17.1	✓			✓		✓	✓
BH223	0.1	74.5	60		✓				✓	✓
BH225	0.22	26.3	18.9		✓			✓	✓	✓

Borehole Reference	Max. Flow Rate (l/hr)	Max. Methane (%)	Max. Carbon Dioxide (%)	Waste type present in response zone						
				Chalky cover material	Non-chalky cover material	Commercial	Old Domestic	Recent Domestic	Industrial	Construction
BH226	0.1	14.9	17.1	✓	✓	✓		✓	✓	✓
BH227	0.1	34.4	16.4	✓	✓		✓		✓	✓
BH228	0.22	45.2	16.7	✓	✓		✓			✓
BH229	0.1	43.9	27.3	✓	✓	✓	✓		✓	✓
BH231	0.2	75.6	8.2	✓	✓					✓
BH232	0.1	60.7	18.1	✓	✓		✓			✓
BH233	0.1	16.6	18.6	✓	✓				✓	✓
BWS212	0.3	48.1	16	✓	✓					✓
BWS216	0.1	0.8	11.9	✓	✓				✓	✓
BWS217	9	25.6	6.9		✓					✓
LFBH03G	0.1	51.8	21.8					✓		✓
LFBH04G	0.3	28.2	15.1		✓			✓		✓
LFBH06	0.3	56.3	20.3		✓		✓	✓		✓
LFBH07	0.2	61.2	23.6		✓			✓		
LFBH08G	0.2	62.1	53.1					✓		
LFBH09	0.1	43	15.9	✓	✓		✓	✓	✓	✓
LFBH10GA	0.1	40.5	7.6		✓					✓
LFBH12A	0.1	6.2	20.8		✓		✓		✓	
PFCPRC38	0.42	48	16.9	✓	✓			✓		✓
PFCPRC39	6.02	46	19.5							
PFCPRC40	5.72	31.8	24.2					✓		✓
PFCPRC41	1.8	59.8	20.8					✓		✓

Borehole Reference	Max. Flow Rate (l/hr)	Max. Methane (%)	Max. Carbon Dioxide (%)	Waste type present in response zone						
				Chalky cover material	Non-chalky cover material	Commercial	Old Domestic	Recent Domestic	Industrial	Construction
PFCPRC41A	3.32	46.2	19.6	✓			✓			
PFCPRC43	0.3	42.7	25.8					✓		
PFCPRC44	2.42	31	23.5		✓			✓		✓
PFWS58A	0.1	2	4.9		✓					✓
WS201	0.2	0.8	9.4	✓						✓
WS203	0.1	54.9	30.3	✓				✓		✓
WS204	0.1	48.3	15.7	✓						✓
WS205A	0.1	64.5	48.3	✓					✓	✓
WS206A	0.1	69.6	29.6		✓				✓	✓
WS207	0.1	40.6	17.2		✓			✓		✓
WS208	0.1	65.2	30		✓				✓	
WS209	0.1	59	34.3	✓	✓				✓	✓
WS210	0.1	64.5	25						✓	✓
WS211	0.1	37.4	20.3		✓				✓	✓
WS212	0.1	73.7	32.2	✓						✓
WS213	0.1	56.2	27.3	✓						✓
WS214	4.62	46.2	5.9		✓					✓
WS215A	0.1	37	21.8	✓	✓				✓	✓
WS216	0.1	37.3	22.7	✓						✓
WS217B	0.1	0.9	6.6							✓
WS218	0.1	52.3	23.6	✓						✓
WS219	0.1	53.6	25.9	✓					✓	✓

Borehole Reference	Max. Flow Rate (l/hr)	Max. Methane (%)	Max. Carbon Dioxide (%)	Waste type present in response zone						
				Chalky cover material	Non-chalky cover material	Commercial	Old Domestic	Recent Domestic	Industrial	Construction
WS220	0.4	72.9	23.2		✓					✓
WS221	0.1	38.6	13	✓	✓					✓
WS222	0.3	76.8	10.1	✓	✓					✓
WS223	0.9	42	8.8		✓					
WS224	0.1	80.6	7.6	✓	✓					✓
WS225	0.82	59.2	18.6		✓					✓

Continuous gas data assessment

4.3.5 A summary of the depth of waste and waste types at each of the continuous ground gas monitoring location is shown in **Table 4.2** below.

Table 4.2: Depth, type and era waste types at continuous gas monitoring locations.

Location	Response zone (mbgl)	Waste types /material	Eras of waste
BH202	2.0-9.0	Non-chalky cover material Chalk cover Construction material	1970-1980
BH206	1.0-8.0	Industrial Recent domestic Construction	1970-1980
BH208	1.0-11.0	Industrial	1970-1980
BH224	8.0	Non-chalky cover Industrial	1960-1970
BWS202	1.0-5.0	No waste outside of landfill boundary- Clay-with-Flints and chalk.	n/a

4.3.6 The detailed assessment of the continuous monitoring data obtained from each individual monitoring well is provided in **Appendix B** of this document and the key trends identified are discussed below.

Landfill waste

4.3.7 The continuous monitoring data collected from the four wells installed within the landfill waste (**locations identified** a strong relationship between ground gas concentrations, gas flow and falling/low barometric pressure. The results from BH202 and BH208 are summarised below as they show the greatest variation in gas conditions within the landfill waste. The results from the other locations are presented in **Appendix B** of this document**.**

4.3.8 BH202 is located in the north of the landfill where approximately 8m of cover material (both chalk and non-chalky) was encountered over a thin layer (approximately 1.4 m) of construction waste predominantly comprising inert materials (brick, chalk and clay) placed in the 1970s and 1980s. The landfill waste in this part of the site is considered to have a lower potential for generation of landfill gas compared with other waste types.

4.3.9 **1.1.1** presents the time-series data, ternary plot and concentration duration plot for well BH202 and indicates the following:

a. Increases in methane and carbon dioxide concentrations and gas flows have been recorded which appear to respond rapidly to changes in barometric pressure conditions, with no significant lag apparent in the data;

b. During periods of rising or steady barometric pressure gas concentrations were typically below or close to the detection limit of the monitoring equipment. This indicates that the landfill is not actively gassing in this part of the site as a gassing landfill will be characterised by consistent methane and carbon dioxide concentrations;

c. There is no sustained gas flow within the well;

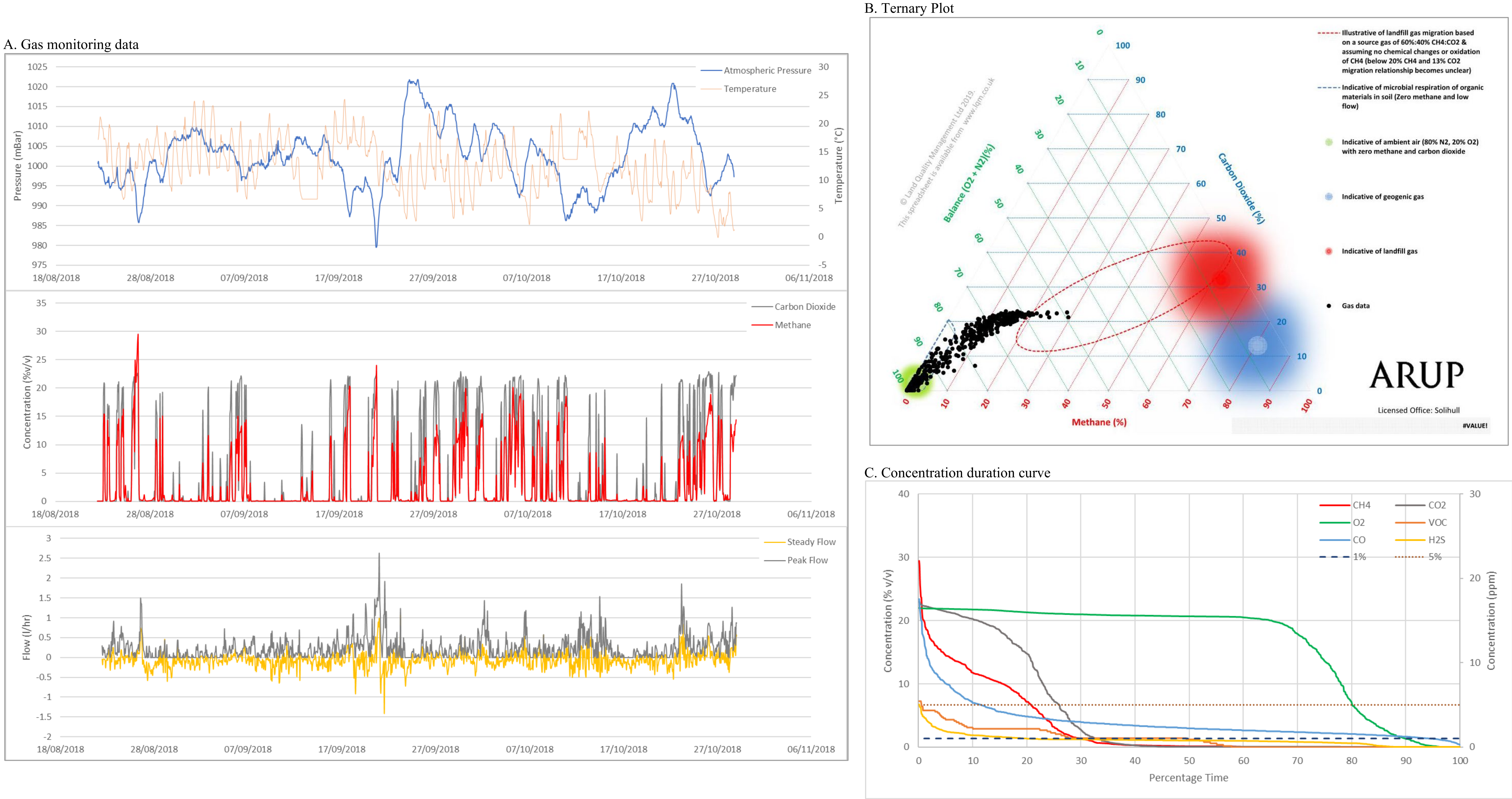
d. The ternary plot indicates that gas concentrations recorded in BH202 generally contain high levels of air (nitrogen and oxygen) and so are not indicative of landfill gas, but a small proportion of the results indicate landfill gas migration from elsewhere; and

e. The concentration duration curve indicates concentrations of ground gases in BH202 are above levels which could be considered to be hazardous approximately 30% of the time. This shows that ground gases are not consistently present in the well and there is evidence of atmospheric air ingress. As described in **Section 4.2**, the concentration duration curve can provide information to characterise the position of a monitoring well in relation to a ground gas source. The concentration duration curve plot has been compared to typical plots along a gas migration pathway presented in CL:AIRE Technical Bulletin 18 (Ref. 14) and the fluctuation of ground gas concentrations recorded indicates that the well is not located in close proximity to the gas source.

4.3.10 The purge and recovery test data from BH202 (see **Appendix B** of this document) recorded limited accumulation of methane within the well which indicates that the level of gas flow in this part of the site is likely to be low.

4.3.11 Overall the ground gas monitoring results from BH202 are considered to be consistent with the types and ages of waste recorded in this part of the landfill.

Image 4.2: Continuous gas monitoring data BH202.



4.3.12 BH208 is located towards the centre of the landfill where waste is approximately 11.5m thick and comprises a mixture of industrial, commercial and construction wastes which was placed in the 1970-1980s. The landfill waste in this part of the site is considered to have a greater potential for generation of landfill gas compared with other waste types and this is reflected in the monitoring data.

4.3.13 **Image 4.3** presents the time-series data, ternary plot and concentration duration plot for well BH208 and indicates the following:

a. Increases in methane and carbon dioxide concentrations and gas flows have been recorded which appear to respond rapidly to changes in barometric pressure conditions, with no significant lag apparent in the data;
b. Concentrations of methane were recorded above the monitoring equipment detection limit most of the time and were only undetectable during prolonged periods of barometric pressure rises which suggests the well is in close proximity to a landfill gas source as there is less evidence of atmospheric air within the well;
c. There is no sustained gas flow within the well, however high gas flows were recorded following rapid decreases in barometric pressure with a maximum follow of 7.31 l/hr recorded;
d. The ternary plot indicates that a large proportion of the gas concentrations recorded in BH208 are indicative of landfill gas and /or landfill gas migration; and
e. The concentration duration curve indicates concentrations of methane in BH208 are above levels which could be considered to be hazardous approximately 80% of the time. This shows that ground gases are predominantly present in the well and there is evidence of limited atmospheric air ingress. The concentration duration curve plot has been compared to typical plots along a gas migration pathway presented in CL:AIRE Technical Bulletin 18 (Ref. 14) and the ground gas concentrations recorded indicate that the well is located in close proximity to a landfill gas source.

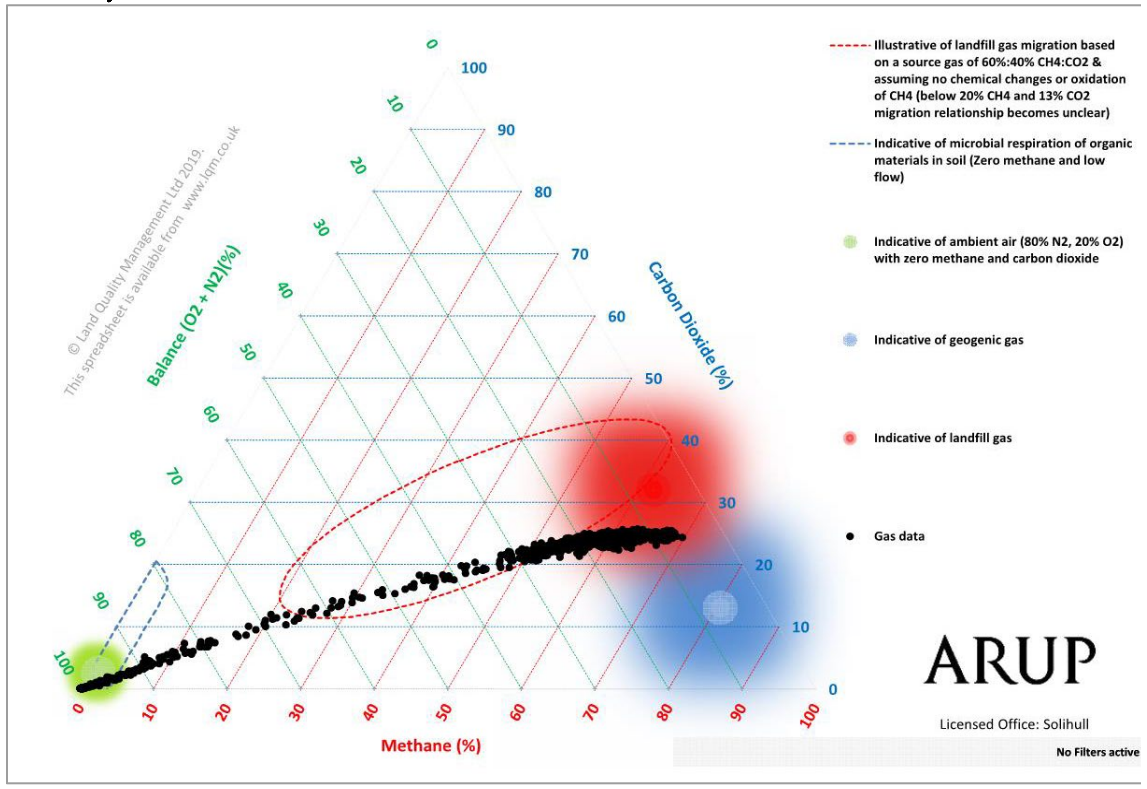
4.3.14 The purge and recovery test data from BH208 (see **Appendix B** of this document) recorded a relatively rapid accumulation of methane within the well which indicates that there was potential for high gas flow in this part of the site.

4.3.15 Overall the ground gas monitoring results from BH208 are considered to be consistent with the types and ages of waste recorded in this part of the landfill.

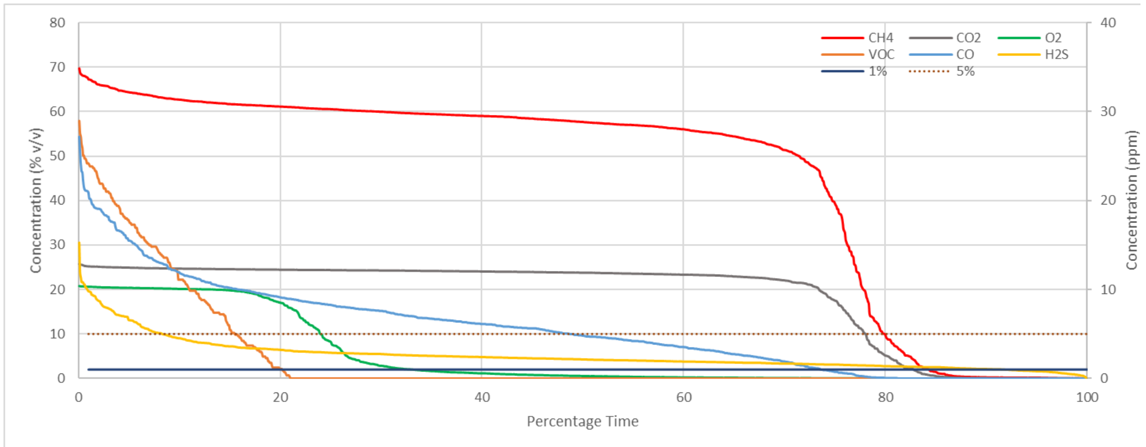
Image 4.3: Continuous gas monitoring data BH208

A. Gas monitoring data

B. Ternary Plot



C. Concentration duration curve



4.3.16 The maximum ground gas concentrations recorded within the landfill waste during the continuous monitoring are similar to those recorded during the spot monitoring.

4.3.17 The spot monitoring did not record any significant gas flows and it is evident from the continuous monitoring data that there is no sustained gas flow generation in the landfill material. Gas flow rates are being influenced by changes in barometric pressure with short duration peaks in gas flow recorded when there is a fall in pressure.

4.3.18 The results correlate with the assumption that the landfill is beyond the peak gas generation period in its current condition. Some pockets of waste material may be present which have some degradable content remaining which is producing landfill gas typically in the 1980s era waste, however the older areas of landfill waste will be generating minimal gas.

Landfill boundary

4.3.19 Continuous gas monitoring was undertaken on one monitoring installation (BWS202) located to the north of the landfill boundary and installed in natural soils.

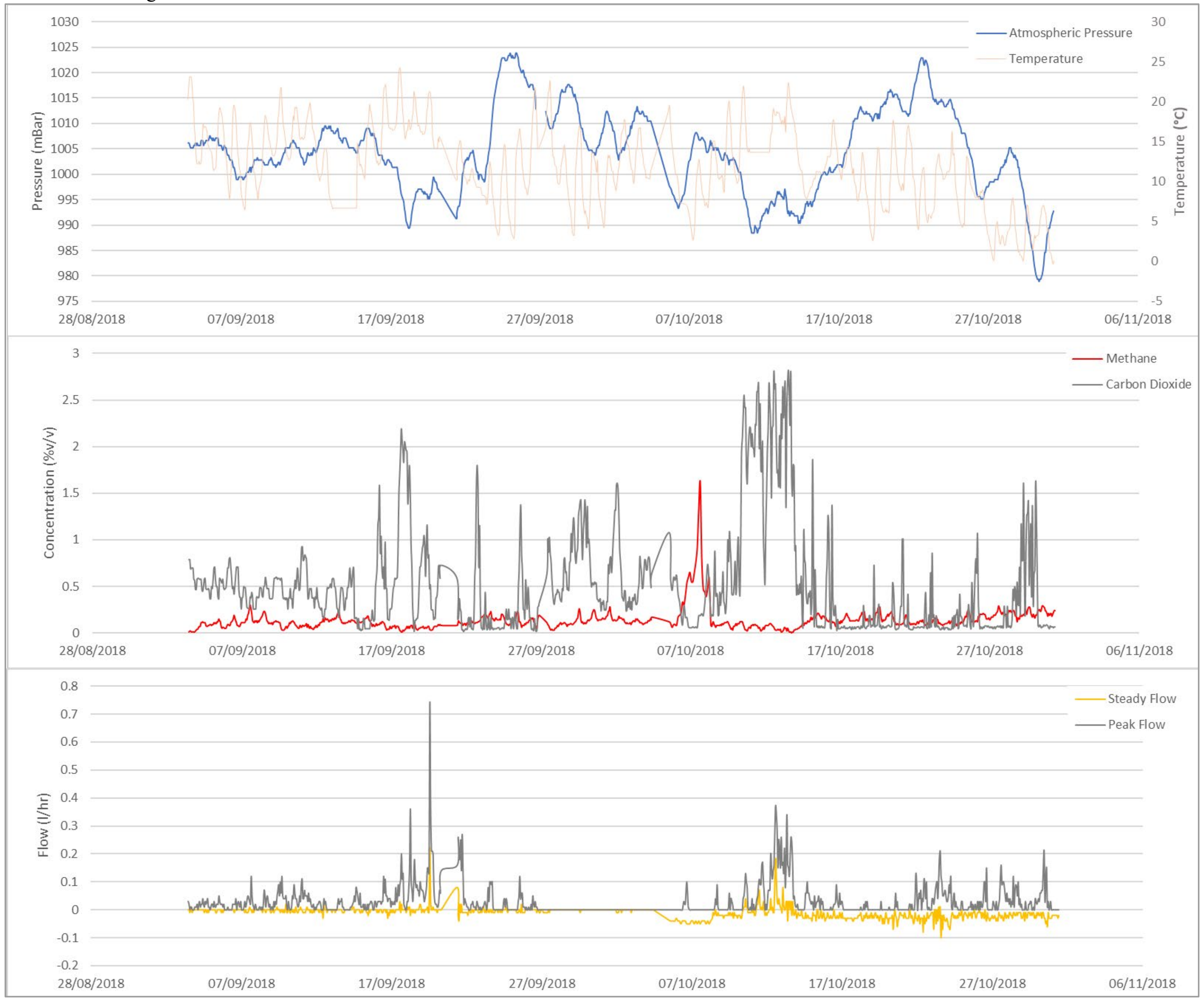
4.3.20 **Image 4.4** presents the time-series data, ternary plot and concentration duration plot for well BWS202 and indicates the following:

a. Concentrations of methane recorded in the well were very low and in general were recorded below the monitoring equipment detection limit for the majority of time which is also reflected in the concentration duration curve plot;
b. During the first week of the monitoring period some VOCs were recorded within BWS202 however the levels decreased and were typically below the limit of detection for the final two months of monitoring. It is considered likely that the VOCs recorded are not a true reflection of ground conditions as no potential source of VOCs was evident in this part of the site and VOC concentrations recorded within the landfill were typically low;
c. Very low gas flow rates were recorded; and
d. The ternary plot indicates that the gas monitoring results are indicative of ambient air concentrations and there is no evidence of landfill gas within the monitoring well.

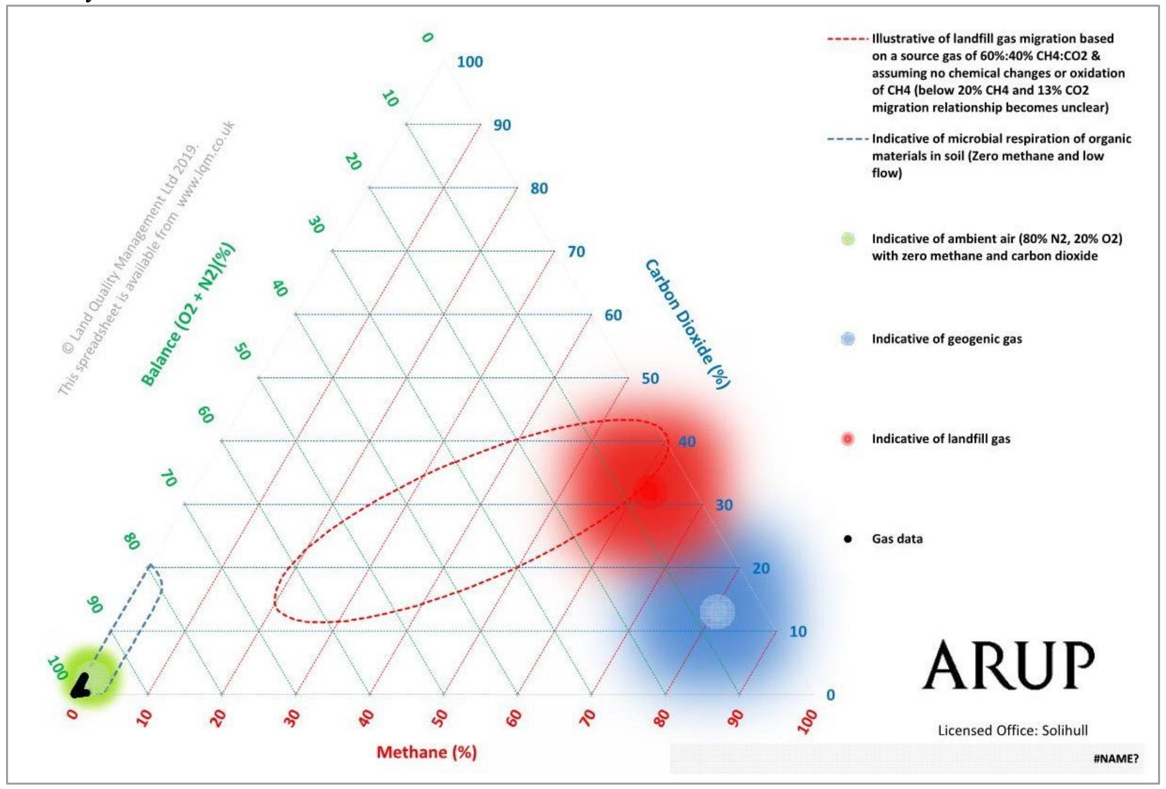
4.3.21 The purge and recovery test data from BWS202 (see **Appendix B** of this document) recorded limited accumulation of methane within the well which indicates that the level of gas flow in this part of the site is likely to be very low.

Image 4.4: Continuous gas monitoring data BWS202.

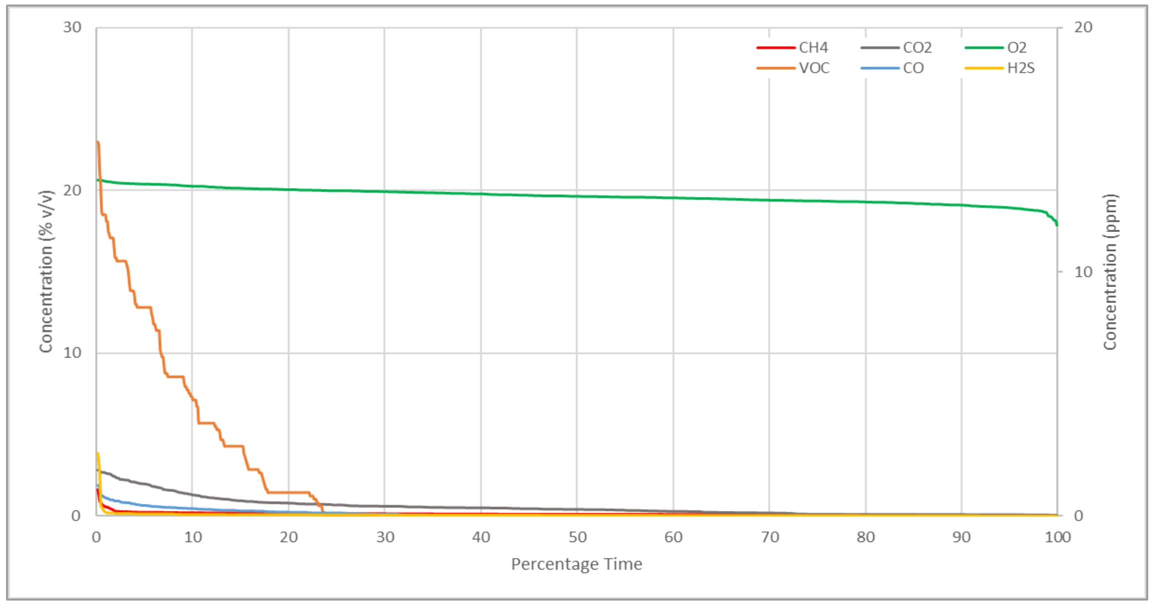
A. Gas monitoring data



B. Ternary Plot



C. Concentration duration curve



4.3.22 The continuous monitoring data from BWS202 does not provide any evidence of gas migration from the landfill. This was reflected in the spot gas monitoring data which indicated there was limited migration of landfill gas occurring beyond the landfill boundary.

Ground gas screening values

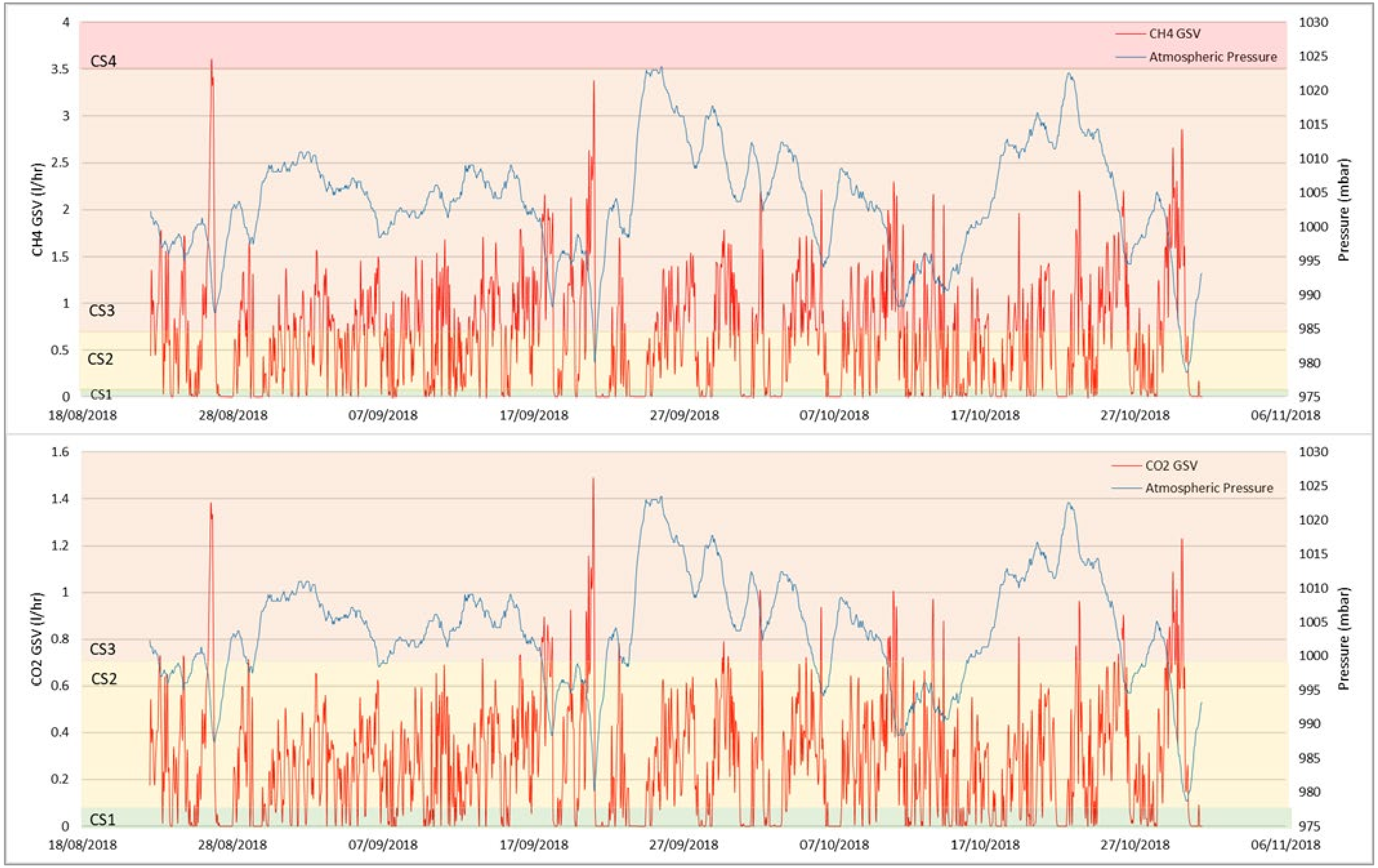
4.3.23 To assess the ground gas risk identified by the continuous monitoring, real-time gas screening values (GSVs) have been calculated for each installation.

4.3.24 The borehole location which shows the highest GSVs (BH208) is shown in **Image 4.5** with all GSV plots provided in **Table 4.2** above. The GSVs indicate that the methane results are generally classed as CS3, for monitoring wells located in landfilled materials which correlates with the GSV calculated based on the gas spot monitoring results.

4.3.25 However, the continuous monitoring indicates that during instances of worst-case atmospheric pressure falls, the landfill can be classed as CS4 in some instances although these occurrences are rare and typically of short duration. This supports the assumption that some active gassing is still occurring in pockets of waste material on site. A CS4 classification is considered typical of old domestic landfill sites.

4.3.26 The GSVs calculated for BWS202, which is located outside the landfill, were classed as CS1. Based on the spot gas monitoring data a small number of wells located adjacent to the landfill boundary recorded some elevated concentrations of gas in spot monitoring and therefore it is considered appropriate for areas outside the landfill to be classified as CS2.

Image 4.5: Ground gas screening values BH208.



Summary

4.3.27 The assessment of the gas monitoring data indicates the current gas regime on site can be characterised as follows:

a. The continuous and spot gas monitoring data suggests that the landfill is still capable of generating gas in localised areas, particularly where the landfill is at its deepest and in areas where there are more recent wastes which still contain some degradable organic matter;
b. While there are high concentrations of bulk landfill gases (carbon dioxide and methane) present within the waste, gas flow rates are relatively low, indicating low rates of continued biodegradation of residual organic matter. Gas flow rates change in response to barometric pressure variations, suggesting that the overall quantities of gas being generated are low;
c. The monitoring results are consistent with the waste types encountered during the ground investigation and the level of degradation observed within the waste;
d. The landfill is beyond the end of its peak gas generation period in its current condition and is likely to be in its residual gas generation phase;
e. There is no evidence that gas is migrating a significant distance off-site based on the gas monitoring undertaken to date; and
f. The GSV assessment indicates that as a worst-case the landfill site should be classified as CS4 and areas outside of the landfill should be classified as CS2. This is considered a precautionary assessment which allows for short and sporadic spikes in gas generation, as the spot monitoring and continuous gas monitoring suggest that for the vast majority of the time the landfill site is more typically CS2 and outside the landfill CS1.

4.4 Future landfill gas generation assessment

4.4.1 Understanding the future gas generation potential of the landfilled wastes is critical to ensure safe development of the site, and to support the identification and design of appropriate gas control measures.

4.4.2 It is also important to recognise that the proposed development will include significant reworking of the landfill which may alter its gassing regime. The precautions and mitigation measures in this regard are discussed in **Section 4.5**.

4.4.3 The assessment described in **Section 4.3**, indicates the landfill is past the point of peak gas generation. However, the results also indicate areas of the landfill associated with high concentrations of methane and carbon dioxide, it is therefore necessary to further quantify the residual risks from landfill gas and long-term gassing potential and a quantitative assessment of future landfill gas potential has been completed.

Methodology

4.4.4 GasSim 2.5 has been identified as an appropriate modelling tool to estimate residual source term gas generation potential and therefore requirement for mitigation measures to be included in development to control the potential long-term risks. The data regarding the current landfill gassing status and knowledge of the landfill characteristics have been used to generate estimates of landfill gas emissions using the GasSim 2.5 Model.

4.4.5 GasSim 2.5 was developed with and endorsed by the Environment Agency. The modelling package is also used by landfill operators and consultants, to provide a standard risk assessment methodology for landfill gas management, to meet EU Directives (Waste Framework and Landfill Directives) which have been translated into UK legislation. GasSim considers the uncertainty in input parameters using a Monte Carlo Simulation to quantitatively evaluate risks and the magnitude of the impacts.

4.4.6 The main element of the modelling process is to define the ‘source term’, for simulation of bulk landfill gas (methane (CH_4); carbon dioxide, (CO_2); hydrogen, (H); hydrogen sulphide, (H_2S)) and trace gas generation.

4.4.7 The main elements controlling landfill gas production which are modelled include:

a. Waste streams, e.g. industrial, commercial domestic;
b. Waste composition, biodegradable and inert components;
c. Waste moisture – important for methane generation; and
d. Biodegradability of the waste fractions.

4.4.8 The definition of these parameters is highly flexible, and the input parameters have been employed which are considered to best reflect the source term in the former landfill.

Input parameters

4.4.9 The input parameters are presented in **Appendix C** along with the justification for their use. The parameters have been obtained from site investigation data and literature sources, the GasSim default values for typical landfills have also been used as appropriate, where no reasonable alternative could be identified.

4.4.10 The following summarises main assumption regarding the input parameters:

a. The operational period of the landfill is assumed as 40 years based on the ground model;
b. Simulation period is 100 years and includes for 60 years post closure, which includes the construction and operational period of the expanded airport;
c. 201 iterations of the model have been applied to provide greater accuracy;

d. Each era/filling period has been modelled as a landfill 'cell' through manual drawing of the extent of each cell in the GasSim model as estimated by the ground model (**Figure 4** of this document);

e. It is assumed there is no liner or formal cap to the landfill as none were identified during the recent ground investigations;

f. Surcharging has been included for cells which are overlapped by waste from later eras;

g. An average moisture content has been assumed given that the waste is generally dry/damp and has been placed above the groundwater table, with minimal leachate recorded from monitoring wells;

h. The waste type and composition has been based on forensic logging data described in the GQRA, **Sections 9.1** and **9.2** (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**;

i. The waste input tonnage has been derived from the volumes in the ground model for each era converted to tonnage based on likely conversion factors from literature sources for typical landfills; and

j. The standard degradable content for 1980-2010 waste streams included as a default in the GasSim model has been applied in the absence of other data.

Results

4.4.11 The outputs from the GasSim modelling for CO_2, methane CH_4 and total landfill gas has been tabulated and presented in **Table 4.3** below, for each filling era (cell) and for the landfill in total. The estimated gas generation are for present day (2019), first year of proposed airport opening (2026) and 100 years after commencement of filling (2040).

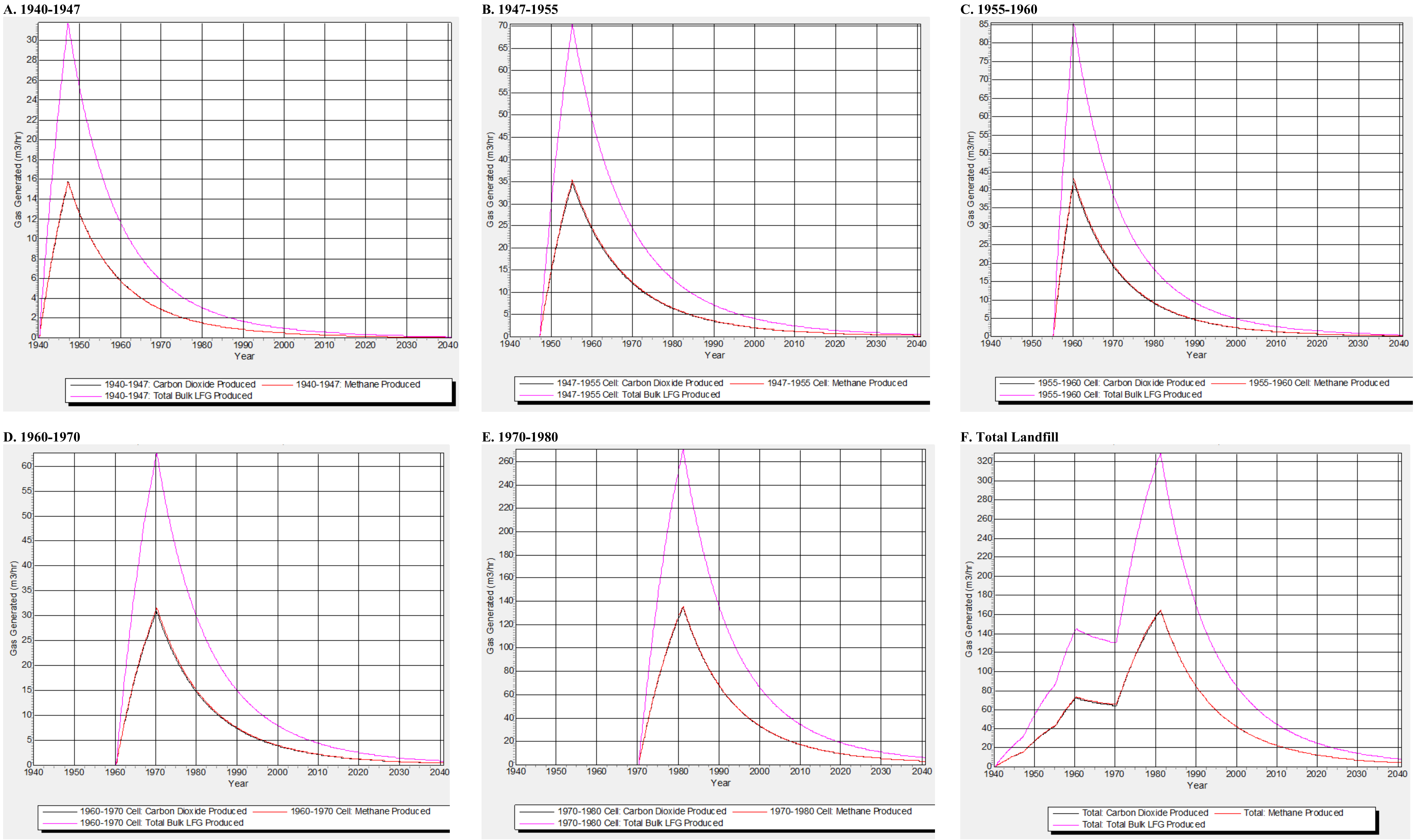
4.4.12 The GasSim model also produces graphical outputs which shows the gas generation from commencement of landfilling for each cell and total landfill, for the duration of the modelled period, produced below in **Image 4.6.**

4.4.13 The CO_2 and CH_4 concentrations have been modelled in the same proportions and therefore the data series are practically synonymous, and are indistinguishable on the graphs.

Table 4.3: GasSim 2.5 estimated gas generation potential.

Gas	Cell	1940-1947			1947-1955			1955-1960			1960-1970			1970-1980			Total Landfill		
	Output year	2019	2026	2040	2019	2026	2040	2019	2026	2040	2019	2026	2040	2019	2026	2040	2019	2026	2040
	Estimated gas volume m^3/hr annual average per cell & total landfill																		
CH_4	Min	0.1	0.09	0.05	0.6	0.4	0.2	0.6	0.4	0.2	1.0	0.7	0.3	7.5	5.0	2.3	10.2	6.9	3.3
	Mean	0.2	0.1	0.06	0.7	0.5	0.3	0.8	0.5	0.3	1.3	0.9	0.4	9.8	6.6	3.0	12.9	8.7	4.1
	Max	0.2	0.1	0.07	1.0	0.7	0.3	1.1	0.7	0.4	1.6	1.1	0.5	12.3	8.2	3.8	16.0	10.8	5.1
CO_2	Min	0.1	0.09	0.05	0.6	0.4	0.2	0.6	0.4	0.2	1.0	0.7	0.3	7.7	5.1	2.4	10.4	7.0	3.3
	Mean	0.2	0.1	0.06	0.8	0.5	0.3	0.8	0.5	0.3	1.3	0.9	0.4	9.6	6.5	3.0	12.7	8.6	4.0
	Max	0.2	0.1	0.07	0.1	0.7	0.3	1.1	0.7	0.4	1.7	1.2	0.6	12.1	8.1	3.8	15.6	10.5	5.0
Total LFG	Min	0.3	0.2	0.1	1.2	0.9	0.4	1.3	0.9	0.4	2.3	1.6	0.8	16.5	11.3	5.3	23.1	15.6	7.4
	Mean	0.3	0.2	0.1	1.5	1.01	0.5	1.6	1.1	0.5	2.7	1.8	0.9	19.4	13.1	6.1	25.6	17.3	8.2
	Max	0.4	0.3	0.1	1.7	1.2	0.6	1.9	1.3	0.6	3.0	2.0	1.0	22.5	14.9	7.0	28.4	19.2	9.0

Image 4.6: GasSim graphical outputs, CO_2, CH_4 and total landfill gas 50th percentile, yearly average.



4.4.14 The output selected is the total gas generated as the former landfill does not have a gas collection system.

4.4.15 Gas production for all eras rises sharply after the first year of filling and is indicated to peak approximately 10 years after first placement of the waste. A sharp decrease in production over the following twenty years, is indicated with production of gas falling at a slower rate for subsequent 30 years.

4.4.16 The results indicate the source term for the waste placed in the eras 1940 to 1970 is essentially depleted with current gas generation estimates for CO_2 and CH_4 between 0.2 to 1.7 m^3/hr. In contrast the 1970 to 1980 cell which contains approximately 50% of the landfill mass is also producing approximately 80% of the landfill gases, producing landfill gas at a maximum rate for total gas of 22.5 m^3/h.

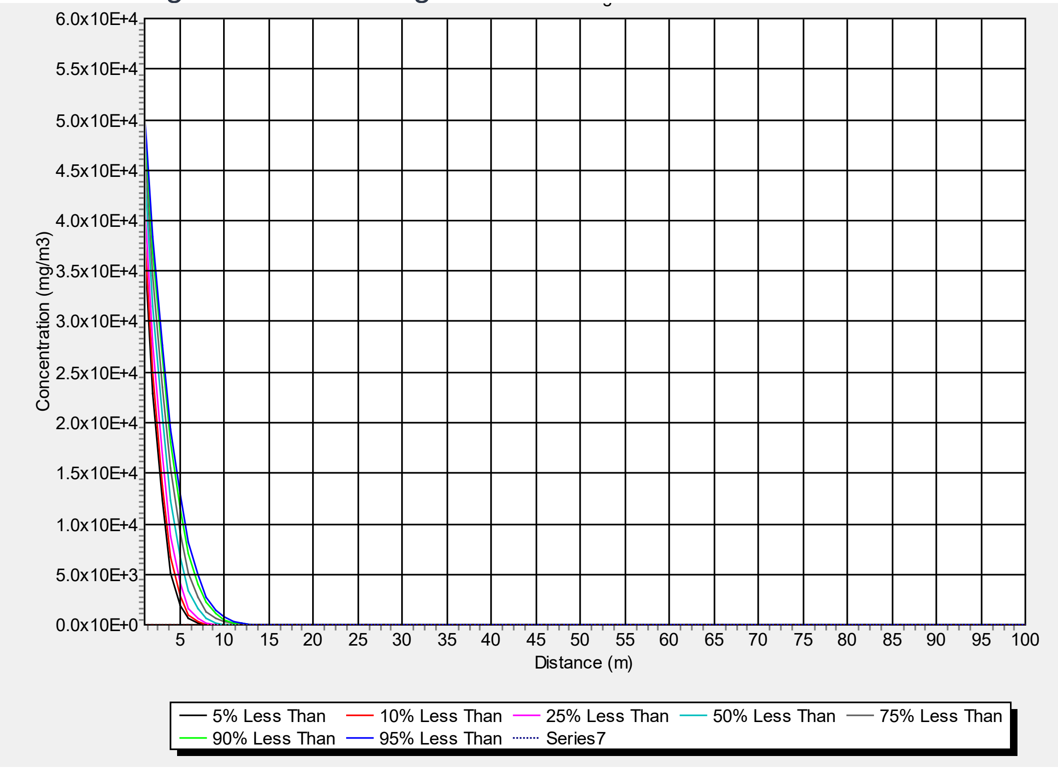
4.4.17 Based on the gas monitoring data the landfill gas typically contains between 10 to 30% v/v methane.

4.4.18 Currently the whole landfill is estimated by the model to be emitting a maximum surface emission of CO_2 and CH_4 at 1.4 and 1.2 m^3/hr respectively.

4.4.19 All modelled priority trace landfill gases are indicated to be depleted before 2019 including H_2S and carbon disulphide (CS_2), which correlates to the very low concentrations of these gases recorded during 2018 gas sampling and analysis results, see **Section 4.5.8** below.

4.4.20 A simulation of lateral flow of gas for 2019 from the 1970 to 1980 cell (worst case) indicates there is limited migration up to approximately 10m from the landfill boundary (see **Image 4.7**) The lateral migration is calculated from Geosphere moisture content and porosity data, both estimated from site data, and air diffusion coefficients for CO_2 and CH_4 for which the GasSim default was applied, see input parameters **Appendix C.** Lateral emissions are only calculated for cell to boundary interfaces, assumed there is no lateral emission or movement between cell internal faces.

Image 4.7: Lateral migration methane from 1970-1980 cell.



4.4.21 The maximum CH_4 concentration falls rapidly from $5.45x10^4$ mg/m^3 at 1.0m, to $1.74x10^4$ mg/m^3 at 5.0m, at 15m this falls to 50 mg/m^3, then to 0.5 mg/m^3 by 20m and at 25m it is $1.3x10^{-3}$ mg/m^3.

Sensitivity

4.4.22 The GasSim 2.5 model was created for use by operators of active landfill sites which are in the process of being filled, and in this instance the model has been used to attempt to retrospectively estimate the generation potential of a closed landfill so the results should be viewed with some caution. Many parameters for the site are unknown and have had to be assumed based on the available data.

4.4.23 For this reason, several iterations of the model were run with changes to parameters to assess the sensitivity, and adopt the most realistic input values, including the following:

a. Capping / no capping;
b. Infiltration;
c. Density of the waste;
d. Waste streams;
e. Waste input; and
f. Degradation rates.

4.4.24 This identified density, percentage of degradable matter and degradation rates as having the most influence on the model outputs. The values input for these parameters were therefore chosen to reflect the most likely scenario, further detail is provided in **Appendix C.**

Summary

4.4.25 To assist in quantifying the likely gas generation potential of the former landfill, a GasSim 2.5 model was generated. The model provides an estimate of the long-term gas generation potential of the landfill and a prediction of lateral extent of gas from the landfill boundary. The model was developed for landfill operators to estimate future gas generation therefore the results should be treated with caution.

4.4.26 However, consistent with the gas monitoring data assessment, the quantitative risk assessment indicates the site is toward the end of the potential gas generation curve.

4.4.27 In the UK there is no legal target value/surrender criteria for the completion of the aftercare phase of a landfill. The UK has adopted a waste stabilisation approach, for permitted sites, surrender criteria are adopted based on a risk-based approach (Ref. 17). Consideration should be given to the expected duration of landfill gas production during the lifetime of the proposed development, and therefore requirement for gas control measures. The GasSim graphs indicate that gas production is already tailing off and is flat lining by 2037 at which point the average yearly gassing rate is < 5 m^3 per hour for the total landfill for CH_4. This would indicate that the landfill would be reaching a stabilisation point, around the time the Phase 3 works are complete.

4.4.28 The potential lateral migration for the 1970 to 1980 cell indicates that in 2021, low concentrations of methane are potentially migrating laterally to about 20 m from the landfill boundary beyond which the concentration is insignificant, <0.001 mg/m^3. This appears consistent with the results of the gas monitoring.

4.4.29 However, the presence of other services i.e. old drains/utilities could provide potential preferential pathways and encourage gas migration off-site over greater distances. A strategy for detecting and treating services was incorporated into the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

4.4.30 A comparison of the current ground gas monitoring data and the GasSim model predictions supports the assessment that the landfill poses a residual ground gas risk to the proposed development and therefore mitigation measures will need to be incorporated into the proposed development to control the potential long-term risks.

4.5 Gas risks to proposed development

4.5.1 The assessment of the gas monitoring data and GasSim modelling has identified that the landfill is past the stage of peak gas generation. Whilst there are high concentrations of bulk landfill gases (CO_2 and CH_4) within the waste, there are low or negligible standpipe emission flow rates, indicating low/very low rates of continuing biodegradation of residual organic matter.

4.5.2 A methane/carbon dioxide assessment of CS4 is considered protective of the landfill area. While CS4 was only encountered on rare occasions within the landfill, it is considered that this will allow for any changes to the gas regime within the landfill as a result of the proposed earthworks and construction to be mitigated. The development areas outside of the landfill can be considered as CS2 due to the low concentrations of ground gases recorded in this part of the site, which is considered low risk. Based on the gas regime across the development site, gas protection measures will be required within all new buildings proposed for the site. The measures proposed for gas protection are discussed in **Section 1.**

4.5.3 The proposed development will involve a programme of major earthworks across the landfill in order to create a development platforms. A large volume (approximately 350,000 m^3) of landfill material will need to be excavated and processed. On completion landfill material will remain under the platforms created for buildings, roads and part of the new apron.

4.5.4 The area to be excavated to create the development platform for the new apron is anticipated to generally comprise 1950s to 1960s waste which is estimated to have a very low gassing potential. However, there may still be some degradable content remaining. At present it is not easily accessible to bacteria and therefore the degradation rates are low. If the material is excavated and processed the degradable material can become available to bacteria and gas generation can re-start at rates which may not be suitable for the proposed development. Although this is likely to be temporary effect, the time to return to low levels of gas generation are unpredictable.

4.5.5 To manage this as part of the reprocessing works, the total organic content (TOC) of the fill material used within the development platform must be controlled following the guidance in CL:AIRE RB17 (Ref. 15) and BS8584:2015+A1:2019 (Ref. 18). Validation criteria for materials to be used in the development platform is defined in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. A period of post-earthworks gas monitoring should also be undertaken to validate the gas regime on site, to ensure the proposed gas protection measures are still sufficiently protective.

4.5.6 In its current state there is no evidence of significant landfill gas migration beyond the landfill which could be considered to pose a risk to other receptors (e.g. neighbouring airport buildings and residential areas). However, it is possible that the proposed development on the landfill could increase the risk of gas migration to offsite receptors due to surcharging the surface of the landfill.

4.5.7 Work completed on other sites (Ref. 19) has indicated that a 3-6 m surcharge of shallow made ground containing ground gases increases soil gas pressure and seals the gas surface which has the effect of causing increased lateral migration from the gas source. It has been predicted that in low to moderate permeability soils increased surface emissions will occur within 5-10 m from the edge of the surcharged area.

4.5.8 It is not possible to predict the impact surcharging of the landfill due to the proposed development will have on the gas migration off-site. Therefore, in order to mitigate any potential risks to off-site properties mitigation measures along the boundaries of the landfill should be incorporated into the proposed development.

5 SOIL GAS VAPOURS

5.1 Background

5.1.1 Microbial action on biodegradable wastes under anaerobic conditions generates methane and carbon dioxide as bulk gases as discussed above in **Section 4**. However, small amounts of other gases are also present in landfill gas. These trace components may arise from volatilisation of materials in the waste or can be formed through biochemical reactions associated with the degradation processes. In total, these trace components generally make up less than one percent of the volume of the gas emitted from the waste in a landfill. However, the impact of some trace gases on the environment and on human health may be more significant than that of the bulk gases (Ref. 20).

5.1.2 Over 500 substances have been reported in landfill gases (Ref. 21). These include:

a. Higher alkanes and alkenes;
b. Ketones;
c. Cycloalkanes and cycloalkenes;
d. Esters;
e. Aromatic, cyclic aromatic and polycyclic aromatic hydrocarbons and derivatives;
f. Organosulphur compounds;
g. Organohalogens;
h. Oxygenated compounds;
i. Alcohols; and
j. Aldehydes.

5.1.3 Soil gas vapour samples were taken during the GI works using the methods recommended within Environment Agency guidance (Ref. 21), see locations on **Figure 3** of this document. There are no published UK guideline values for comparison to measured soil gas vapour concentrations, therefore GQRA of the soil gas vapour measurements was not possible. The methodology to assess the soil gas vapour measurements is discussed below.

5.2 Methodology

5.2.1 Measurements of soil gas vapour concentrations were taken from boreholes on the landfill. Due to the high number of compounds which exceeded the limit of detection a methodology based on Environment Agency Technical Report P1-491-TR (Ref. 22) was used to identify priority contaminants for further assessment using CLEA software (version v.1.071) (Ref. 23).

5.2.2 The CLEA model (Ref. 23) has been used in 'ratio mode' whereby a starting concentration is input into the model which calculates an associated predicted daily dose in mg/kg body weight (bw)/day for the receptor under evaluation (the ADE). The maximum measured concentration of vapour in the well has been used in the assessment or the limit of detection, whichever is the greater. The predicted daily dose is then divided by the acceptable daily dose within the CLEA model (Ref. 23) to calculate a Hazard Index (HI). A HI greater than 1.0 indicates a potential risk and further consideration is required. A HI of less than 1.0 indicates that the vapour concentration does not pose a potential risk to future users of the site.

5.2.3 The majority of contaminants detected within the soil gas already have chemical and toxicological data available within the CLEA model (Ref. 23) as GACs have been derived for these contaminants. Where there was no data, a range of literature sources have been reviewed and applicable chemical properties have been adopted where possible, in line with Science Report 2 (Ref. 24).

5.2.4 The soil gas vapour CLEA assessment, along with the key chemical and toxicological properties, and methodology for deriving priority compounds, is presented in **Appendix D** of this document.

5.3 Results

Human health risk assessment

5.3.1 The results of the soil vapour assessment are shown in **Table 5.1** below. None of the soil vapour concentrations have a hazard index greater than 1.0, indicating that the soil vapours are unlikely to pose a risk to future occupants of the site. The CLEA model assessment used to assess the soil vapour concentrations is provided in **Appendix D** of this document.

Table 5.1: Priority Trace Compounds assessed using CLEA v.1.071

Compound	Max. $\mu g/m^3$	No. > LOD	Location	Hazard Index
Vinyl Chloride (chloroethene)	1730	13	WS224	0.03
Benzene	1040	38	WS206	0.00**
Chloroethane	1220	14	BH207	0.00
Arsenic	200***	1	BH06	0.00**
Trichloroethene (TCE)	1080	5	BWS216	0.01
1,1-Dichloroethene (1,1-Dichloroethylene)	267*	3	BH220	0.00
Hydrogen sulphide	13500+	79	BH08G/ BH03G	0.16
Carbon Disulphide	783	18	BH207	0.00
1,1-Dichloroethane	300	4	BH207	0.00
Carbon Tetrachloride (tetrachloromethane)	423*	1	BH220	0.00
1,3-Butadiene	148*	1	BH220	0.00
Formaldehyde (Methanal)	50***	3	BH07	0.00
Mercury	1.3***	1	BH03	0.00
Chloromethane	137*	1	BH220	0.00

Compound	Max. $\mu g/m^3$	No. > LOD	Location	Hazard Index
Dichloromethane (Methylene Chloride)	703	7	BH203	0.00
Tetrachloroethene (PCE)	456*	20	BH220	0.00
Dichlorodifluoromethane (F-12)	2580	25	BH213	0.00
Styrene	286*	1	BH220	0.00
1,2-Dichloroethane (1,2-DCA)	272*	1	BH220	0.01
n-Hexane	6320	35	WS224	0.00
Trichlorofluoromethane (F-11)	1420	16	BH207	0.00
1,1,2,2-Tetrachloroethane	1300	6	BH08G	0.00
1,4-Dichlorobenzene	588	5	BH08G	0.00
Chloroform (trichloromethane)	327*	3	BH220	0.00
trans-1,2-Dichloroethene	267*	2	BH220	0.00
Toluene	2060	34	WS224	0.00
Ethylbenzene	5330	31	BH216	0.00
Xylene, m/p-	101000	54	WS206	0.00
Xylene, o-	2070	25	BH220	0.00
TPH-aliphatic EC5-EC6	62200	28	BH08	0.00
TPH-aliphatic EC6-EC8	50200	27	BH08	0.00
TPH-aliphatic EC8-EC10	71600	25	BH08G	0.00
TPH-aliphatic EC10-EC12	22100	19	BH08	0.00
TPH-aromatic EC5-EC7	472*	8	BH08	0.00
TPH-aromatic EC7-EC8	642*	10	BH08	0.00
TPH -aromatic EC8-EC10	5220*	12	BH08	0.00
TPH-aromatic EC10-EC12	8910*	0	BH08	0.00
* Highest LOD used ** Soil saturation limit exceeded *** Converted from mg + Includes spot monitoring data from gas monitoring to obtain reasonable worst case				

Age and odour assessment

5.3.2 An age and odour assessment has been completed on the monitoring results, the full results are provided in **Appendix E** of this document. The VOC concentrations recorded for the former landfill are lower than those in a typical landfill as obtained from literature (Ref. 17), in some instances by several orders of magnitude, see examples in **Table 5.2** below.

Table 5.2: Average concentrations of trace components of landfill gas compared to concentrations recorded in former landfill.

Compound	Typical Landfill VOC Concentrations			Luton Rising Landfill Monitoring Results		
	Chemical Group	Median µg/m³	Average µg/m³	Median* µg/m³	Average* µg/m³	Max * µg/m³
1,1-Dichloroethane	HO	13,260	476,223	95.35	113.5	300
Chlorobenzene	HO	11,880	246,589	108.5	126.23	311
1,1,1-Trichloroethane	HO	12,905	189,826	128.5	153.30	490
Hydrogen sulphide	SC	2,833	134,233	150**	255**	3690**
Tetrachloroethene	HO	16,640	112,746	161.50	197.67	456
Toluene	AH	11,995	86,221	158.0	203.69	2060
Xylene	AH	4,700	23,900	182.50+	210.41+	2070+
				192.0++	2872.86++	101000++
n-butane	Alk	13,623	67,412	2828**	4810**	18100**
n-hexane	Alk	5,000	19,850	242.50	804.53	6320

Notes:
HO- halogenated organics SC- sulphured compounds AH-aromatic hydrocarbons Alk-alkanes
* using LODs as values **converted from ppm +ortho ++meta/para

5.3.3 The age assessment is based on the relative proportions of chemical groups found within the samples. The VOC results are dominated (>60%) by alkanes, studies completed by the EA (Ref. 22) indicate high concentrations of alkanes are representative of old landfill waste.

5.3.4 The low VOC concentrations, high methane (in places) and low H_2S which have been recorded in the former landfill are also indicative of methanogenic conditions, which appears to be still actively producing gases in some areas of the landfill.

5.3.5 An odour assessment (presented in **Appendix E** of this document) was completed for compounds with an odour threshold criterion (Ref. 22). Fourteen samples were found to have concentrations greater than the odour detection limit, of these, two chemicals (CS_2 and dimethyl sulphide (C_2H_6S)) have an odour importance of 6 or greater (10 being the maximum). Unfortunately, no odour rank was available for the remaining chemical exceedances. This indicates there could be a risk of strong odours arising from any earthworks undertaken on site, which is considered in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

5.3.6 A simple assessment on the total thickness of waste and total concentration of volatiles was undertaken to identify any correlations. It was found that there is a positive correlation between landfill waste thickness and total concentration of volatiles.

5.3.7 The data was further interrogated (**Appendix E** of this document) to highlight any correlations between the type of landfill waste present within each borehole and the chemical composition of the gas sampled. No ‘chemical fingerprint’ was identified for each waste type, however domestic waste appeared to typically have high total volatile concentrations.

5.3.8 A large proportion of the results in the dataset were below the limit of detection, which varied between samples and boreholes. Therefore, all assessments were run twice; using a dataset which included samples with values as the LOD and a second using a dataset with only those results above the LOD. The outcome for each assessment did not vary significantly between the two datasets.

5.4 Summary

5.4.1 The results show none of the soil vapour concentrations have a HI greater than 1.0, indicating the soil vapours are unlikely to pose a risk to future occupants of the site. The model is run assuming assessment of inhalation of indoor vapour and therefore the results indicate a vapour membrane will not be required within the development.

5.4.2 Monitoring of trace gases was completed over an 8-month period with samples taken from 18 boreholes located across the landfill with response zones in all waste eras and types. The data on which the risk assessment is based is considered comprehensive and a good representation of current conditions and adequate to inform the risk assessment**,** see **Section 11** of the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**.

5.4.3 However, due to the variable nature of the fills and potential for variability in vapour generation over time, vapour monitoring will be continued; prior to commencement of earthworks and during construction works to confirm this assessment, further detail is included in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. Post earthworks verification monitoring will also be completed, and the results assessed to confirm whether a vapour membrane will be required in the development

5.4.4 The age assessment of the likely age of the landfill also supports the assertion that the landfill waste is old and the source term is nearing depletion.

5.4.5 The odour assessment, **Section 5.3** and **Appendix E** of this document indicates odour suppression techniques are likely to be required during the excavation works.

6 GAS PROTECTION MEASURES

6.1.1 The gas risk assessment presented in **Section 4** above identified the requirement for gas protection measures to be incorporated into the proposed development to mitigate any potential risks from ground gases.

6.1.2 Gas protection measures will need to be incorporated into all new buildings and infrastructure on site. Mitigation is also required to prevent any lateral migration of ground gases reaching off-site receptors i.e. residential areas to the north and the adjacent airport.

6.1.3 The gas protection requirements considered for the proposed development are discussed in the following sections and have been developed in accordance with guidance in BS8485 (Ref. 18).

6.2 General design considerations

6.2.1 The design considerations include the following:

a. The potential risks from the bulk landfill gases (CH_4 and CO_2) arise if they accumulate in enclosed spaces below or above ground (in buildings or services spaces) at harmful concentrations;
b. The excavation of significant quantities of waste and loading of the landfill with the development has the potential to alter the current ground gas regime. Placement of fill materials during earthworks should be carefully controlled;
c. The objectives of the landfill gas management strategy should therefore be to preclude the migration and build-up of CH4 and CO2 in enclosed spaces by a combination of barriers and preferential pathway venting;
d. Natural (passive) systems of venting are always preferable to active venting, provided they are sufficiently effective;
e. It is assumed that low level vent points, such as airbricks, bollard vents and ground level vertical or trench gravel drains will be acceptable in public open space areas, due to the negligible levels of VOCs;
f. The gas management measures will need to be integrated with the geotechnical and structural design of the buildings and pavements, and with the requirement to minimise surface water infiltration into the underlying waste;
g. It is assumed that all surface water falling on buildings and hard paved areas will be collected by a positive drainage system and directed to the surface water sewer via attenuation tanks; and
h. It should be possible to select an appropriate gas protection membrane which will also serve as the damp proof membrane, beneath buildings.

6.3 Gas management for buildings

6.3.1 The objective for all buildings is to provide multi-element protection to prevent landfill gases from entering into the building and to provide a “pressure relief pathway" for gases to discharge safely beyond the edges of the building. Each of the buildings should be considered on a case-by-case basis, taking into account: the depth and nature of the landfill, GI results, the form and size of the building, the foundation and floor slab structural design, the size, use and ventilation of internal spaces and any other relevant details.

6.3.2 BS8485 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings (Ref. 18) provides a methodology for determining suitable protection measures. This utilises the GSV values calculated as outlined in CIRIA C665 (Ref. 25) in conjunction with building type to determine a minimum gas protection score.

6.3.3 BS8485 (Ref. 18) attributes scores to protection measures, requiring a selection of a minimum of two measures with a combined score equal to or greater than the minimum gas protection score previously determined.

6.3.4 It has been assumed that the terminal building is a Type D building and smaller rooms within the terminal and the Green Horizons Park buildings may be considered to be Type C. The characteristics of these buildings from the descriptions in BS8485 (Ref. 18) are provided below:

a. "Type C building: commercial building with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, including the gas protection measures. Single occupancy of ground floor and basement areas. Small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas. Probably civil engineering construction. Examples include offices, some retail premises, and parts of some public buildings (such as schools, hospitals, leisure centre and parts of hotels)".
b. "Type D building: industrial style building having large volume internal space(s) that are well ventilated. Corporate ownership with building management controls on alterations to the ground floor and basement areas of the building and on maintenance of ground gas protective measures. Probably civil engineering construction. Examples are retail park sales buildings, factory shop floor areas, warehouses. (Small rooms within these style buildings should be separately categorized as Type B or Type C)."

6.3.5 **Table 6.1** below summarises the classifications and relevant protection scores for the Terminal and other buildings based on a worst case assumption of CS4.

Table 6.1: Minimum gas protection scores based on CS4 for proposed buildings.

Area	Building classification	Minimum gas protection score
Terminal building	Type D	3.5

Area	Building classification	Minimum gas protection score
Office buildings and smaller rooms within terminal building	Type C	4.5

6.3.6 When the minimum gas protection score has been determined for the building as a whole, or for each part of the building, then a combination of two or more of the following three types of protection measures should be used to achieve that score:

a. The structural barrier of the floor slab, or of the basement slab and walls if a basement is present;
b. Ventilation measures; and
c. Gas resistant membrane.

6.3.7 The sections below detail the potential protection measures options which could be used to achieve the required gas protection score.

6.4 Structural barrier

6.4.1 The foundations of the Terminal building structure may act as a barrier to ground gas. **Table 6.2** below summarises the potential gas protection scores as defined by BS8485 (Ref. 18) for structural barriers.

Table 6.2: Structural Barrier Protection Scores.

Structural Barrier Type	Protection Score
Precast suspended segmental subfloor (i.e. beam and block)	0
Cast in situ ground-bearing floor slab (with only nominal mesh reinforcement)	0.5
Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations	1.0 or 1.5*
Basement floor and walls conforming to BS 8102:2009, Grade 2 waterproofing	2.0
Basement floor and walls conforming to BS 8102:2009, Grade 3 waterproofing	2.5
*To achieve 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in. The scores are conditional on all breaches within the floor slabs effectively sealed	

6.4.2 The Terminal building and other buildings to be made on the landfill are likely to utilise piled foundations with a suspended floor slab. Based on **Table 6.2** above, a reinforced cast in situ suspended floor slab with minimal penetration and suitable reinforcement to prevent cracking would be able achieve a minimum gas protection score of 1.0.

6.5 Gas membrane

6.5.1 Gas resistant membranes can also be installed to achieve the minimum protection score (see **Table 6.3** below)**.** The effectiveness of the membrane is highly dependent on the quality and design of the installation, resistance to damage after installation and integrity of the joints.

Table 6.3: Gas Membrane Protection Score

Structural Barrier Type	Protection Score
Gas resistant membrane meeting all of the following criteria: • Sufficiently impervious both in sheeting material and in the sealing of sheets, and sealing around sheet penetrations, to prevent any significant passage of methane and/or carbon dioxide through the membrane. • Sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions. • Sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools.) and to withstand in-service stresses (e.g. settlement if placed below a floor slab). • Capable, after installation, of providing a complete barrier to the entry of relevant gas. • Verified in accordance with CIRIA C735 (Ref. 26).	2

6.5.2 It has been assumed that all buildings in the proposed development will be fitted with a suitable gas membrane.

6.6 Ventilation measures

6.6.1 Ventilation measures can be installed to help achieve the minimum gas protection score. A summary of potential solutions is shown in **Table 6.4** below.

Table 6.4: Ventilation Measures Protection Scores.

Ventilation protection measure	Protection Score
Pressure relief pathway (commonly formed of low fines gravel or with a thin geocomposite or strips terminating in a gravel trench external to the building)	0.5[1]
Passive sub floor dispersal layer: Very good performance Good performance Means of achieving this can be: clear void;	2.5 1.5[2]

Ventilation protection measure	Protection Score
polystyrene void former; geocomposite void former; and no fines gravel layer with gas drains.	
Active dispersal layer, usually comprising fans with active abstraction (suction) from a subfloor dilution layer, with roof level vents. The dilution layer may comprise a clear void or be formed of geocomposite or polystyrene void formers.	1.5 to 2.5[3]
Active positive pressurisation by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite layer.	1.5 to 2.5[4]
Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park).	4
[1] If it does not terminate in a venting trench then the score is zero. [2] Dependant on transmissivity of the medium, building with, ventilation spacing and type. Further information can be found in BS8485 (Ref. 18) [3] The system relies on continued serviceability of the pumps, therefore alarm and response systems should be in place. There should be robust management systems in place to ensure continued maintenance of the system, including pumps and vents. [4] The score assigned should be based on the efficient "coverage" of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet good performance.	

6.6.2 A pressure relief pathway layer (0.5 gas protection points) or passive gas dispersal layer (at least 1.0 gas protection points) should be installed beneath the membrane. The pressure relief pathway layer could be formed of either a layer of no/low fines granular material, a blanket of geocomposite void former or interleaved strips of geocomposite void former. It is important that the layer is terminated with effective vents at the perimeters of the building, for example with periscope airbricks, low level bollards or high (roof) level vent pipes. For Type C buildings in a CS4 situation, where 1.0 ventilation gas protection points are required, high (roof) level vents will probably be required.

6.6.3 For large buildings, such as the Terminal building, achieving passive sub floor ventilation is difficult as it requires maintaining continuous airflows underneath the full expanse of the building. The terminal building is currently proposed to have baggage handling and plant service areas on ground level which will be open to the sides. Therefore, it will have a significant amount of ventilation. However, until the detailed design of the terminal is finalised it has been assumed that an active dispersal layer is required.

6.7 Summary of gas protection requirements

6.7.1 **Table 6.5** below summarises potential options for ground gas protection measures to achieve the gas protection score for buildings associated with the proposed development.

Table 6.5: Summary of Ground Gas Protection Measures.

Area	Building type	Ground gas protection measures	Ground gas protection score	Total protection score	Required protection score
Terminal building	Type D	***Structural barrier (foundations)*** Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations	1.0-1.5	4.5-6	3.5
		Ventilation measures Active dispersal layer*	1.5-2.5		
		Gas membrane	2		
Office buildings and smaller rooms within terminal building	Type C	***Structural barrier (foundations)*** Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations	1.0-1.5	4.5-6.0	4.5
		Ventilation measures Passive sub floor dispersal layer	1.5-2.5		
		Gas membrane	2		
* Once design of ground floor terminal is confirmed it may be possible to assume ventilated and achieve score of 4.					

6.7.2 **Table 6.5** above indicates that sufficient ground gas protection including allowing for redundancy in the design can be achieved for the buildings proposed on the site. This is based on initial conservative assumptions regarding the gassing potential of the former landfill and conservative assumptions regarding building design.

6.8 Gas management for hard paved areas

6.8.1 Below hard paved areas it is recommended that a high permeability gas pathway/venting layer is installed across the area at the top of the landfill waste. This would be vented via a network of gravel filled vertical drains, gravel filled trenches (or bollard type low level vents in areas where these are more suitable).

6.8.2 The multi-storey car park (MSCP) can be regarded as a hard-paved area and not as a building.

6.9 Gas management for landscaped areas

6.9.1 It is assumed that soft landscaped areas will have a geomembrane or a clay fill layer installed to prevent surface water infiltration into the underlying waste. This low permeability layer will confine additional landfill gases generated and potentially cause them to migrate laterally. In view of this, a passive pressure relief layer should be installed below the geomembrane leading to vents at the perimeters of the areas.

6.10 Gas management for the Luton DART tunnel

6.10.1 The Luton Direct Air to Rail Transit (DART) is a new cable-hauled fast passenger transit connecting Luton Airport Parkway station to the airport (the announcement of an official opening date will be made in early 2023).

6.10.2 This structure should be protected by a combination of:

a. Appropriate structural detailing of the tunnel (to resist gas ingress);
b. An external gas membrane tanking of the tunnel; and
c. The high level of internal ventilation that will be provided.

6.11 Gas management for aviation apron

6.11.1 The aviation apron will be partially constructed over landfill and therefore will also require gas protection measures to prevent build up of gases beneath the pavement.

6.11.2 Venting gases within the area of aviation is undesirable from an aviation operation perspective. Therefore, where landfill is present beneath the proposed apron area, it is recommended that the high permeability ‘gas pathway/venting layer’ is installed across the area. This would be vented via a network of gravel trenches, located in areas away from the stands and taxiways and would diffuse gases away preventing any build up.

6.11.3 Further details will need to be developed at the detailed design stage alongside the development of the design for the aviation apron.

6.12 Gas management for off-site properties

6.12.1 The proposed development has the potential to alter the current ground gas regime within the landfill and increase the potential for lateral migration of ground gas which could pose a risk to off-site properties including the residential area to the north of the site. Landfill boundary gas protection measures should be incorporated into the development to mitigate against any potential risks. This will likely be in the form of a vent trench or barrier.

6.12.2 The presence of other services i.e. old drains/utilities could provide potential preferential pathways and encourage gas migration off-site over greater distances. A strategy for detecting and treating services has been incorporated into the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

7 REVISED CONCEPTUAL SITE MODEL

7.1.1 The conceptual site model summarised in **Section 2.1** has been updated following the risk assessments detailed in this report. The updated CSM with respect to human health PCLs is provided in **Table 7.1** below.

7.1.2 The PCLs have been classified as follows, consistent with the GQRA (Ref. 2) (**Appendix 17.2**) of the ES **[TR020001/APP/5.02]**:

	Confirmed relevant pollutant linkage (RCL) requires inclusion in ORS.
	PCL requires further consideration through Detailed Quantitative Risk Assessment (DQRA).
	Impact is possible but can be mitigated by design and/or managed under an alternative regime such as permitted operation or occupational safety. Measure should be included in the ORS.
	Impact ruled out no further assessment required.

Table 7.1: Updated human health CSM.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
On-site						
1	DEV	Ground gases from former landfill e.g. methane	Migration into future buildings and aviation apron resulting in build-up of gases	Users of future development – public/airport operatives/ Green Horizons Park users- risk of explosion	Moderate	High concentrations of bulk landfill gases (carbon dioxide and methane) were recorded within the waste but there are low or negligible standpipe emission flow rates, indicating low/very low rates of continuing biodegradation of residual organic matter. A methane/carbon dioxide of CS4 (maximum) is considered protective – many parts of the site might be only CS2 or CS3. Gas protection measures are required in proposed buildings consistent with those detailed in **Section 6** of this document and BS8485.
2	DEV CON		Migration off-site	Adjacent site users (e.g. residential housing and other buildings on the airport, WVP Community Centre/ pavilion)-	Low/ Moderate	Results to not suggest a current potential risk from gas migration but the proposed development may increase the potential risk of migration therefore boundary mitigation measures are required. Measures will be required to treat existing preferential pathways e.g. TVD.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
				- risk of explosion		
11	CON	Waste in former landfill Waste in former landfill	Inhalation of vapours	Construction workers	Low	The GI provided sufficient information to characterise the potential risks from soils vapours. No elevated soil vapours were identified. However, due to the variable nature of landfill and potential for variability in vapour generation over time, vapour monitoring should be continued; prior to, during and post earthworks to confirm this assessment. A detailed monitoring strategy is included in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. In addition, due to the heterogenous nature of the landfill, the ORS includes measures to detect and appropriately deal with material encountered which is different from those assessed and may have high vapour generation potential. The odour assessment indicates odour suppression techniques are likely to be required during the excavation works. Any future works should have an odour management plan in place to control any odours generated during works.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
12	DEV			Future maintenance workers	Low	The GI provided sufficient information to characterise the potential risks from soils vapours. No elevated soil vapours identified during DQRA assessment which could be considered to pose a risk to the future development. Post earthworks monitoring will be undertaken to confirm assessment. A detailed monitoring strategy is included in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. If elevated concentrations are detected post earthworks the need for specific mitigation measures to prevent vapour intrusion into buildings should be reassessed.
13	DEV			Users of future development – public/airport operatives/Green Horizons Park users	Low	
14	DEV		Inhalation of airborne contaminants/ dust/ asbestos fibres and microorganisms	Users of future development – public/airport operatives/Green Horizons Park users	Low	The future development will comprise buildings & hardstanding, therefore there is unlikely to be any contact with landfilled wastes. However, given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required, particularly in landscape areas to prevent generation of dusts which may contain asbestos fibres.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
15	CON	Waste in former landfill Waste in former landfill		Adjacent site users (e.g. residential housing, Luton Airport visitors and operatives, users of WVP)	Low	The GI provided sufficient information to characterise the condition of asbestos present within the landfill and inform this assessment. Overall the risk is considered to be low based on; the ACMs types encountered, their degradation state and fibre content. However, it is recognised that the landfill is heterogenous in nature and as such localised areas of increased frequency of ACMs may exist. Future works will require significant movement of waste i.e. for waste processing/re-engineering, therefore there is the potential for generation of airborne contaminants, which could affect adjacent site users. Careful consideration of techniques for waste processing/re-engineering will be required to minimise dust production, as well as good site management practices, monitoring and mitigation measures to reduce the potential risk. Any future works should have appropriate Environmental Management Plans in place to include perimeter monitoring, with adoption of additional control measures as necessary.

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
16	CON			Construction workers	Moderate	The GI provided sufficient information to characterise the condition of asbestos present within the landfill/Made Ground and inform this assessment, but it is recognised that the landfill/Made Ground is heterogenous in nature and as such localised areas of increased frequency of ACMs may exist. Therefore, a strategy for managing ACMs was developed as part of a ORS for the works (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. Due to the nature of the ACMs and frequency of occurrence being different between the former scrapyard area and the rest of the former landfill the risk management strategy for these areas may vary. Construction workers are likely to be exposed to areas of landfill waste during future excavation. Any excavation work would adopt appropriate site management protocols and PPE to include personal monitoring and protection against airborne asbestos fibres as necessary based on outcome of risk assessments.
31	CON	Contaminants in Made Ground (car park, capping material)	Inhalation of soil derived dusts/asbestos fibres	Construction workers	Moderate	

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
32	DEV	Contaminants in Made Ground (car park, capping material)		Future maintenance workers	Low	The future development will comprise buildings & hardstanding, therefore there is unlikely to be the potential for generation of soil derived dusts. Maintenance workers may be exposed to areas of Made Ground during future excavation. This can be reduced by placing of services in a clean cover system and adoption of appropriate site management protocols and PPE.
33	DEV			Users of future development – public/ airport workers/users of Green Horizons Park	Low	The future development will comprise buildings & hardstanding, therefore there is unlikely to be the potential for generation of soil derived dusts. However, given the heterogeneous nature of landfills and the lack of engineered cover system, it should be assumed that measures will be required, particularly in landscape areas to prevent generation of dusts which may contain asbestos fibres.
34	CON			Adjacent site users (e.g. residential housing, the airport, WVP)	Low	The GI provided sufficient information to characterise the condition of asbestos present within the Made Ground and inform this assessment. Overall the risk is considered to be low based on; the ACMs types encountered, their degradation state and fibre

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
						content. However, it is recognised that Made Ground is heterogenous in nature and as such localised areas of increased frequency of ACMs may exist. Future works will require significant movement of material, therefore there is the potential for generation of airborne contaminants, which could affect adjacent site users. Careful consideration of techniques will be required to minimise dust production, as well as good site management practices, monitoring and mitigation measures to reduce the potential risk. Any future works should have appropriate Environmental Management Plans in place to include perimeter monitoring, with adoption of additional control measures as necessary.
35	CON	Contaminants in Made Ground (car	Inhalation of vapours	Construction worker	Low	The GI provided sufficient information to characterise the potential risks from soils vapours. No elevated soil vapours were identified. However, due to the variable nature of Made Ground and potential for variability in vapour generation over time, vapour monitoring should be continued; prior to, during and post earthworks to confirm this assessment. A monitoring strategy is included in the ORS (Ref. 4) (**Appendix 17.5** of the ES

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
		park, capping material)				**[TR020001/APP/5.02]**) further detail of the monitoring will be prepared by the lead contractor for agreement post DCO. The ORS includes measures to detect and appropriately deal with material encountered which is different from those assessed and may have high vapour generation potential.
36	DEV	Contaminants in Made Ground (car park, capping material)		Future maintenance workers	Low	The GI provided sufficient information to characterise the potential risks from soils vapours. No elevated soil vapours identified during DQRA assessment which could be considered to pose a risk to the future development. Post earthworks monitoring will be undertaken to confirm assessment. A detailed monitoring strategy is included in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. If elevated concentrations are detected post earthworks the need for specific mitigation measures to prevent vapour intrusion into buildings should be reassessed.
37	DEV			Users of future development – public/ airport workers/users of Green Horizons Park	Moderate/ Low	
38	DEV			Adjacent site users (e.g. residential housing, Luton	Low	DQRA indicated that risks from soil vapours is low. During construction works an appropriate Environmental Management Plan should be in place to include perimeter monitoring, with

PCL No.	Phase applicable to (see key)	Source	Pathway	Receptor	Qualitative Assessment of Risk	Justification of Qualitative Assessment of Risk
				Airport, WVP Buildings)		adoption of additional control measures as necessary. Post earthworks monitoring will be undertaken to confirm assessment.

KEY:
CON- PCL during excavation, remediation and construction phase
DEV- PCL associated with future use of Proposed Development

8 CONCLUSION AND RECOMMENDATIONS

8.1.1 A detailed assessment of the risk that the landfill presents to human health has been undertaken, it was based upon a cautious assessment of the GI data and reasonably conservative assumptions about ground conditions.

8.1.2 The proposed development will involve a programme of major earthworks across the south of the landfill in order to create a development platform. A large volume (approximately 350,000 m^3) of landfill material will need to be excavated and processed. The potential risks to human health associated with these earthworks has been assessed as well as the potential risks to future and adjacent users of the development.

8.1.3 The GI gathered sufficient information to characterise the condition and chemistry of the landfill. However, it is recognised that the landfill is heterogenous in nature and as such localised accumulations of contaminants may exist. The ORS includes measures to detect and appropriately deal with such accumulations (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

8.1.4 The key conclusions of the detailed assessment are presented in the Sections below.

8.2 Asbestos in soils

8.2.1 No gross asbestos contamination was identified during the ground investigation, with only sporadic occurrences of visual asbestos identified in the soil.

8.2.2 In the landfill area asbestos was detected in 73 of 355 (21 %) representative soil samples taken from the different eras of waste.

8.2.3 The suspected ACMs visually identified within the landfill area mainly consisted of sporadic intact or weathered floor tile, cement or insulation board. Only a few potential observations of fibrous debris were noted. Where asbestos was detected under microscopic analysis, it was typically identified as very low or below limit of quantification concentrations. This suggests that the ACMs identified are largely intact, with little disaggregation of the bonded ACMs.

8.2.4 In the scrapyard area the asbestos was detected slightly more frequently. Out of the 17 exploratory locations, visual observations of ACMs were made in six of the locations (35%). The visual observations of asbestos were all located within the bund material surrounding the area of the current Tidy Tip. The suspected ACM visually identified mainly consisted of fibrous debris. Historical maps and previous reports suggest the bunds were formed when the scrapyard was cleared and levelled to form the Tidy Tip site. The suspected ACM visually identified fibrous disaggregated asbestos debris and cement board. Where the ACM was visually identified there was also some instances of the matrix surrounding the fibrous debris containing loose fibres. Where asbestos fibres were detected under microscopic analysis, it was typically identified as very low or below quantification concentrations.

8.2.5 Construction works has the highest potential to physically disturb any ACMs and ACS, therefore leading to an increased risk of fibre release. Using

CARSOIL™ (Ref. 6) guidance and JIWG (Ref. 7) DST a hazard and exposure ranking for the earthworks involving the soil and landfill material has been assessed to determine the anticipated preliminary licensing status for the works. The JIWG (Ref. 7) assessment indicated the overall hazard and exposure ranking was medium for both the landfill area and former scrapyard.

8.2.6 Sensitivity analysis was undertaken in the JIWG DST, which indicated that even assuming the worst-case scenario of clearly identifiable insultation or lagging with a high respirable fibre index the work would be still be considered non-licensed work. Therefore, the preliminary licensing status for groundworks, including ground excavation is anticipated as non-licensable works (NLW). However, it may be prudent to assume some works may be Notifiable Non-Licensed Work (NNLW) so that this is planned as a contingency should certain conditions prevail. This is turn may limit the potential for delay due to the requirements for advance notifications and the associated procedures and assessments required.

8.2.7 The GI provided sufficient information to characterise the condition of asbestos present within the landfill and inform this assessment, but it is recognised that the landfill is heterogenous in nature and as such localised areas of increased frequency of ACMs may exist. Therefore, a strategy for managing ACMs was developed as part of a ORS for the works (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

8.2.8 A number of measures are recommended for the control of risks associated with asbestos during the works and after development. The enhanced measures include dampening down and dust suppression measures to prevent airborne asbestos fibres. The monitoring and management measures are detailed further in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

8.2.9 Potential risks to future users and maintenance workers are considered low as the development will be mainly hardstanding. The potential risk can be further controlled by ensuring that soils for use as backfill to service trenches and in areas of soft landscaping/tree pits should be free of asbestos.

8.3 Soil gas vapours

8.3.1 The GI provided sufficient information to characterise the potential risks from soils vapours. The vapour assessment results show none of the soil vapour concentrations have a HI greater than 1.0, indicating the soil vapours are unlikely to pose a risk to future occupants of the site. Therefore, a vapour membrane is unlikely to be required within the development. However, due to the variable nature of landfill and potential for variability in vapour generation over time, vapour monitoring should be continued; prior to, during and post earthworks to confirm this assessment. A detailed monitoring strategy is included in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

8.3.2 In addition, due to the heterogenous nature of the landfill, the ORS includes measures to detect and appropriately deal with material encountered which is different from those assessed and may have high vapour generation potential (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

8.3.3 The age assessment of the likely age of the landfill supports the assertion that the landfill waste is old and the source term is nearing depletion.

8.3.4 The odour assessment indicates there could be a risk of strong odours arising during any earthworks undertaken on site, this is considered in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**.

8.4 Ground gas

8.4.1 The assessment of the gas monitoring data and GasSim modelling has identified that the landfill is past the stage of peak gas generation. Whilst there are high concentrations of bulk landfill gases (CH_4 and CO_2) within the waste, there are low or negligible standpipe emission flow rates, indicating low/very low rates of continuing biodegradation of residual organic matter.

8.4.2 A CH_4/CO_2 of CS4 is considered protective of the landfill area. While CS4 was only encountered on rare occasions within the landfill, it is considered that this will allow for any changes to the gas regime within the landfill as a result of the proposed earthworks and construction to be mitigated The development areas outside of the landfill can be considered as CS2 due to the low concentrations of ground gases recorded in this part of the site, which is considered low risk. Based on the gas regime across the development site, gas protection measures will be required within all new buildings proposed for the site. A combination of measures is required to achieve the gas protection score for buildings associated with the proposed development. Other areas of the development located on the landfill will also require gas mitigation measures to prevent build up of gases, such as the aviation apron area.

8.4.3 The landfill waste which will be excavated as part of the earthworks is estimated to have a very low gassing potential. However, there may still be some degradable content remaining. At present it is not easily accessible to bacteria and therefore the degradation rates are low. If the material is excavated and processed the degradable material can become available to bacteria and gas generation can re-start at rates which may not be suitable for the proposed development. Although this is likely to be temporary effect, the time to return to low levels of gas generation are unpredictable.

8.4.4 Validation criteria for materials used in the development platform is defined in the ORS (Ref. 4) (**Appendix 17.5**) of the ES **[TR020001/APP/5.02]**. A period of post-earthworks gas monitoring should also be undertaken to validate the gas regime on site, to ensure the proposed gas protection measures are still sufficiently protective.

8.4.5 In its current state there is no evidence of significant landfill gas migration beyond the landfill which could be considered to pose a risk to other receptors (e.g. neighbouring airport buildings and residential areas). However, it is possible that the proposed development on the landfill could increase the risk of gas migration to offsite receptors due to surcharging the surface of the landfill. It is not possible to predict the impact surcharging of the landfill due to the proposed development will have on the gas migration off-site. Therefore, in order to mitigate any potential risks to off-site properties mitigation measures along the boundaries of the landfill should be incorporated into the proposed development.

Glossary/Abbreviations

Term	Definition
Abbreviations	
AAR	airport access road
ACM	asbestos containing material
ACoP	approved codes of practise
ACS	asbestos containing soils
AIB	asbestos insulating board
AOD	above ordnance datum
BS	British Standard
CL:AIRE	Contaminated Land: Applications in Real Environments
CIRIA	Construction Industry Research and Information Association
CLR	contaminated land report
CLEA	contaminated land exposure assessment
CPT	cone penetration test
CS	characteristic situation
CSM	conceptual site model
CWS	County wildlife site
Luton DART	Luton Direct Air-Rail Transport
DCO	Development Consent Order
DEFRA	Department of Environment Food and Rural Affairs
DST	decision support tool
DQRA	Detailed Quantitative Risk Assessment
ES	Environmental Statement
GAC	generic assessment criteria
GSV	gas screening value
GQRA	Generic Quantitative Risk Assessment
GI	ground investigation
HI	hazard index
LCRM	Land Contamination Risk Management
LOD	limit of detection
LoQ	limit of quantification
LLAOL	London Luton Airport Operator Limited
LW	licensed work
NLW	non-licensable work
NNLW	notifiable non-licensable work
ORS	Outline Remediation Strategy
PCL	potential contaminant linkage
PCOM	phase contrast optical microscopy
PFAS	per- and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulphonate
PPE	personal protective equipment
PRA	Preliminary Risk Assessment
RCL	relevant contaminant linkage

Abbreviations	
RPE	respiratory protective equipment
SALI	sporadic and low intensity
TPH	total petroleum hydrocarbons
TVD	Thames Valley Drain
UXO	unexploded ordnance
VOC	volatile organic compound
WVP	Wigmore Valley Park
Glossary	
Above ordnance datum (AOD)	Above ordnance datum (AOD) is a vertical measurement used by ordnance survey as the basis for deriving altitudes on maps, usually by comparison with the mean sea level.
Aquifer	An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt).
Application Site	The area covered by the proposed planning application boundary.
Beneficial (environmental) effect	An advantageous or positive effect to an environmental resource or receptor.
Conceptual Site Model (CSM)	A representation of the characterisation of a site in diagrammatic and/or written form that shows the possible relationships between the contaminants, pathway and receptors. This helps to evaluate the potential risks that the site poses given the intended operations and future use of the site.
Cumulative effects	Impacts that result from incremental changes caused by other present or reasonably foreseeable actions together with the project. NOTE: For the purpose of this guidance, a cumulative impact can arise as the result of the: a. Combined impact of a number of different environmental factors-specific impacts from a single project on a single receptor/resource b. Combined impact of a number of different projects within the vicinity (in combination with the environmental impact assessment project) on a single receptor/resource
Detailed assessment	Method applied to gain an in-depth appreciation of the beneficial and adverse consequences of the project and to inform project decisions. Detailed Assessments are likely to require detailed field surveys and/or quantified modelling techniques.

Glossary	
Development Consent Order (DCO)	A Development Consent Order (DCO) is the means of obtaining permission for developments categorised as Nationally Significant Infrastructure Projects. This includes energy, transport, water and waste projects.
Effect	Term used to express the result/consequence of an impact (expressed as the 'significance of effect').
Emission	A material that is expelled or released to the environment. Usually applied to gaseous or odorous discharges to the atmosphere.
Environment Agency	The Environment Agency is responsible for environmental protection and regulation in England and plays a central role in implementing the government's environmental strategy. The Environment Agency is the main body responsible for managing the regulation of major industry and waste, treatment of contaminated land, water quality and resources, fisheries, inland river, estuary and harbour navigations, and conservation and ecology. They are also responsible for managing the risk of flooding from main rivers, reservoirs, estuaries and the sea.
Environmental Statement (ES)	A statutory report (this document) produced by the developer including: a. A description of the project b. A description of the likely significant effects of the project on the environment c. A description of the features of the project and/or measures envisaged in order to avoid, prevent or reduce and, if possible, offset likely significant adverse effects on the environment d. A description of the reasonable alternatives e. A non-technical summary f. Any additional information relevant to the characteristics of a project
Gas Screening Values (GSV)	The product of the groundwater flow rate and gas concentration within a borehole.
Groundwater	Groundwater is the water present beneath Earth's surface in rock and soil pore spaces and in the fractures of rock formations.
Hardstanding	Ground improvement by the use of compacted stone or other materials which facilitates increased surface loading from vehicles or other plant.
Impact	The change or action. Either beneficial or adverse.
In-situ	In the natural, original or appropriate position.

Glossary	
Inert materials	Inert material is material which is neither chemically or biologically reactive and will not decompose. Examples of this are sand, drywall, and concrete. This has particular relevance to landfills as inert materials typically require lower disposal fees than biodegradable waste or hazardous waste.
Limit of Detection (LOD)	The lowest contaminant concentration that can be detected by the apparatus used, usually dependent on the resolution of the equipment.
Limit of Quantification (LoQ)	Stands for the smallest amount or lowest concentration of a contaminant that can be determined by means of analytical procedures with an established accuracy, precision and uncertainty.
Leachate	A liquid that forms within waste accumulations such as landfills that contain increased concentrations of contaminants, specifically heavy metals, ammoniacal nitrogen and organic compounds. It is therefore hazardous and either must be indefinitely contained within the landfill or collected and suitably disposed of.
Made Ground	Made Ground is an area where the pre-existing (natural or artificial) land surface is raised or filled by artificial deposits consisting of materials such as refuse, demolition rubble etc.
Main Application Site	The airport site excluding off-site works.
Mitigation measure	Measure aiming at preventing/reducing an adverse environmental effect.
Phase Contrast Optical Microscopy (PCOM)	A contrast-enhancing optical technique that can be utilized to produce high-contrast images of transparent specimens, such as asbestos fibres and microorganisms.
Piled foundation	A series of columns constructed or inserted into the ground to transmit structural loads to a lower level of the subsoil
Pile cap	Thick concrete pad rests on the pile
Pollutant	A substance that pollutes something, especially water or the atmosphere.
Potential contaminant linkage	The potential contaminant linkage determines how contaminant travels from the contaminant source to a receptor.

Glossary	
Preliminary Environmental Information (PEI) Report	The PEI Report was prepared in compliance with the EIA Regulations to enable the local community, any other interested person and stakeholders to understand the environmental effects of the Proposed Development and enable an informed response to the consultation. The document set out how each environmental topic area is being assessed, the potential environmental effects of the Proposed Development based on the information available at the time, and measures proposed to avoid or reduce such effects. This is to support consultees in developing an informed view of the likely significant environmental effects of the Proposed Development, and allow them to provide additional information for inclusion in the EIA.
Proposed Development	The proposed expansion of Luton Airport with new terminal and stands and associated developments (as described in **Chapter 4** of the ES **[TR020001/APP/5.01]**).
Receptor (sensitive)	A component of the natural, created, or built environment such as human
Residual effects	Those effects of the Proposed Development that cannot be mitigated following implementation of mitigation proposals.
Resource	A defined but generally collective environmental feature usually associated with soil, water, air, climatic factors, landscape, material assets, including the architectural and archaeological heritage that has potential to be affected by a project.
Surface water	Water that collects on the surface of the ground.
Trace Components	Chemical constituents present in soil gas or air at trace levels derived directly from materials present in waste materials in the subsurface or from degradation of waste.
Volatile Organic Compounds (VOC)	Organic compounds that are volatile under normal environmental/atmospheric conditions. They may be found in the ground in a solid or liquid phase form as well as in a gaseous phase form.

Glossary	
Waste	Waste is defined in Article 3(1) of the European Waste Framework Directive 2008/98/EC (OJL 312/3) as any substance or object which the holder discards or intends or is required to discard. The term ‘holder’ is defined under article 3(6) as ‘the waste producer or the natural or legal person who is in possession of the waste’. The waste ‘producer’ is defined under article 3(5) as ‘anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of the waste’. Waste can be further classified as hazardous, non-hazardous or inert.
Worst-case (scenario)	The definition of a ‘worst-case’ varies by the field to which it is being applied, however ultimately it is the most unfavourable foreseen scenario. Often assessments use a worst-case scenario.

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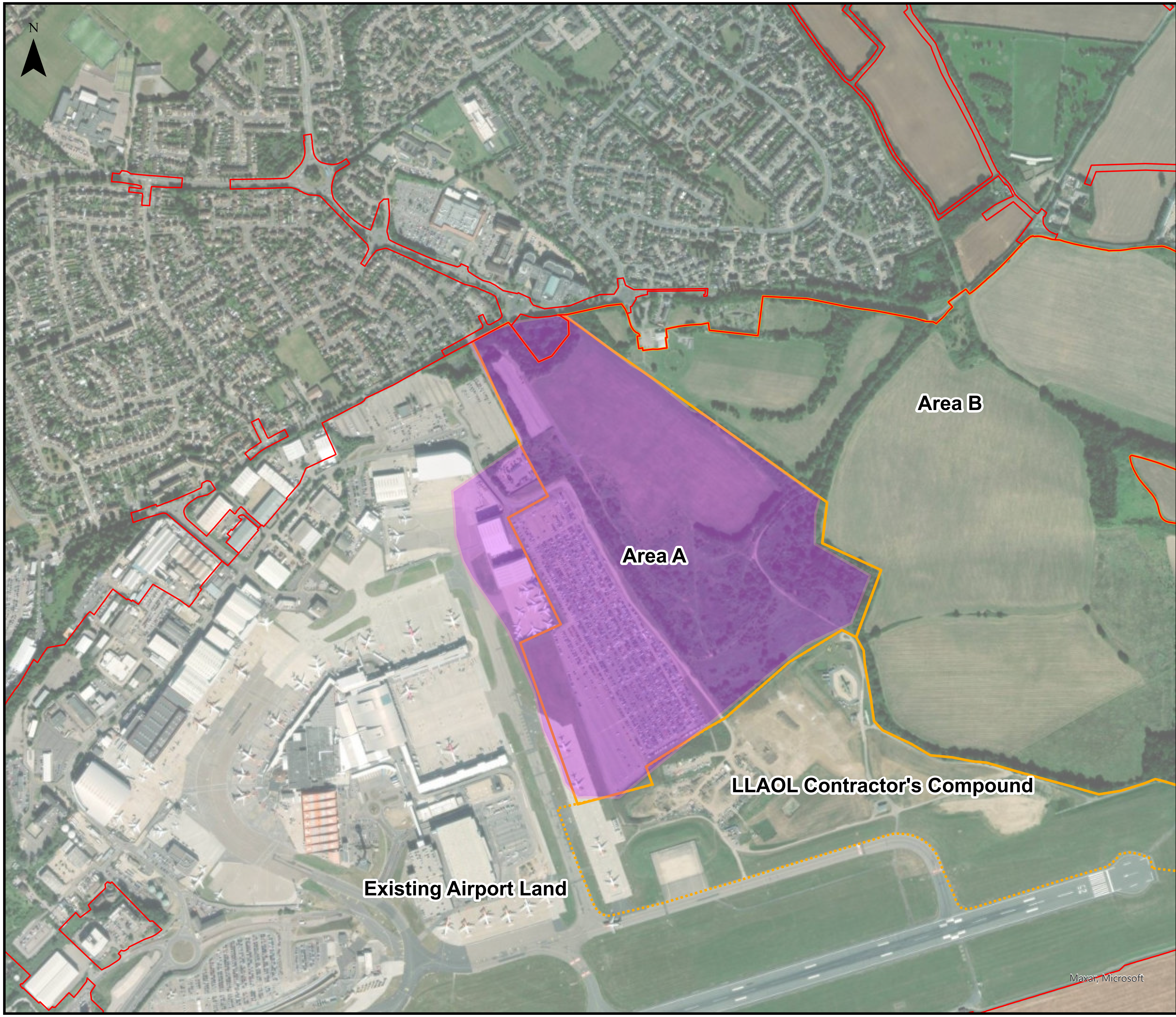
FIGURES



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

Legend

- Order Limits
- Interpreted Landfill Extent
- Site Subdivisions

First Issue	AB	RB TB	26/09/22	P02
Revision History	Drawn	Checked Approved	Date	Rev.

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London Luton Airport Expansion Development Consent Order

Drawing Title

Figure 1 Location of Landfill

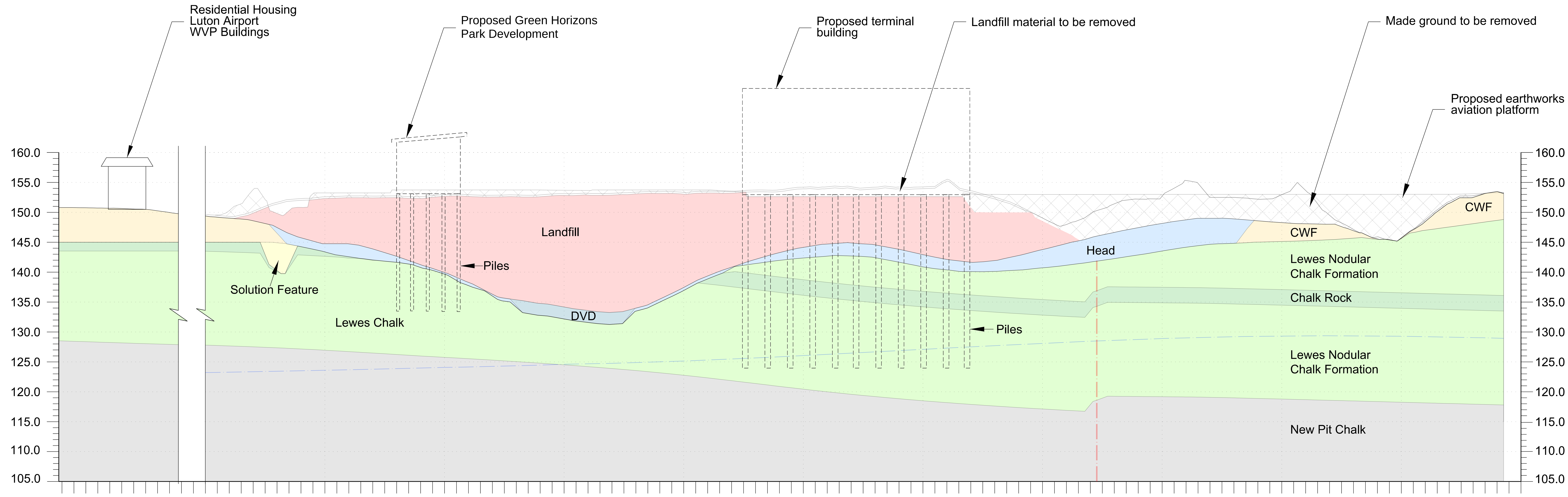
Purpose of issue				Suitability	
SUITABLE FOR INFORMATION				S2	
Drawn	Checked	Approved	Date	Scale	Size
AB	RB	TB	26/09/22	1:7,000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	APFP 5(2)(a)	TR020001/APP/5.03

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0176	P02

Project - Phase - Originator - Asset/Zone - Sub Asset - Type- Discp. - Number

Section A-A



Interactive Buttons

Please Note: This is an interactive PDF. Either the Conceptual Site Model Potential Contaminant Linkage No. (see GQRA Table 13-1) or the sources below can be clicked to display the relevant pathway and receptors.

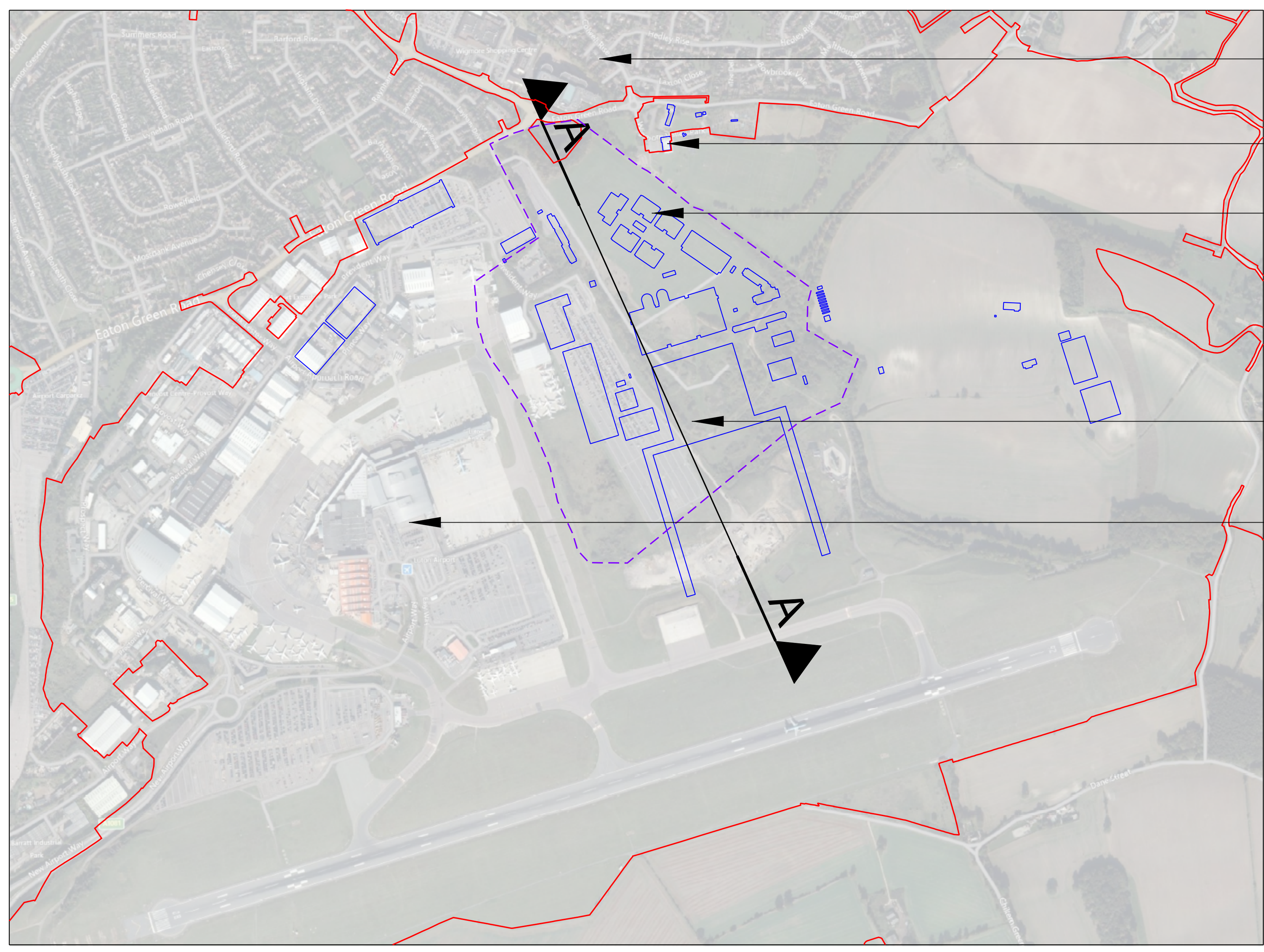
Conceptual Site Model Potential Contaminant Linkage No.

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41

PCL requires further consideration through Detailed Quantitative Risk Assessment (DQRA).

Sources	Pathways	Receptors
1 Landfill ground gas + vapour	i Migration	A Future site users
2 Volatile radionuclides in landfill	ii Inhalation	B Adjacent site users
3 Landfill waste	iii Dermal contact/ingestion	C Construction workers
4 Japanese knotweed	iv Driving of contaminants downwards by piling	D Future maintenance workers
5 Landfill leachate	v Direct contact	E Principal chalk aquifer
6 Perched water in landfill	vi Plant uptake	F Foundations /floor slabs and buried concrete
7 Made ground contaminants		G Planting
8 Contaminants in groundwater		H Potable water extraction
9 UXO		J Drainage and pavements

Legend



Residential housing
WVP Buildings
Proposed Green Horizons Park Development
Proposed terminal building
Luton Airport

Key Plan

Notes

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2. All levels are in metres above ordnance datum unless noted otherwise.
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It is intended to provide a guide as to likely ground conditions and as such should be regarded as indicative. It is recommended that design decisions made on the basis of this information are confirmed by investigation.
5. This is an interactive 2D PDF. For full interactivity it is recommended that the original digital version it is opened and viewed using Adobe Reader 7.0 or higher.
6. Bing Maps Aerial - © 2021 Microsoft Corporation © 2021 Maxar ©CNES (2021) Distribution Airbus DS

Revision History	Drawn	Checked / Approved	Date	Rev.
Issue	IJ	RB / TB	30/09/22	P02
Issue	IJ	RB / TB	16/12/21	P01

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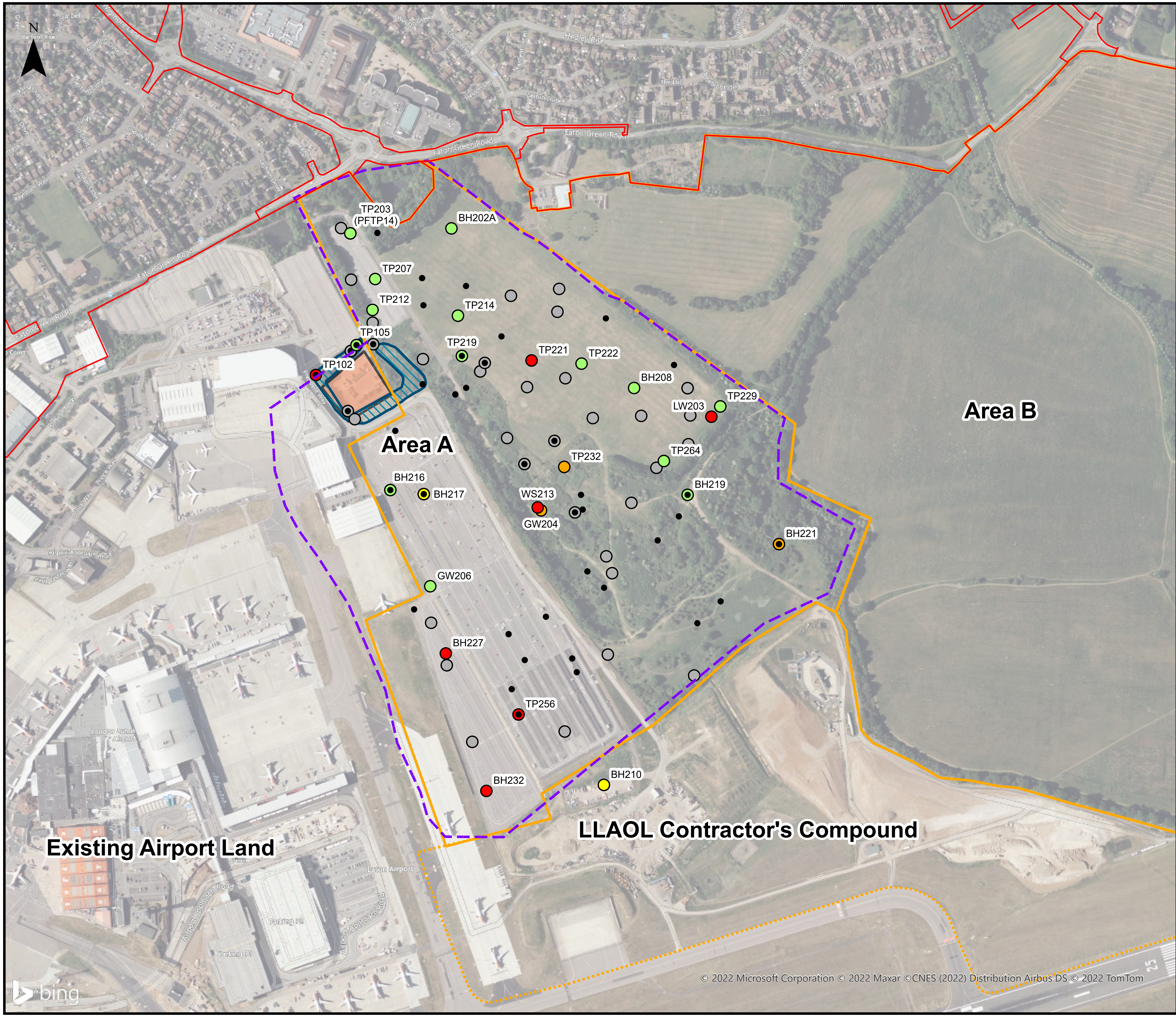
Drawing Title

Figure 02
Conceptual Site Model (CSM)

Purpose of issue				Suitability	
SUITABLE FOR COORDINATION				S2	
Drawn	Checked	Approved	Date	Scale	Size
IJ	RB	TB	30/09/22	NTS	A1
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001	APFP 5(2)(a)	TR020001/APP/5.03			

Drawing Number: LLADCO-3C-ARP-00-00-DR-YE-0177 (Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number)

Revision: P02



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

Legend

- Order Limits
- Site Subdivisions
- Former Scrapyard
- Existing bund
- Landfill boundary

Asbestos Quantification Results

- High (>0.1% w/w)
- Moderate (>0.05 - <0.1% w/w)
- Low (>0.01 - <0.05% w/w)
- Very Low (>0.001 - <0.01% w/w)
- Below quantification (<0.001% w/w)
- Visual observation of potential Asbestos containing material (ACM)

First Issue	AB	RB / TB	26/09/22	P02
Revision History	Drawn	Checked / Approved	Date	Rev.

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Drawing Title

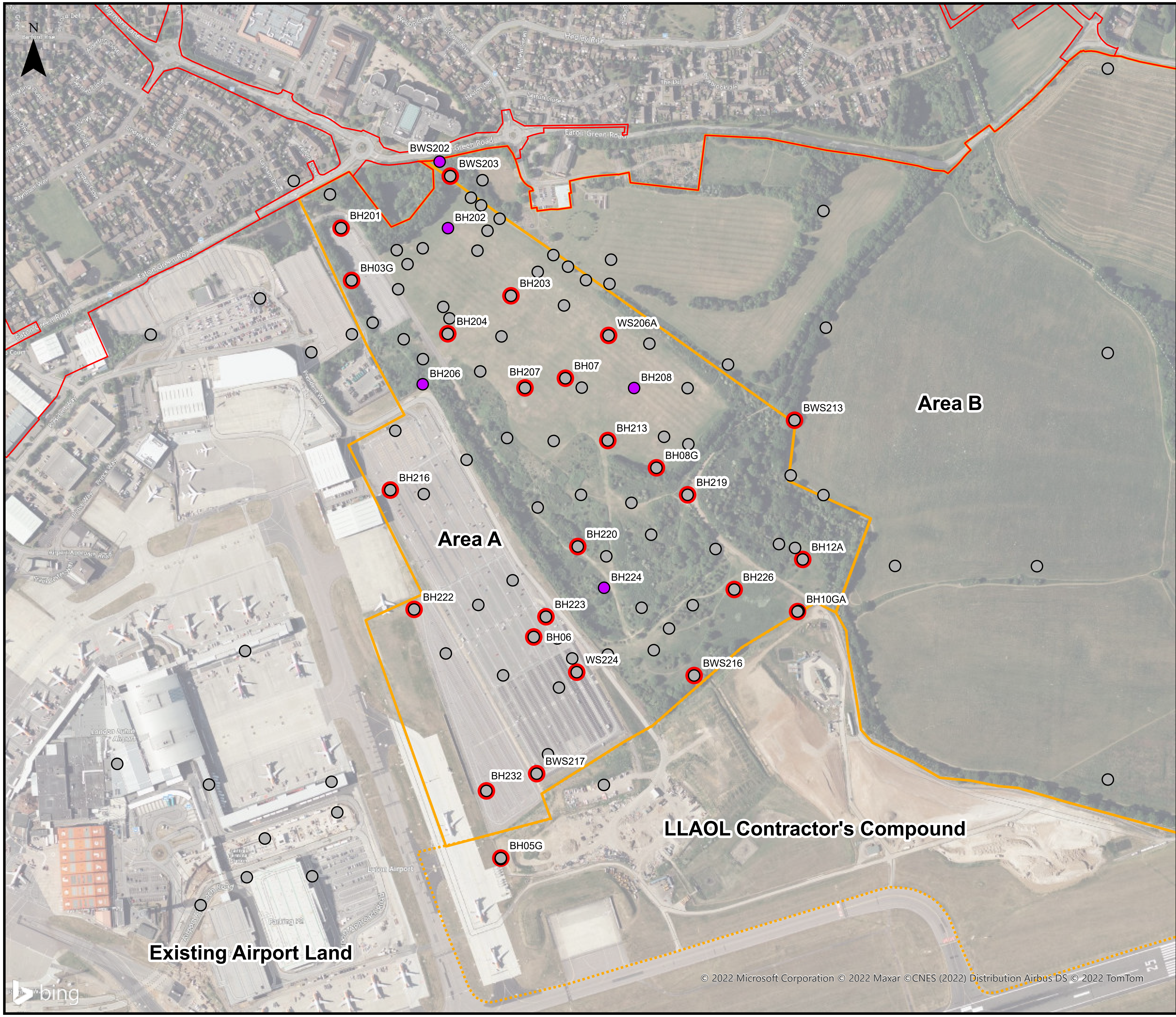
Figure 3
Asbestos in soil - Quantification Results

Purpose of issue					Suitability
SUITABLE FOR INFORMATION					S2
Drawn	Checked	Approved	Date	Scale	Size
AB	RB	TB	26/09/22	1:5,000	A3

DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	APFP 5(2)(a)	TR020001/APP/5.03

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0178	P02

Project - Phase - Originator - Asset/Zone - Sub Asset - Type- Discp. - Number



All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

Legend

Order Limits

Site Subdivisions

Ground Gas Monitoring

Continuous Monitoring

Spot Monitoring

VOC Monitoring wells

First Issue	AB	RB TB	26/09/22	P02
Revision History	Drawn	Checked Approved	Date	Rev.

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Drawing Title

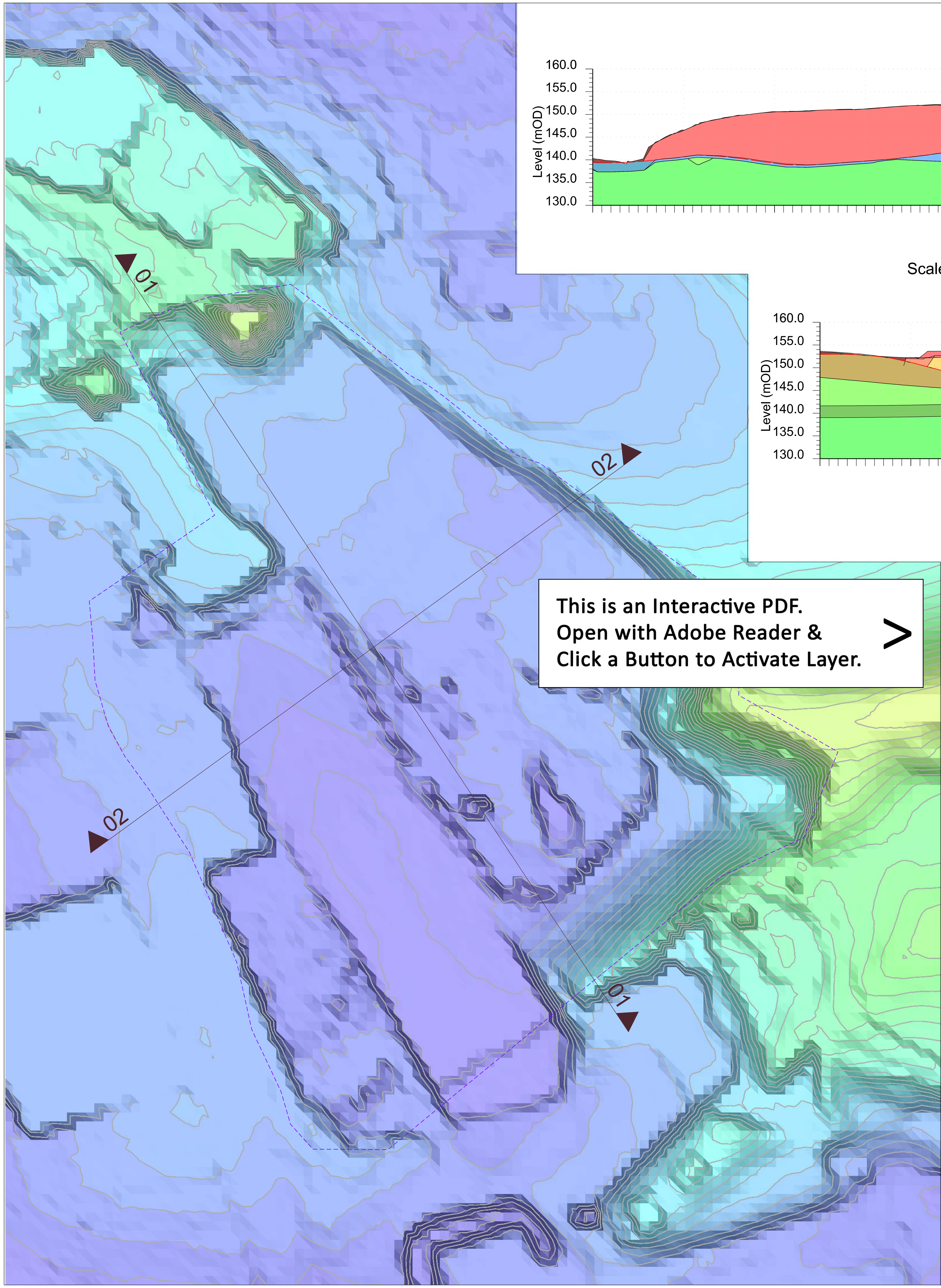
Figure 4 Gas Monitoring Locations

Purpose of issue					Suitability
SUITABLE FOR INFORMATION					S2
Drawn	Checked	Approved	Date	Scale	Size
AB	RB	TB	26/09/22	1:5,000	A3

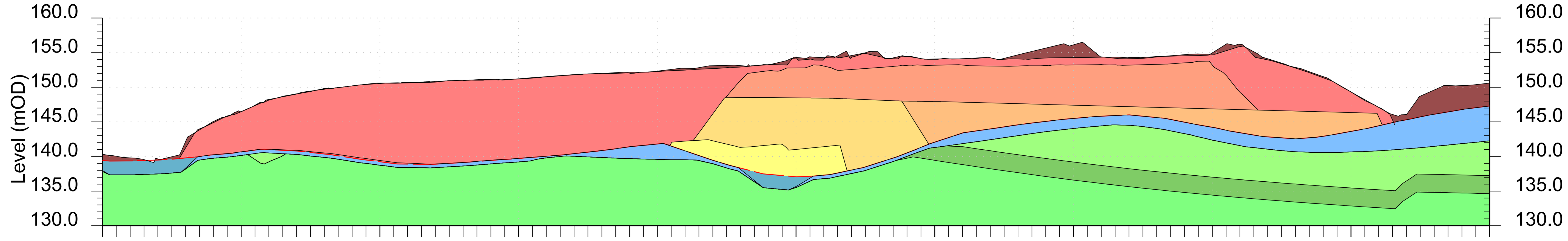
DCO Application Ref.	APFP Regulation	DCO Document Ref.
TR020001	APFP 5(2)(a)	TR020001/APP/5.03

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0290	P02

Project - Phase - Originator - Asset/Zone - Sub Asset - Type- Discp. - Number

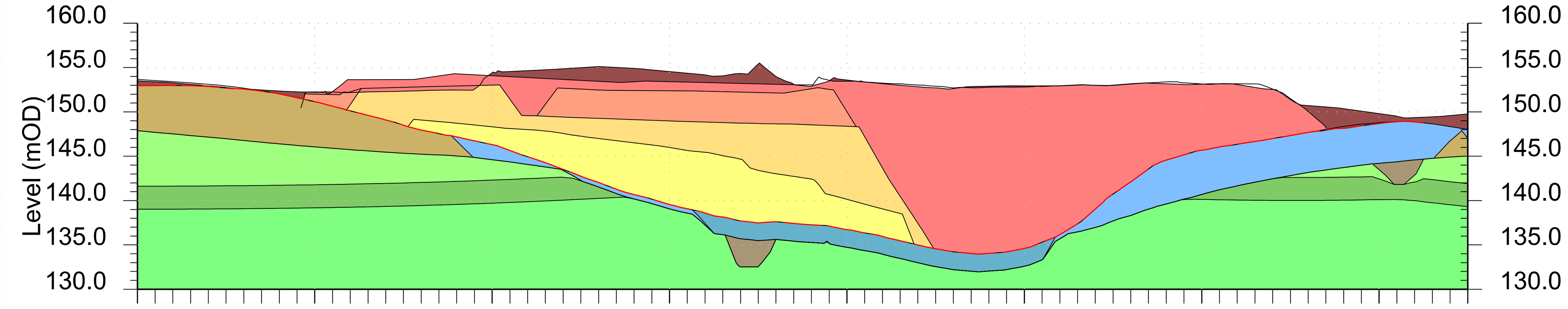


This is an Interactive PDF.
Open with Adobe Reader &
Click a Button to Activate Layer.
>



Section 01

Scale = Horizontal 1:5000 Vertical 1:1000



Section 02

Scale = Horizontal 1:5000 Vertical 1:1000

Interactive Buttons

Click to Cycle through Interpreted Filling Periods

Before Filling

Up to 1947

1947 - 1955

1955 - 1960

1960 - 1970

1970 - 1980

Post 1982

Colour Coded Height Map of Historical Levels (mOD)

Plan Legend:

Mapped Extent of Landfill from Historical Aerials

Section Legend:

Base of Made Ground / Top of Natural Ground

Made Ground Post 1980

Dry Valley Deposits

Head

Clay with Flints

Pipe

Lewes Nodular Chalk

Chalk Rock

1970 - 1980

1960 - 1970

1955 - 1960

1947 - 1955

Pre 1947

Landfill Waste Ages of Filling

All structure positions are indicative. The proposed works will be subject to detailed design development. The changes will be within limits of deviation specified in the Development Consent Order.

Notes

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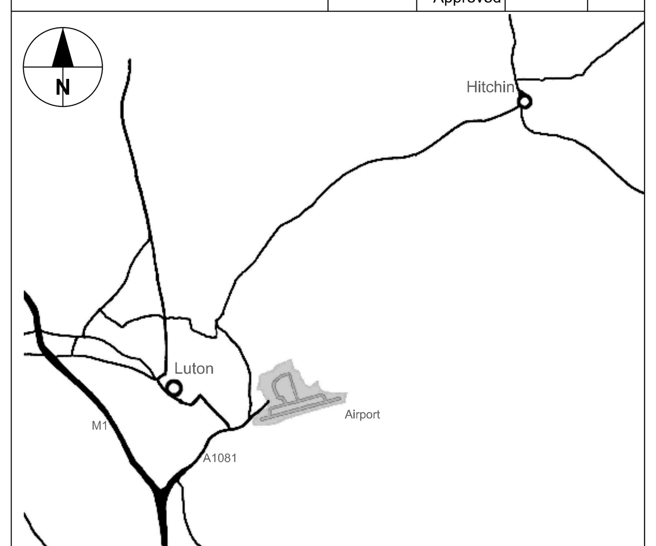
5. This is an interactive 2D PDF. For full interactivity it is recommended that the original digital version is opened and viewed using Adobe Reader 7.0 or higher.

Revision History	Drawn	Checked / Approved	Date	Rev.
Issue	IJ	RB / TB	30/09/22	P02
Issue	IJ	RB / TB	30/09/22	P01



Sheet Location Key Plan

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Drawing Title

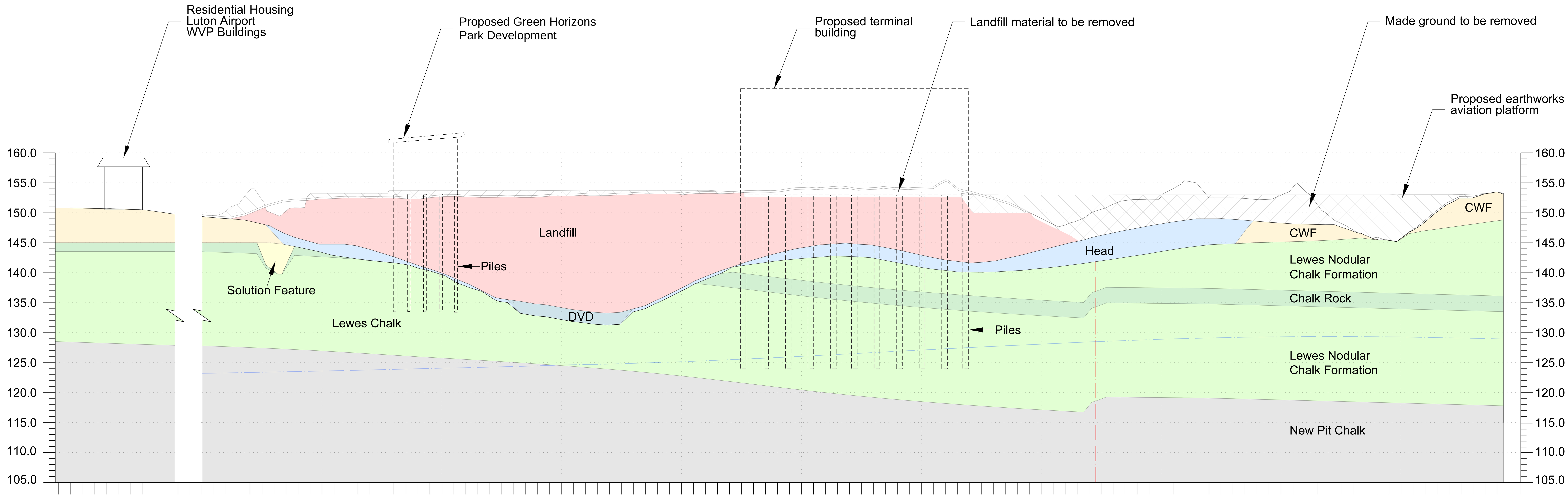
Figure 05
Periods of Landfill Filling

Purpose of issue				Suitability	
SUITABLE FOR COORDINATION				S2	
Drawn	Checked	Approved	Date	Scale	Size
IJ	RB	TB	30/09/22	1:2500	A1
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001	APFP 5(2)(a)	TR020001/APP/5.03			

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0180	P02

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Section A-A



Interactive Buttons

Please Note: This is an interactive PDF. Either the Conceptual Site Model Potential Contaminant Linkage No. (see DQRA - HH Table 7-1) or the sources below can be clicked to display the relevant pathway and receptors.

Conceptual Site Model Potential Contaminant Linkage No.

01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41

Confirmed Relevant Contaminant Linkage (RCL) requires inclusion in Remediation Strategy.

Impact is possible but can be mitigated by design and/or managed under an alternative regime such as permitted operation or occupational safety. Measure should be included in the Remediation Strategy.

Sources	Pathways	Receptors
1 Landfill ground gas + vapour	i Migration	A Future site users
2 Volatile radionuclides in landfill	ii Inhalation	B Adjacent site users
3 Landfill waste	iii Dermal contact/ingestion	C Construction workers
4 Japanese knotweed	iv Driving of contaminants downwards by piling	D Future maintenance workers
5 Landfill leachate	v Direct contact	E Principal chalk aquifer
6 Perched water in landfill	vi Plant uptake	F Foundations /floor slabs and buried concrete
7 Made ground contaminants		G Planting
8 Contaminants in groundwater		H Potable water extraction
9 UXO		J Drainage and pavements

Legend

Key Plan

Notes

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2. All levels are in metres above ordnance datum unless noted otherwise.
3. These drawings are primarily intended to be viewed electronically. Some details may not be clear or visible on a printed version.
4. Strata and other levels have been drawn from interpolated 3D models of various boundaries logged in trial pits and boreholes, topographical data and data from geological maps etc.
It is intended to provide a guide as to likely ground conditions and as such should be regarded as indicative. It is recommended that design decisions made on the basis of this information are confirmed by investigation.
5. This is an interactive 2D PDF. For full interactivity it is recommended that the original digital version it is opened and viewed using Adobe Reader 7.0 or higher.
6. Bing Maps Aerial - © 2021 Microsoft Corporation © 2021 Maxar ©CNES (2021) Distribution Airbus DS

Revision History	Drawn	Checked / Approved	Date	Rev.
Issue	IJ	RB / TB	30/09/22	P02
Issue	IJ	RB / TB	16/12/21	P01

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Drawing Title

Figure 06
Updated Conceptual Site Model (CSM)

Purpose of issue				Suitability	
SUITABLE FOR COORDINATION				S2	
Drawn	Checked	Approved	Date	Scale	Size
IJ	RB	TB	30/09/22	NTS	A1
DCO Application Ref.	APFP Regulation	DCO Document Ref.			
TR020001	APFP 5(2)(a)	TR020001/APP/5.03			

Drawing Number	Revision
LLADCO-3C-ARP-00-00-DR-YE-0181	P02

Project – Phase – Originator – Asset/Zone – Sub Asset – Type – Discp. – Number

Appendix A – DST assessment

Sensitivity analysis- Landfill most common scenario

JIWG
Joint Industry Working Group
Asbestos in Soil and Construction & Demolition Materials

Project Reference	Luton Expansion Project
Site Name	Former Eaton Green Landfill
Client	Luton Rising
Run by	
Date	04-Sep-19
Scenario details	Earthworks involving excavation of landfill material

Decision Support Tool for CAR2012 Work Categories

Stage 1
Hazard Factors

		Score
Select ACM type (run model for each type to generate 'Worst Case' output)	Bonded ACMs: cement, vinyl, composites, textured decorative coatings, bitumen products	1
Extent of degradation of ACMs at outset of work	Weathered (Slight degradation in ACM; material still retains its basic integrity)	2
Friability and degree of bonding by matrix (ACM matrix, not ground materials)	Non-friable ACM or ACM with fibres firmly linked in a matrix	0
Distribution of Visible Asbestos Across Affected Area	Moderate/frequent occurrences of visible contamination by ACMs	3
Amount of asbestos fibre in selected ACM/fibre type as % of host material	Large quantities - >0.1 %wt/wt	4
Sub-total		**10**

Note: the asbestos licensing regime is unaffected by the type of asbestos fibre present in ACMs

Hazard ranking	Low

No warranty, expressed or implied, or reliance, is provided in relation to the use of this tool.
It is contingent on users to satisfy themselves that the output from the tool is relevant and appropriate to the assessment being made.

Stage 2

Exposure Factors

		Score
Anticipated airborne fibre concentration - Control Limit or SALI?	<0.01 fibres/ml	1
Anticipated duration of exposure to asbestos	> 2 hours in a 7 day period and Up to 10 hours in a day (e.g. full time occupational exposure)	4
Activity type and effect on deterioration of ACMs during work	Sampling, manual or mechanical (significant deterioration expected)	2
Best description of primary host material matrix (soil/made ground)	Made Ground - Recycled Aggregate, Track Ballast	4
Respirable fibre index for ACM - RIVM report 711701034 (2003)	Very low	1
Sub-total		**12**
Exposure ranking		Medium
Combined hazard and exposure ranking	**22**	Medium

Stage 3

Risk Assessment Outputs

Probable Licensing Status	Non-Licensed Work
RPE*	EN140 with P3 filter half mask
Dust Suppression**	Localised mechanical dust suppression
Hygiene/Decontamination***	Localised and enhanced personal decontamination facilities

*Where RPE has to be worn continuously for long periods (e.g. more than 1-hour), then powered RPE may be necessary.
**Reduction in control measures possible if natural mitigation factors are present (e.g. raining, wet ground)
***Guide only; suitability of selected personal hygiene measures may be reviewed on a site/contamination-specific basis

Sensitivity analysis- Landfill worst case scenario

JIWG
Joint Industry Working Group
Asbestos in Soil and Construction & Demolition Materials

Project Reference	Luton Expansion Project
Site Name	Former Eaton Green Landfill
Client	Luton Rising
Run by	
Date	04-Sep-19
Scenario details	Earthworks involving excavation of landfill material

Decision Support Tool for CAR2012 Work Categories

Stage 1
Hazard Factors

		Score
Select ACM type (run model for each type to generate 'Worst Case' output)	Clearly identifiable insulation or lagging	3
Extent of degradation of ACMs at outset of work	Disaggregated (dominated by loose fibrous material; extreme degradation in ACM and/or free asbestos fibres/fibre bundles)	4
Friability and degree of bonding by matrix (ACM matrix, not ground materials)	Friable ACM or ACM with fibres not linked in any matrix (free dispersed fibres/fibre bundles)	4
Distribution of Visible Asbestos Across Affected Area	Moderate/frequent occurrences of visible contamination by ACMs	3
Amount of asbestos fibre in selected ACM/fibre type as % of host material	Low quantities - >0.01 to <0.05 %wt/wt	2
Sub-total		**16**

Note: the asbestos licensing regime is unaffected by the type of asbestos fibre present in ACMs

Hazard ranking	High

No warranty, expressed or implied, or reliance, is provided in relation to the use of this tool.
It is contingent on users to satisfy themselves that the output from the tool is relevant and appropriate to the assessment being made.

Stage 2

Exposure Factors

		Score
Anticipated airborne fibre concentration - Control Limit or SALI?	<0.01 fibres/ml	1
Anticipated duration of exposure to asbestos	> 2 hours in a 7 day period and Up to 10 hours in a day (e.g. full time occupational exposure)	4
Activity type and effect on deterioration of ACMs during work	Sampling, manual or mechanical (significant deterioration expected)	2
Best description of primary host material matrix (soil/made ground)	Made Ground - Recycled Aggregate, Track Ballast	4
Respirable fibre index for ACM - RIVM report 711701034 (2003)	High	4
Sub-total		**15**
Exposure ranking		Medium
Combined hazard and exposure ranking	**31**	High

Stage 3
Risk Assessment Outputs

Probable Licensing Status	Non-Licensed Work
RPE*	EN136 with P3 filter full face mask
Dust Suppression**	General mechanical dust suppression
Hygiene/Decontamination***	Mobile self-contained personal decontamination facilities

*Where RPE has to be worn continuously for long periods (e.g. more than 1-hour), then powered RPE may be necessary.
**Reduction in control measures possible if natural mitigation factors are present (e.g. raining, wet ground)
***Guide only; suitability of selected personal hygiene measures may be reviewed on a site/contamination-specific basis

Sensitivity analysis- scrapyard most common scenario

JIWG
Joint Industry Working Group
Asbestos in Soil and Construction & Demolition Materials

Project Reference	Luton Expansion Project
Site Name	Former Eaton Green Landfill
Client	Luton Rising
Run by	
Date	01/010/19
Scenario details	Excavation works within landfill to create landform

Decision Support Tool for CAR2012 Work Categories

Stage 1
Hazard Factors

		Score
Select ACM type (run model for each type to generate 'Worst Case' output)	Free dispersed fibres/fibre bundles	2
Extent of degradation of ACMs at outset of work	Disaggregated (dominated by loose fibrous material; extreme degradation in ACM and/or free asbestos fibres/fibre bundles)	4
Friability and degree of bonding by matrix (ACM matrix, not ground materials)	Friable ACM or ACM with fibres not linked in any matrix (free dispersed fibres/fibre bundles)	4
Distribution of Visible Asbestos Across Affected Area	Moderate/frequent occurrences of visible contamination by ACMs	3
Amount of asbestos fibre in selected ACM/fibre type as % of host material	Low quantities - >0.01 to <0.05 %wt/wt	2
Sub-total		**15**

Note: the asbestos licensing regime is unaffected by the type of asbestos fibre present in ACMs

Hazard ranking	Medium

No warranty, expressed or implied, or reliance, is provided in relation to the use of this tool.
It is contingent on users to satisfy themselves that the output from the tool is relevant and appropriate to the assessment being made.

Stage 2

Exposure Factors

		Score
Anticipated airborne fibre concentration - Control Limit or SALI?	<0.01 fibres/ml	1
Anticipated duration of exposure to asbestos	> 2 hours in a 7 day period and Up to 10 hours in a day (e.g. full time occupational exposure)	4
Activity type and effect on deterioration of ACMs during work	Sampling, manual or mechanical (significant deterioration expected)	2
Best description of primary host material matrix (soil/made ground)	Made Ground - Recycled Aggregate, Track Ballast	4
Respirable fibre index for ACM - RIVM report 711701034 (2003)	Low	2
Sub-total		**13**
Exposure ranking		Medium
Combined hazard and exposure ranking	**28**	Medium

Stage 3

Risk Assessment Outputs

Probable Licensing Status	Non-Licensed Work
RPE*	EN140 with P3 filter half mask
Dust Suppression**	Localised mechanical dust suppression
Hygiene/Decontamination***	Localised and enhanced personal decontamination facilities

*Where RPE has to be worn continuously for long periods (e.g. more than 1-hour), then powered RPE may be necessary.

**Reduction in control measures possible if natural mitigation factors are present (e.g. raining, wet ground)

***Guide only; suitability of selected personal hygiene measures may be reviewed on a site/contamination-specific basis

Sensitivity analysis- scrapyard worst case scenario

JIWG
Joint Industry Working Group
Asbestos in Soil and Construction & Demolition Materials

Project Reference	Luton Expansion Project
Site Name	Former Eaton Green Landfill
Client	Luton Rising
Run by	
Date	01/010/19
Scenario details	Excavation works within landfill to create landform

Decision Support Tool for CAR2012 Work Categories

Stage 1
Hazard Factors

		Score
Select ACM type (run model for each type to generate 'Worst Case' output)	Loose fibrous asbestos debris	3
Extent of degradation of ACMs at outset of work	Disaggregated (dominated by loose fibrous material; extreme degradation in ACM and/or free asbestos fibres/fibre bundles)	4
Friability and degree of bonding by matrix (ACM matrix, not ground materials)	Friable ACM or ACM with fibres not linked in any matrix (free dispersed fibres/fibre bundles)	4
Distribution of Visible Asbestos Across Affected Area	Gross/very frequent occurrences of visible contamination by ACMs	4
Amount of asbestos fibre in selected ACM/fibre type as % of host material	Large quantities - >0.1 %wt/wt	4
Sub-total		**19**

Note: the asbestos licensing regime is unaffected by the type of asbestos fibre present in ACMs

Hazard ranking	High

No warranty, expressed or implied, or reliance, is provided in relation to the use of this tool.
It is contingent on users to satisfy themselves that the output from the tool is relevant and appropriate to the assessment being made.

JIWG

Joint Industry Working Group
Asbestos in Soil and Construction & Demolition Materials

Stage 2

Exposure Factors

		Score
Anticipated airborne fibre concentration - Control Limit or SALI?	<0.01 fibres/ml	1
Anticipated duration of exposure to asbestos	> 2 hours in a 7 day period and Up to 10 hours in a day (e.g. full time occupational exposure)	4
Activity type and effect on deterioration of ACMs during work	Sampling, manual or mechanical (significant deterioration expected)	2
Best description of primary host material matrix (soil/made ground)	Made Ground - Recycled Aggregate, Track Ballast	4
Respirable fibre index for ACM - RIVM report 711701034 (2003)	High	4
Sub-total		**15**
Exposure ranking		Medium
Combined hazard and exposure ranking	34	High

Stage 3

Risk Assessment Outputs

Probable Licensing Status	Non-Licensed Work
RPE*	EN136 with P3 filter full face mask
Dust Suppression**	General mechanical dust suppression
Hygiene/Decontamination***	Mobile self-contained personal decontamination facilities

*Where RPE has to be worn continuously for long periods (e.g. more than 1-hour), then powered RPE may be necessary.
**Reduction in control measures possible if natural mitigation factors are present (e.g. raining, wet ground)
***Guide only; suitability of selected personal hygiene measures may be reviewed on a site/contamination-specific basis

Sensitivity analysis- Parameters required for licensed status
(nb: not encountered)

JIWG
Joint Industry Working Group
Asbestos in Soil and Construction & Demolition Materials

Project Reference	Luton Expansion Project
Site Name	Former Eaton Green Landfill
Client	Luton Rising
Run by	
Date	04-Sep-19
Scenario details	Earthworks involving excavation of landfill material

Decision Support Tool for CAR2012 Work Categories

Stage 1
Hazard Factors

		Score
Select ACM type (run model for each type to generate 'Worst Case' output)	Clearly identifiable insulation or lagging	3
Extent of degradation of ACMs at outset of work	Disaggregated (dominated by loose fibrous material; extreme degradation in ACM and/or free asbestos fibres/fibre bundles)	4
Friability and degree of bonding by matrix (ACM matrix, not ground materials)	Friable ACM or ACM with fibres not linked in any matrix (free dispersed fibres/fibre bundles)	4
Distribution of Visible Asbestos Across Affected Area	Moderate/frequent occurrences of visible contamination by ACMs	3
Amount of asbestos fibre in selected ACM/fibre type as % of host material	Moderate quantities - >0.05 to <0.1 %wt/wt	3
Sub-total		**17**

Note: the asbestos licensing regime is unaffected by the type of asbestos fibre present in ACMs

Hazard ranking	High

No warranty, expressed or implied, or reliance, is provided in relation to the use of this tool.
It is contingent on users to satisfy themselves that the output from the tool is relevant and appropriate to the assessment being made.

Stage 2

Exposure Factors

		Score
Anticipated airborne fibre concentration - Control Limit or SALI?	>0.1 fibres/ml (4 Hr TWA) or >0.6 fibres/ml (10 minute STEL)	4
Anticipated duration of exposure to asbestos	> 2 hours in a 7 day period and Up to 10 hours in a day (e.g. full time occupational exposure)	4
Activity type and effect on deterioration of ACMs during work	Sampling, manual or mechanical (significant deterioration expected)	2
Best description of primary host material matrix (soil/made ground)	Made Ground - Recycled Aggregate, Track Ballast	4
Respirable fibre index for ACM - RIVM report 711701034 (2003)	High	4
Sub-total		**18**
Exposure ranking		High
Combined hazard and exposure ranking	**35**	High

Stage 3

Risk Assessment Outputs

Probable Licensing Status	Licensed Work
RPE*	EN136 with P3 filter full face mask
Dust Suppression**	General mechanical dust suppression
Hygiene/Decontamination***	Mobile self-contained personal decontamination facilities

*Where RPE has to be worn continuously for long periods (e.g. more than 1-hour), then powered RPE may be necessary.
**Reduction in control measures possible if natural mitigation factors are present (e.g. raining, wet ground)
***Guide only; suitability of selected personal hygiene measures may be reviewed on a site/contamination-specific basis

Appendix B – Continuous ground gas monitoring assessment

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Ambisense Factual Report

Luton, AECOM

Prepared for:

AECOM

For: AECOM
Issue Date: 05/06/19
Ref: No. JOB0079_01

FOREWORD

This report has been prepared based on information made available to Ambisense UK Ltd (AUL) at the time of the reporting using all reasonable skill, care and diligence and within the limitations of the scope of works agreed with, and resources provided by, the client.

AUL has relied on information provided by others and has prepared this report on the basis of this information being accurate.

The report is provided based on information made available to AUL at the time of preparing the report and completed in-line recognised UK guidance and legislation, where applicable. AUL will not accept any liability for inaccurate or incomplete information provided to AUL or any liability arising from the future change of any such guidance or legislation.

AUL is not obliged and disclaims any obligation to carry out further works or update the report for events occurring after such works have been carried out, and / or report issued in final form. This also applies to transfer of the report to other parties.

This report must be issued as final and be signed by the author and approved by a company director or senior management before the report may be relied upon by the client and subject to full payment for our services being made.

Any third parties using or relying on the information do so at their own risk. Should any third party wish to use or rely upon the content of the report, written approval must be sought from an AUL Director; a charge may be levied against such approval.

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Appendix A – Site Plan

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Appendix C – Time Series Data

Appendix D – GasfluX Specification

1. Introduction

1.1. Background

In August 2018, Ambisense UK Limited (Ambisense) was commissioned by AECOM to undertake a 10 week period of continuous ground-gas monitoring in five borehole monitoring installations at the Wigmore Valley Park site, Luton, Bedfordshire and prepare a factual report.

The scope of the monitoring was specified by AECOM and comprised continuous ground gas and flow monitoring and provision of real time data.

The investigation was performed in accordance with the contract specification and the general requirements of relevant related standards.
This report presents the factual records of the fieldwork and laboratory testing.

1.2. Scope of Works

The scope of works involved the following tasks:

- Deployment of 5no. Ambisense GasfluX units equipped with TVOC sensors;

- Gasflux unit located at BWS202 was removed on 20th September and redeployed on the 21st September. This was to replace a faulty CO/H2S sensor. The sensor was faulty for the first time on the 18th September at 07:35am. No other data was affected.

- Gasflux unit located at BH224 was removed on 4th September and redeployed on the 5th September. This was to replace a faulty CO2 sensor. The sensor was faulty for the first time on the 28th August. No other data was affected.

- Conduct two interim site visits to swap the GasfluX units on borehole BWS202 on the 5th October & 8th October 2018 respectively to calibrate the unit, no data was affected.;

- Conduct ten weeks of continuous ground gas and flow monitoring at boreholes BH202, BH206, BH208, BH224 and BWS202 as specified by the client; and

- Demobilisation of instrumentation;

- Provision of a factual report.

2. Site Details

2.1. Site Location

The site is located at Wigmore Valley Park, Luton, LU2 9JB approximately 3 km of Luton centre and adjacent to the northeast of London Luton Airport.

The units were deployed at the borehole positions shown in the Exploratory Hole Location Plan (Please see Figure 1, Appendix A)

2.2. Site Description

The site currently comprises an open public park with associated walkways, sports pitches and recreational amenities situated within the bounds of the historical Luton Airport Landfill site.

Access to the site is from the Eaton Green Rd to the north

The site is bounded by Eaton Green Rd to the north, London Luton Airport car parking to the south west and agricultural land to the east.

3. Fieldwork Methodology

3.1. GasfluX

Continuous ground gas and monitoring was carried out using Ambisense GasfluX units between 22nd August 2018 and 31st October 2018 at boreholes: BH202, BH206, BH208, BH224 and BWS202. Each unit was calibrated prior to deployment and deployed in-line with manufacturers guidelines and internal procedures.

The GasfluX units were set to record, at hourly intervals, bulk gases including methane (CH_4), carbon dioxide (CO_2) and oxygen (O_2) and trace gases including hydrogen sulphide (H_2S) and carbon monoxide (CO) and volatile organic carbons (VOC's) for the duration of the monitoring period. The GasfluX units also measured and recorded atmospheric pressure, differential pressure and gas humidity. Synchronised weather data was also imported from a local weather station (station ID ILUTON8 from Weather Underground) which includes temperature, humidity, precipitation (hourly and daily) and atmospheric pressure.

4. Monitoring Results

4.1. Continuous Monitoring Data

Continuous ground gas data provides reliable information to assist in the identification of the dominant ground-gas generation and driving processes occurring at a site. The data also assists in both qualitative and quantitative risk assessment and provide confidence to spot sampling results.

When the sampling frequency is increased to match the frequency of environmental change, the data collected can be termed 'continuous'. A continuous data set therefore captures the full range of variation in the environment.

4.2. Summary of Monitoring Data

A summary of the monitoring data for the specified monitoring period between 22nd August 2018 and 31st October 2018 is provided in Table 1 below.

Time series graphs for all boreholes and time series data recorded over this monitoring period are available in Appendices B and C respectively.

Key Data Observations:

- Methane has been recorded at generally high concentrations within a majority of the boreholes with the exception to BWS202. The highest methane concentration of 70% was recorded at BH208.
- Carbon Dioxide is recorded at concentrations above 5.0% in all boreholes monitored except BWS202.
- Carbon Monoxide (CO) and H_2S is recorded at low parts per million volume (ppmv) concentrations in majority of the boreholes, with a peak CO concentration of 126 ppmv detected within BH206 and a peak H_2S concentration of 15.27ppmv detected within BH208.
- The concentration of total volatile organic compounds have been recorded at low ppm concentrations within most boreholes with the highestpeak concentration of 191 ppm at BH206.
- Diurnal changes in differential pressure are observed in: BH202, BH206, BH208, BH224 and BWS202.
- Isolated recordings of CO (6th, 16th September and 21st September) were reported as NaN within BH206. No other data was affected.
- Due to a failure of the CO/H2S sensor within the BWS202 unit the data between 18th September and 21st September is not guaranteed to be accurate and should not be relied upon.
- Due to a failure of the CO2 sensor within the BH224 unit the data between 28th August and 5th September is not guaranteed to be accurate and should not be relied upon.

BH Ref	**CH_4** (% v/v)		**CO_2** (% v/v)		**O_2** (% v/v)		Volatile Organic Carbons (VOC's)		Barometric Pressure (millibars)		**CO** (ppmv)		**H_2S** (ppmv)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
BH202	0	29.44	0.03	22.96	0	22	0	6.1	979	1021	0.22	17.55	0	5.08
BH206	0.01	54.33	0.01	28.18	0.09	20.28	0	191.37	977	1022	0	126	0	1.47
BH208	0.02	69.72	0.01	25.72	0	20.78	0	28.96	978	1023	0	27.16	0	15.27
BH224	0	56.73	0.03	114*	0	21.07	0	41.13	977	1022	0	25.27	0	11.58
BWS202	0	1.62	0.02	2.82	0	20.62	0	15.34	978	1023	0	1.27	0	8.63

Table 1 Summary of GasfluX results for each monitored borehole

Note: % v/v = percentage by volume, ppmv = parts per million by volume

*Value of 114% recorded during CO2 sensor failure. See key data observations above for more detail.

5. Limitations

Ambisense UK Ltd (AUL) has prepared this factual report for the use of the Client and those parties whom a warranty agreement has been executed, or with whom an assignment has been agreed.

AUL accepts no responsibility for the consequences of this document being used for any purpose or project other than for which it was commissioned or for the consequences arising from this document's use by any third party with whom an agreement has not been executed.

AUL accept no responsibility for the interpretation of this factual data. A reviewer of the data provided must take into account other available information and the context in which this data was collected. For example, site setting, conceptual site model, environmental conditions, gases present (that are not monitored as part of this contract, but may interfere with the sensors used), borehole construction and response zone information.

AUL accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this factual report.

Appendix A

Site Plan

A1

Legend: The items in this legend are interactive. Click to alter the view.

Indicative Landfill Extents

Badger Sett Location and Standoff Zone

Extent of 1947 Landfill

Wigmore Park CWS

Thames Valley Drain (CCTV survey)

Previous GI Location

ARP16-CP-BH55

Hole Location

Consultant / Contractor

Year

Area

Hole Name/Number

Previous Installation Location and Type

Leachate

Gas

Groundwater

Proposed GI Location

BH201 - 233	Boreholes
BBH201 - 211	Boundary Borehole
BWS201 - 220	Boundary Window Sample
WS201 - 223	Window Sample
GW201 - 207	Groundwater Hole
LW201 - 205	Leachate Borehole
DP201 - 280	Dynamic Probehole
TP201 - 260	Shallow Trial Pits (max depth 4.5m)
TP261 - 276	Deep Trial Pits (max depth 6m)

Proposed Install Type

Colour of proposed location denotes the install type:

Green	Gas
Blue	Groundwater
Pink	Leachate

Proposed GI Layout

Clear All

Issue	Date	By	Chkd	Appd
03	25/04/18	HS	YM	TB
02	22/02/18	HS	YM	TB
01	05/12/17	IJ	YM	TB
	For Information			

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Client
London Luton Airport Ltd

Job Title
Ground Investigation Strategy

Proposed Landfill Ground Investigation Locations

Figure 01

Scale at A1 1:2000

Discipline Geotechnical

Job No 245580-00

Drawing Status For Information

Drawing No LLA-ARP-LF-XX-DR-G-00031

Issue 03

\\global.arup.com\europe\Midlands\jobs\245000\245580-00\4 Internal Project Data\4-03 Drawings\C_Civil\CG_Geotechnics\SHARED\02 Drawings & Sketches\2017-12-05 Proposed LF3 GI\LLA-ARP-LF-XX-DR-G-00031.dgn

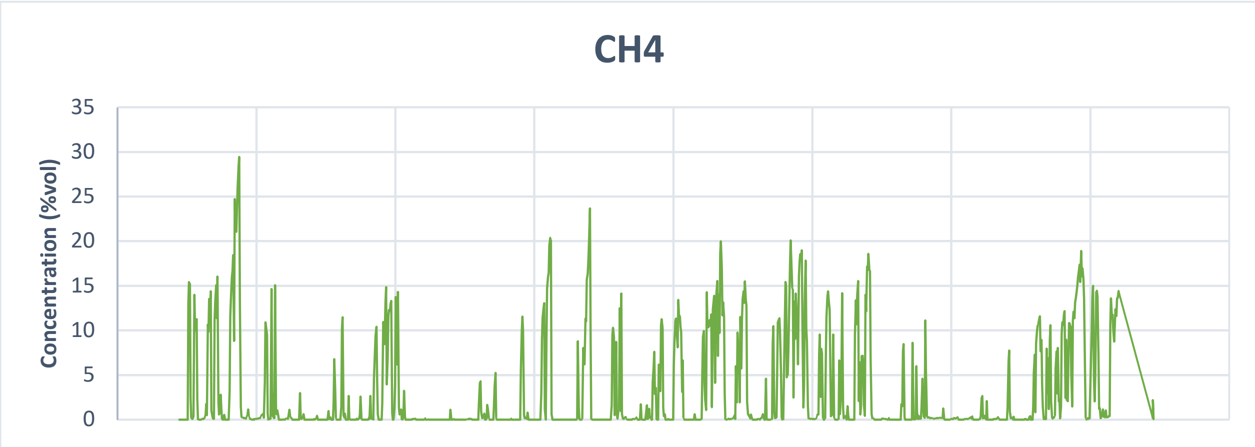
Do not scale

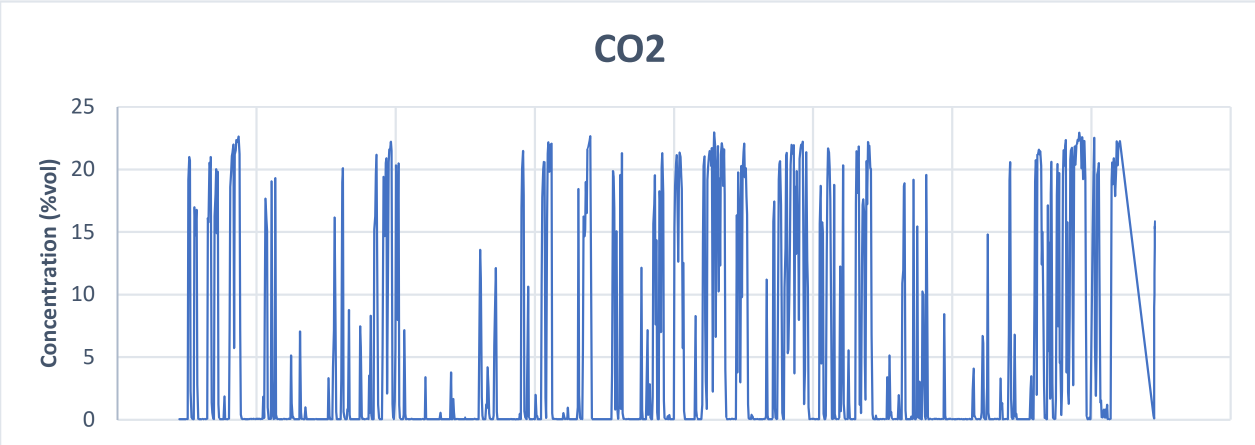
Appendix B

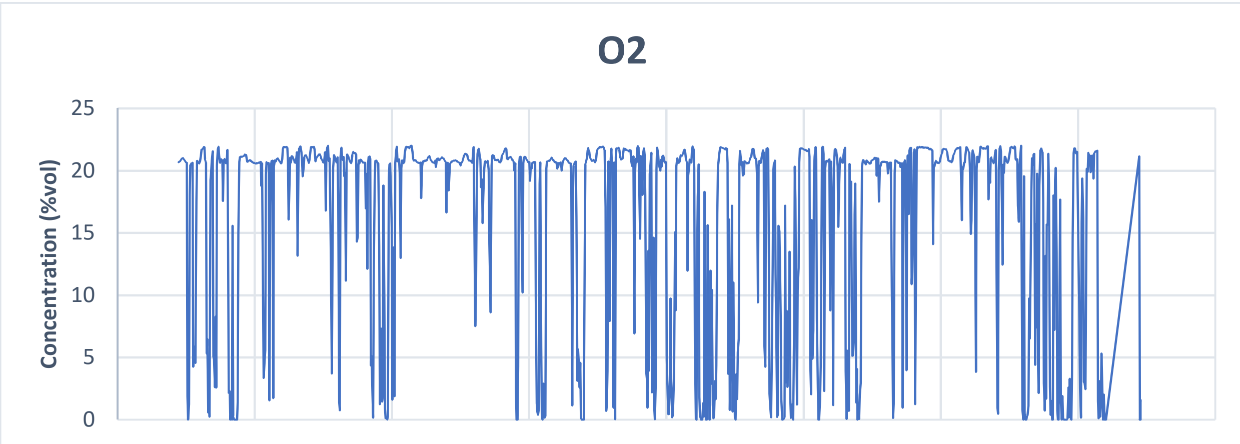
Time Series Graphs

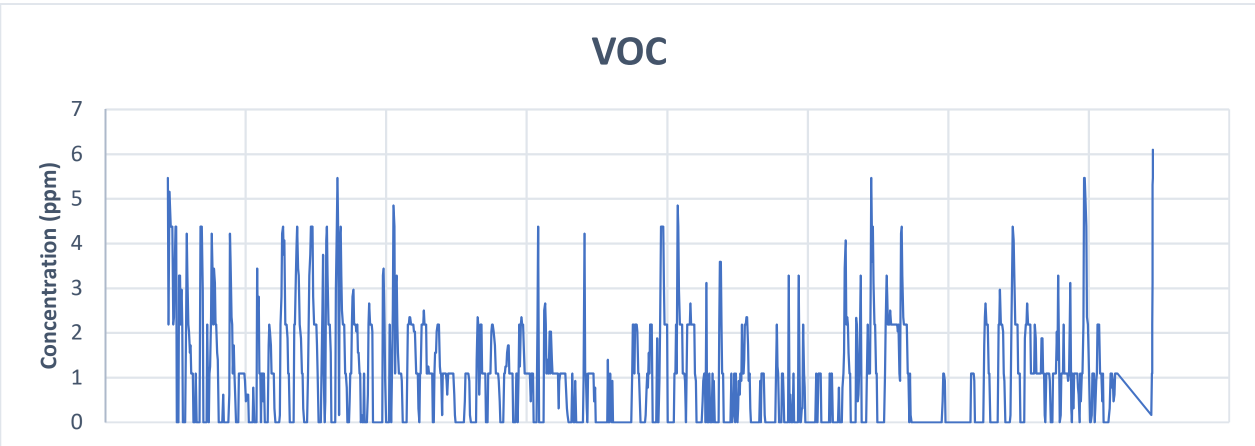
Appendix B - Time Series Graphs

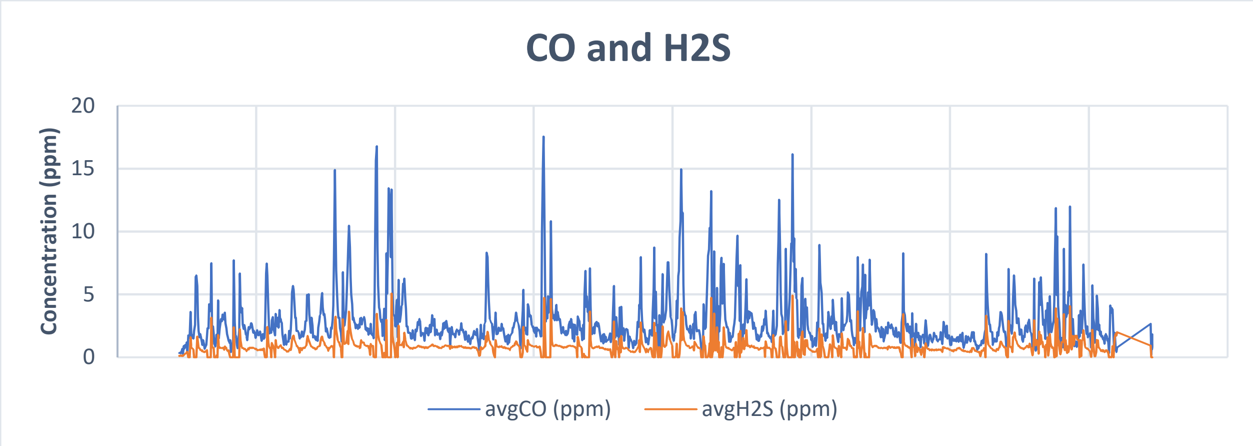
Luton_BH202

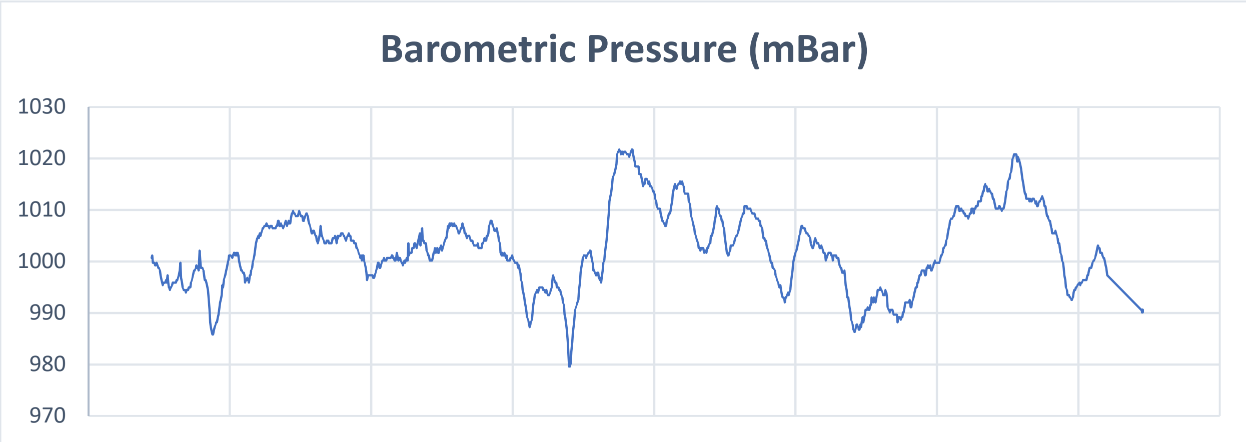


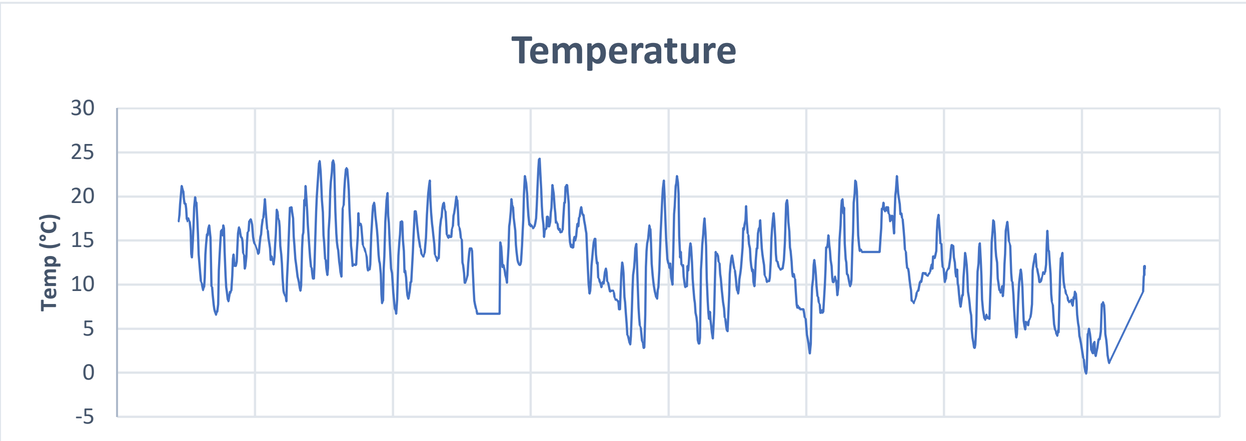




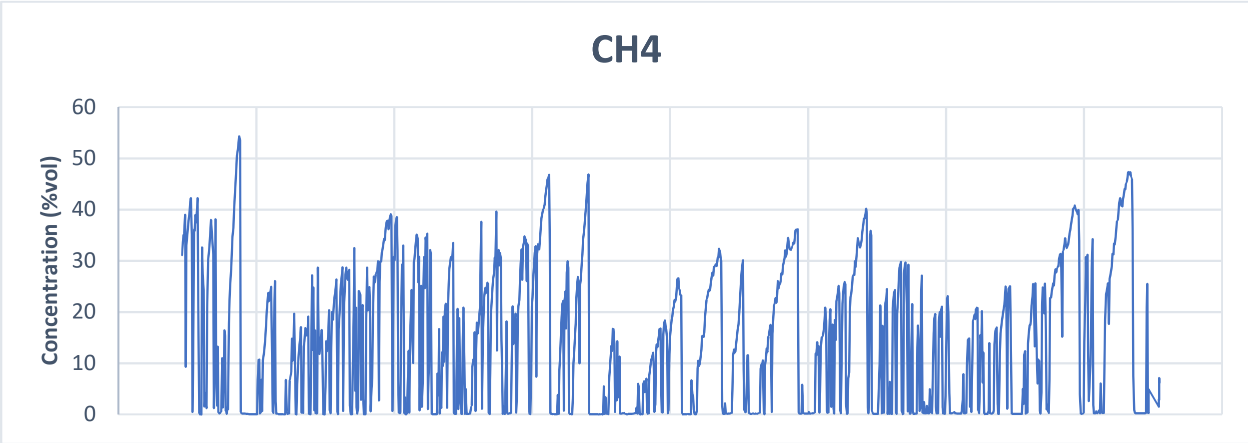


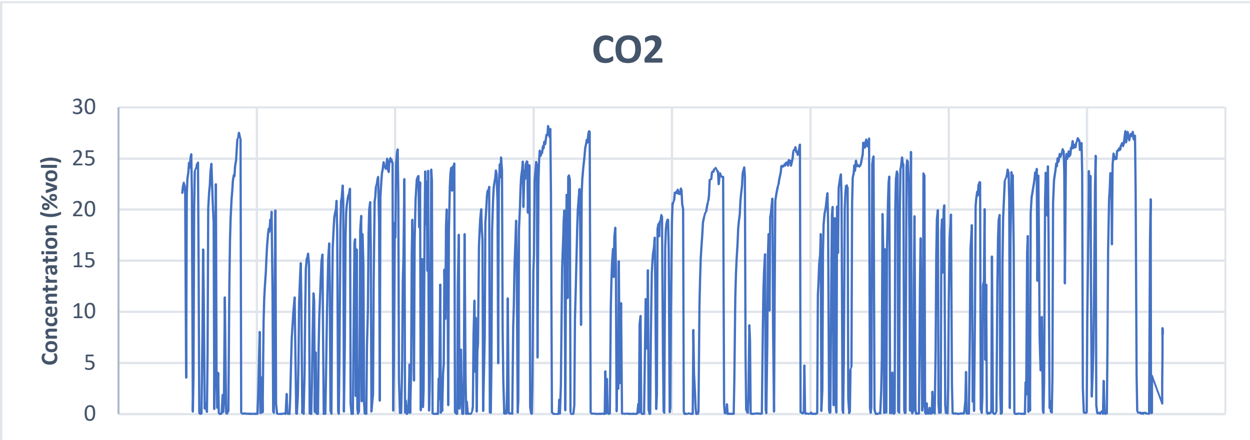

CO and H2S
Concentration (ppm)
20
15
10
5
0
avgCO (ppm)
avgH2S (ppm)

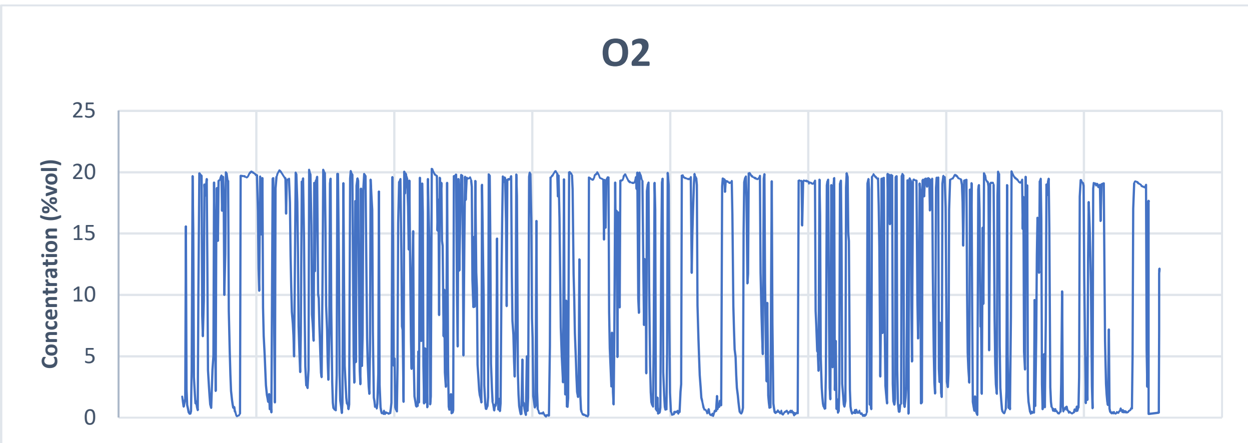

Barometric Pressure (mBar)
1030
1020
1010
1000
990
980
970

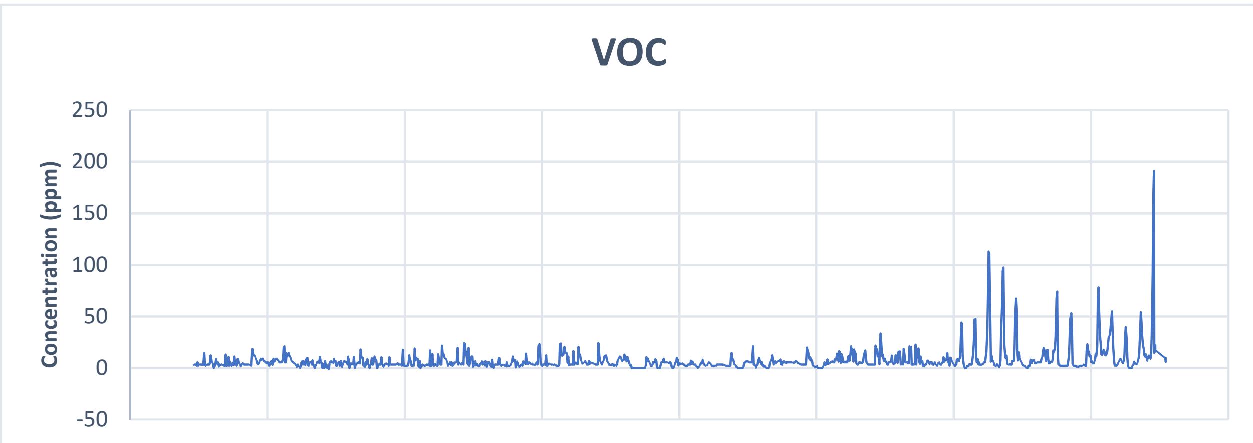

Temperature
Temp (°C)
30
25
20
15
10
5
0
-5

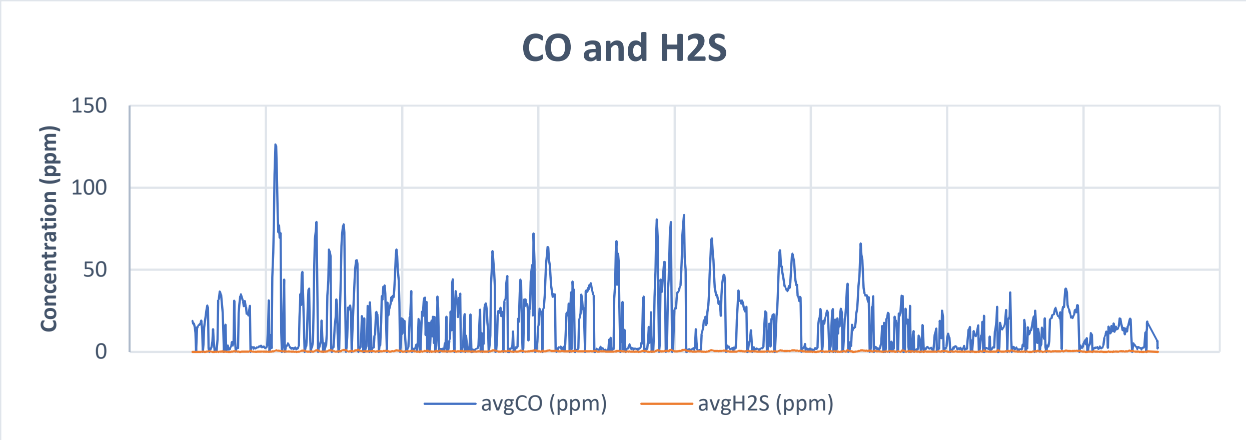
Luton_BH206

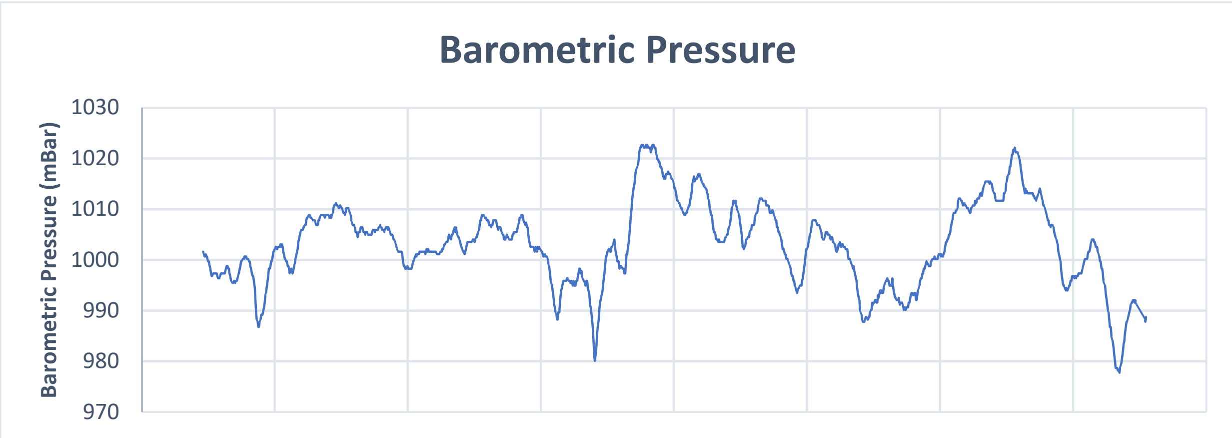

CH4
Concentration (%vol)
0
10
20
30
40
50
60

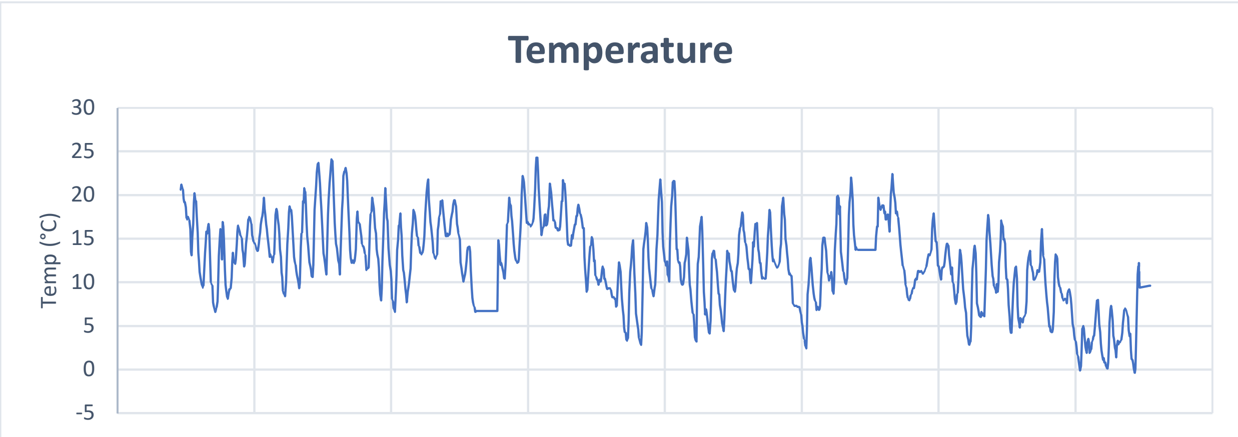

CO2
Concentration (%vol)
0
5
10
15
20
25
30


O2
Concentration (%vol)
0
5
10
15
20
25

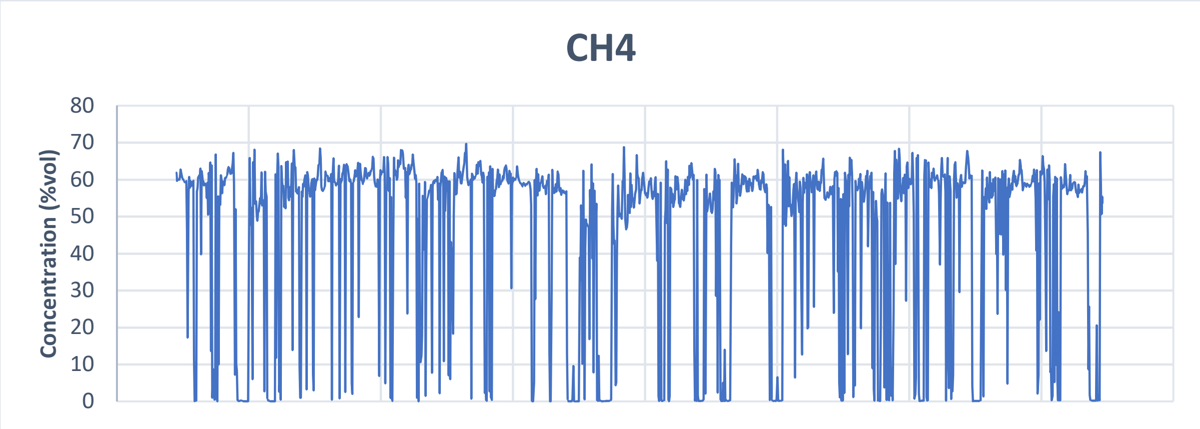

VOC
Concentration (ppm)
-50
0
50
100
150
200
250


CO and H2S
Concentration (ppm)
150
100
50
0
avgCO (ppm)
avgH2S (ppm)

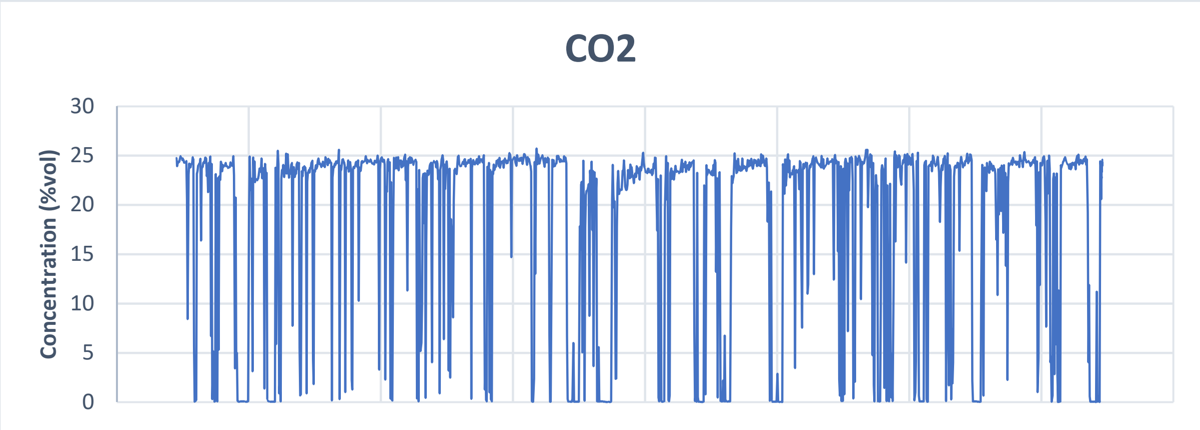

Barometric Pressure
Barometric Pressure (mBar)
1030
1020
1010
1000
990
980
970


Temperature
Temp (°C)
30
25
20
15
10
5
0
-5

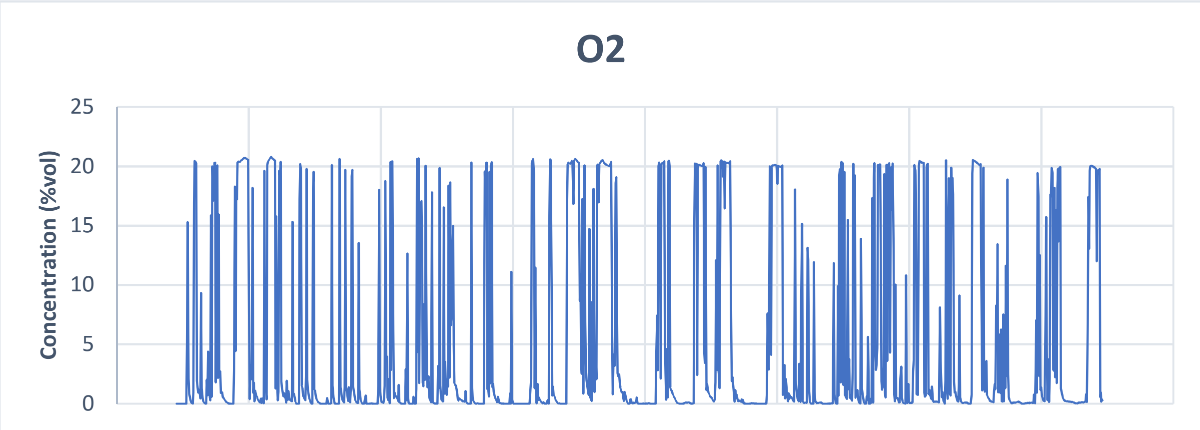
Luton_BH208



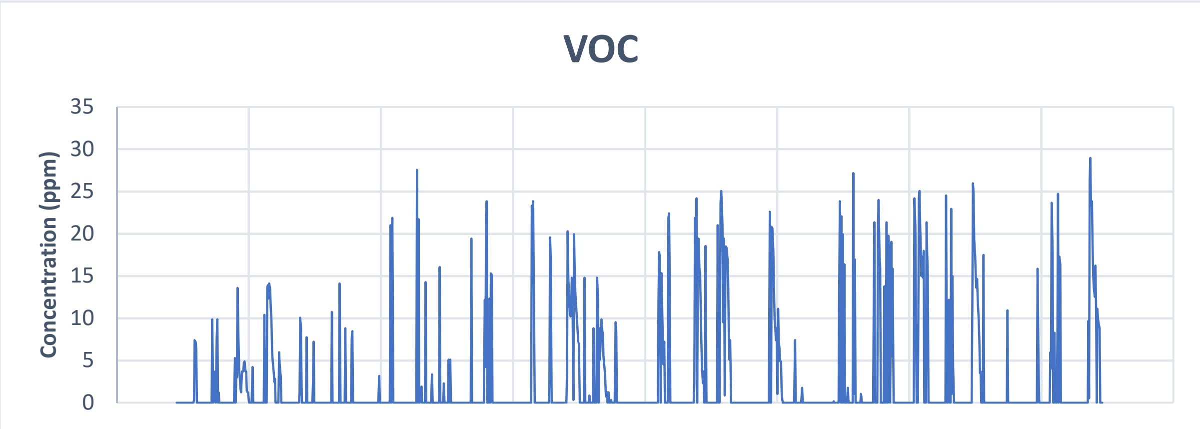
CH4
Concentration (%vol)
80
70
60
50
40
30
20
10
0



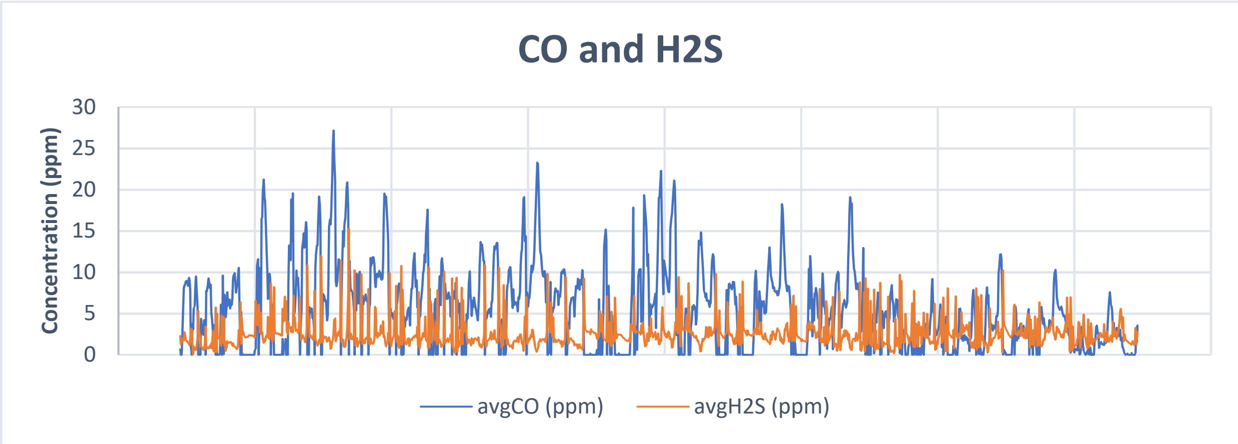
CO2
Concentration (%vol)
30
25
20
15
10
5
0

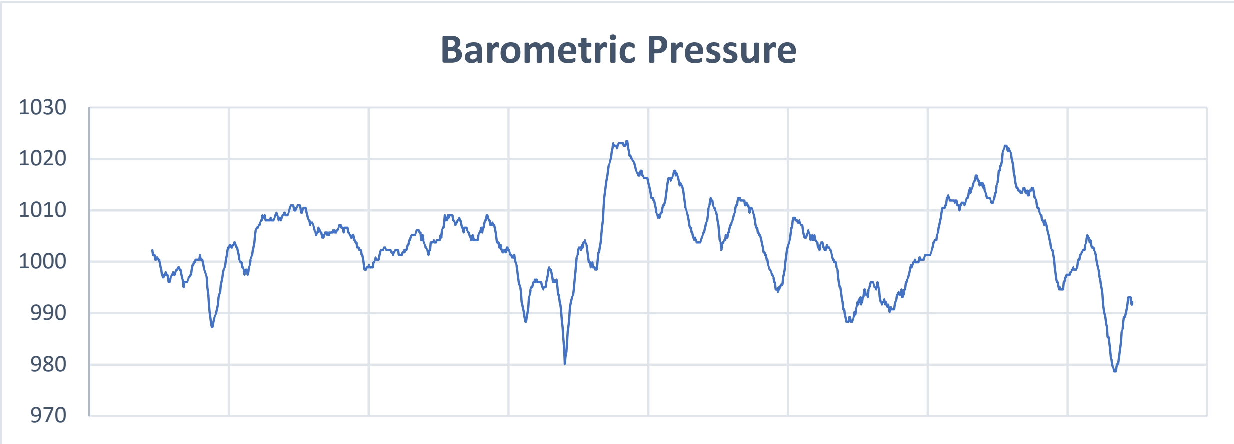


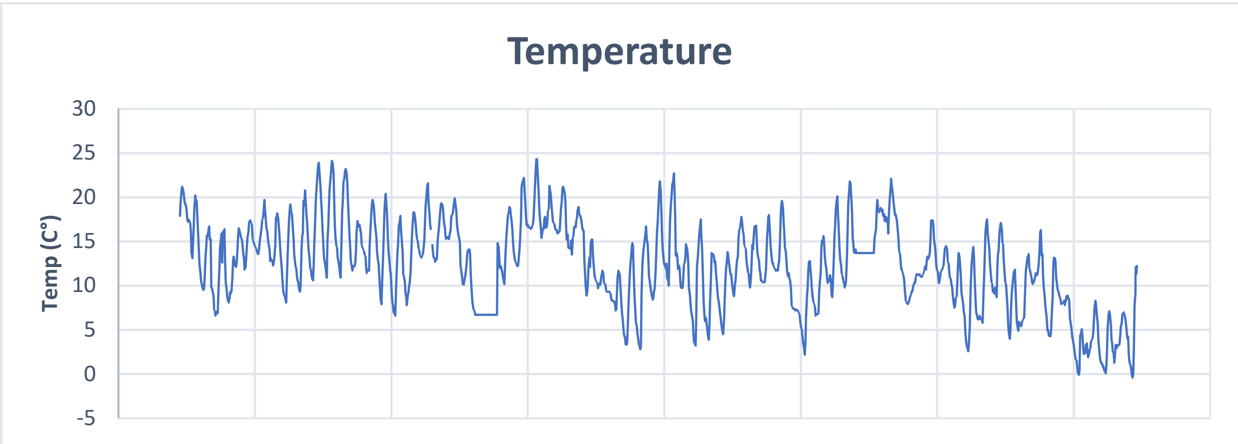
O2
Concentration (%vol)
25
20
15
10
5
0



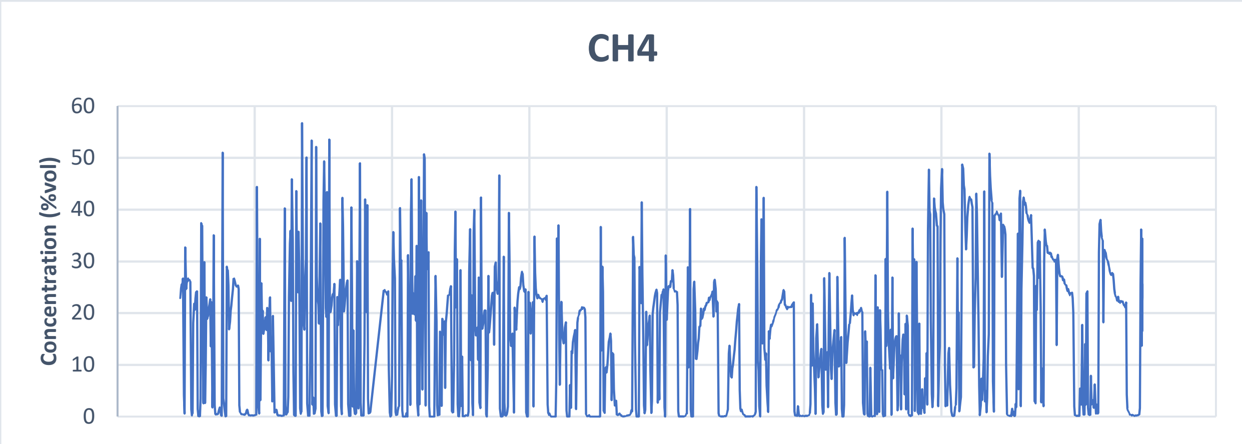
VOC
Concentration (ppm)
35
30
25
20
15
10
5
0

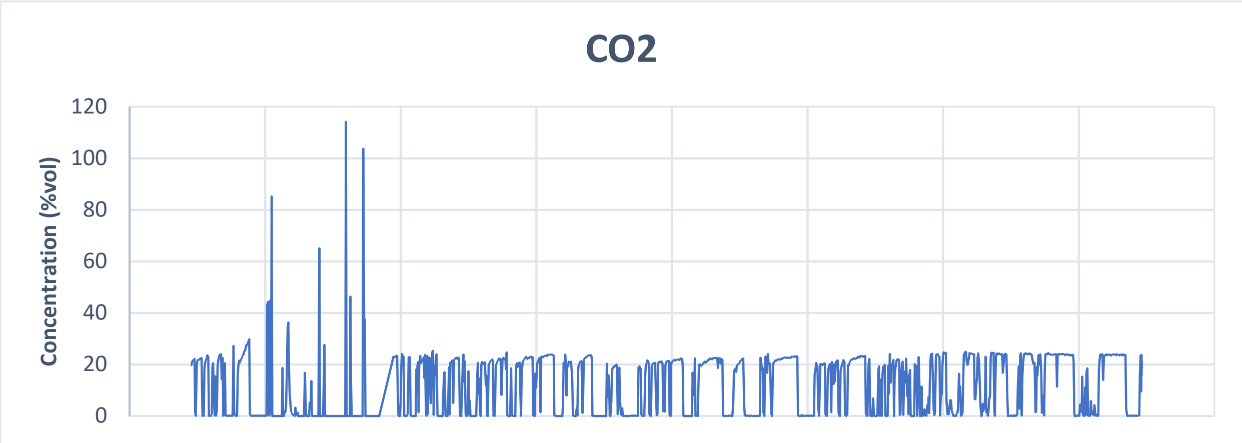

CO and H2S
Concentration (ppm)
30
25
20
15
10
5
0
avgCO (ppm)
avgH2S (ppm)


Barometric Pressure
1030
1020
1010
1000
990
980
970

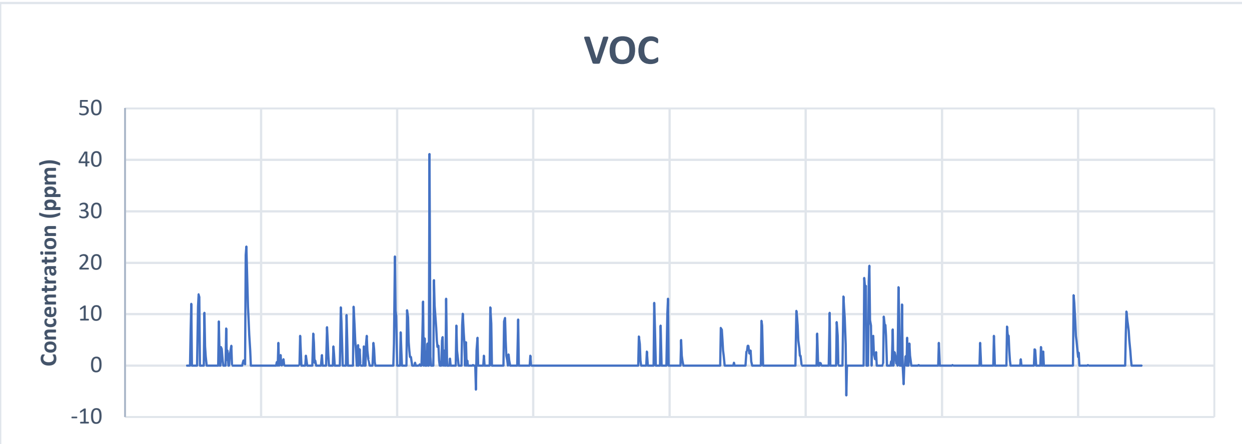

Temperature
Temp (C°)
30
25
20
15
10
5
0
-5

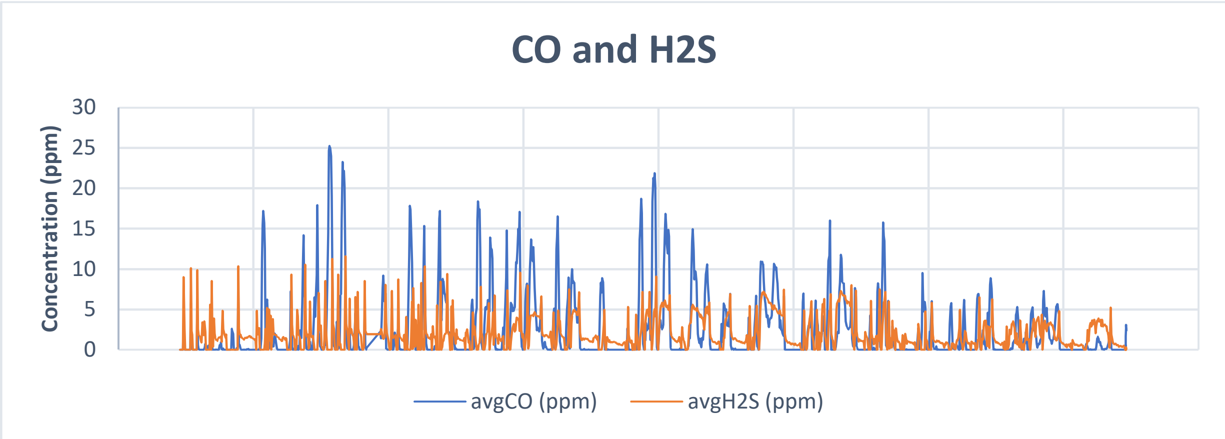
Luton_BH224

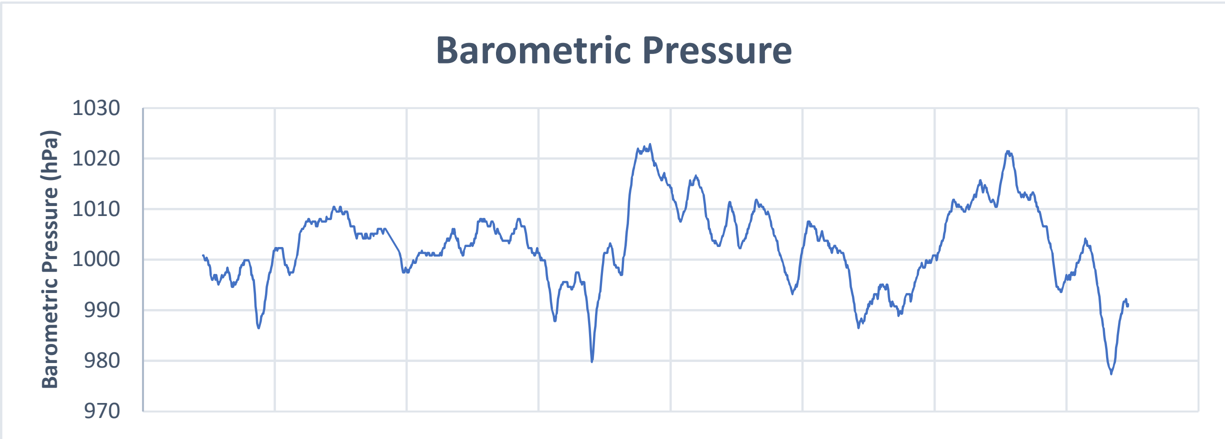

CH4
Concentration (%vol)
60
50
40
30
20
10
0

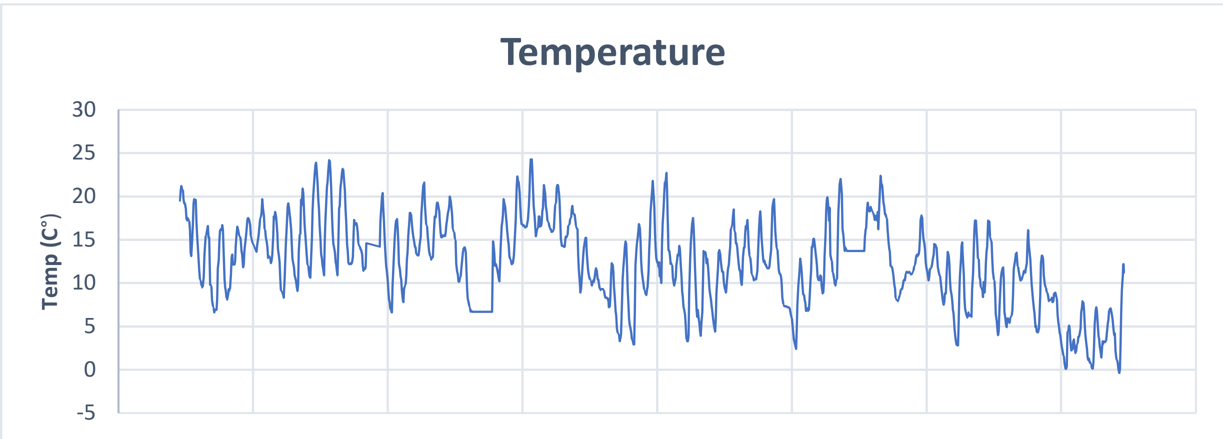

CO2
Concentration (%vol)
120
100
80
60
40
20
0


O2
Concentration (%vol)
25
20
15
10
5
0

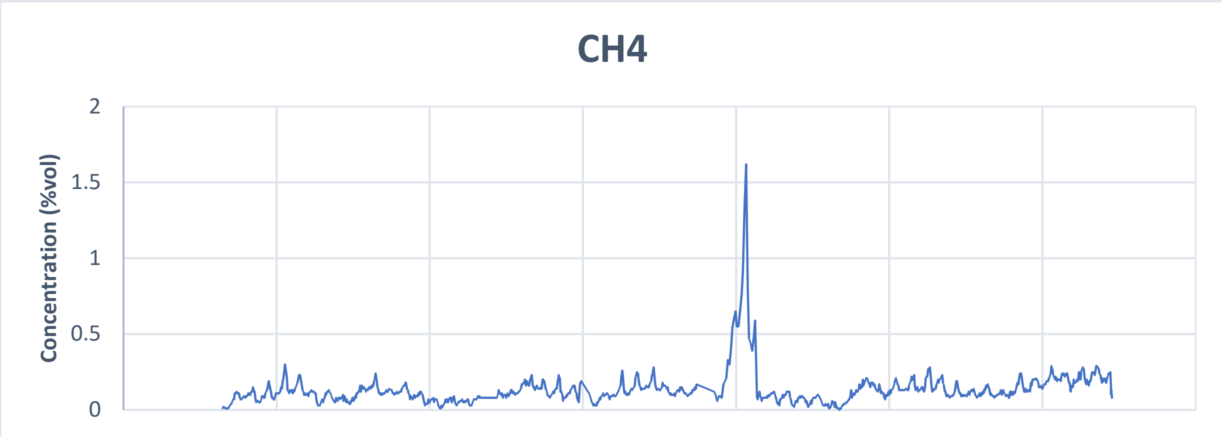

VOC
Concentration (ppm)
50
40
30
20
10
0
-10

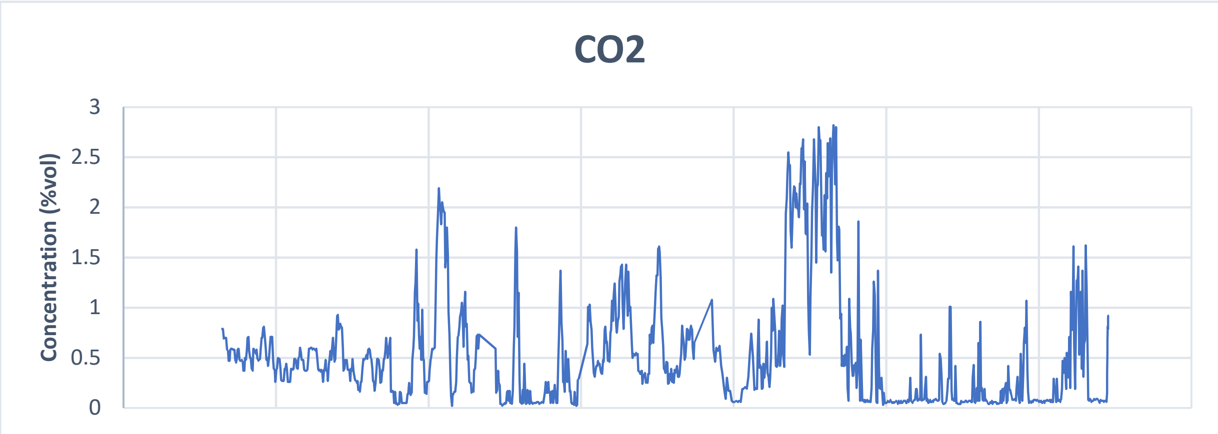

CO and H2S
Concentration (ppm)
30
25
20
15
10
5
0
avgCO (ppm)
avgH2S (ppm)

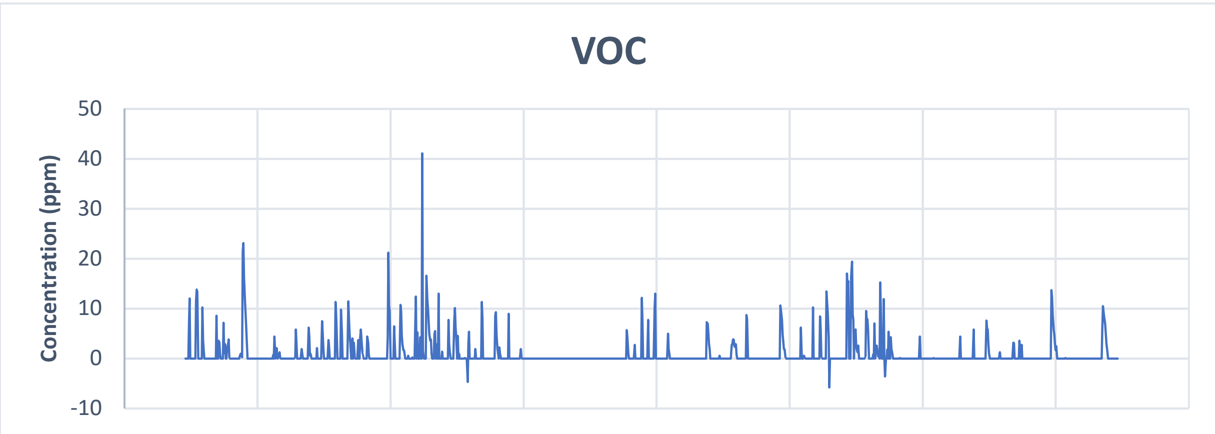

Barometric Pressure
Barometric Pressure (hPa)
1030
1020
1010
1000
990
980
970

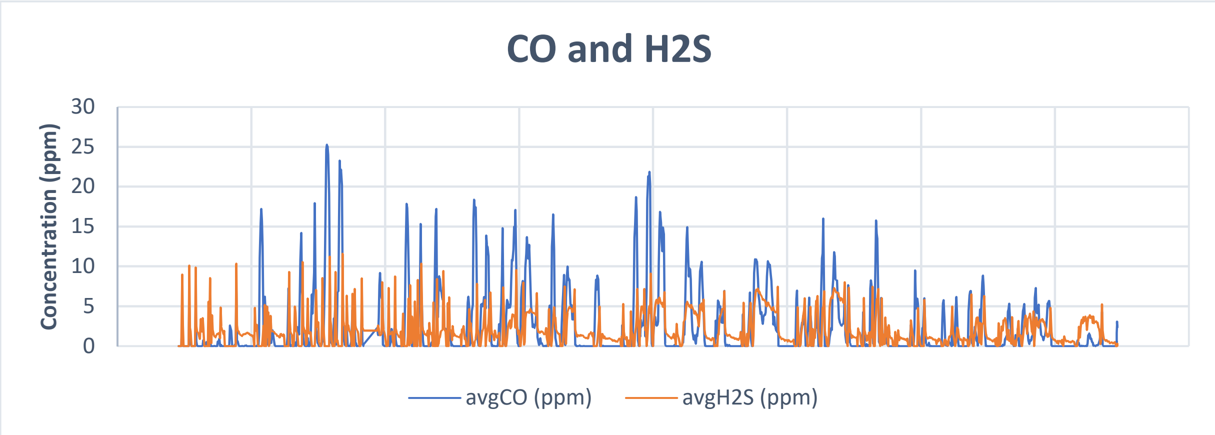

Temperature
Temp (C°)
30
25
20
15
10
5
0
-5

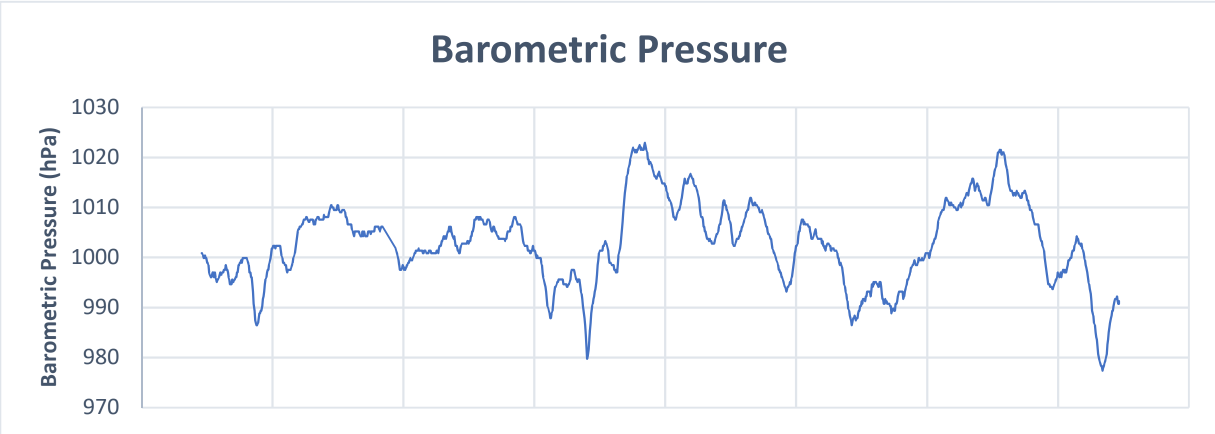
Luton_BWS202

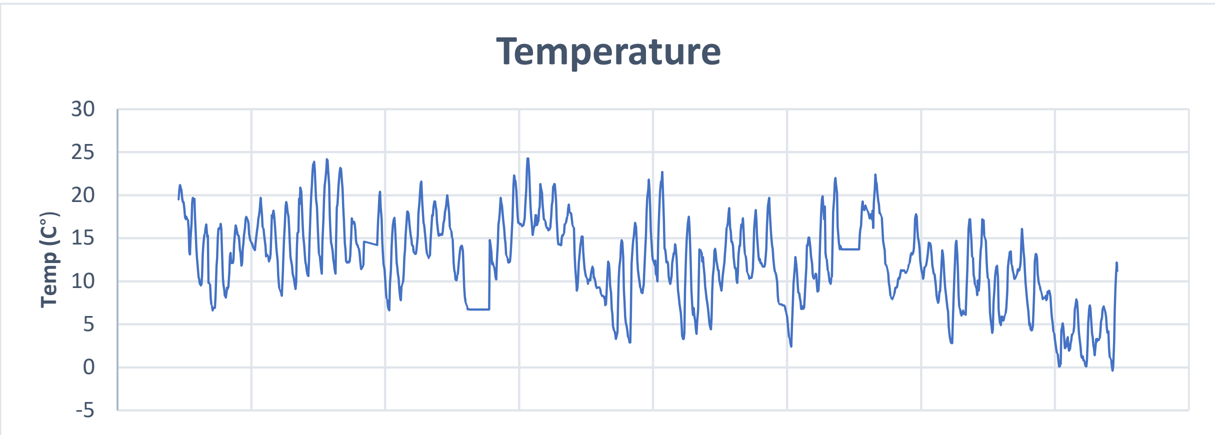







CO and H2S
Concentration (ppm)
30
25
20
15
10
5
0
avgCO (ppm)
avgH2S (ppm)


Barometric Pressure
Barometric Pressure (hPa)
1030
1020
1010
1000
990
980
970


Temperature
Temp (C°)
30
25
20
15
10
5
0
-5

Appendix C

Time Series Data

Included electronically in excel format as follows:

UK_AECOM_Luton_BH202-FinalReport

UK_AECOM_Luton_BH206-FinalReport

UK_AECOM_Luton_BH208-FinalReport

UK_AECOM_Luton_BH224-FinalReport

UK_AECOM_Luton_BWS202-FinalReport

Appendix D

GasFlux Specification

GasFlux Specification

Technical Specification

Sampling Frequency	Customisable: 1 to 12 hourly
	CH_4: 0-70 %vol, typical accuracy ±2 %vol
	CO_2: 0-40 %vol, typical accuracy ±2 %vol
	O_2: 0-25 %vol, typical accuracy ±1 %vol
	CO: 0-500ppm
	H_2S: 0-200ppm
	tVOCs: 0-4000ppm
	NH_3: 0 – 2000 ppm
	Pressure: Gauge ± 150 mB / Barometric: 850-1150 hPa
	Humidity: 0-100% RH (non-condensing)
	Temperature: -10 to +40 °C
	External interface: voltage or 4-20mA inputs e.g. thermal flowmeters
	Borehole flow: 0-60 L/hr
	Water levels: customisable
Power	3 month battery life & indefinite with supplied solar charging device
Memory	Internal memory storage for 12 months non-volatile data backup
Communications	GSM & 3G/4G
Physical	360x220x200 mm; 2.4 kg; IP68-rated enclosure; Wall/pole mountable; Suitable for installation on borehole wells, manifolds, pipes

Appendix B Continuous Gas Monitoring Data

B1.1 Continuous gas monitoring data

B1.1.1 High-frequency gas monitoring undertaken on five selected monitoring installations (BH202, BH206, BH208, BH224 and BWS202) allows the data to be assessed for temporal variations. Correlations between variations in gas concentration and/or borehole flow and changes in atmospheric pressure, borehole pressure, temperature and groundwater fluctuations all provide information into the gas regime of a site. The apparent trends from the data recorded are discussed below.

B1.2 Atmospheric pressure

B1.2.1 The variation in atmospheric pressure recorded during the monitoring period (August to October 2018) is shown in Figure B1. The data indicates that a range of atmospheric pressure conditions were recorded during this time with a minimum pressure of 979 mbar and maximum pressure of 1021 mbar recorded. The monitoring coincided with a number of falls in pressure.

Figure B1 Atmospheric pressure recorded during high-frequency monitoring period

B1.2.2 The atmospheric pressure data has been reviewed to assess if the data has been collected over a sufficient number of relevant pressure variations to allow the prediction of “worst-case” atmospheric pressure conditions[1]. A fall in atmospheric pressure is an important ground-gas driver on many sites and in particular the rate and duration of the fall are considered to be the key factors[2].

B1.2.3 The pressure falls and duration recorded on site are shown in Figure B2. Most of the data is within Zone 2 which is considered to represent a normal range of pressure changes. The “worst-case” zone

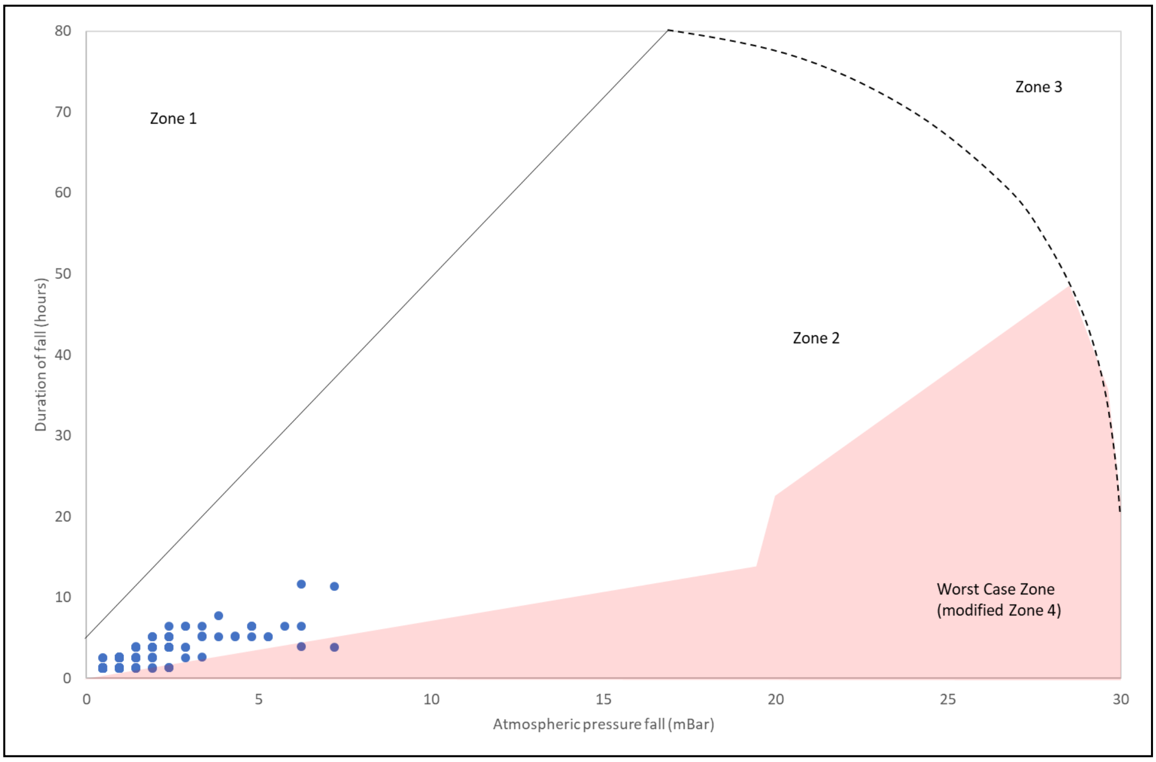
[1] CL:AIRE, 2018. Technical Bulletin 18, Ground gas monitoring and ‘worst-case’ conditions
[2] Wilson, S., Oliver, S., Mallett, H., Hutchings, H. and Card, G., 2007. CIRIA Report 66c, assessing risks posed by hazardous ground gases in buildings. CIRIA, London, UK.

represents situations where very large pressure falls are recorded within a short period of time. Two of the pressure falls recorded on site are within the worst-case zone and a third drop is on the boundary of this zone. Based on these results it is concluded that data has been collected from the site which can be used to assist in predicting worst-case gas conditions within the landfill.

B1.2.4 The three "worst-case" pressure falls were recorded on the following dates:

- 20th September 2018, fall of 7.2mbar over 3.9 hours
- 26th August 2018, fall of 6.24 mbar over 3.95 hours
- 10th September 2018, fall of 2.4 mbar over 1.3 hours

Figure B2 Atmospheric pressure fall vs duration (based on CL:AIRE TB17)

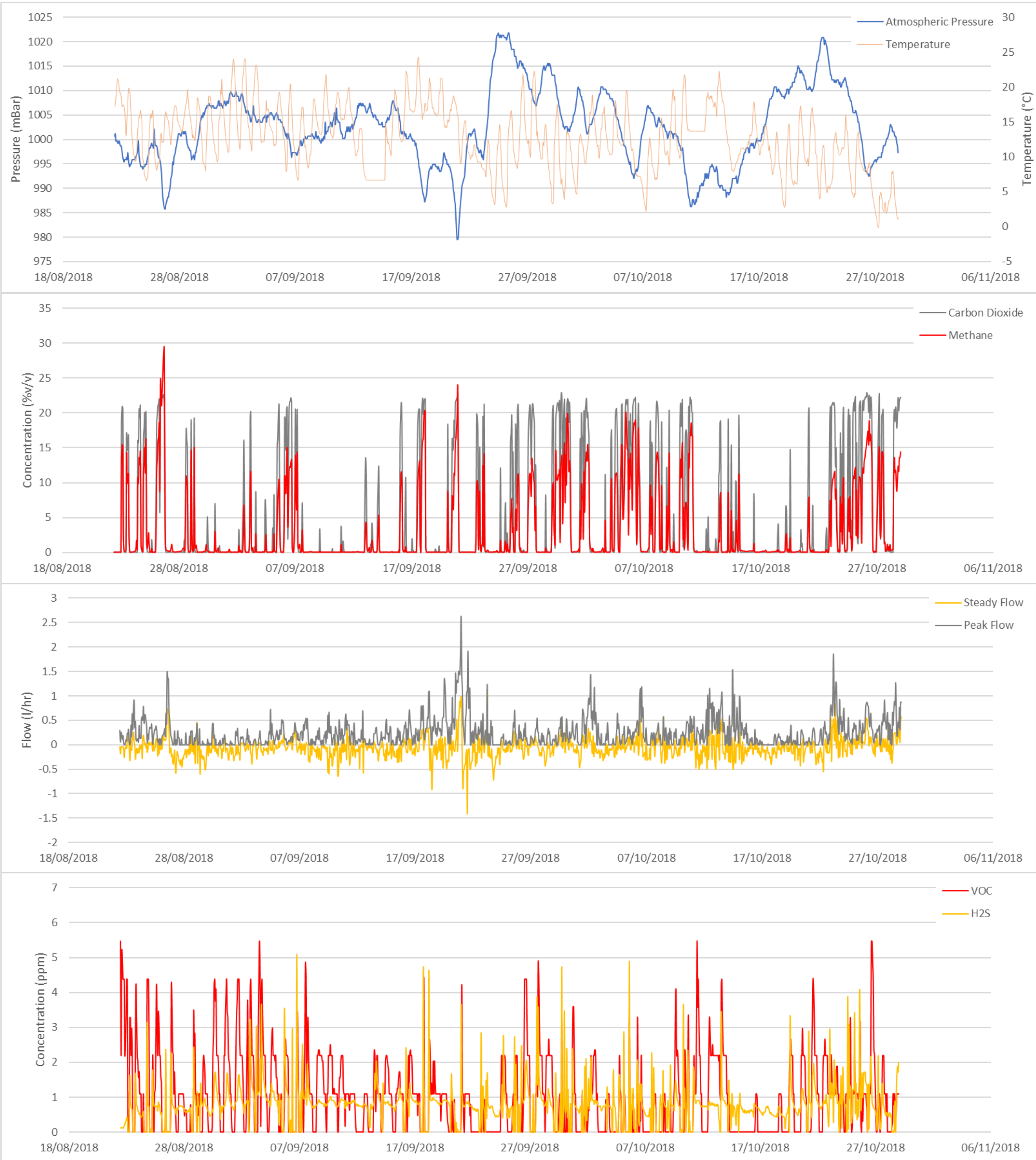


B1.3 BH202

B1.3.1 The high frequency monitoring data for BH202 (see Figure B3) suggests a strong relationship between ground gas concentrations, gas flow and falling/low atmospheric pressure at this location. Increases in methane and carbon dioxide concentrations and gas flows that have been recorded appear to respond rapidly to change in atmospheric pressure conditions, with no significant lag apparent in the data. During periods of rising or steady atmospheric pressure methane and carbon dioxide concentrations are typically below or close to the limit of detection of the monitoring equipment.

B1.3.2 The maximum flow rate recorded in BH202 was 2.63 l/hr and followed a rapid decrease in atmospheric pressure on the 20th September 2018. The maximum methane concentration of 29.44% was recorded on 26th August 2018. The maximum concentration of carbon dioxide recorded was 22.96%. Peak concentrations of hydrogen sulphide and VOCs were 5.08ppm and 5.47ppm respectively.

Figure B3 High frequency gas monitoring data BH202



B1.3.3 Concentration duration analysis converts the total monitoring period for each well into percentage time and sorts all recorded ground gas concentrations from highest to lowest to produce a concentration duration curve. This enables observations to be made about the proportion of the monitoring period spent at each gas concentration. The concentration duration curve for BH202 is shown in Figure B4 and a summary of methane and carbon dioxide analysis is provided in Table B1. The analysis indicates that concentrations of methane and carbon dioxide in BH202 are above levels that could be considered hazardous approximately 30% of the time.

Figure B4 BH202 gas concentration duration curve

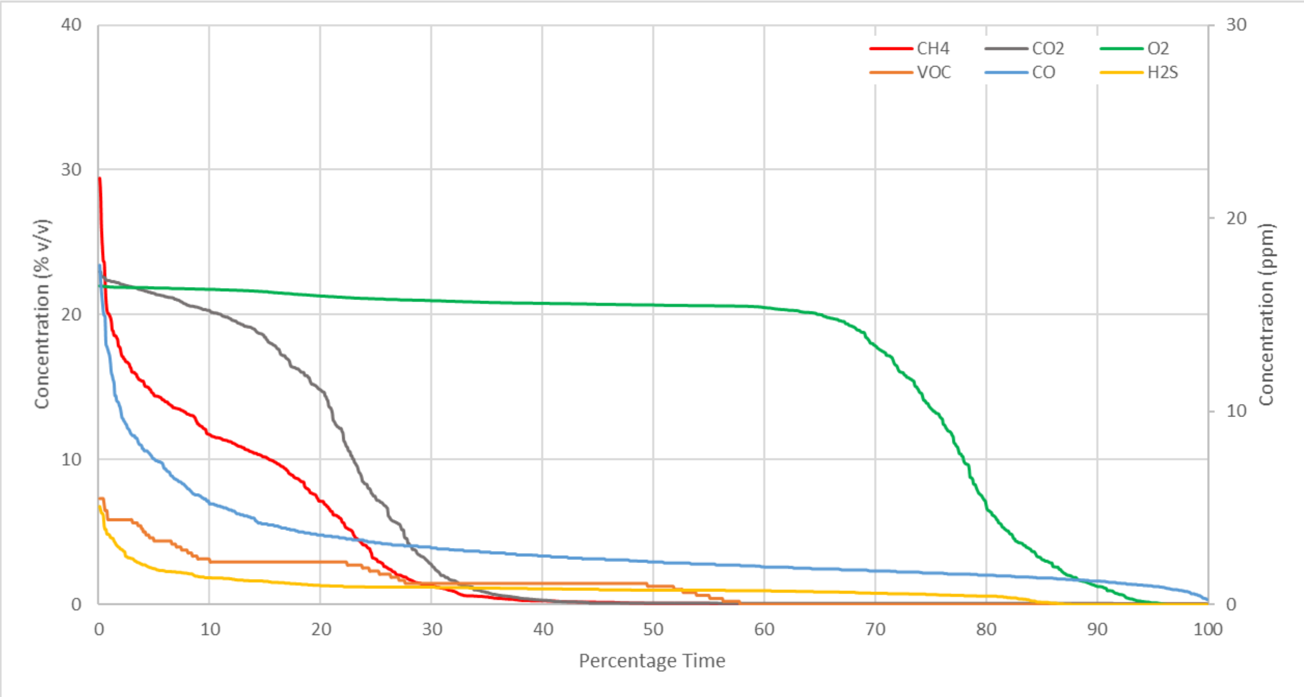
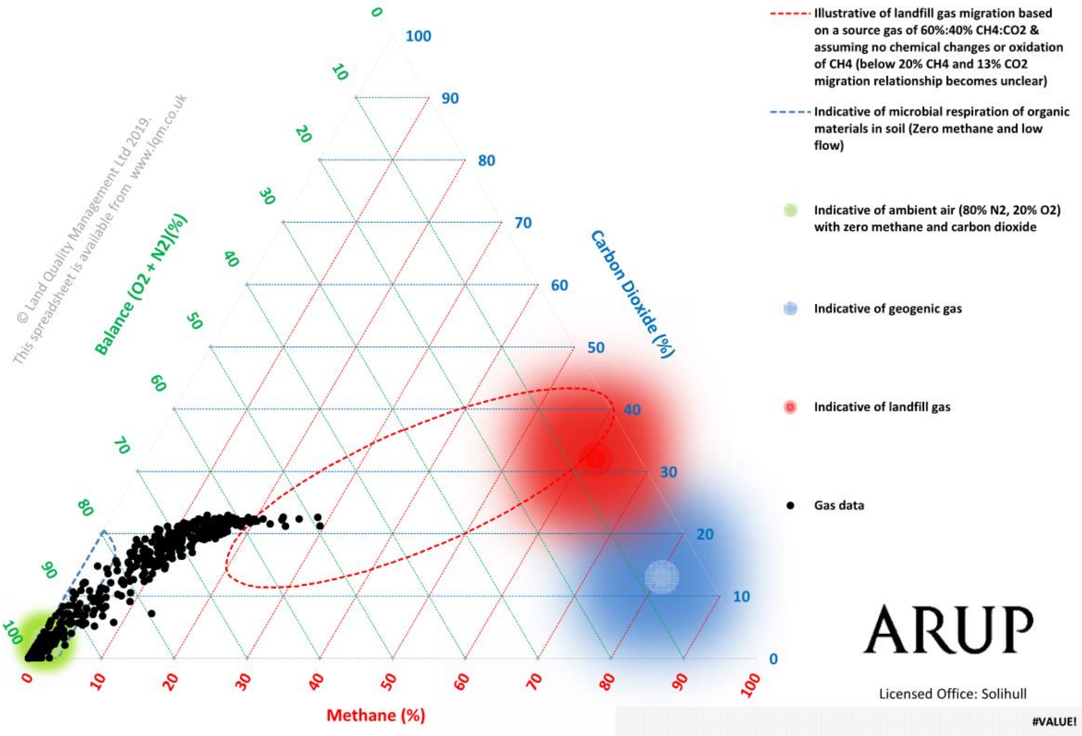


Table B1 BH202 methane and carbon dioxide duration

% monitoring period CH_4 exceeded or equalled			% monitoring period CO_2 exceeded or equalled		
1% v/v	5% v/v	20% v/v	5% v/v	10% v/v	30% v/v
31.6	22.9	0.9	27.5	23	0

B1.3.4 The gas data has been plotted on a ternary plot to further characterise the ground gas regime and differentiate between potential sources of ground gas detected in the monitoring well (see Figure B5). The ternary plot identifies that the majority of gas recorded in the well is indicative of ambient air with a low number of readings illustrative of landfill gas migration into the well.

Figure B5 BH202 ternary plot



B1.3.5 The rise and fall of methane concentrations in direct response to changes in atmospheric pressure may indicate that methane is migrating to the monitoring well from elsewhere within the landfill and is not being generated locally within the landfill waste immediately surrounding this well.

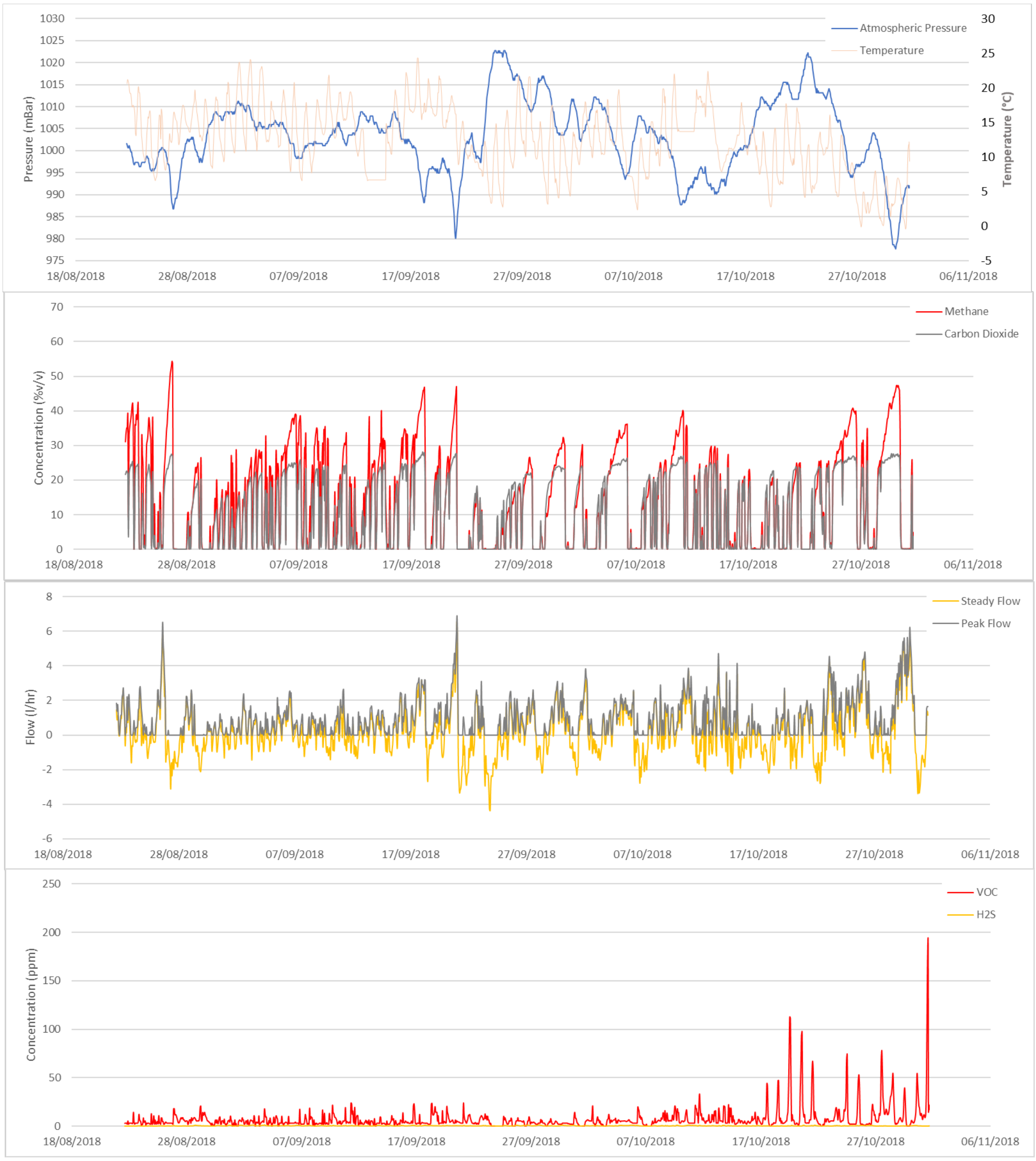
B1.3.6 BH202 is located in the north of the landfill where approximately 8m of cover material (both chalky and non-chalky) was encountered over a thin layer (approximately 1.4m) of construction waste comprising brick, chalk and clay. This material is considered to have a lower potential for generation of landfill gas compared with other waste types.

B1.4 BH206

B1.4.1 The high frequency monitoring data for BH206 (see Figure B6) suggests a strong relationship between ground gas concentrations, gas flow and falling/low atmospheric pressure at this location. Increases in methane and carbon dioxide concentrations and gas flows that have been recorded appear to respond to change in atmospheric pressure conditions, with no significant lag apparent in the data.

B1.4.2 The maximum flow rate recorded in BH206 was 6.86 l/hr and followed a rapid decrease in atmospheric pressure on the 20th September 2018. The maximum methane concentration of 54.3% was recorded on 26th August 2018. The maximum concentration of carbon dioxide recorded was 28.18%. Peak concentrations of hydrogen sulphide and VOCs were 1.18ppm and 191.37ppm respectively.

Figure B6 High frequency gas monitoring data BH206



B1.4.3 The concentration duration curve for BH206 is shown in Figure B7 and a summary of methane and carbon dioxide analysis is provided in Table B2. The analysis indicates that concentrations of methane and carbon dioxide in BH206 are above levels that could be considered hazardous approximately 60% of the time.

Figure B7 Gas Concentration duration curve BH206

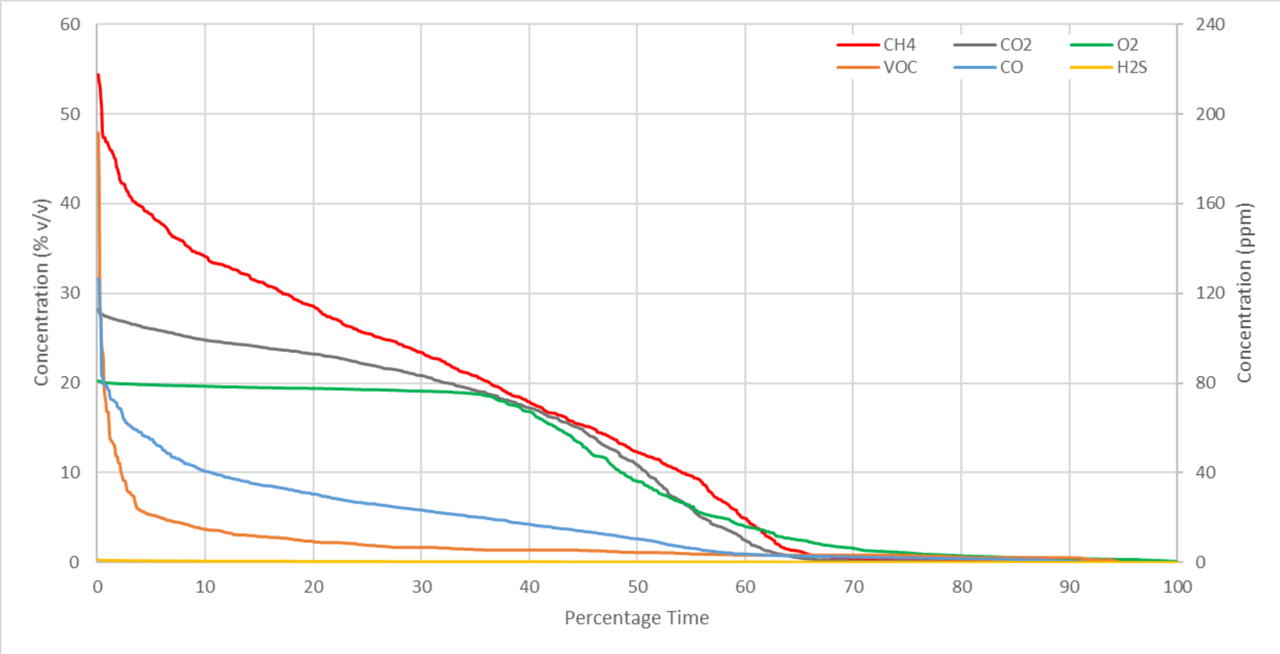
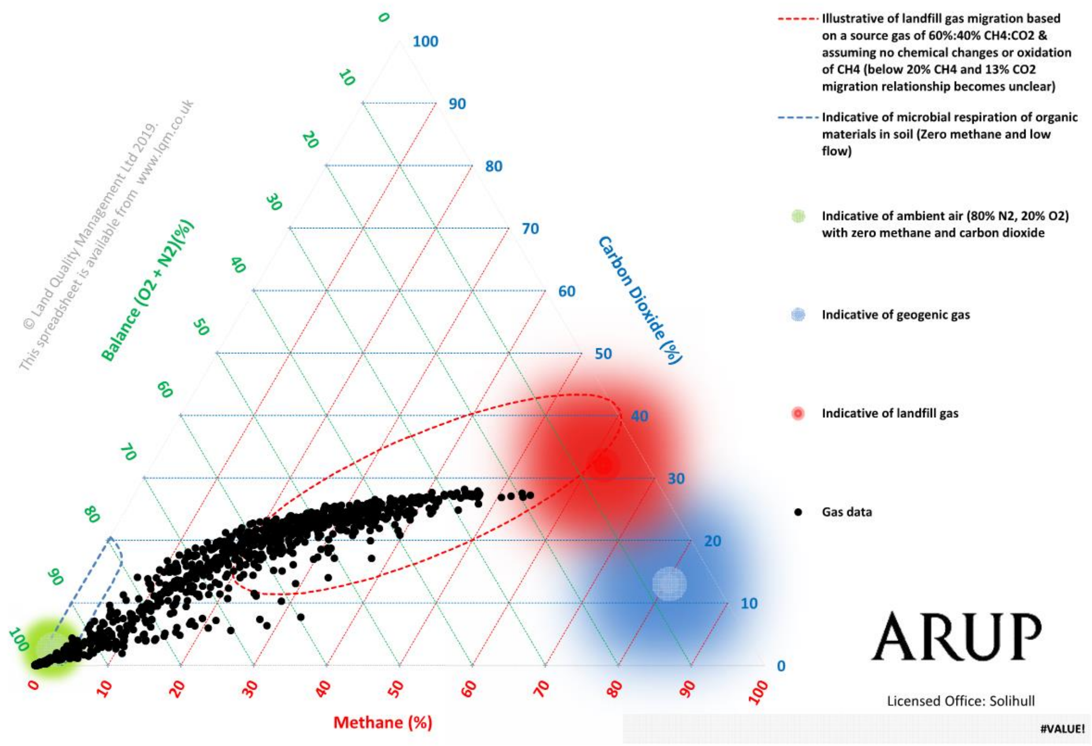


Table B2 BH206 methane and carbon dioxide duration

% monitoring period CH_4 exceeded or equalled			% monitoring period CO_2 exceeded or equalled		
1% v/v	5% v/v	20% v/v	5% v/v	10% v/v	30% v/v
65.7	59.8	36.3	56	50.9	0

B1.4.4 The ternary plot (Figure B8) identifies that the majority of gas recorded in the well is indicative of landfill gas migration indicating that the borehole is located in close proximity to actively gassing waste material.

Figure B8 BH206 ternary plot



B1.4.5 The rise and fall of methane concentrations in direct response to changes in atmospheric pressure and prolonged period of elevated methane concentrations indicates that the monitoring well may be in an area which is within or in close proximity to waste materials which are actively generating landfill gas.

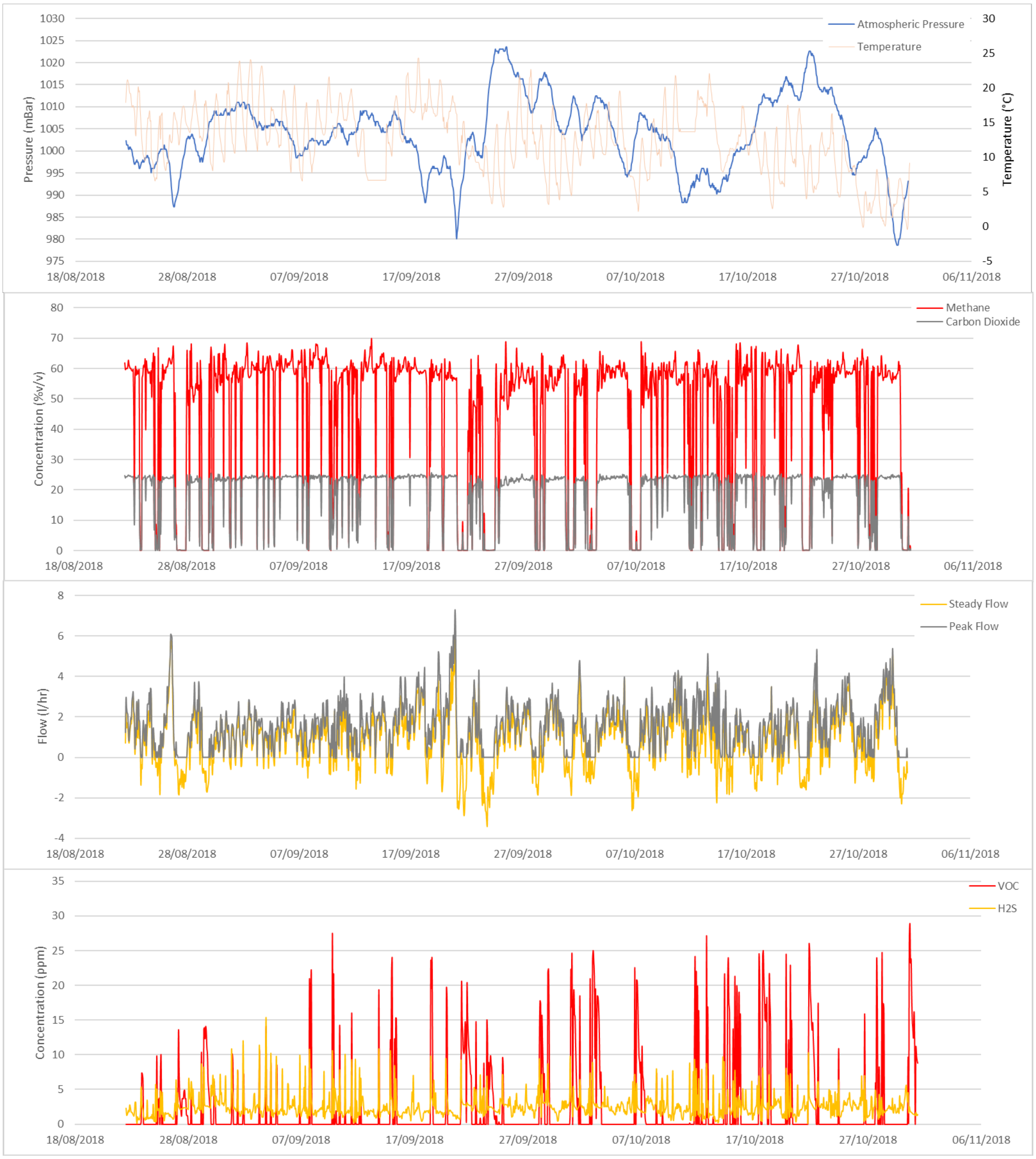
B1.4.6 BH206 is located towards the centre of the landfill where approximately 8m of waste was encountered which predominantly comprised a mixture of industrial and construction wastes with a minor amount of recent domestic waste. Some of this material is considered to have a high potential for generation of landfill gas.

B1.5 BH208

B1.5.1 The high frequency monitoring data for BH208 (see Figure B9) suggests a strong relationship between ground gas concentrations, gas flow and falling/low atmospheric pressure at this location. Increases in methane and carbon dioxide concentrations and gas flows that have been recorded appear to respond to change in atmospheric pressure conditions. In general methane concentrations are recorded the majority of the time, with concentrations only dropping below the monitoring equipment limit of detection during time of long duration atmospheric pressure rises.

B1.5.2 The maximum flow rate recorded in BH208 was 7.31 l/hr and followed a rapid decrease in atmospheric pressure on the 20th September 2018. The maximum methane concentration of 69.72% was recorded on 13th September 2018. The maximum concentration of carbon dioxide recorded was 25.72%. Peak concentrations of hydrogen sulphide and VOCs were 15.27ppm and 28.96ppm respectively.

Figure B9 High frequency gas monitoring data BH208



B1.5.3 The concentration duration curve for BH208 is shown in Figure B10 and a summary of methane and carbon dioxide analysis is provided in Table B3. The analysis indicates that concentrations of methane and carbon dioxide in BH208 are above levels that could be considered hazardous over 80% of the time.

Figure B10 Gas concentration duration curve BH208

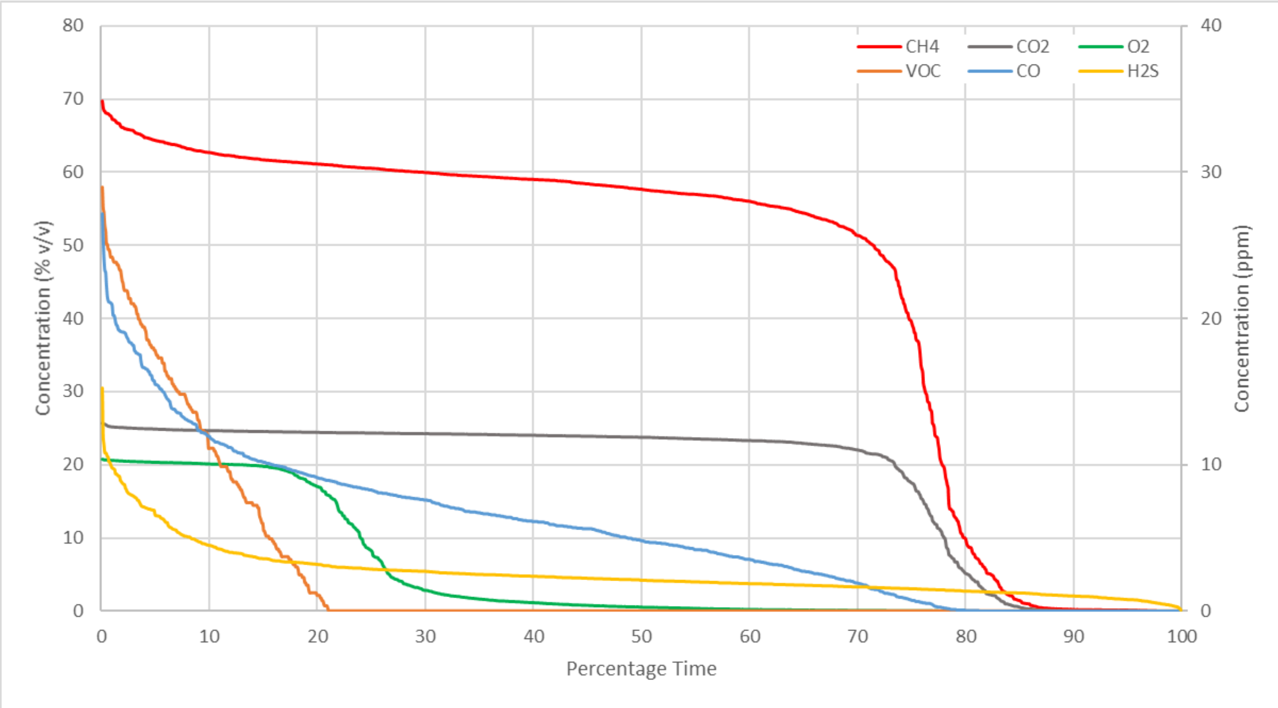
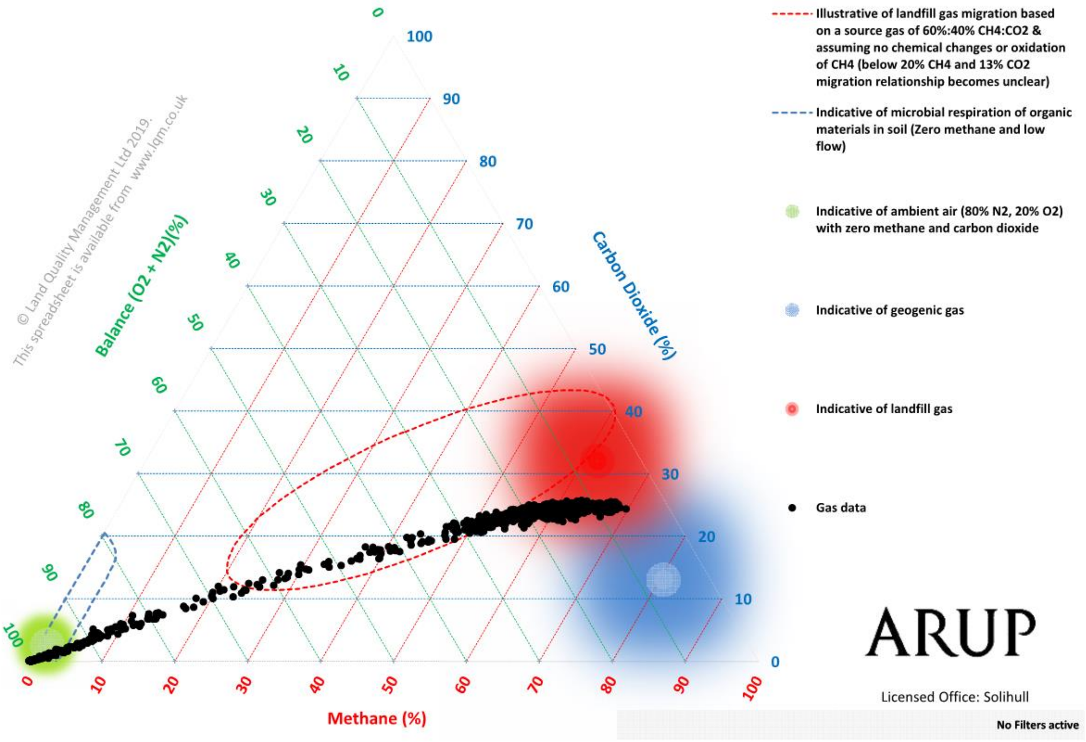


Table B1 BH208 methane and carbon dioxide duration

% monitoring period CH_4 exceeded or equalled			% monitoring period CO_2 exceeded or equalled		
1% v/v	5% v/v	20% v/v	5% v/v	10% v/v	30% v/v
85.9	82.4	77.8	80.2	78.1	0

B1.5.4 The ternary plot (Figure B11) identifies that the majority of gas recorded in the well is indicative of landfill gas indicating that the borehole is located within or in close proximity to actively gassing waste material.

Figure B11 BH208 ternary plot



B1.5.5 The results indicate BH208 is in an area of the landfill within or in very close proximity to material which is actively generating landfill gas.

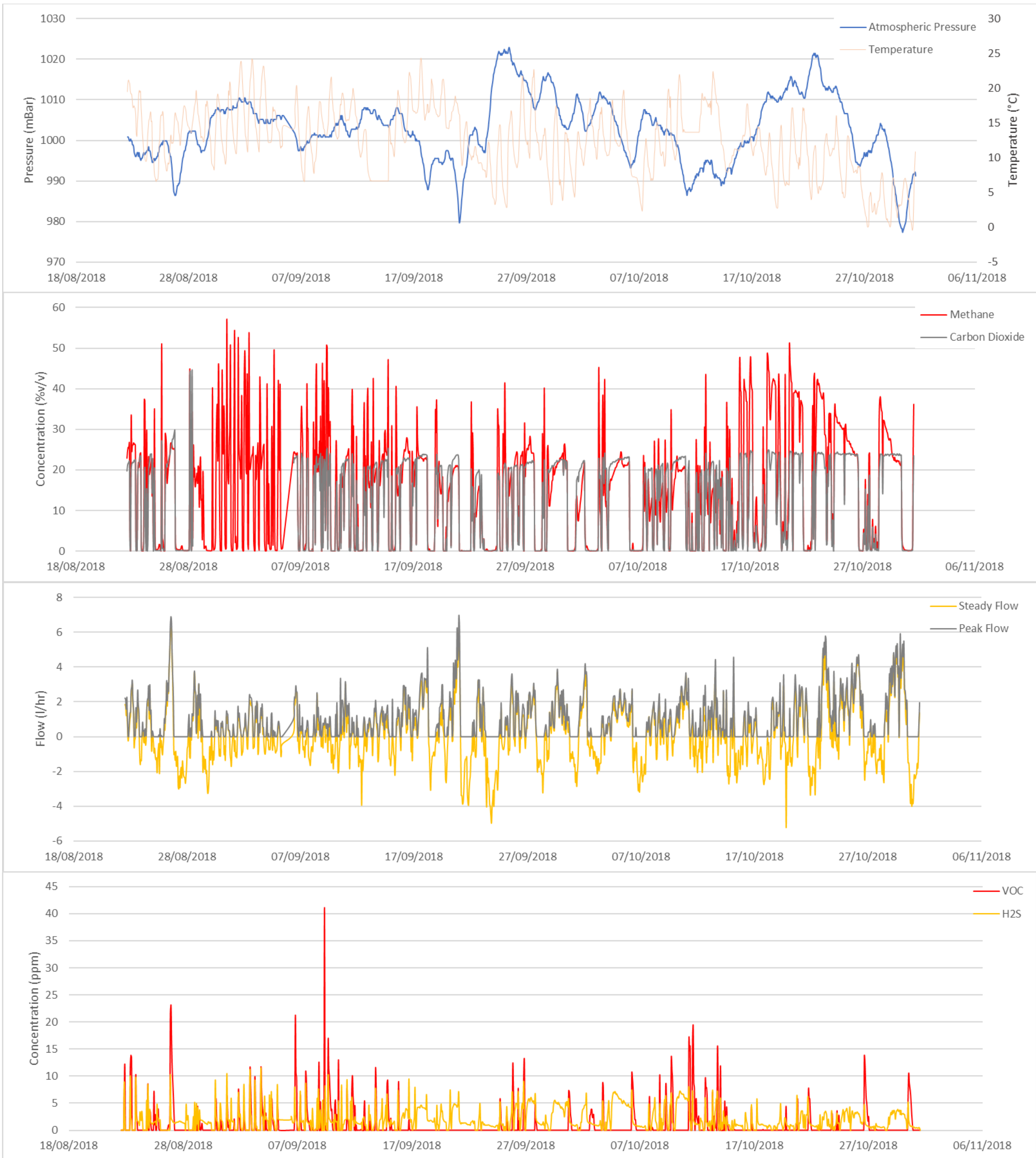
B1.5.6 BH208 is in the centre of the landfill where approximately 11.5m of waste was encountered which predominantly comprised a mixture of industrial waste with smaller quantities of some construction and commercial waste.

B1.6 BH224

B1.6.1 The high frequency monitoring data for BH224 (see Figure B12) suggests a relationship between ground gas concentrations, gas flow and falling/low atmospheric pressure at this location. Increases in methane and carbon dioxide concentrations and gas flows that have been recorded appear to respond to change in atmospheric pressure conditions.

B1.6.2 The maximum flow rate recorded in BH224 was 6.97 l/hr and followed a rapid decrease in atmospheric pressure on the 20th September 2018. The maximum methane concentration of 56.73% was recorded on 31st August 2018. The maximum concentration of carbon dioxide recorded was 44.69%, however it is noted that this was recorded immediately prior to a fault being identified on the CO2 sensor and may not be a representative concentration as it is significantly higher than other concentrations during the monitoring period when the sensor was working correctly. Omitting this data, the peak concentration of carbon dioxide recorded was 29.81% was recorded. Peak concentrations of hydrogen sulphide and VOCs were 11.58ppm and 41.13ppm respectively.

Figure B12 High frequency gas monitoring BH224



B1.6.3 The concentration duration curve for BH224 is shown in Figure B13 and a summary of methane and carbon dioxide analysis is provided in Table 4. The analysis indicates that concentrations of methane and carbon dioxide in BH224 are above levels that could be considered hazardous over 60% of the time.

Figure B13 Gas concentration duration curve BH224

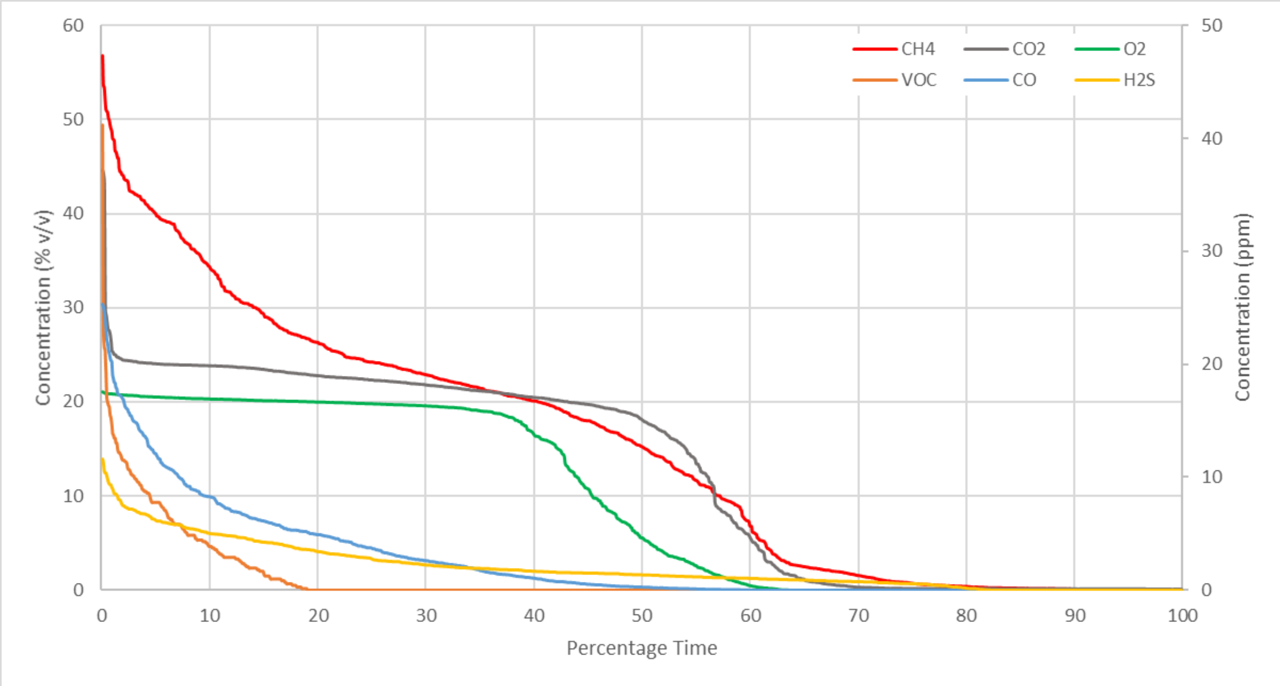
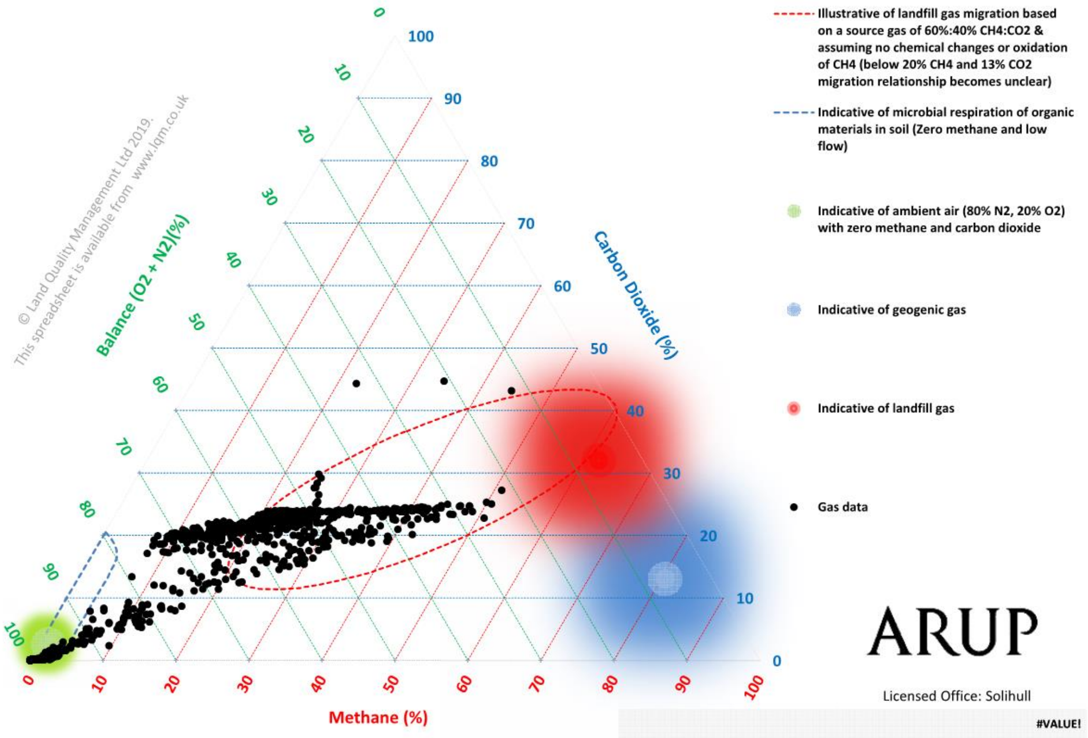


Table B4 BH224 methane and carbon dioxide duration

% monitoring period CH_4 exceeded or equalled			% monitoring period CO_2 exceeded or equalled		
1% v/v	5% v/v	20% v/v	5% v/v	10% v/v	30% v/v
72.7	61.4	40.3	60.4	56.7	0.35

B1.6.4 The ternary plot (Figure B14) identifies that the majority of gas recorded in the well is indicative of landfill gas migration indicating that the borehole is located in close proximity to actively gassing waste material.

Figure B14 BH224 ternary plot



B1.6.5 The results indicate BH224 is in an area of the landfill within or in very close proximity to material which is actively generating landfill gas.

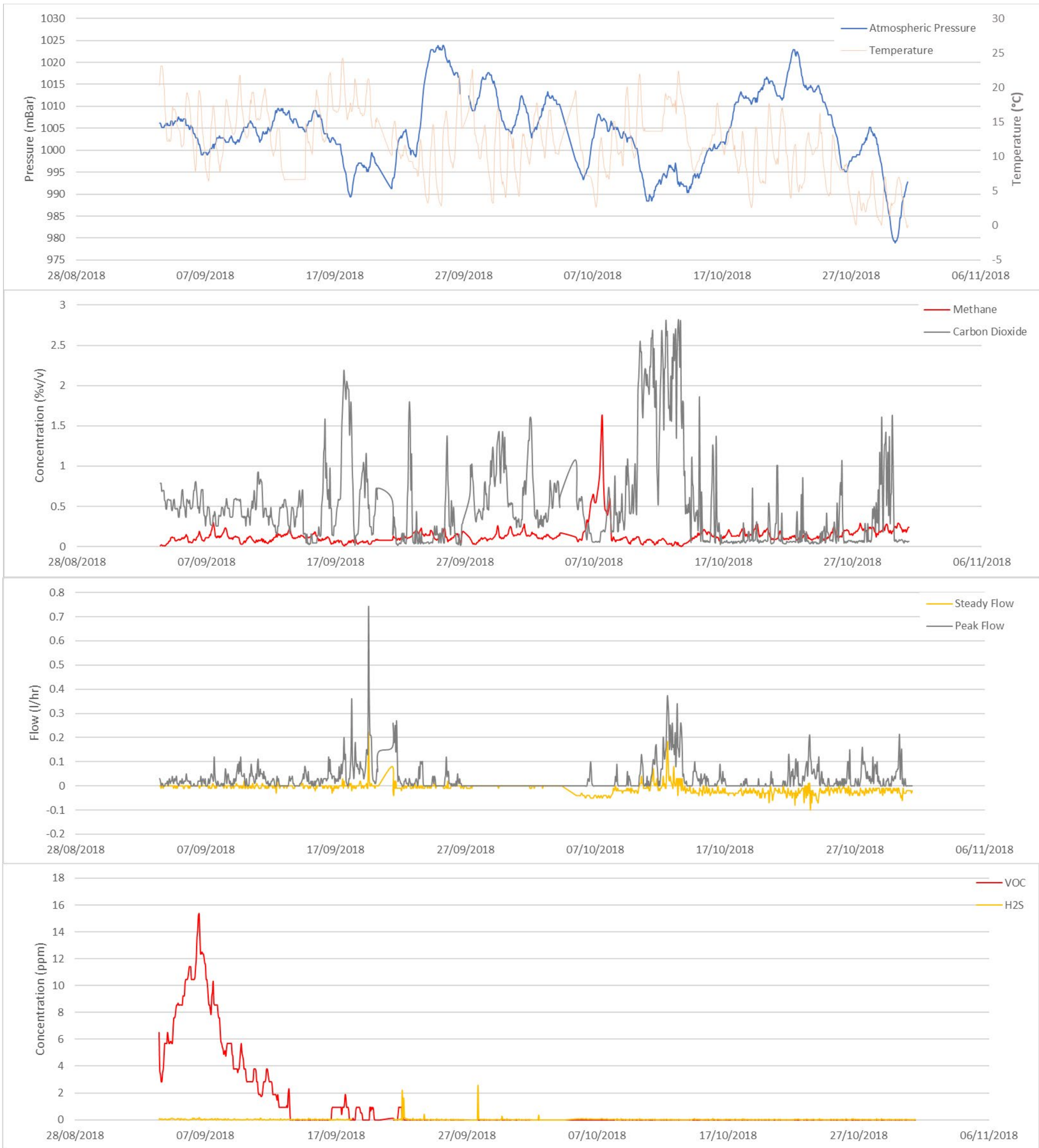
B1.6.6 BH224 is located in the southern part of the landfill where approximately 7m of waste was encountered which predominantly comprised industrial waste with a small quantity of construction waste.

B1.7 BWS202

B1.7.1 The high frequency monitoring data for BWS202 (see Figure B15) suggests a slight correlation between carbon dioxide concentrations, gas flow and falling/low atmospheric pressure at this location. BWS202 is located within natural soils outside of the landfill and very little methane has been recorded.

B1.7.2 The maximum flow rate recorded in BWS202 was 0.74 l/hr recorded on the 19th September 2018. The maximum methane concentration of 1.62% was recorded on 7th October 2018. Peak concentrations of hydrogen sulphide and VOCs were 2.59ppm and 15.34ppm respectively.

Figure B15 High frequency gas monitoring BWS202



B1.7.3 The concentration duration curve for BWS202 is shown in Figure B16 and a summary of methane and carbon dioxide analysis is provided in Table B5. The analysis indicates that concentrations of methane and carbon dioxide in BWS202 were not recorded at levels that could be considered hazardous.

Figure B16 Gas concentration duration curve BWS202

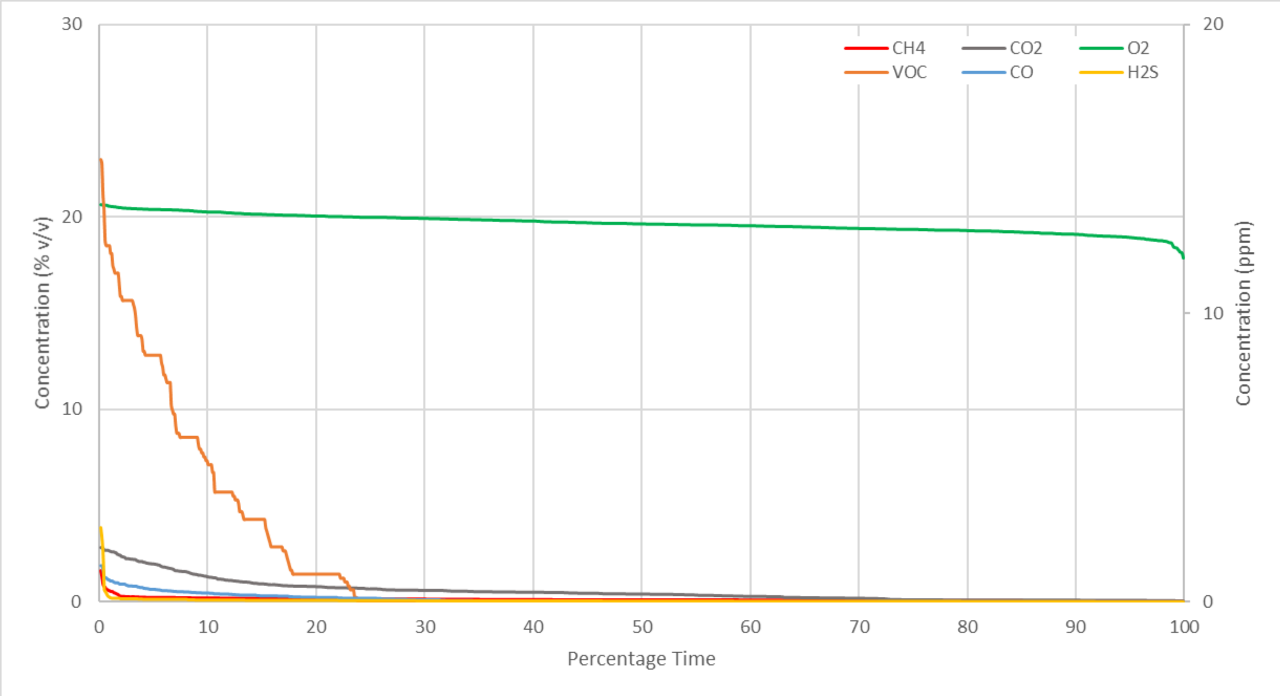
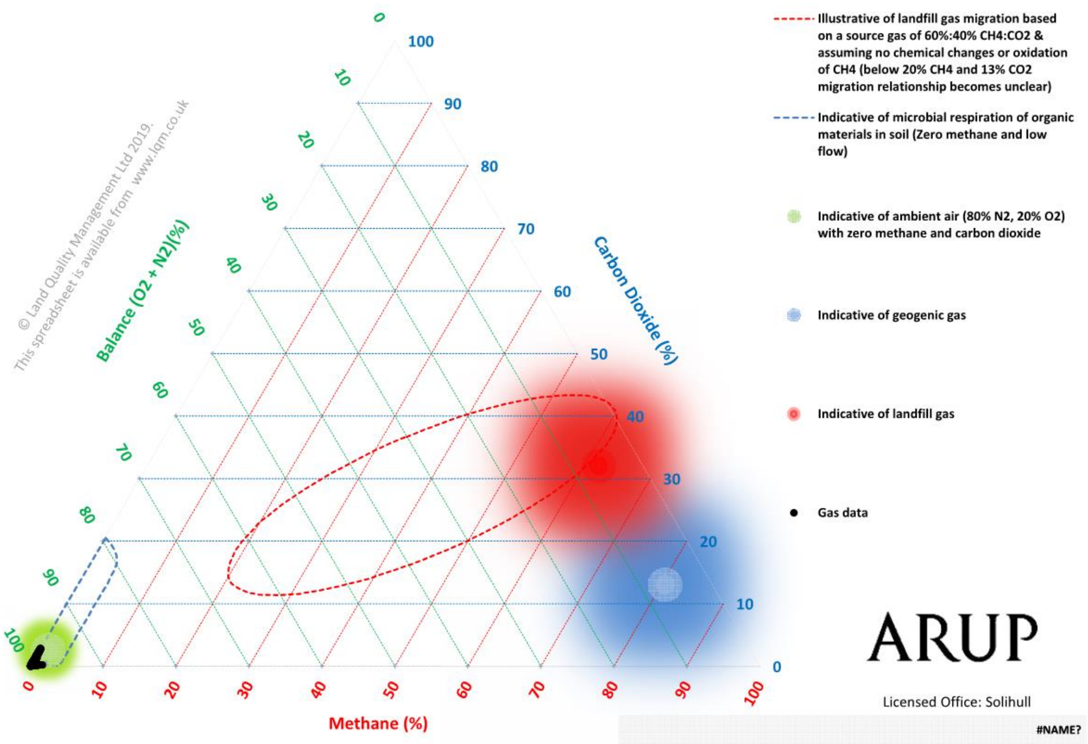


Table B5 BH224 methane and carbon dioxide duration

% monitoring period CH_4 exceeded or equalled			% monitoring period CO_2 exceeded or equalled		
1% v/v	5% v/v	20% v/v	5% v/v	10% v/v	30% v/v
0.3	0	0	0	0	0

B1.7.4 The ternary plot (Figure 16) identifies that the gas recorded in the well is indicative of ambient air concentrations and there is no evidence landfill gas migration into the borehole.

Figure B16 BWS202 ternary plot



B1.7.5 The gas concentration and flows recorded in BWS202 are consistent with the location within natural soils outside of the landfill area. The low methane concentrations recorded indicate that there is limited migration of landfill gas off site.

B1.8 Purge and recovery tests

B1.8.1 On completion of the high frequency monitoring, Ambisense undertook a series of purge and recovery tests (PRT) in the same five installations. PRTs involve pumping inert nitrogen gas into the installation to displace other gases that may be present and then monitoring the gas conditions within the installation as hazardous soil-gas concentrations recover. The time vs concentration curves for the PRT tests are provided in the Ambisense report included in at the end of this appendix. These curves can be summarised as follows:

B1.8.2 **BH202:** methane concentration peaked at 2.18% after 30 minutes had elapsed and was then followed by a slow decline. The carbon dioxide concentration began to rise from the first reading to 15.68% at the end of the test (after 1 hour 48 minutes). The results suggest recharge of both methane and carbon dioxide, however due to the accumulation of methane being prevented the level of flow is likely to be low;

B1.8.3 **BH206:** methane concentrations rose steadily and peaked at 7.9% after 54 minutes. The carbon dioxide recovery peaked at 8.4% after 54 minutes. The results show a slow but steady recharge of methane into the borehole;

B1.8.4 **BH208:** methane concentrations rose rapidly and were up to 51.44% by the time of the first reading (after 11 minutes) and then remained relatively stable for the remainder of the test. Carbon dioxide followed a similar trend and was at 20.59% by the first reading. The results indicate a rapid recharge of the borehole with high flow levels for both methane and carbon dioxide;

B1.8.5 **BH224:** methane concentrations rose very rapidly and were up to 13.72% by the time of the first reading (after 11 minutes), the concentration continued to rise steadily for the duration of the test period (1 hour 35 minutes). The carbon dioxide followed a similar trend and was up to 9.515 at the first reading followed by a steady rise in concentration. Oxygen did not recover and remained at 0% for the duration of the test. The results suggest a steady recovery of methane and carbon dioxide. The flow level is considered to be significant due to the jump in concentration from the purged state to the first reading and the oxygen level remaining at 0% for the duration of the test;

B1.8.6 **BWS202:** methane concentrations recovered to 0.16% by the first reading (11 minutes) and then generally remained steady over the remainder of the test period. Caron dioxide concentrations showed a slow and steady rise with a peak concentration of 0.92% at the end of the test (after 1 hour 39 minutes). The results suggest recharge of both methane and carbon dioxide, however due to the accumulation of methane being prevented the level of flow is likely to be low.

B1.9 Ground gas screening values

B1.9.1 To assess the ground gas risk identified by the high-frequency monitoring, real-time Gas Screening Values (GSVs) have been calculated for each installation. This has been done by taking each value of methane and carbon dioxide concentration recorded and calculating the GSV based on the flow rate recorded at the corresponding point in time. Once GSVs for methane and carbon dioxide have been calculated, the highest GSV has been used to define the Characteristic Situation for each installation. The results for each borehole are shown in Figures B17 to B21.

Figure B17: BH202 gas screening values

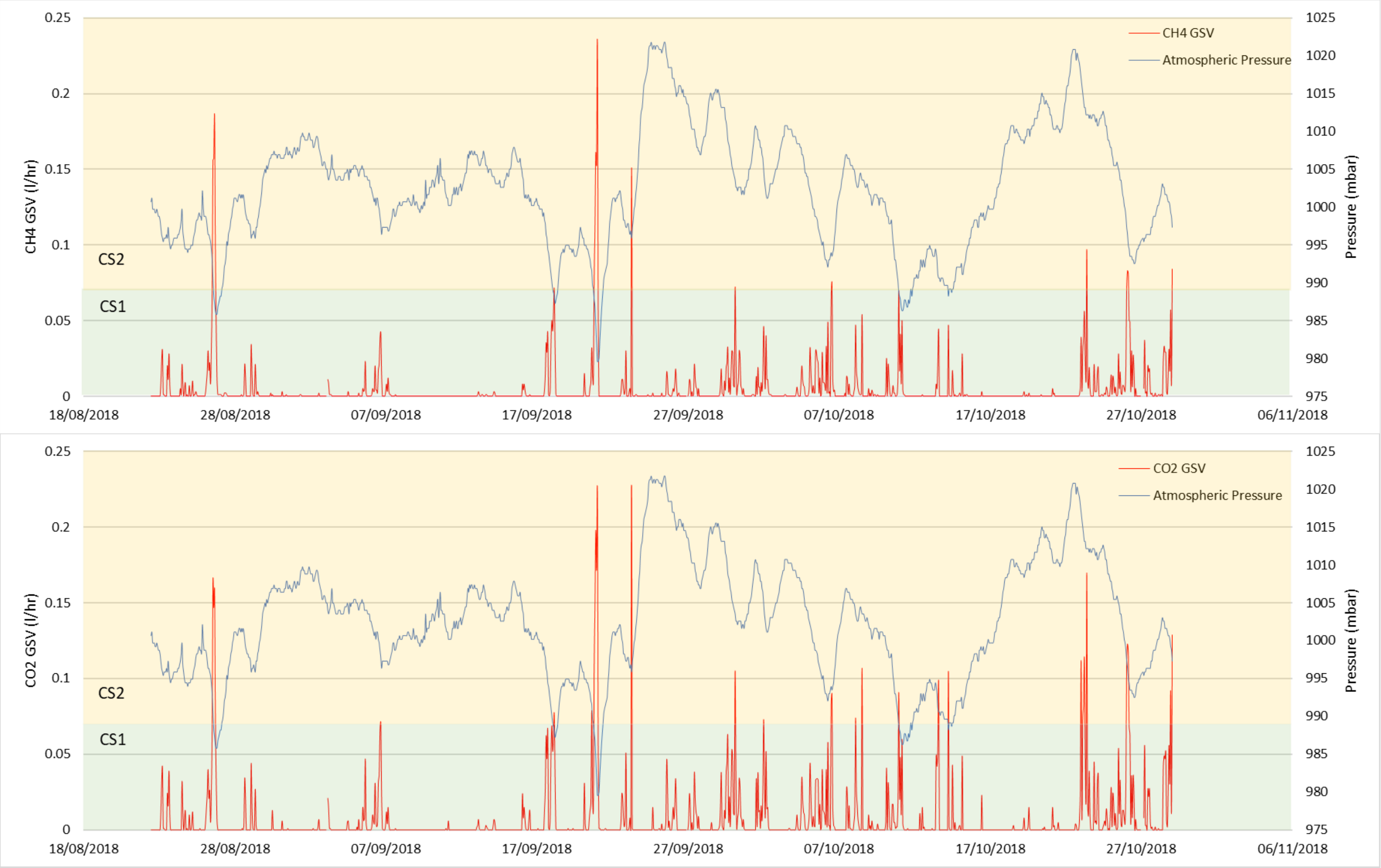


Figure B18: BH206 gas screening values

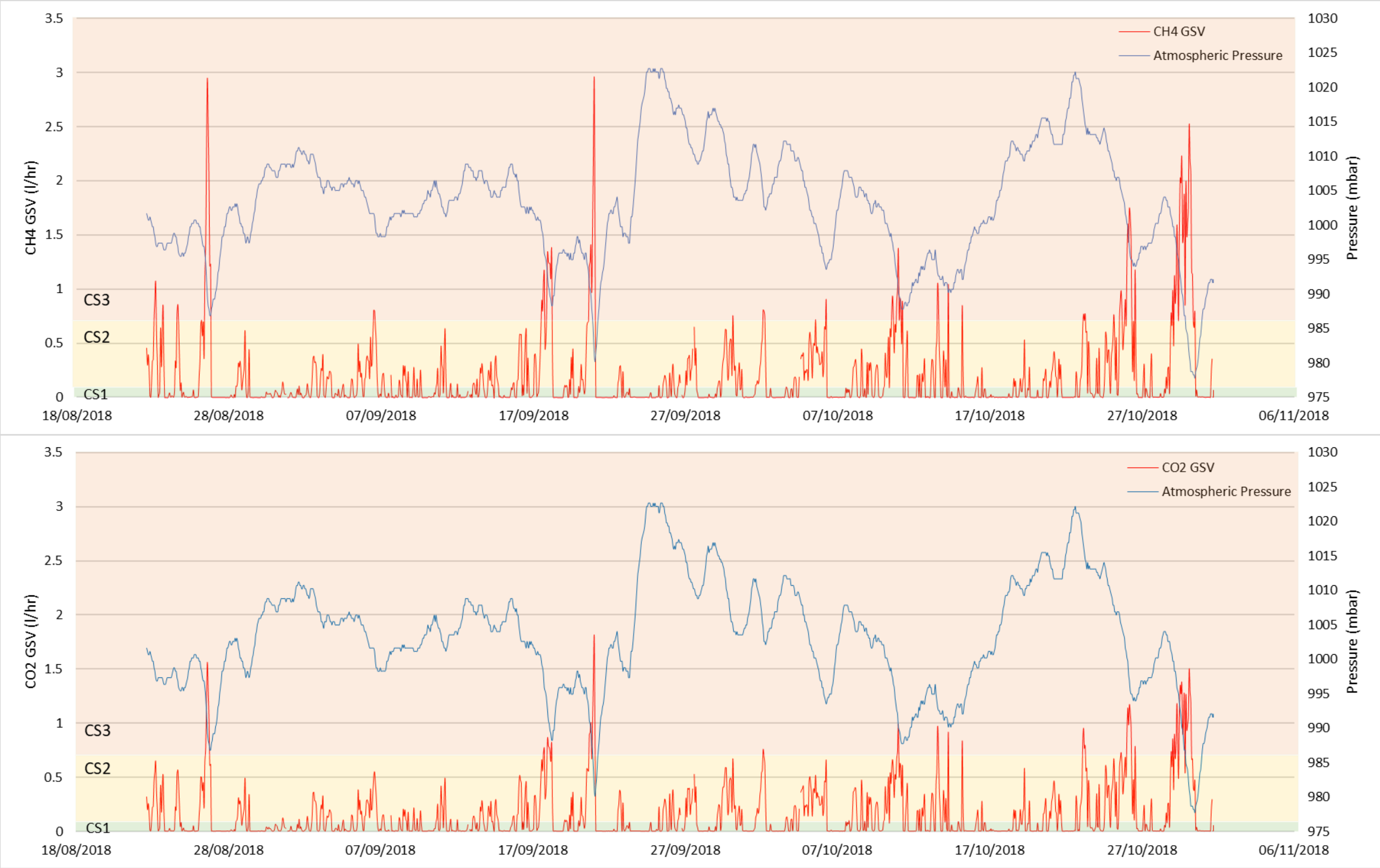


Figure B19: BH208 gas screening values

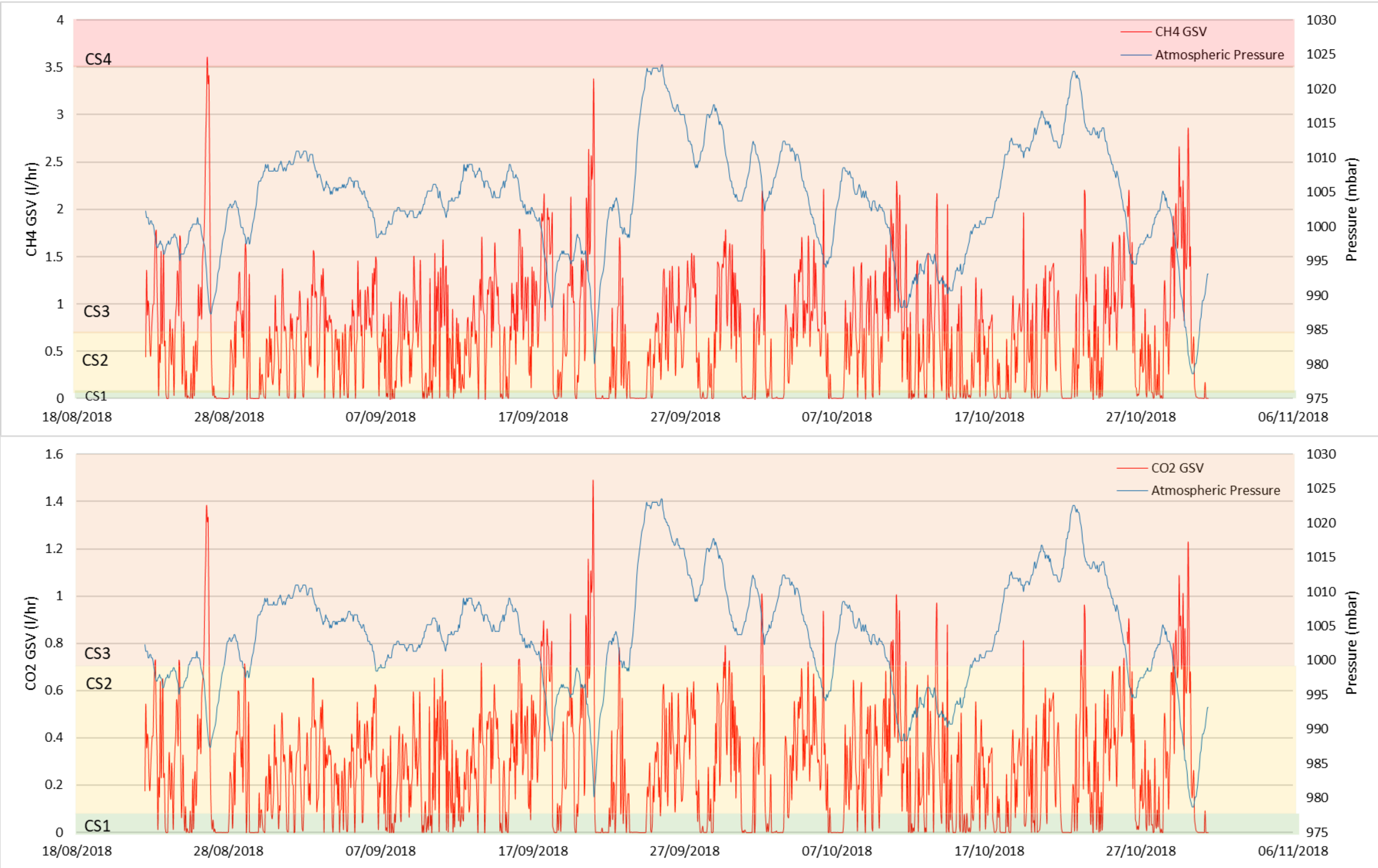
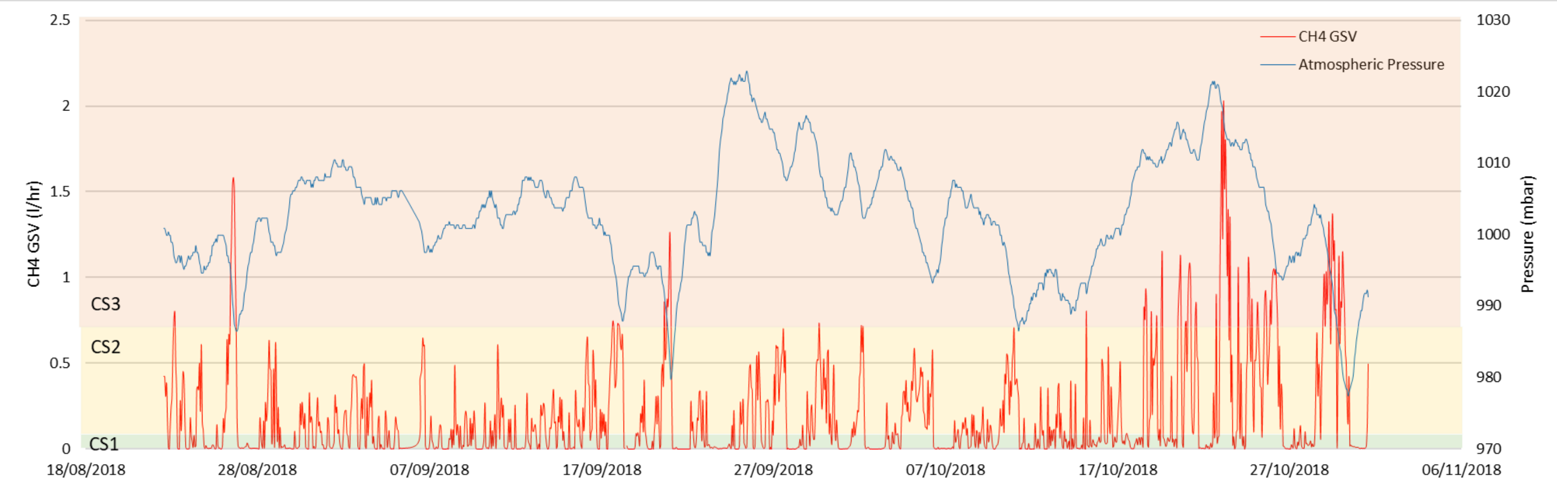


Figure B20: BH224 gas screening values



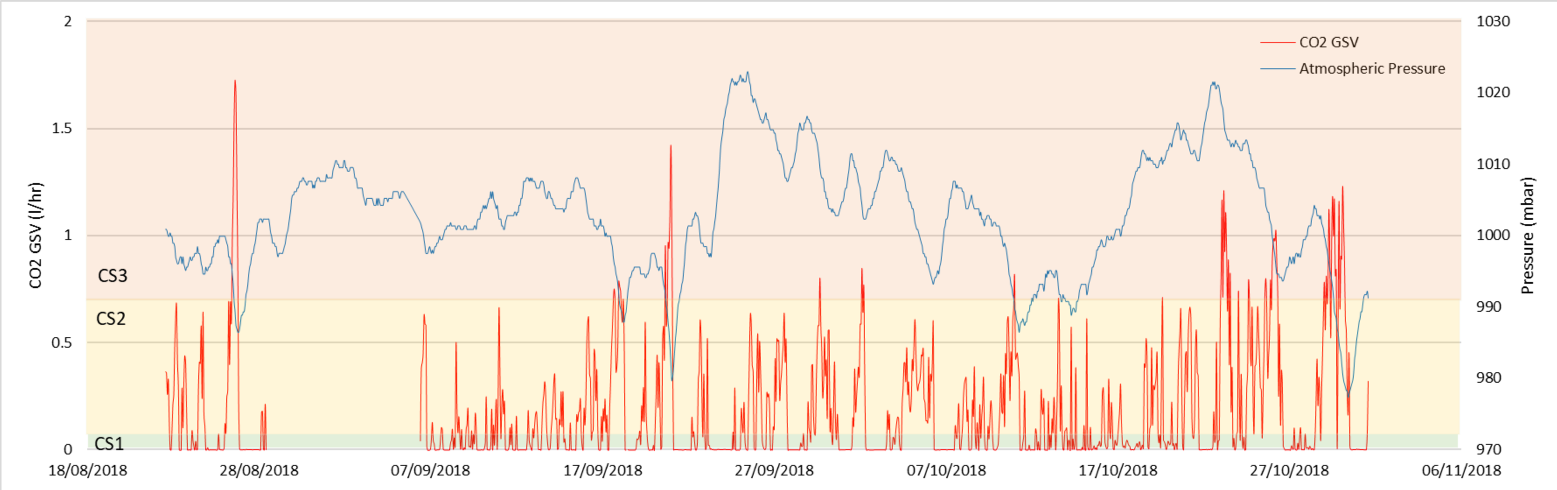
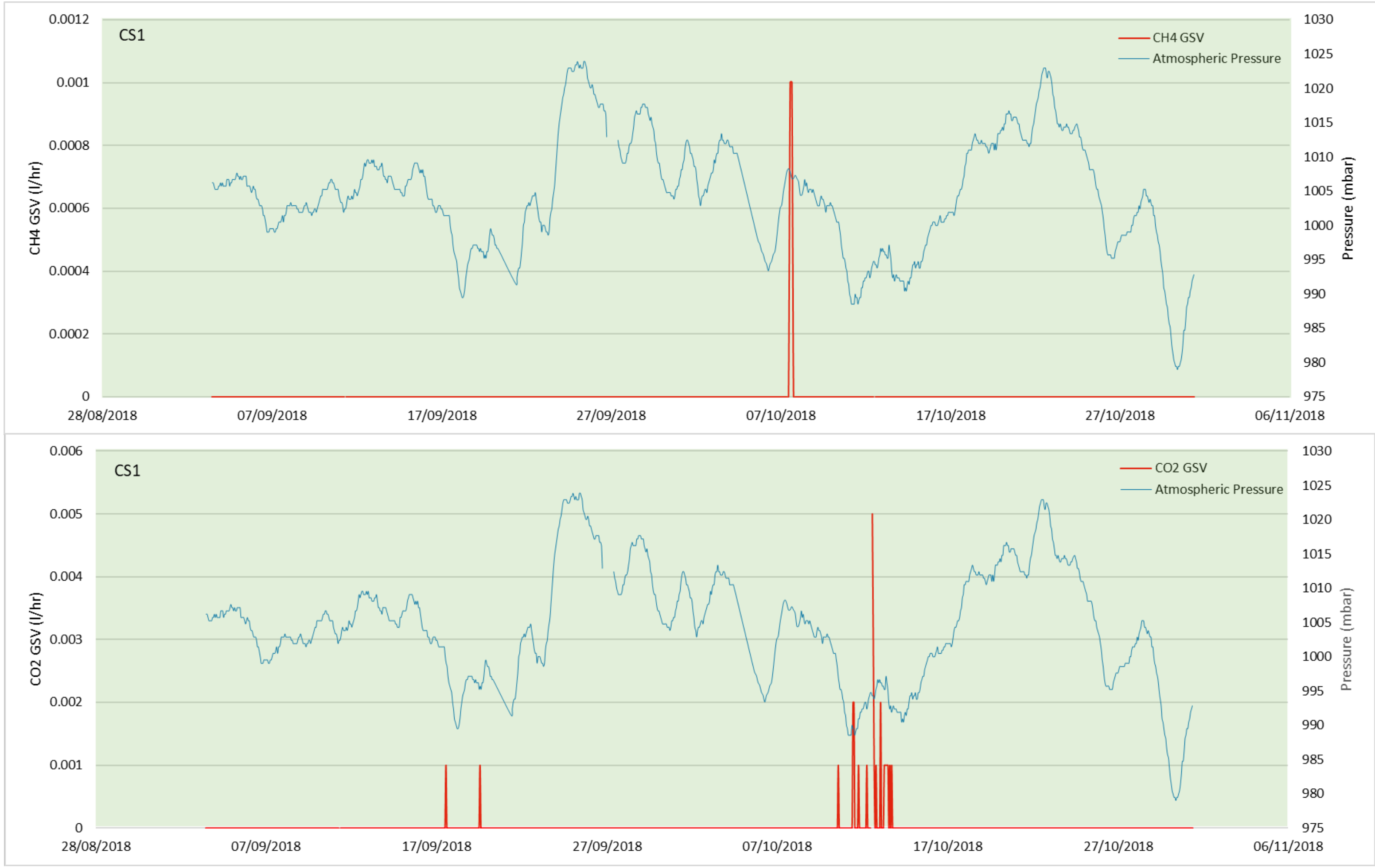


Figure B21: BWS202 gas screening values



Nitrogen Purge Report

AECOM : Luton

October 2018

Approval Sheet

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1	FINAL	26/11/2018	[redacted]	[redacted]	26/11/18
			Approved By	**Signature**	**Date**
			[redacted]	[redacted]	26/11/18

Foreword

The findings discussed in this document relating to information provided by the Client relate only to those to which we have had access. No attempt has been made to validate any data or information provided. It is acknowledged that certain aspects may be superseded or rendered irrelevant by information in documentation to which we have not accessed.

enitial cannot accept responsibility to any parties whatsoever, following the issue of this report, for any matters arising which may be considered outside the agreed scope of works.

This report is issued solely to the Client. enitial does not accept any responsibility to any third parties to whom this report may be circulated, in part or in full, and any such parties rely on the contents at their own risk.

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3. Results 7

4. Conclusion 14

Appendices

A. Field Data

B. Risk Assessment

1.0 Introduction

enitial have been commissioned by AECOM to undertake a nitrogen purging exercise at Luton Development Site (Wigmore Park, Eaton Green Road, Luton, LU2 9JB). Suspected ground gas has been detected in boreholes that requires further investigation to identify what action is required to prevent gas migration off site.

The principle behind nitrogen purging of a borehole is to replace the atmosphere within the borehole with inert nitrogen. Any ingress of gas into the borehole will displace the nitrogen, initially close to the point of ingress and then the incoming gas will diffuse within the borehole.

The overall aim of the exercise was to conduct a nitrogen purging trial on five boreholes experiencing elevated levels of methane. In this case, a nitrogen purge was carried out on boreholes (BH202, BH206, BH208, BH224 & BWS202) in order to ascertain the level at which methane enters the borehole and whether there is significant gas recharge post purge.

The nitrogen purge was conducted on 31st October & 1st November 2018.

2.0 Methodology

There are a number of methods that can be used to conduct a nitrogen purge at a gas monitoring borehole however the aims are the same; namely to purge the borehole of all in situ gas and undertake multi-level monitoring within the installation in order to ascertain at what level the gas is entering the borehole.

The nitrogen purge trial was undertaken as per the Ambisense method statement, WI 0032 Nitrogen Purge Testing Procedure. This was written in line with CL:AIRE Research Bulletin 13. (RB13 February 2011)

The Ambisense GasfluX unit already in situ was utilised for monitoring the gas concentrations at the top of the well. An additional infra-red gas analyser was attached to the bung at the top of the well to monitor the initial purge stage of the methodology.

Nitrogen was released via riser tubing to the base of the well and the purge was stopped once gas concentrations monitored at the top of the borehole via infra-red gas analyser was reduced to zero or stabilised with no further reduction in methane, carbon dioxide, or oxygen.

The Ambisense unit was set up for data logging with the sampling interval set to the minimum possible time.

3.0 Results

Table 1: BH202 Recovery of gas levels (concentration %v/v & ppm) at top of well after N2 purge on 31/10/18.

Time	CH4 (%)	CO2 (%)	O2 (%)	CO (ppm)	H2S (ppm)	VOC (ppm)
11:56:00	0.18	0.09	0	0.22	0.02	1.09
12:07:00	1.67	5.03	0.01	0.9	0	1.09
12:17:00	2.18	8.97	0	1.52	0	2.02
12:28:00	1.61	10.02	0	1.12	0	2.19
12:39:00	1.21	11.07	0	1.21	0	3.12
12:50:00	1.27	11.63	0	1.07	0	3.44
13:01:00	0.18	13.8	0.71	1	0	5.31
13:11:00	0.09	15.41	1	0.62	0	5.47
13:22:00	0.09	15.28	1.45	0.84	0	6.1
13:33:00	0.09	15.86	1.57	1.83	0	6.1

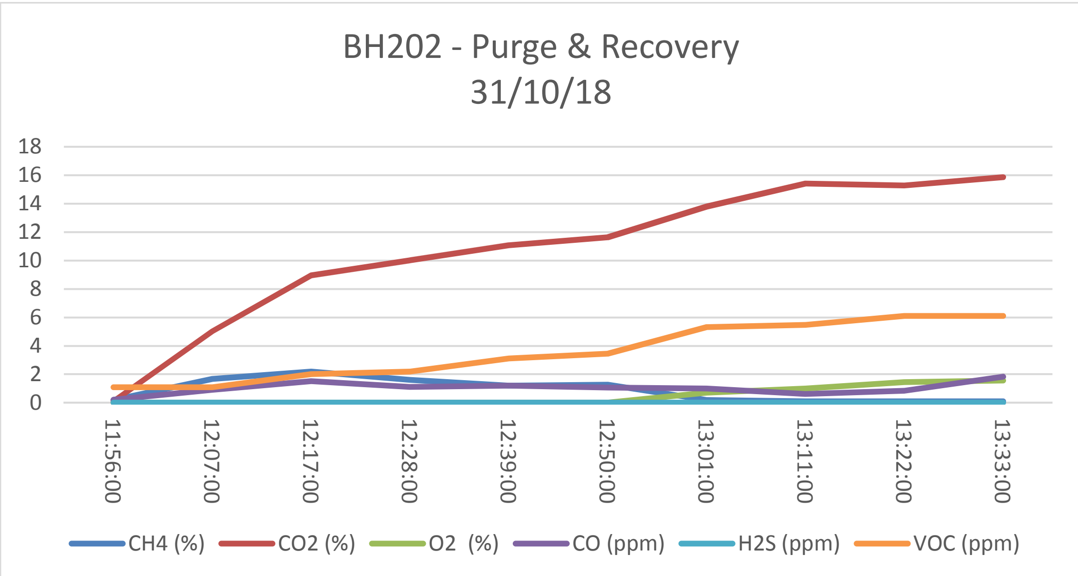


Figure 1: BH202 Gas concentration (%v/v & ppm) against time.

Table 1 and figure 1 show the gas recharge rate in borehole BH202 following the nitrogen purge.

The initial methane level present in the borehole was 14.47%.

The methane was then completely purged from the borehole leaving only a trace concentration of ground gas.

The methane concentration began to rise from the first reading before peaking at 2.18% by the third reading in the monitoring period (elapsed time 30 minutes) followed by a slow decline over the remainder of the monitoring period.

The carbon dioxide level began to rise from the first reading (elapsed time 11 minutes) and continued to rise to 15.86% at the final reading (elapsed time 1 hour 48 minutes).
This steady rise was echoed by the VOC levels rising to 6.1ppm by the final reading. Whereas the initial rise and fall seen by the methane concentration was echoed by carbon monoxide concentration.

The Oxygen concentration was slower to recover but by the end of the monitoring period it had risen to 1.57%.

Table 2: BH206 Recovery of gas levels (concentration %v/v & ppm) at top of well after N2 purge on 1/11/18.

Time	CH4 (%)	CO2 (%)	O2 (%)	CO (ppm)	H2S (ppm)	VOC (ppm)
09:57:00	1.48	1.02	0.41	6.78	0.01	9.4
10:08:00	2.92	2.65	0.79	6.42	0	8.76
10:18:00	2.84	3.09	1.1	6.62	0	9.86
10:29:00	4.41	5.82	7.17	3.51	0	7.32
10:40:00	7.09	8.4	9.58	2.1	0.01	5.73
10:51:00	6.25	8.18	11.75	2.52	0	6.69
11:02:00	6.34	7.78	12.15	2.25	0.01	6.69
11:13:00	6.95	8.31	11.94	2.52	0.01	6.53

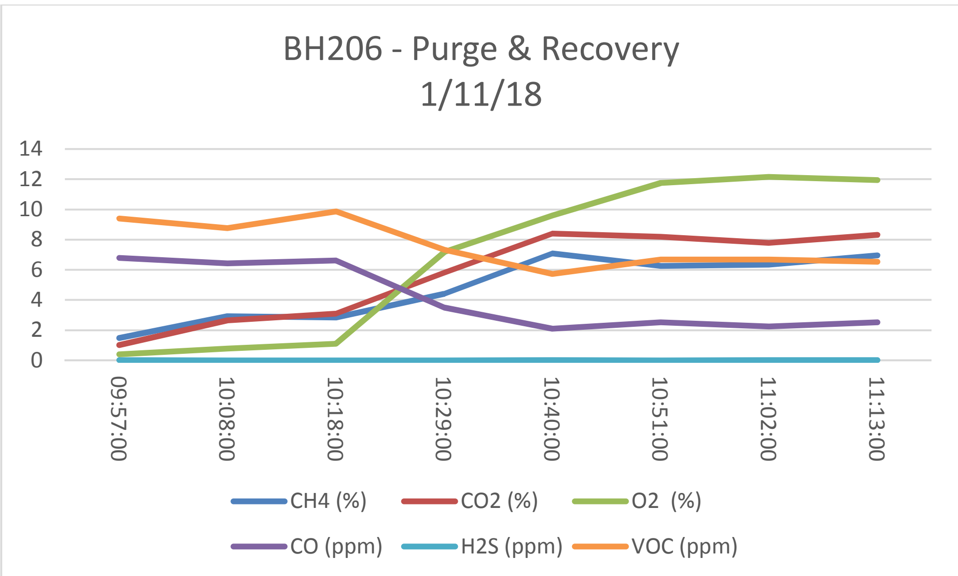


Figure 2: BH206 Gas concentration (%v/v & ppm) against time.

Table 2 and figure 2 show the gas recharge rate in borehole BH206 following the nitrogen purge.

The initial methane level present in the borehole was 4.96%.

The methane was then completely purged from the borehole leaving only a trace concentration of ground gas.

The methane concentration began to rise steadily from the first reading 1.48% (elapsed time 11 minutes) before peaking at 7.9 % by the fifth reading in the monitoring period (elapsed time 54 minutes) followed by a drop to 6.25% on the next reading and then a slow rise over the remainder of the monitoring period.

The carbon dioxide level recovery followed almost exactly the methane recovery. It began to rise from the first reading (elapsed time 11 minutes) before peaking at 8.4 % by the fifth reading in the monitoring period (elapsed time 54 minutes) followed by a drop to 8.18% then 7.78% and a slight recovery on the last reading.

The Oxygen concentration was initially slower to recover than the other gases but by the end of the monitoring period it had risen to 11.94%.

VOC and carbon monoxide levels recovered quickly, 9.4ppm and 6.78ppm respectively at the first reading (elapsed time 11 minutes) followed by a slight decline and levelling off of the concentrations.

Table 3: BH208 Recovery of gas levels (concentration %v/v & ppm) at top of well after N2 purge on 31/10/18.

Time	CH4 (%)	CO2 (%)	O2 (%)	CO (ppm)	H2S (ppm)	VOC (ppm)
12:48:00	51.44	20.59	0.16	2.36	1.28	0
12:59:00	55.15	22.07	0.26	1.43	1.75	0
13:09:00	50.63	21.92	0.34	1.75	1.81	0
13:20:00	52.15	22.85	0.32	1.55	2.06	0
13:30:00	52.05	22.71	0.36	2.77	2.06	0
13:40:00	52.32	23.44	0.35	2.45	2.14	0
13:51:00	54.98	24.02	0.33	2.2	2.14	0
14:01:00	53.67	23.73	0.35	3.34	2.1	0
14:12:00	50.82	23.34	0.36	3.43	2.43	0
14:22:00	53.1	23.93	0.34	2.94	2.47	0
14:33:00	55.37	24.33	0.28	2.73	2.52	0
14:43:00	54.01	23.94	0.32	3.34	2.49	0
14:54:00	53.56	24.21	0.32	3.22	2.77	0
15:04:00	54.96	24.57	0.28	3.55	2.77	0

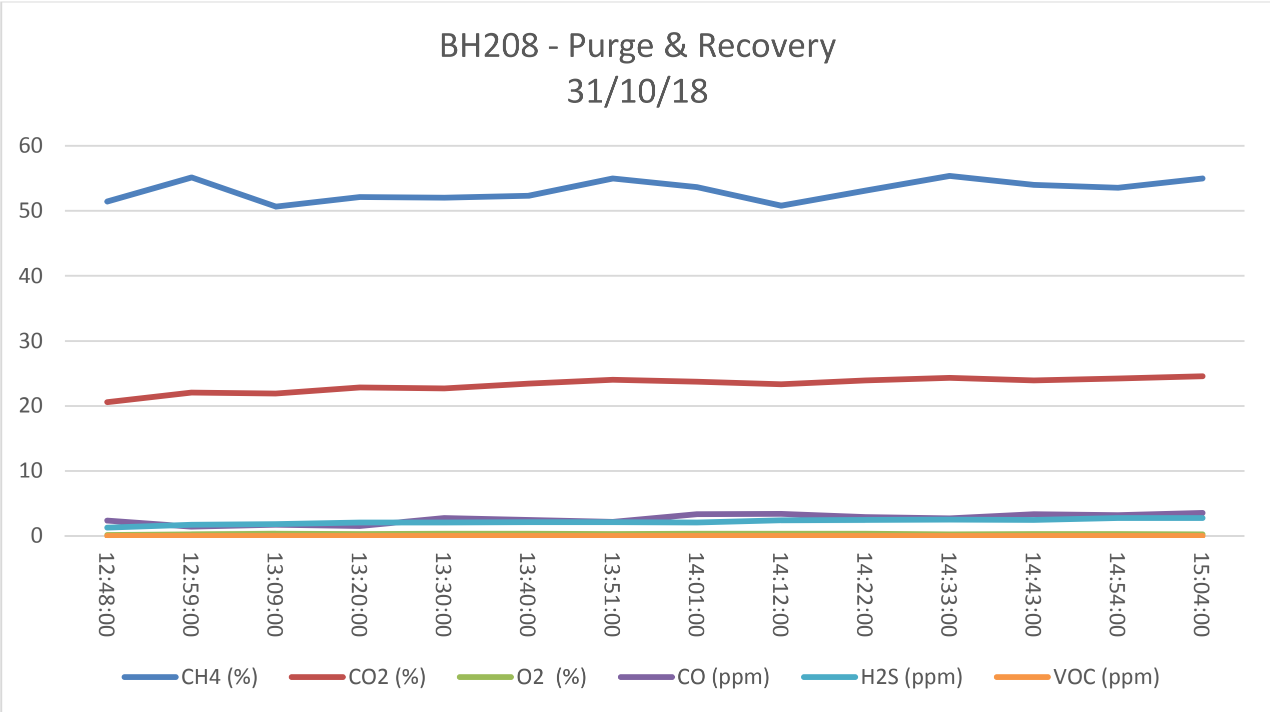


Figure 3: BH208 Gas concentration (%v/v & ppm) against time.

Table 3 and figure 3 show the gas recharge rate in borehole BH208 following the nitrogen purge.

The initial methane level present in the borehole was 67.42%.

The methane was then completely purged from the borehole leaving only a trace concentration of ground gas.

The methane concentration rose very rapidly and was at 51.44% by the first reading in the monitoring period (elapsed time 11 minutes) this then remained relatively stable over the remainder of the monitoring period.

The carbon dioxide concentration followed the same pattern as the methane and was at 20.59% by the first reading in the monitoring period (elapsed time 11 minutes) this then remained relatively stable over the remainder of the monitoring period.

The Oxygen concentration remained low during the entire monitoring period peaking at 0.36% at the fifth and ninth readings of the monitoring period.

Table 4: BH224 Recovery of gas levels (concentration %v/v & ppm) at top of well after N2 purge on 31/10/18.

Time	CH4 (%)	CO2 (%)	O2 (%)	CO (ppm)	H2S (ppm)	VOC (ppm)
14:23:00	13.72	9.51	0	0	0.07	0
14:34:00	14.27	12.33	0	0.1	0.01	0
14:44:00	14.47	13.68	0	0.53	0	0
14:54:00	16.51	15.49	0	1.65	0	0
15:05:00	18.97	17.26	0	2.63	0.01	0
15:15:00	21.11	18.37	0	3.08	0	0
15:26:00	23.11	19.64	0	2.85	0.08	0
15:36:00	24.11	20.5	0	2.36	0.11	0
15:47:00	25.6	20.95	0	2.45	0.31	0

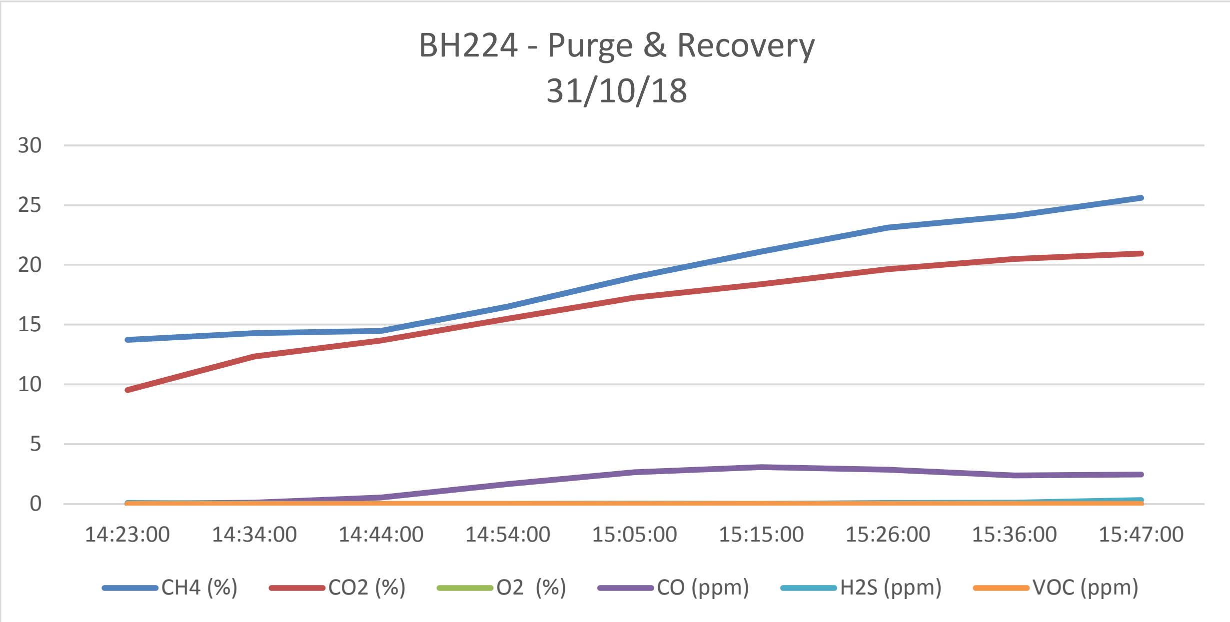


Figure 4: BH224 Gas concentration (%v/v & ppm) against time.

Table 4 and figure 4 show the gas recharge rate in borehole BH224 following the nitrogen purge.

The initial methane level present in the borehole was 36.18%.

The methane was then completely purged from the borehole leaving only a trace concentration of ground gas.

The methane concentration rose very rapidly and was at 13.72% by the first reading in the monitoring period (elapsed time 11 minutes) this then continued to steadily rise through the monitoring period peaking at 25.6% at the final (ninth reading, 1hour 35minutes elapsed).

The carbon dioxide concentration followed the same pattern as the methane and was at 9.51% at the first reading in the monitoring period (elapsed time 11 minutes) this then continued to steadily rise through the monitoring period peaking at 20.95% at the final (ninth reading, 1hour 35minutes elapsed).

The Oxygen concentration did not recover and remained at 0.0% throughout the monitoring period.

Table 5: BWS202 Recovery of gas levels (concentration %v/v & ppm) at top of well after N2 purge on 31/10/18.

Time	CH4 (%)	CO2 (%)	O2 (%)	CO (ppm)	H2S (ppm)	VOC (ppm)
11:20:00	0.16	0.15	0	0.17	0	0
11:31:00	0.11	0.34	0.38	0	0.01	0
11:42:00	0.12	0.56	0.94	0.08	0	0
11:53:00	0.13	0.56	1.43	0.13	0.01	0
12:04:00	0.1	0.67	1.9	0.36	0.01	0
12:15:00	0.11	0.81	2.35	0.04	0.03	0
12:26:00	0.11	0.8	2.8	0.01	0.01	0
12:37:00	0.1	0.79	3.19	0.01	0.01	0
12:47:00	0.09	0.91	3.58	0	0.03	0
12:58:00	0.08	0.92	4.04	0	0.01	0

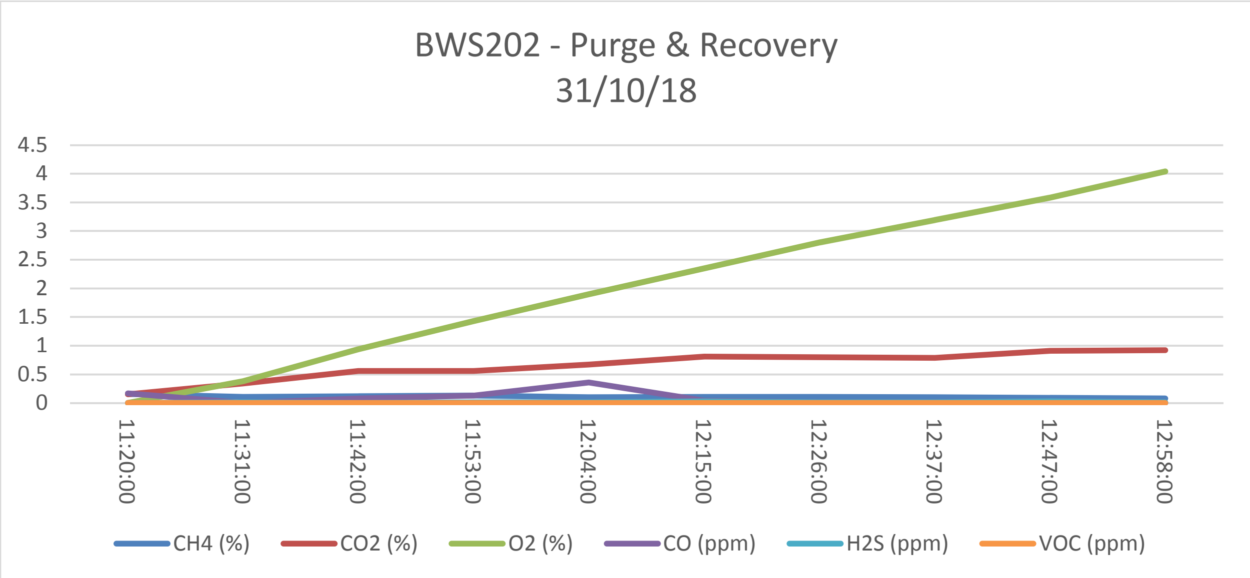


Figure 5: BWS202 Gas concentration (%v/v & ppm) against time.

Table 5 and figure 5 show the gas recharge rate in borehole BH224 following the nitrogen purge.

The initial methane level present in the borehole was 0.25%.

The methane was then completely purged from the borehole leaving only a trace concentration of ground gas.

The methane concentration recovered slightly to 0.16% at the first reading remaining steady with slight fluctuation over the remaining monitoring period.

The carbon dioxide level showed the same pattern as the methane concentration with a slow and steady rise (with slight fluctuations) over the entire monitoring period. The peak concentration of the monitoring period was at 0.92% for the final reading (elapsed time 1 hour 39 minutes).

The Oxygen concentration showed steady recovery throughout the monitoring period. The peak concentration of the period was at 4.04% for the final reading (elapsed time 1 hour 39 minutes).

The carbon monoxide and VOC levels show some very low level recovery and stayed steady with some slight fluctuations just above the limit of detection for these gases.

4.0 Conclusion

BH202

The nitrogen purge carried out on borehole BH202 suggests recharge of both methane and carbon dioxide during the monitoring period. The level of flow is likely to be low as the accumulation of methane was prevented; most likely due to the removal of gas during the sampling procedure.

BH206

The nitrogen purge carried out on borehole BH202 suggests slow but steady recharge of methane in the borehole. Corroborated by the carbon dioxide results.

BH208

The nitrogen purge carried out on borehole BH208 suggests a rapid recharge of the borehole with high flow levels for both carbon monoxide and methane.

BH224

The nitrogen purge carried out on borehole BH224 suggests a steady recovery of methane and carbon dioxide. The flow level would be significant for the jump from purged state to the levels found at the first reading. The oxygen level also remained at 0% for the monitoring period and would require a significant flow to maintain this.

BWS202

The nitrogen purge carried out on borehole BWS202 suggests recharge of both methane and carbon dioxide during the monitoring period. The level of flow is likely to be low as the accumulation of methane was prevented; most likely due to the removal of gas during the sampling procedure.

APPENDIX A

BH202

locationName	senseDate	01.CH4	02.CO2	03.O2	04.CO	05.H2S	07.VOC	09.ExtFlow	08.Humidity	10.PumpPres	09.GaugePres	11.BaroPres	NA	12.Batt
UK_AECOM_Luton_BH202	31/10/2018 10:47	0.49	0.33	21.15	2.68	0.93	0.16	-6.33	100	-10.77	3.57	990.62	-6.33	6.25
UK_AECOM_Luton_BH202	31/10/2018 11:56	0.18	0.09	0	0.22	0.02	1.09	-6.33	100	-11.81	-0.07	990.14	-6.33	6.17
UK_AECOM_Luton_BH202	31/10/2018 12:07	1.67	5.03	0.01	0.9	0	1.09	-6.33	100	-8.29	2.06	990.62	-6.33	6.16
UK_AECOM_Luton_BH202	31/10/2018 12:17	2.18	8.97	0	1.52	0	2.02	-6.33	100	-7.43	3.19	990.62	-6.33	6.15
UK_AECOM_Luton_BH202	31/10/2018 12:28	1.61	10.02	0	1.12	0	2.19	-6.33	99.69	-7.35	0.68	990.14	-6.33	6.15
UK_AECOM_Luton_BH202	31/10/2018 12:39	1.21	11.07	0	1.21	0	3.12	-6.33	94.64	-6.53	3.57	990.14	-6.33	6.14
UK_AECOM_Luton_BH202	31/10/2018 12:50	1.27	11.63	0	1.07	0	3.44	-6.33	90.31	-5.52	0.93	990.62	-6.33	6.13
UK_AECOM_Luton_BH202	31/10/2018 13:01	0.18	13.8	0.71	1	0	5.31	-6.33	86.66	-5.48	0.55	990.14	-6.33	6.1

UK_AECOM_Luton_BH202	31/10/2018 13:11	0.09	15.41	1	0.62	0	5.47	-6.33	82.29	-4.66	0.68	990.62	-6.33	6.07
UK_AECOM_Luton_BH202	31/10/2018 13:22	0.09	15.28	1.45	0.84	0	6.1	-6.33	78.37	-8.94	2.43	990.62	-6.33	6.08
UK_AECOM_Luton_BH202	31/10/2018 13:33	0.09	15.86	1.57	1.83	0	6.1	-6.33	77.41	-9.11	0.93	990.62	-6.33	6.06

BH206

locationName	senseDate	01.CH4	02.CO2	03.O2	04.CO	05.H2S	07.VOC	09.ExtFlow	08.Humidity	10.PumpPres	09.GaugePres	11.BaroPres	NA	12.Batt
UK_AECOM_Luton_BH206	01/11/2018 09:57	1.48	1.02	0.41	6.78	0.01	9.4	-6.18	100	-46.61	-0.62	988.24	-6.18	6.31
UK_AECOM_Luton_BH206	01/11/2018 10:08	2.92	2.65	0.79	6.42	0	8.76	-6.17	100	-48.18	0.95	988.24	-6.18	6.31
UK_AECOM_Luton_BH206	01/11/2018 10:18	2.84	3.09	1.1	6.62	0	9.86	-6.18	100	-47.86	-0.51	987.76	-6.18	6.3
UK_AECOM_Luton_BH206	01/11/2018 10:29	4.41	5.82	7.17	3.51	0	7.32	-6.18	100	-49.22	1.55	988.24	-6.18	6.3

UK_AECOM_Luton_BH206	01/11/2018 10:40	7.09	8.4	9.58	2.1	0.01	5.73	-6.18	100	-48.28	2.89	988.24	-6.18	6.31
UK_AECOM_Luton_BH206	01/11/2018 10:51	6.25	8.18	11.75	2.52	0	6.69	-6.18	100	-50.54	-0.38	988.24	-6.18	6.29
UK_AECOM_Luton_BH206	01/11/2018 11:02	6.34	7.78	12.15	2.25	0.01	6.69	-6.17	100	-48.7	0.82	988.72	-6.18	6.28
UK_AECOM_Luton_BH206	01/11/2018 11:13	6.95	8.31	11.94	2.52	0.01	6.53	-6.18	100	-49.67	1.43	988.24	-6.18	6.28

BH208

locationName	senseDate	01.CH4	02.CO2	03.O2	04.CO	05.H2S	07.VOC	09.ExtFlow	08.Humidity	10.PumpPres	09.GaugePres	11.BaroPres	NA	12.Batt
UK_AECOM_Luton_BH208	31/10/2018 11:12	67.42	24.42	0.55	0.24	3.26	0	9.97	100	-9.27	2.17	993.13	-7.25	6.72
UK_AECOM_Luton_BH208	31/10/2018 12:28	58.62	23.9	0.94	2.24	2.1	0	9.96	100	-9.48	1.68	993.13	-7.25	6.72
UK_AECOM_Luton_BH208	31/10/2018 12:48	51.44	20.59	0.16	2.36	1.28	0	-7.25	100	-9.13	1.44	992.17	-7.25	6.72
UK_AECOM_Luton_BH208	31/10/2018 12:59	55.15	22.07	0.26	1.43	1.75	0	-7.25	100	-7.45	1.19	992.17	-7.25	6.72

UK_AECOM_Luton_BH208	31/10/2018 13:09	50.63	21.92	0.34	1.75	1.81	0	-7.25	100	-9.69	1.93	992.17	-7.25	6.72
UK_AECOM_Luton_BH208	31/10/2018 13:20	52.15	22.85	0.32	1.55	2.06	0	-7.25	100	-10.04	1.44	992.17	-7.25	6.68
UK_AECOM_Luton_BH208	31/10/2018 13:30	52.05	22.71	0.36	2.77	2.06	0	-7.25	100	-9.31	1.07	992.17	-7.25	6.72
UK_AECOM_Luton_BH208	31/10/2018 13:40	52.32	23.44	0.35	2.45	2.14	0	-7.25	100	-10.21	1.19	992.17	-7.25	6.62
UK_AECOM_Luton_BH208	31/10/2018 13:51	54.98	24.02	0.33	2.2	2.14	0	-7.25	100	-8.54	0.83	992.17	-7.25	6.67
UK_AECOM_Luton_BH208	31/10/2018 14:01	53.67	23.73	0.35	3.34	2.1	0	-7.25	100	-7.63	1.07	991.69	-7.25	6.7
UK_AECOM_Luton_BH208	31/10/2018 14:12	50.82	23.34	0.36	3.43	2.43	0	-7.25	100	-10.53	0.95	992.17	-7.25	6.6
UK_AECOM_Luton_BH208	31/10/2018 14:22	53.1	23.93	0.34	2.94	2.47	0	-7.25	99	-9.76	1.32	992.17	-7.25	6.54
UK_AECOM_Luton_BH208	31/10/2018 14:33	55.37	24.33	0.28	2.73	2.52	0	-7.25	92.08	-10.14	1.07	992.17	-7.25	6.6
UK_AECOM_Luton_BH208	31/10/2018 14:43	54.01	23.94	0.32	3.34	2.49	0	-7.25	87.99	-10.74	1.44	991.69	-7.25	6.61

UK_AECOM_Luton_BH208	31/10/2018 14:54	53.56	24.21	0.32	3.22	2.77	0	-7.25	85.64	-9.76	0.58	991.69	-7.25	6.57
UK_AECOM_Luton_BH208	31/10/2018 15:04	54.96	24.57	0.28	3.55	2.77	0	-7.25	83.75	-9.16	0.83	992.17	-7.25	6.55

BH224

locationName	senseDate	01.CH4	02.CO2	03.O2	04.CO	05.H2S	07.VOC	09.ExtFlow	08.Humidity	10.PumpPres	09.GaugePres	11.BaroPres	NA	12.Batt
UK_AECOM_Luton_BH224	31/10/2018 14:23	13.72	9.51	0	0	0.07	0	-7.19	100	-10.27	-1.08	990.77	-7.19	6.44
UK_AECOM_Luton_BH224	31/10/2018 14:34	14.27	12.33	0	0.1	0.01	0	-7.19	100	-9.37	1.69	991.25	-7.19	6.43
UK_AECOM_Luton_BH224	31/10/2018 14:44	14.47	13.68	0	0.53	0	0	-7.19	100	-6.76	0.24	990.77	-7.19	6.44
UK_AECOM_Luton_BH224	31/10/2018 14:54	16.51	15.49	0	1.65	0	0	-7.19	100	-7.08	0.48	990.77	-7.19	6.43
UK_AECOM_Luton_BH224	31/10/2018 15:05	18.97	17.26	0	2.63	0.01	0	-7.19	98.86	-10.48	-0.36	991.25	-7.19	6.41

UK_AECOM_Luton_BH224	31/10/2018 15:15	21.11	18.37	0	3.08	0	0	-7.19	94.28	-8.6	1.21	990.77	-7.19	6.41
UK_AECOM_Luton_BH224	31/10/2018 15:26	23.11	19.64	0	2.85	0.08	0	-7.18	91.08	-11.1	0.72	990.77	-7.19	6.4
UK_AECOM_Luton_BH224	31/10/2018 15:36	24.11	20.5	0	2.36	0.11	0	-7.19	88.57	-8.71	1.33	990.77	-7.19	6.39
UK_AECOM_Luton_BH224	31/10/2018 15:47	25.6	20.95	0	2.45	0.31	0	-7.19	86.68	-9.54	1.69	991.25	-7.19	6.39

BWS202

locationName	senseDate	01.CH4	02.CO2	03.O2	04.CO	05.H2S	07.VOC	09.ExtFlow	08.Humidity	10.PumpPres	09.GaugePre
UK_AECOM_Luton_BWS202	31/10/2018 10:16	0.25	0.06	19.27	0	0.02	0	3.03	100	-26.69	3.1
UK_AECOM_Luton_BWS202	31/10/2018 11:20	0.16	0.15	0	0.17	0	0	-6.16	100	-49.14	0.3
UK_AECOM_Luton_BWS202	31/10/2018 11:31	0.11	0.34	0.38	0	0.01	0	-6.17	100	-49.21	2.
UK_AECOM_Luton_BWS202	31/10/2018 11:42	0.12	0.56	0.94	0.08	0	0	-6.16	100	-48.52	2.5
UK_AECOM_Luton_BWS202	31/10/2018 11:53	0.13	0.56	1.43	0.13	0.01	0	-6.16	100	-45.46	1.8
UK_AECOM_Luton_BWS202	31/10/2018 12:04	0.1	0.67	1.9	0.36	0.01	0	-6.17	100	-47.72	2.0

UK_AECOM_Luton_BWS202	31/10/2018 12:15	0.11	0.81	2.35	0.04	0.03	0	-6.17	100	-49.46	4.2
UK_AECOM_Luton_BWS202	31/10/2018 12:26	0.11	0.8	2.8	0.01	0.01	0	-6.16	100	-48.2	3.0
UK_AECOM_Luton_BWS202	31/10/2018 12:37	0.1	0.79	3.19	0.01	0.01	0	-6.16	99.96	-45.22	-0.9
UK_AECOM_Luton_BWS202	31/10/2018 12:47	0.09	0.91	3.58	0	0.03	0	-6.17	98.44	-49.7	3.6
UK_AECOM_Luton_BWS202	31/10/2018 12:58	0.08	0.92	4.04	0	0.01	0	-6.17	96.85	-48.21	1.9

APPENDIX B

Risk Assessment Record

Assessor: [redacted]	**Original Assessment Date:** Oct 16	**Review Date:** January 2018
Activity Assessed: Ambisense Installation/ Decommission	**Location:** On site – this risk assessment covers working both on and off an active active construction sites where harmful ground gas may be present	**Next Review Due:** January 2019 **Updated:** November s2018

B

THOSE AFFECTED					
A. Employees	**B.** Members of The Public	**C.** Adjacent Workers	**D.** Children/Young Persons	**E.** Contractors	**F.** Visitors
Others (state)					

C

HAZARDS		**Those Affected**	**HAZARDS**		**Those Affected**	**HAZARDS**		**Those Affected**	**HAZARDS**		**Those Affected**	**HAZARDS**		**Those Affected**
Falling/ working at height	✔	A	Fire + explosion	✔	A, C	Friction or abrasion			Ejection of Objects	Y	A, C	Radiation		
Falling objects	✔	A, C	Substances	✔	A	Shearing			Confined space			Dust/ fumes	✔	A
Vehicles	✔	A	Access/ Egress	✔	A	*Entanglement*	✔	A	Manual handling	✔	A	Water/ Drowning		
Noise	✔	A, C	Slips/ Trips	✔	A	Puncture/ Stabbing			Lighting	✔	A	Others (state below)		
Electricity	✔	A	Crushing			Severing or Cutting			Temperature	✔	A	General Site Safety	✔	A

Vibration	✔	A	Trapping			*Ejection of fluid*			Weather	✔	A	Animals	✔	A

D

HAZARDS (as identified above)	**Existing Control Measures** (e.g. design, guarding; procedures; training; PTW; PPE; signs etc.)	**Risk H,M,L**	**Additional Control measures to Reduce the Risk** (e.g. elimination; alternative methods; additional guarding; design changes; additional procedures; increased supervision to monitor controls; PPE , additional training etc.)	**Completion date**	**Residual Risk H, M, L**
Vehicles	Site traffic - Wear high visibility jacket / waistcoat. Alert vehicle operators to your presence on site. Use designated roadways; ensure site speed limits are observed. Ensure that your working area is segregated from vehicle access routes prior to undertaking the installation/decomission.	**L**			
Substances	Landfill gas - asphyxiant. Avoid confined spaces. Ensure that personal multi gas alarm is worn at all times. Be aware of the contents of the CoSHH assessment for landfill gas. Be aware of any hazardous tipping that may take place on an active site e.g. asbestos waste – check with site staff before starting work and query with liaison manager before proceeding if in doubt. Asbestos is a potential contaminant on brownfield sites, especially former landfills.	**M**	A personal multi gas alarm should be worn during all installations due to the potential for gas being present. 1. All staff have undertaken asbestos awareness training. 2. Site staff will wear disposable coveralls and dispose of the appropriately. 3. Site staff will wear face fit FP3 masks. If asbestos is encountered in sufficient quantities to pose a risk of airborne release work will stop immediately. 4. The asbestos is to be covered and if possible / appropriate damped down to prevent release. 5. Seek instruction from AECOM site manager.	**August 18 - Complet e**	**L**

Falling/working at height	It may be necessary to install equipment slightly above the height that can be reached from the ground. If this is the situation the work should be assessed and a suitable access method determined. A suitable access may be a ladder with a second person to foot the base however this must be assessed on a site specific basis.	**M**	This work is expected to take no more than 15 minutes and that access will be required on an infrequent basis. Should regular access be required it may be necessary to reassess the access method. If a ladder is deemed suitable for the short term access then it must be visually inspected prior to use to ensure that it is undamaged and suitable for the work.		
Falling objects	Wear hard hat. Do not carry any more equipment at height than is needed and do not allow personnel to walk under the ladder whilst work is taking place.	**L**			
General Safety	Follow site rules as per induction. Obtain Permit to Work if necessary. Use agreed access points and walkways. Every installation will be different so a dynamic risk assessment should be undertaken prior to work taking place. If necessary a site specific safe system of work shall be agreed.	**L**			

Electricity	Wear earthing band. Electricity involved with the Ambisense unit is below 7V at 4.5Ah and has been assessed to require no additional safety precautions. If drilling is required to secure the unit this should be carried out by personnel deemed competent to use the equipment and safety glasses should be worn during drilling.	**L**	Any portable electrical appliances e.g. portable drill should have been tested and should display a PAT sticker to confirm this. The equipment should also be visually inspected prior to use.		
Entanglement	A drill should only be used by personnel competent in its use. Hair should be tied back and any loose clothing secured or removed prior to use. The drill should only be used in accordance with any manufacturer's instructions.	**L**			
Slips / Trips	Wear hard hat / safety boots – steel mid sole & toe cap. Use designated pathways where appropriate. During cold weather be aware of the possibility of ice on the ground which may make the use of a ladder unsuitable.	**L**			
Fire / Explosion	Landfill gas - Training given, follow method statement in accordance with best practice & DSEAR regs. No smoking on site. Ensure public are not in close proximity. Where the unit is being installed/decomissioned outside of an active landfill site but in an area where landfill gas may be found a personal multi gas alarm should be worn as a precaution.	**M**	Ensure site zoning plan is obtained (if available) prior to work and additional measures introduced as appropriate. Drilling should not be undertaken in a zoned area unless a separate risk assessment has been undertaken.		L

Lighting/ temperature/ weather	In winter, plan work to avoid hours of darkness. Be aware that work may have to be postponed due to adverse weather and that cold or wet weather may make ground conditions slippery. During hot weather site staff may suffer heat stress.	**L / M (During hot weather)**	• Site staff will take regular comfort breaks. • A plentiful supply of bottled water will be available at work sites. • Site staff will be expected to protect exposed skin with Sun cream.	August 18 - Complete	**L**
Noise	If drilling is required there will generate noise for brief periods. Hearing protection should be available for use, if required.	**L**			
Dust/fumes	Ensure that personal multi gas alarm is worn at all times. Do not work in confined spaces, if in doubt seek advice. Where possible stand up wind of gas/leachate collection wells. Avoid areas of dust created by site operations; wear a dust mask as appropriate.	**L**			
Manual handling	Only light manual handling is anticipated however every installation/decommission will be different so assess any lifting/carrying activity prior to carrying it out. If in doubt seek assistance from a second person.	**L**			
Animals	Contact with animals is not anticipated however assess the situation prior to starting work. If necessary request animals are secured prior to starting work. Do not work at height if animals are unsecured in the work area.	**L**			

Access/egress	Follow any site specific instructions regarding accessing the installation/decomission point. Ensure that the location is not within a confined space.	**L**			
Manual Labor	Use of a Pick axe, Sledge hammer and shovel will be required to install/remove HDPE Pedestals and reinstall borehole covers if required. Along with post creting in the pedestal/ borehole covers.	**M/L**	Gloves are required for this, dermatitis and skin burning are possible from the post crete. Eye protection also needed in case of projectiles.	August 2018 - Complet e	**L**

<u>Any Additional Comments/Observations</u>

Guidance for the Completion of the Risk Assessment Record

Table A

***Activity Assessed**: Describe the activity that is being assessed. This could be a specific task e.g. floor cleaning, operation of a machine; maintenance activities etc.*

***Location:** Describe the location of the activity.*

Review Date: Enter the date that the assessment will be reviewed.

Table B

Those affected: When carrying out a risk assessment any person who may be affected by the work that is being assessed must be identified. Should there be categories of persons not identified, then enter additional categories in the boxes provided.

Table C

Hazards: Identify the hazards in the activity being assessed by putting a cross in the appropriate boxes. The list provided is not comprehensive. Should there be hazards that are not on the list then enter additional hazards in the boxes provided.

Those Affected: Enter the identification letters of those affected, from Table B, against the appropriate hazard. ***Note**: The definition of a **HAZARD** is:- something with the potential to cause harm.*

Table D

***Hazards:** List the hazards identified in Table C.*

***Existing Control Measures**: Outline the existing measures which will reduce the risk arising from each of the hazards listed. Check that they meet legal requirements, industry standards and represent good practice. Typical control measures include: safe design; preventing access to the hazard e.g. guarding; written procedures and instructions; training; provision of PPE etc.*

Risk

Assess the risks arising out of the hazards identified using the criteria set out below. When carrying this out consideration must be given to, what is reasonably foreseeable in relation to the identified hazards and recognition of the existing control measures that reduce the risk. Enter the appropriate letter, L for low, M for medium or H for high. If the overall risk category is low, then the assessment is complete and the information contained within the assessment disseminated to those affected. However if the overall risk category is medium or high then Additional Control Measures are required (see below).

***Note**: The definition of a **RISK** is:-risk is the likelihood of potential harm from a particular hazard being realized. The extent of the risk will depend on the potential severity of the harm and the population that might be affected.*

	LIKELIHOOD		
SEVERITY	Certain or near certain to occur	Reasonably likely to occur	Very seldom or never occurs
Fatality; major injury or illness causing long term disability	**HIGH**	**HIGH**	MEDIUM
Injury or illness causing short term disability	**HIGH**	MEDIUM	LOW
Other injury or illness	MEDIUM	LOW	LOW
	RISK		

Additional Control Measures: ***Additional control measures that will reduce the risks further should be noted. For example, elimination of the hazard should be considered first. If this is not possible, then try to reduce the risk E.g. risks from electrical hazards might be reduced by using low voltage electrical appliances. Also consider: safer design; additional guards; additional procedures and instructions; increased supervision; personal protective equipment (PPE). The*** *completion date* ***for the introduction of each control measure should be recorded.***

Residual Risk: The assessment process must be repeated, taking into account, the existing and additional control measures. Enter the appropriate letter, L for low, M for medium or H for high. If the residual risk category is low, then the assessment is complete and the information should be disseminated to those affected. If the overall risk is **medium** then additional control measures should be introduced within the completion date period and the information contained within the assessment disseminated to those affected. If the Residual Risk remains **high,** work **must not** proceed and the risks arising out of the hazards re-assessed to identify further risk reduction measures.

Appendix C – GasSim modelling

Appendix C GasSim 2.5 Modelling Parameters - Former Landfill

Table C1: Model Parameters

Project Details		
Factor	**Input**	**Justification**
Operational period (years)	40	All eras modelled, 1940 to 1980
Simulation Period (years)	100	Based on continued production of LFG 60 years post closure
Iterations	201	Noted in GasSim 2.5 Example Landfill, increased accuracy
Landfill Characteristics		
Area m2 Total landfill area	 401,098	Calculated by model. Areas drawn by eye within Landfill Boundary dxf file from 05.06.19 used as base, extent of cells based on cross sections in Figure 13 from DQRA.
1940-1947	87,567	
1947-1955	99,409	
1955-1960	157,916	
1960-1970	117,204	
1970-1980	187,480	
Biological Methane Oxidation %		
	10	Default Minimal topsoil present generally less than 300mm therefore assume methane oxidation is not occurring. Used DEFRA recommended value which is default.
Simulate Fissures & Soil Cap		
Soil Depth (m)	Not required	Topsoil 300mm or less so cannot apply simulation.
% of area occupied by fissures	Not required	Topsoil 300mm or less so cannot apply simulation.
Cap and Liner Details		
Infiltration		
Uncapped infiltration (mm/yr)	Normal: mean and standard deviation	GasSim 2.5 Default 500mm + 50mm Standard deviation, equates to 70% infiltration of mean annual rainfall from Rothamstead meteorological station of 712.3mmyr^{-1} –
Capped infiltration (mm/yr)	Normal distribution Mean = 50 Std = 5	Gassim 2.5 default
Temporary Cap		
Thickness (m)	Uniform 0.3, 0.6	GasSim 2.5 Default
Hydraulic Conductivity (m/s)	Loguniform 1.0×10^{-07} to 1.0×10^{-05}	GasSim 2.5 Default
Cap type	None	No formal cap identified across the landfill
Thickness (m)	N/A	
Hydraulic conductivity (m/s)	N/A	
Liner	None	No liner found during GIs
Installation Dates		
Temporary Cap Year /Month	1975 / January	Arbitrary midpoint of filling cycle
Permanent cap year/Month	1980 / November	End of filling period
Sacrificial gas collection year/month	1975 / January	As per Gassim 2.5 same as temporary cap year and month

Project Details		
Factor	**Input**	**Justification**
Permanent Gas collection year/month	1980 / December	As per Gassim 2.5, permanent gas collection 1 month after permanent cap installed
Geosphere		
Ground Surface (mAOD)	Single Value only can be inputted. 152.5m AOD	Average of 150 to 155m AOD PRA Para 5.2.3
Water Table (mAOD)	Single Value only can be inputted, 112m AOD	Typical level DQRA Vol 1 Para 7.2.2
Unsaturated zone Moisture Content (% v/v)	Triangular 5, 15, 35	Based on observations, waste is generally damp to dry. Average for typical landfill is 35% used as a max value. Values from GIR show max 35% min 14% and average 25.1% - more representative of capping layers than actual waste which is likely to be less.
Unsaturated Zone Total Porosity (% v/v)	Triangular 10, 15, 30	Likely values based on observations for landfilled waste and capping
Gas Collection Efficiency Estimates %		
Sacrificial GCS		Gassim Default settings
Permanent GCS		Gassim Default Settings
Gas Plant		
	No engines/flares	No gas collection system on the landfill
	CO_2, uniform 40, 60% CH_4, uniform, 40 to 60%	Reflect proportions recorded in monitoring data – does not produce significant changes to results compared to 50/50, min slightly lower, max slightly higher mean value about the same.
Waste Moisture Content and Waste Degradation Rates		
Degradation Rate – Filing phase yr-1	Average Slow single 0.046 Moderate single 0.076 Fast single 0.116	Landfill is generally on the drier site as the waste is above the groundwater table, so average is considered to be most realistic – Gassim 2.5 settings
Year/Month of degradation rate change	1972 / January	Based on defaults in Gassim change is 1 year after start of filling, Jan seems to be default month
Degradation rate after change yr-1	Average Slow single 0.046 Moderate single 0.076 Fast single 0.116	As per Gassim degradation rate stays the same after change. This is used to model impact of draining the site or recirculating leachate. Stays the same because these processes were not known to have been used to manage the landfill.
Waste Density (t/m3)	Triangular 0.5 1.0 1.2	Based on literature values, and upper GasSim 2.5 value
Effective porosity (%)		Not required
Leachate Head (m)	Triangular – from monitoring data table 12; 0,1,2.11	Values from Monitoring data, Table 12, DQRA.
Conductivity (m/s)	Loguniform $1.0e^{-09}$ to $1.0e^{-05}$	Gassim 2.5 default
Adsorptive capacity(%v/v)		Not required
Leachate Recirculation (m^3/hr)		Not required
Trace Gas Inventory Priority Trace Components		
	Priority Trace components selected	Gassim Default
Trace Gas Half-life (years)	Normal mean – 4.11, STD 1.56	Gassim Default
Lateral Migration Simulation		Cell cannot be surcharge cell otherwise the simulation will not be completed

Project Details		
Factor	**Input**	**Justification**
		Unconfined migration pathway. Default air diffusion co-efficient used for CO_2 and CH_4.
		Confined pathway produces worst case results
Source		
Waste input - annual tonnage of (T)	Triangular 0.5, 1.0, 1.2	Based on using input conversion factors with 1.0 most likely, results similar to uniform input results – this gives most realistic values considering uncertainty with regard to density of the waste – no empirical data for this factor. Upper value (1.2) from Gassim default
Waste type per year – commercial/domestic etc (%)	Single data input	Based on breakdown of waste types for each era as estimated from DQRA DWG 6.
Waste composition per year -	1940-1980	1940-1980 Waste Stream Based on forensic logging '*Waste Type %tge Data'*. Single data input and repeated for each year Degradable content is Gassim Default values for 1980 to 2010 waste streams.

Waste composition – fraction of different materials within waste streams – can be altered to site specific and used to calculate quantity of carbon available for slow, moderate and fast degradation & therefore rate of LFG production.

Temporary Capping – Year and month of cap and temporary gas collection system, this determines volume of gas in the capped area that can be utilised, assumes gas generated in uncapped area lost to atmosphere. Default used as no gas collection system has been installed, but model requires data to be entered in these fields.

Proportions of methane and proportions of carbon dioxide allow LFG composition to be anticipated over simulation period, entered as percentages as single value or probability distribution function (pdf) to reflect unpredictable nature of landfills.

Trace Gas Inventory – GasSim default values, select gas species to be simulated, source concentrations can be edited. Raw gas is concentration in LFG rather than as combustion product. Input half-life to define a declining source term, very large half-life will keep concentration of trace component relatively constant.

Waste Moisture Content - sensitive element key factor controlling waste degradation and therefore LFG production – determines waste degradation constants. The leachate recirculate, effective porosity and adsorptive capacity – only input if moisture content requires calculating.

Gas Plant – not required no utilisation of gas.

Meteorological data Sources - https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcpy8jchu , http://resources.rothamsted.ac.uk/rothamsted-highs-and-lows#loaded

Recommend change default values to reflect site specific data.

Infiltration - effective rainfall – obtain from on-site weather station or meteorological office or literature sources.

Parameter sensitivity analysis

The following parameters were adjust to assess the models sensitivity:

Capping

No formal capping has been identified across the landfill, although the presence of layers of chalky and non-chalky materials indicates a daily cover system was used during the operational period. The model was varied to assess the effect of a capping layer using GasSim default values for a single clay layer or no cap being present. This did not produce any significant changes to gas production and therefore the final model was used without a formal cap being present to better represent actual site conditions.

Infiltration

Infiltration rate was also varied using 100% infiltration of average yearly rainfall for Rothamstead Meteorological Station 712.3mmyr^{-1} and 70% infiltration which is also the GasSim default of 500mmyr^{-1}. This produced slightly lower gas production rates associated with the lower infiltration rate, this was applied to the model as it was considered unlikely that there would be 100% infiltration and there is a variable depth of cover material across the site.

Waste Density

Reducing the density to 0.5t/m^3 reduces the gas generation potential by approximately 50%, however this is more representative of waste with a higher biodegradable content which is not present in the Eaton Green Landfill. A triangular probability distribution function was adopted with 0.5t/m^3 as a minimum 1.2t/m^3 as a maximum (GasSim default) and 1.0t/m^3 as the most likely value, based on a literature search. British Colombia Ministry of Environment (2009) [13] 'Apparent waste density in a landfill site can range from less than 500 kg/m^3 to more than 1,000 kg/m^3, this is further supported by recording of in-place density achieved after compaction of wastes at the Deonar Landfill in Mumbai to be between 900 to 1000kg/m^3 [12].

The waste densities noted above were used to calculate the waste input for each era, and the same triangular pdf was applied, see Table C2 below

Table C2: Waste Input table by Era, per year of operation

Era	Operational Years	Volume m^3	Tonnage yr^{-1} Density 1.7t/m^3	Tonnage yr-1 Density 1.2 t/m^3	Tonnage yr^{-1} Density 1.0 t/m^3	Tonnage yr^{-1} Density 0.5 t/m^3
1940-1947	7	190,000	46,143	32,571	27,143	13,571
1947-1955	8	350,000	74,375	52,500	43,750	21,875
1955-1960	5	580,000	197,200	139,200	116,000	58,000
1960-1970	10	520,000	88,400	62,400	52,000	26,000
1970-1980	11	2,500,000	386,364	272,727	227,273	113,636

Degradation Rates

The degradation rates were varied to obtain results based on average, wet and dry degradation rates using the GasSim 2.5 default values. This produced results which indicated wet degradation rate would deplete the source term at a faster rate producing lower current gas generation. At the other extreme the dry rates indicate the landfill would be gassing at significantly higher volumes currently which would be sustained for a longer period into the future. The average degradation rate was chosen to reflect the site conditions as all wastes were placed above the groundwater table and are generally recorded to be damp/dry, considered to be a more realistic representation of prevailing conditions.

Waste input Streams

Waste input streams were varied to reflect the overall landfill composition which has been calculated to have a 14% contribution from recent/old domestic waste streams slightly lower than the contribution calculated for some of the individual eras e.g. 1940 to 1947 and 1947 to 1955 where old domestic waste has been estimated to comprised 40 % of the waste stream. This did not produce any significant change in gas generation rates and therefore the waste streams per era were used in the model.

The composition of the waste is based on the forensic logging for each waste stream e.g. recent domestic, old domestic, with percentages of paper, newspaper, organics and inorganic content, this was inputted into GasSim 2.5 with a few constituents modified to match the GasSim 2.5 categories see, Table C3 and key below.

Table C3: Waste streams – Composition based on Forensic Logging

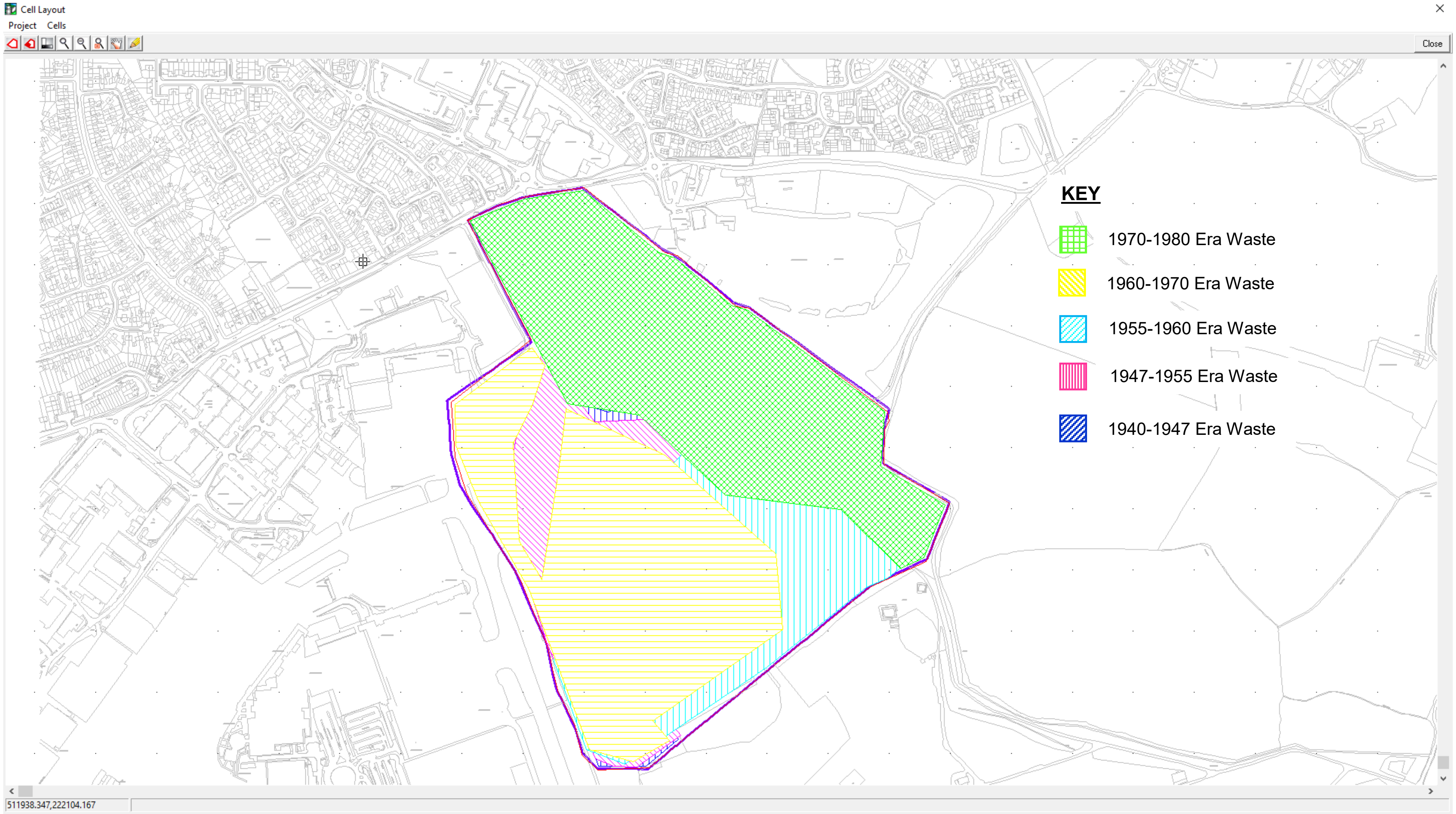
Category	Constituent	Recent Domestic %	Old Domestic %	Construction %	Industrial %
Paper/ Card	Newspaper	SINGLE(3.58)	SINGLE(3.33)	SINGLE(0.12)	SINGLE(0.63)
	Magazines	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Other paper	SINGLE(2.84)	SINGLE(2.29)	SINGLE(0.13)	SINGLE(1.2)
	Liquid Cartons	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Card packaging	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Other card	SINGLE(1.48)	SINGLE(0.53)	SINGLE(0.2)	SINGLE(0.32)
	Wood	SINGLE(7.93)	SINGLE(5.87)	SINGLE(4.27)	SINGLE(10.85)
Textiles	Textiles	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Miscellaneous combustible	Disposable nappies	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Other misc. combus.	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Putrescible	Garden waste	SINGLE(1.5)	SINGLE(0.0)	SINGLE(0.05)	SINGLE(0.03)
	Other putrescible	SINGLE(9.27)	SINGLE(5.58)	SINGLE(1.49)	SINGLE(8.67)
Fines	10mm fines	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Sewage Sludge	Sewage Sludge	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Compost	Composed Organic	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Ash	Incinerator ash	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Non-degradable	Non-degradable	SINGLE(73.4)	SINGLE(82.39)	SINGLE(93.75)	SINGLE(78.3)
		Commercial %	**Made Ground %**	**Non-chalky inert %**	**Chalky inert %**
Paper/ Card	Newspaper	SINGLE(5.51)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Magazines	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Other paper	SINGLE(8.02)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Liquid Cartons	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Card packaging	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Other card	SINGLE(2.43)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Wood	SINGLE(12.16)	SINGLE(0.18)	SINGLE(0.02)	SINGLE(0.03)
Textiles	Textiles	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Miscellaneous combustible	Disposable nappies	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Other misc. combus.	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Putrescible	Garden waste	SINGLE(0.2)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
	Other putrescible	SINGLE(10.33)	SINGLE(0.0)	SINGLE(0.01)	SINGLE(0.05)
Fines	10mm fines	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Sewage Sludge	Sewage Sludge	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Compost	Composed Organic	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Ash	Incinerator ash	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)	SINGLE(0.0)
Non-degradable	Non-degradable	SINGLE(61.37)	SINGLE(99.82)	SINGLE(99.97)	SINGLE(99.92)

GasSim2.5 Consituent	Forensic Logging Constituent
Newspaper	Newsprint
Other paper	Mixed paper
Other card	Corrugated
Other putrescible	Food + biological + other organics

Non-degradable	Ferrous + aluminium + glass + plastic + other non-organics + construction

The model was also run using the GasSim default 1980-2010 Waste Stream for the 1970s cell with Industrial and Commercial waste streams from the forensic logging added, as these are not part of the default waste stream. Due to the increased percentage of degradable matter in this typical landfill waste stream the volumes of gas generated are in the order of four times greater with around 40% m^3hr^{-1} of methane estimated for 2019. Given the actual flow rate being recorded, this was considered an unrealistic scenario and the waste streams derived from the forensic logging have been used. However, this could be an underestimate as the degradable content is based on what is currently evident, and therefore will not include easily degradable matter which will have fully decomposed.

GasSim 2.5 Landfill Cells



Appendix D – Soil vapour assessment

CLEA Software Version 1.071

Report generated 06/12/19

Report title Vapour risk assessment for commercial development, [redacted] Airport Expansion

Created by [redacted]

BASIC SETTINGS

Land Use Commercial

Building Office (post 1970)
Receptor Female (com) Start age class 17 End age class 17 Exposure Duration 49 years
Soil Sand

Exposure Pathways

Direct soil and dust ingestion	✗	Dermal contact with indoor dust	✗	Inhalation of indoor dust	✗
Consumption of homegrown produce	✗	Dermal contact with soil	✗	Inhalation of soil dust	✗
Soil attached to homegrown produce	✗			Inhalation of indoor vapour	✓
				Inhalation of outdoor vapour	✗

Environment Agency

Land Use Commercial **Receptor** Female (com)

Age Class	Exposure Frequencies (days yr^{-1})						Occupation Periods (hr day^{-1})		Soil to skin adherence factors (mg cm^2)						Max exposed skin factor		
	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with indoor dust	Dermal contact with soil	Inhalation of dust and vapour, indoor	Inhalation of dust and vapour, outdoor	Indoors	Outdoors	Indoor	Outdoor	Direct soil ingestion rate (g day^{-1})	Body weight (kg)	Body height (m)	Inhalation rate (m^3 day^{-1})	Indoor (m^2 m^{-2})	Outdoor (m^2 m^{-2})	Total skin area (m^2)
1	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	5.60	0.7	8.5	0.00	0.00	3.43E-01
2	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	9.80	0.8	13.3	0.00	0.00	4.84E-01
3	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	12.70	0.9	12.7	0.00	0.00	5.82E-01
4	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	15.10	0.9	12.2	0.00	0.00	6.36E-01
5	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	16.90	1.0	12.2	0.00	0.00	7.04E-01
6	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	19.70	1.1	12.2	0.00	0.00	7.94E-01
7	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	22.10	1.2	12.4	0.00	0.00	8.73E-01
8	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	25.30	1.2	12.4	0.00	0.00	9.36E-01
9	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	27.50	1.3	12.4	0.00	0.00	1.01E+00
10	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	31.40	1.3	12.4	0.00	0.00	1.08E+00
11	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	35.70	1.4	12.4	0.00	0.00	1.19E+00
12	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	41.30	1.4	13.4	0.00	0.00	1.29E+00
13	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	47.20	1.5	13.4	0.00	0.00	1.42E+00
14	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	51.20	1.6	13.4	0.00	0.00	1.52E+00
15	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	56.70	1.6	13.4	0.00	0.00	1.60E+00
16	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	59.00	1.6	13.4	0.00	0.00	1.63E+00
17	230	0	230	170	230	170	8.3	0.7	0.14	0.14	0.05	70.00	1.6	**20.0**	0.08	0.08	1.78E+00
18	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.90	1.6	12.0	0.00	0.00	1.80E+00

Consumption Rates

Environment Agency

Consumption rates (g FW kg^{-1} bodyweight day^{-1}) by Produce Group

Age Class	MEAN RATES: Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit	90TH PERCENTILE RATES: Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit
1							7.12E+00	1.07E+01	1.60E+01	1.83E+00	2.23E+00	3.82E+00
2							6.85E+00	3.30E+00	5.46E+00	3.96E+00	5.40E-01	1.20E+01
3							6.85E+00	3.30E+00	5.46E+00	3.96E+00	5.40E-01	1.20E+01
4							6.85E+00	3.30E+00	5.46E+00	3.96E+00	5.40E-01	1.20E+01
5							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
6							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
7							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
8							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
9							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
10							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
11							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
12							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
13							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
14							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
15							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
16							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
17							2.94E+00	1.40E+00	1.79E+00	1.61E+00	2.20E-01	2.97E+00
18							2.94E+00	1.40E+00	1.79E+00	1.61E+00	2.20E-01	2.97E+00

Top 2 applied? No

Where top 2 method is applied, two produce categories use 90th percentile rates, while the remainder use the mean. Produce categories vary on a chemical-by-chemical basis. Where top 2 method is not used, all produce categories for all chemicals assume 90th percentile rates.

Building Office (post 1970)

Building footprint (m^2)	**9.35E+02**
Living space air exchange rate (hr^{-1})	1.00E+00
Living space height (above ground, m)	1.28E+01
Living space height (below ground, m)	0.00E+00
Pressure difference (soil to enclosed space, Pa)	5.10E+00
Foundation thickness (m)	1.50E-01
Floor crack area (cm^2)	1.98E+03
Dust loading factor ($\mu g\ m^{-3}$)	1.00E+02

Soil Sand

Porosity, Total ($cm^3\ cm^{-3}$)	5.40E-01
Porosity, Air-Filled ($cm^3\ cm^{-3}$)	3.00E-01
Porosity, Water-Filled ($cm^3\ cm^{-3}$)	2.40E-01
Residual soil water content ($cm^3\ cm^{-3}$)	7.00E-02
Saturated hydraulic conductivity ($cm\ s^{-1}$)	7.36E-03
van Genuchten shape parameter *m* (dimensionless)	3.51E-01
Bulk density ($g\ cm^{-3}$)	1.18E+00
Threshold value of wind speed at 10m ($m\ s^{-1}$)	7.20E+00
Empirical function (F_x) for dust model (dimensionless)	1.22E+00
Ambient soil temperature (K)	2.83E+02
Soil pH	7.00E+00
Soil Organic Matter content (%)	1.00E+00
Fraction of organic carbon ($g\ g^{-1}$)	5.80E-03
Effective total fluid saturation (unitless)	3.62E-01
Intrinsic soil permeability (cm^2)	9.83E-08
Relative soil air permeability (unitless)	7.68E-01
Effective air permeability (cm^2)	7.54E-08

Soil - Vapour Model

Depth to top of source (no building) (cm)	0
Depth to top of source (beneath building) (cm)	65
Default soil gas ingress rate?	**No**
Soil gas ingress rate (cm^3 s^{-1})	3.23E+02
Building ventilation rate (cm^3 s^{-1})	3.32E+06
Averaging time surface emissions (yr)	49
Finite vapour source model?	No
Thickness of contaminated layer (cm)	200

Air Dispersion Model

Mean annual windspeed at 10m (m s^{-1})	5.00
Air dispersion factor at height of 0.8m *	68.00
Air dispersion factor at height of 1.6m *	120.00
Fraction of site cover (m^2 m^{-2})	0.8

* Air dispersion factor in g m^{-2} s^{-1} per kg m^{-3}

Soil - Plant Model

	Dry weight conversion factor	Homegrown fraction Average	Homegrown fraction High	Soil loading factor	Preparation correction factor
	g DW g^{-1} FW	dimensionless		g g^{-1} DW	dimensionless
Green vegetables	0.096	0.05	0.33	1.00E-03	2.00E-01
Root vegetables	0.103	0.06	0.40	1.00E-03	1.00E+00
Tuber vegetables	0.210	0.02	0.13	1.00E-03	1.00E+00
Herbaceous fruit	0.058	0.06	0.40	1.00E-03	6.00E-01
Shrub fruit	0.166	0.09	0.60	1.00E-03	6.00E-01
Tree fruit	0.157	0.04	0.27	1.00E-03	6.00E-01

Gardener type None

CLEA Software Version 1.071

Report generated	6-Dec-19
Report title	Vapour risk assessment for commercial development [redacted] Airport Expar
Created by	[redacted]

RESULTS

Environment Agency

		Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?		Top Two applied?	Apply Top 2 Approach to Produce Group					
		oral	inhalation	combined	oral	inhalation	combined		Oral	Inhal		Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
1	Chloroethene (Vinyl Chloride)	0.00E+00	0.00E+00	0.00E+00	0.00	0.03	0.03	1.35E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2	Benzene	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	1.11E+03 (sol)	No	No	No	No	No	No	No	No	No
3	Chloroethane	0.00E+00	0.00E+00	0.00E+00	NR	0.00	NR	2.44E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4	Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	NR	NR	No	No	No	No	No	No	No	No	No
5	Trichloroethene (TCE)	0.00E+00	0.00E+00	0.00E+00	0.00	0.01	0.01	1.46E+03 (vap)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
6	1,1-Dichloroethene	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	2.18E+03 (vap)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
7	Carbon disulphide	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	2.04E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
8	1,1-dichloroethane	0.00E+00	0.00E+00	0.00E+00	0.00	NR	NR	1.62E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
9	Tetrachloromethane (Carbon Tetr	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	1.50E+03 (vap)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
10	1,3-Butadiene (Arup)	0.00E+00	0.00E+00	0.00E+00	NR	0.00	NR	7.85E+02 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
11	Mercury, elemental	0.00E+00	0.00E+00	0.00E+00	NR	0.00	NR	4.30E+00 (vap)	No	No	No	No	No	No	No	No	No
12	Chloromethane	0.00E+00	0.00E+00	0.00E+00	NR	0.00	NR	1.67E+03 (sol)	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
13	Dichlorodifluoromethane (F-12)	0.00E+00	0.00E+00	0.00E+00	NR	0.00	NR	1.45E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
14	Styrene	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	6.07E+02 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
15	1,2-Dichloroethane (1,2-DCA)	0.00E+00	0.00E+00	0.00E+00	0.00	0.01	0.01	2.82E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
16	n-Hexane (Arup)	0.00E+00	0.00E+00	0.00E+00	NR	0.00	NR	1.68E+02 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
17	Trichlorofluoromethane (F-11)	0.00E+00	0.00E+00	0.00E+00	NR	0.00	NR	2.21E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
18	1,1,2,2-Tetrachloroethane	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	2.46E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
19	1,4-Dichlorobenzene	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	2.21E+02 (vap)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
20	Trichloromethane (Chloroform)	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	4.60E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Environment Agency

		Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?		Top Two applied?	Apply Top 2 Approach to Produce Group						
		oral	inhalation	combined	oral	inhalation	combined		Oral	Inhal		Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
21	Trans 1,2 Dichloroethene	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	3.14E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
22	Formaldehyde (Methanal) (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	1.50E+05 (sol)	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
23	Hydrogen Sulphide (Arup)	0.00E+00	0.00E+00	0.00E+00	NR	0.16	NR	2.08E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
24	Dichloromethane	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	5.98E+03 (vap)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
25	Tetrachloroethene (PCE)	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	4.15E+02 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
26																	
27																	
28																	
29																	
30																	

Environment Agency

		Soil Distribution				Media Concentrations													
		Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
		%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
1	Chloroethene (Vinyl Chloride)	51.1	41.5	7.3	100.0	6.00E-03	**1.73E+00**	NA	NA	NA	1.34E-04	NA	NA	NA	NA	NA	NA	NA	NA
2	Benzene	67.4	32.5	0.1	100.0	3.70E-01	**1.04E+00**	NA	NA	NA	7.67E-06	NA	NA	NA	NA	NA	NA	NA	NA
3	Chloroethane	49.0	47.9	3.1	100.0	1.00E-02	**1.22E+00**	NA	NA	NA	9.36E-05	NA	NA	NA	NA	NA	NA	NA	NA
4	Arsenic	100.0	0.0	0.0	100.0	1.13E+02	NR	NA	NA	NA	0.00E+00	NA	NA	NA	NA	NA	NA	NA	NA
5	Trichloroethene (TCE)	80.9	19.0	0.1	100.0	2.40E-01	**1.08E+00**	NA	NA	NA	7.76E-05	NA	NA	NA	NA	NA	NA	NA	NA
6	1,1-Dichloroethene	72.1	27.3	0.7	100.0	1.00E-02	**2.67E-01**	NA	NA	NA	1.99E-05	NA	NA	NA	NA	NA	NA	NA	NA
7	Carbon disulphide	79.1	20.9	0.0	100.0	9.35E-01	**7.83E-01**	NA	NA	NA	6.00E-05	NA	NA	NA	NA	NA	NA	NA	NA
8	1,1-dichloroethane	54.0	46.0	0.0	100.0	3.86E-01	**3.00E-01**	NA	NA	NA	2.21E-05	NA	NA	NA	NA	NA	NA	NA	NA
9	Tetrachloromethane (Carbon Tetrachloride	77.8	11.5	10.8	100.0	1.00E-03	**4.23E-01**	NA	NA	NA	3.02E-05	NA	NA	NA	NA	NA	NA	NA	NA
10	1,3-Butadiene (Arup)	0.0	0.0	0.0	0.0	0.00E+00	**1.48E-01**	NA	NA	NA	1.13E-05	NA	NA	NA	NA	NA	NA	NA	NA
11	Mercury, elemental	99.8	0.2	0.0	100.0	1.50E+01	**1.30E-03**	NA	NA	NA	8.78E-08	NA	NA	NA	NA	NA	NA	NA	NA
12	Chloromethane	34.9	65.1	0.0	100.0	1.00E-01	**1.37E-01**	NA	NA	NA	1.09E-05	NA	NA	NA	NA	NA	NA	NA	NA
13	Dichlorodifluoromethane (F-12)	30.5	3.9	65.6	100.0	1.00E-03	**2.58E+00**	NA	NA	NA	1.63E-04	NA	NA	NA	NA	NA	NA	NA	NA
14	Styrene	90.1	9.7	0.2	100.0	3.27E-02	**2.86E-01**	NA	NA	NA	2.00E-05	NA	NA	NA	NA	NA	NA	NA	NA
15	1,2-Dichloroethane (1,2-DCA)	34.0	62.5	3.5	100.0	2.00E-03	**2.72E-01**	NA	NA	NA	2.00E-05	NA	NA	NA	NA	NA	NA	NA	NA
16	n-Hexane (Arup)	0.0	0.0	0.0	0.0	0.00E+00	**6.32E+00**	NA	NA	NA	4.52E-04	NA	NA	NA	NA	NA	NA	NA	NA
17	Trichlorofluoromethane (F-11)	89.8	10.1	0.0	100.0	7.89E-01	**1.42E+00**	NA	NA	NA	1.05E-04	NA	NA	NA	NA	NA	NA	NA	NA
18	1,1,2,2-Tetrachloroethane	74.5	24.2	1.3	100.0	2.50E-02	**1.30E+00**	NA	NA	NA	8.99E-05	NA	NA	NA	NA	NA	NA	NA	NA
19	1,4-Dichlorobenzene	95.3	4.7	0.0	100.0	3.40E+00	**5.88E-01**	NA	NA	NA	4.05E-05	NA	NA	NA	NA	NA	NA	NA	NA
20	Trichloromethane (Chloroform)	59.6	39.6	0.8	100.0	1.00E-02	**3.27E-01**	NA	NA	NA	2.40E-05	NA	NA	NA	NA	NA	NA	NA	NA

Environment Agency

		Soil Distribution				Media Concentrations													
		Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
		%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
21	Trans 1,2 Dichloroethene	66.0	34.0	0.0	100.0	2.00E+00	**2.67E-01**	NA	NA	NA	1.99E-05	NA	NA	NA	NA	NA	NA	NA	NA
22	Formaldehyde (Methanal) (Arup)	0.0	0.0	0.0	0.0	0.00E+00	**5.00E-02**	NA	NA	NA	4.56E-06	NA	NA	NA	NA	NA	NA	NA	NA
23	Hydrogen Sulphide (Arup)	0.0	0.0	0.0	0.0	0.00E+00	**1.35E+01**	NA	NA	NA	1.12E-03	NA	NA	NA	NA	NA	NA	NA	NA
24	Dichloromethane	31.6	68.3	0.1	100.0	3.41E-01	**7.03E-01**	NA	NA	NA	5.34E-05	NA	NA	NA	NA	NA	NA	NA	NA
25	Tetrachloroethene (PCE)	89.0	11.0	0.0	100.0	1.00E+00	**4.56E-01**	NA	NA	NA	3.18E-05	NA	NA	NA	NA	NA	NA	NA	NA
26																			
27																			
28																			
29																			
30																			

Environment Agency

		Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
		Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
1	Chloroethene (Vinyl Chloride)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.37E-06	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
2	Benzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.78E-07	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
3	Chloroethane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.83E-06	0.00E+00	1.93E-04	0.00	0.00	0.00	0.00	2.93	0.00	0.00	97.07
4	Arsenic	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Trichloroethene (TCE)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.83E-06	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
6	1,1-Dichloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-06	8.57E-05	5.71E-06	0.00	0.00	0.00	0.00	1.34	0.00	92.50	6.17
7	Carbon disulphide	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.74E-06	5.00E-02	1.43E-02	0.00	0.00	0.00	0.00	0.01	0.00	77.76	22.24
8	1,1-dichloroethane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.38E-06	2.86E-04	5.71E-05	0.00	0.00	0.00	0.00	0.40	0.00	83.00	16.60
9	Tetrachloromethane (Carbon Tetrachloride)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.88E-06	2.86E-06	7.14E-04	0.00	0.00	0.00	0.00	0.26	0.00	0.40	99.34
10	1,3-Butadiene (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.03E-07	0.00E+00	3.83E-06	0.00	0.00	0.00	0.00	15.52	0.00	0.00	84.48
11	Mercury, elemental	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.47E-09	0.00E+00	7.14E-07	0.00	0.00	0.00	0.00	0.76	0.00	0.00	99.24
12	Chloromethane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.80E-07	0.00E+00	3.03E-03	0.00	0.00	0.00	0.00	0.02	0.00	0.00	99.98
13	Dichlorodifluoromethane (F-12)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.02E-05	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
14	Styrene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.25E-06	1.43E-05	8.00E-05	0.00	0.00	0.00	0.00	1.31	0.00	14.95	83.74
15	1,2-Dichloroethane (1,2-DCA)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-06	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
16	n-Hexane (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.82E-05	0.00E+00	1.40E-03	0.00	0.00	0.00	0.00	1.97	0.00	0.00	98.03
17	Trichlorofluoromethane (F-11)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.51E-06	0.00E+00	0.00E+00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	0.00
18	1,1,2,2-Tetrachloroethane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.60E-06	2.86E-05	2.86E-05	0.00	0.00	0.00	0.00	8.92	0.00	45.54	45.54
19	1,4-Dichlorobenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.52E-06	3.14E-04	1.04E-03	0.00	0.00	0.00	0.00	0.19	0.00	23.11	76.70
20	Trichloromethane (Chloroform)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.49E-06	1.43E-03	1.43E-03	0.00	0.00	0.00	0.00	0.05	0.00	49.97	49.97

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		Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
		Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
21	Trans 1,2 Dichloroethene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.24E-06	5.71E-05	8.57E-05	0.00	0.00	0.00	0.00	0.86	0.00	39.66	59.49
22	Formaldehyde (Methanal) (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.84E-07	0.00E+00	8.51E-03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
23	Hydrogen Sulphide (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.96E-05	0.00E+00	1.35E-04	0.00	0.00	0.00	0.00	34.09	0.00	0.00	65.91
24	Dichloromethane	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.33E-06	1.26E-03	5.00E-03	0.00	0.00	0.00	0.00	0.05	0.00	20.10	79.84
25	Tetrachloroethene (PCE)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.98E-06	1.20E-04	2.86E-03	0.00	0.00	0.00	0.00	0.07	0.00	4.03	95.91
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Environment Agency

		Oral Health Criteria Value (μg kg^{-1} BW day^{-1})		Inhalation Health Criteria Value (μg kg^{-1} BW day^{-1})		Oral Mean Daily Intake (μg day^{-1})	Inhalation Mean Daily Intake (μg day^{-1})	Air-water partition coefficient (K_{aw}) (cm^3 cm^{-3})	Coefficient of Diffusion in Air (m^2 s^{-1})	Coefficient of Diffusion in Water (m^2 s^{-1})	log K_{oc} (cm^3 g^{-1})	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor (g g^{-1} DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
1	Chloroethene (Vinyl Chloride)	ID	0.014	ID	0.3	NR	NR	7.47E-01	1.11E-05	8.34E-10	1.22	1.38	0.1	0.5	1	1	1
2	Benzene	ID	0.29	ID	1.4	NR	NR	1.16E-01	8.77E-06	6.64E-10	1.83	2.13	0.1	0.5	10	1	1
3	Chloroethane	NR	0	TDI	2857	0	13.5	4.45E-01	1.05E-05	7.83E-10	1.27	1.44	0.1	0.5	1	1	1
4	Arsenic	ID	0.3	ID	0.002	NR	NR	NR	NR	NR	NR	NR	0.03	0.5	1	1	1
5	Trichloroethene (TCE)	ID	0.5	ID	0.57	NR	NR	1.87E-01	7.91E-06	6.23E-10	2.15	2.53	0.1	0.5	1	1	1
6	1,1-Dichloroethene	TDI	46	TDI	57	6	0.4	5.93E-01	9.18E-06	7.08E-10	1.83	2.13	0.1	0.5	1	1	1
7	Carbon disulphide	TDI	100	TDI	28.6	3500	1001	4.08E-01	1.04E-05	8.28E-10	2.06	2	0.1	0.5	1	1	1
8	1,1-dichloroethane	TDI	200	NR	0	20	4	1.29E-01	8.73E-06	6.74E-10	1.55	1.79	0.1	0.5	1	1	1
9	Tetrachloromethane (Carbon Tetrachloride)	TDI	4	TDI	3.26	0.2	50	5.82E-01	7.69E-06	6.03E-10	2.39	2.83	0.1	0.5	1	1	1
10	1,3-Butadiene (Arup)	NR	0	TDI	0.571	0	0.268	2.23E+00	1.02E-05	7.15E-10	1.71	1.99	0.1	0.5	1	1	1
11	Mercury, elemental	NR	0	TDI	0.06	0	0.05	1.17E-01	6.34E-06	2.00E-09	4.16	0.62	0	0.5	1	1	1
12	Chloromethane	NR	0	TDI	5.14	0	212	2.71E-01	1.28E-05	9.70E-10	0.84	0.91	0.1	0.5	1	1	1
13	Dichlorodifluoromethane (F-12)	NR	0	TDI	28.6	0	0	1.67E+01	5.20E-06	1.05E-09	2.11	1.82	0.1	0.5	1	1	1
14	Styrene	TDI	12	TDI	240	1	5.6	5.33E-02	7.19E-06	5.48E-10	2.51	2.98	0.1	0.5	1	1	1
15	1,2-Dichloroethane (1,2-DCA)	ID	0.12	ID	0.12	NR	NR	2.38E-02	8.60E-06	6.74E-10	1.3	1.48	0.1	0.5	1	1	1
16	n-Hexane (Arup)	NR	0	TDI	200	0	98	3.74E+01	7.77E-06	5.61E-10	3.14	3.75	0.1	0.5	1	1	1
17	Trichlorofluoromethane (F-11)	NR	0	TDI	200	0	0	4.03E+00	8.70E-06	9.70E-10	2.13	2.13	0.1	0.5	1	1	1
18	1,1,2,2-Tetrachloroethane	TDI	5.8	TDI	5.8	2	2	7.08E-03	6.84E-06	5.43E-10	2.04	2.39	0.1	0.5	1	1	1
19	1,4-Dichlorobenzene	TDI	70	TDI	120	22	73	4.70E-02	6.77E-06	5.37E-10	2.85	3.4	0.1	0.5	1	1	1
20	Trichloromethane (Chloroform)	TDI	13.7	TDI	40	100	100	7.65E-02	8.60E-06	6.80E-10	1.7	1.97	0.1	0.5	1	1	1

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		Oral Health Criteria Value ($\mu g\ kg^{-1}\ BW\ day^{-1}$)		Inhalation Health Criteria Value ($\mu g\ kg^{-1}\ BW\ day^{-1}$)		Oral Mean Daily Intake ($\mu g\ day^{-1}$)	Inhalation Mean Daily Intake ($\mu g\ day^{-1}$)	Air-water partition coefficient (K_{aw}) ($cm^3\ cm^{-3}$)	Coefficient of Diffusion in Air ($m^2\ s^{-1}$)	Coefficient of Diffusion in Water ($m^2\ s^{-1}$)	log K_{oc} ($cm^3\ g^{-1}$)	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor ($g\ g^{-1}$ DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
21	Trans 1,2 Dichloroethene	TDI	17	TDI	17	4	6	1.77E-01	9.09E-06	7.08E-10	1.78	2.08	0.1	0.5	1	1	1
22	Formaldehyde (Methanal) (Arup)	TDI	200	TDI	14.06	0	596	9.11E-06	1.09E-05	6.15E-10	1.2	0.35	0.1	0.5	1	1	1
23	Hydrogen Sulphide (Arup)	NR	0	TDI	0.571	0	9.42	3.02E-01	1.61E-05	1.21E-09	1.28	0.5	0.1	0.5	1	1	1
24	Dichloromethane	TDI	6	TDI	134.3	88.118	350	5.64E-02	9.97E-06	7.91E-10	1.14	1.28	0.1	0.5	1	1	1
25	Tetrachloroethene (PCE)	TDI	6	TDI	11	8.4	200	3.16E-01	7.10E-06	5.61E-10	2.43	2.88	0.1	0.5	1	1	1
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		Soil-to-water partition coefficient ($cm^3 g^{-1}$)	Vapour pressure (Pa)	Water solubility ($mg L^{-1}$)	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
1	Chloroethene (Vinyl Chloride)	9.63E-02	2.20E+05	2.76E+03	model	model	model	0.00E+00	0.00E+00	model
2	Benzene	3.92E-01	6.24E+03	1.78E+03	model	model	model	0.00E+00	0.00E+00	model
3	Chloroethane	1.08E-01	9.33E+04	5.74E+03	Model	Model	Model	Model	Model	Model
4	Arsenic	5.00E+02	NR	1.25E+06	0.00043 fw	0.0004 fw	0.00023 fw	0.00033 fw	0.0002 fw	0.0011 fw
5	Trichloroethene (TCE)	8.19E-01	4.58E+03	1.37E+03	model	model	model	0.00E+00	0.00E+00	model
6	1,1-Dichloroethene	3.92E-01	4.20E+04	3.10E+03	Model	Model	Model	Model	Model	Model
7	Carbon disulphide	6.66E-01	2.65E+04	2.10E+03	model	model	model	0.00E+00	0.00E+00	model
8	1,1-dichloroethane	2.06E-01	1.55E+04	3.67E+03	Model	Model	Model	Model	Model	Model
9	Tetrachloromethane (Carbon Tetrachloride)	1.42E+00	7.53E+03	8.46E+02	model	model	model	0.00E+00	0.00E+00	model
10	1,3-Butadiene (Arup)	2.97E-01	1.51E+05	7.35E+02	model	model	model	model	model	model
11	Mercury, elemental	8.38E+01	7.03E-02	5.60E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	Chloromethane	4.01E-02	3.31E+05	5.35E+03	Model	Model	Model	Model	Model	Model
13	Dichlorodifluoromethane (F-12)	7.47E-01	6.47E+05	2.80E+02	model	model	model	model	model	model
14	Styrene	1.88E+00	3.50E+02	2.90E+02	Model	Model	Model	Model	Model	Model
15	1,2-Dichloroethane (1,2-DCA)	1.16E-01	4.92E+03	8.68E+03	model	model	model	0.00E+00	0.00E+00	model
16	n-Hexane (Arup)	8.01E+00	1.05E+04	9.50E+00	model	model	model	model	model	model
17	Trichlorofluoromethane (F-11)	7.82E-01	1.07E+05	1.10E+03	model	model	model	model	model	model
18	1,1,2,2-Tetrachloroethane	6.36E-01	2.91E+02	2.93E+03	model	model	model	0.00E+00	0.00E+00	model
19	1,4-Dichlorobenzene	4.11E+00	3.85E+01	5.12E+01	model	model	model	0.00E+00	0.00E+00	model
20	Trichloromethane (Chloroform)	2.91E-01	1.35E+04	8.95E+03	model	model	model	0.00E+00	0.00E+00	model

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		Soil-to-water partition coefficient (cm^3 g^{-1})	Vapour pressure (Pa)	Water solubility (mg L^{-1})	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
21	Trans 1,2 Dichloroethene	3.49E-01	2.26E+04	5.25E+03	Model	Model	Model	Model	Model	Model
22	Formaldehyde (Methanal) (Arup)	9.19E-02	2.94E+05	5.10E+05	model	model	model	model	model	model
23	Hydrogen Sulphide (Arup)	1.11E-01	7.78E+05	5.32E+03	model	model	model	model	model	model
24	Dichloromethane	8.01E-02	3.14E+04	2.01E+04	Model	Model	Model	Model	Model	Model
25	Tetrachloroethene (PCE)	1.56E+00	1.01E+03	2.25E+02	model	model	model	0.00E+00	0.00E+00	model
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CLEA Software Version 1.071

Report generated 26.11.19

Report title Vapour risk assessment for commercial development, [redacted] Airport Expansion

Created by [redacted]

BASIC SETTINGS

Land Use	Commercial
Building	Office (post 1970)
Receptor	Female (com)
Soil	Sand

Start age class 17 End age class 17 Exposure Duration 49 years

Exposure Pathways

Pathway		Pathway		Pathway	
Direct soil and dust ingestion	✗	Dermal contact with indoor dust	✗	Inhalation of indoor dust	✗
Consumption of homegrown produce	✗	Dermal contact with soil	✗	Inhalation of soil dust	✗
Soil attached to homegrown produce	✗			Inhalation of indoor vapour	✓
				Inhalation of outdoor vapour	✗

Land Use Commercial

Receptor Female (com)

Age Class	Exposure Frequencies (days yr^{-1}): Direct soil ingestion	Consumption of homegrown produce	Dermal contact with indoor dust	Dermal contact with soil	Inhalation of dust and vapour, indoor	Inhalation of dust and vapour, outdoor	Occupation Periods (hr day^{-1}): Indoors	Outdoors	Soil to skin adherence factors (mg cm^{2}): Indoor	Outdoor	Direct soil ingestion rate (g day^{-1})	Body weight (kg)	Body height (m)	Inhalation rate (m^3 day^{-1})	Max exposed skin factor: Indoor (m^2 m^{-2})	Outdoor (m^2 m^{-2})	Total skin area (m^2)
1	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	5.60	0.7	8.5	0.00	0.00	3.43E-01
2	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	9.80	0.8	13.3	0.00	0.00	4.84E-01
3	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	12.70	0.9	12.7	0.00	0.00	5.82E-01
4	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	15.10	0.9	12.2	0.00	0.00	6.36E-01
5	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	16.90	1.0	12.2	0.00	0.00	7.04E-01
6	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	19.70	1.1	12.2	0.00	0.00	7.94E-01
7	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	22.10	1.2	12.4	0.00	0.00	8.73E-01
8	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	25.30	1.2	12.4	0.00	0.00	9.36E-01
9	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	27.50	1.3	12.4	0.00	0.00	1.01E+00
10	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	31.40	1.3	12.4	0.00	0.00	1.08E+00
11	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	35.70	1.4	12.4	0.00	0.00	1.19E+00
12	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	41.30	1.4	13.4	0.00	0.00	1.29E+00
13	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	47.20	1.5	13.4	0.00	0.00	1.42E+00
14	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	51.20	1.6	13.4	0.00	0.00	1.52E+00
15	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	56.70	1.6	13.4	0.00	0.00	1.60E+00
16	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	59.00	1.6	13.4	0.00	0.00	1.63E+00
17	230	0	230	170	230	170	8.3	0.7	0.14	0.14	0.05	70.00	1.6	**20.0**	0.08	0.08	1.78E+00
18	0	0	0	0	0	0	0.0	0.0	0.00	0.00	0.00	70.90	1.6	12.0	0.00	0.00	1.80E+00

Consumption Rates

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Consumption rates (g FW kg^{-1} bodyweight day^{-1}) by Produce Group

Age Class	MEAN RATES Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit	90TH PERCENTILE RATES Green veg	Root veg	Tuber veg	Herb. Fruit	Shrub fruit	Tree fruit
1							7.12E+00	1.07E+01	1.60E+01	1.83E+00	2.23E+00	3.82E+00
2							6.85E+00	3.30E+00	5.46E+00	3.96E+00	5.40E-01	1.20E+01
3							6.85E+00	3.30E+00	5.46E+00	3.96E+00	5.40E-01	1.20E+01
4							6.85E+00	3.30E+00	5.46E+00	3.96E+00	5.40E-01	1.20E+01
5							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
6							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
7							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
8							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
9							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
10							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
11							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
12							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
13							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
14							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
15							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
16							3.74E+00	1.77E+00	3.38E+00	1.85E+00	1.60E-01	4.26E+00
17							2.94E+00	1.40E+00	1.79E+00	1.61E+00	2.20E-01	2.97E+00
18							2.94E+00	1.40E+00	1.79E+00	1.61E+00	2.20E-01	2.97E+00

Top 2 applied? No

Where top 2 method is applied, two produce categories use 90th percentile rates, while the remainder use the mean. Produce categories vary on a chemical-by-chemical basis. Where top 2 method is not used, all produce categories for all chemicals assume 90th percentile rates.

Building Office (post 1970)

Building footprint (m^2)	**9.35E+02**
Living space air exchange rate (hr^{-1})	1.00E+00
Living space height (above ground, m)	1.28E+01
Living space height (below ground, m)	0.00E+00
Pressure difference (soil to enclosed space, Pa)	5.10E+00
Foundation thickness (m)	1.50E-01
Floor crack area (cm^2)	1.98E+03
Dust loading factor ($\mu g\ m^{-3}$)	1.00E+02

Soil Sand

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Porosity, Total ($cm^3\ cm^{-3}$)	5.40E-01
Porosity, Air-Filled ($cm^3\ cm^{-3}$)	3.00E-01
Porosity, Water-Filled ($cm^3\ cm^{-3}$)	2.40E-01
Residual soil water content ($cm^3\ cm^{-3}$)	7.00E-02
Saturated hydraulic conductivity ($cm\ s^{-1}$)	7.36E-03
van Genuchten shape parameter *m* (dimensionless)	3.51E-01
Bulk density ($g\ cm^{-3}$)	1.18E+00
Threshold value of wind speed at 10m ($m\ s^{-1}$)	7.20E+00
Empirical function (F_x) for dust model (dimensionless)	1.22E+00
Ambient soil temperature (K)	2.83E+02

Soil pH	7.00E+00
Soil Organic Matter content (%)	1.00E+00
Fraction of organic carbon ($g\ g^{-1}$)	5.80E-03

Effective total fluid saturation (unitless)	3.62E-01
Intrinsic soil permeability (cm^2)	9.83E-08
Relative soil air permeability (unitless)	7.68E-01
Effective air permeability (cm^2)	7.54E-08

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Soil - Vapour Model

Depth to top of source (no building) (cm)	0
Depth to top of source (beneath building) (cm)	65
Default soil gas ingress rate?	**No**
Soil gas ingress rate ($cm^3\ s^{-1}$)	3.23E+02
Building ventilation rate ($cm^3\ s^{-1}$)	3.32E+06
Averaging time surface emissions (yr)	49
Finite vapour source model?	No
Thickness of contaminated layer (cm)	200

Air Dispersion Model

Mean annual windspeed at 10m ($m\ s^{-1}$)	5.00
Air dispersion factor at height of 0.8m *	68.00
Air dispersion factor at height of 1.6m *	120.00
Fraction of site cover ($m^2\ m^{-2}$)	0.8

* Air dispersion factor in $g\ m^{-2}\ s^{-1}$ per $kg\ m^{-3}$

Soil - Plant Model

	Dry weight conversion factor	Homegrown fraction Average	Homegrown fraction High	Soil loading factor	Preparation correction factor
	$g\ DW\ g^{-1}\ FW$	dimensionless		$g\ g^{-1}\ DW$	dimensionless
Green vegetables	0.096	0.05	0.33	1.00E-03	2.00E-01
Root vegetables	0.103	0.06	0.40	1.00E-03	1.00E+00
Tuber vegetables	0.210	0.02	0.13	1.00E-03	1.00E+00
Herbaceous fruit	0.058	0.06	0.40	1.00E-03	6.00E-01
Shrub fruit	0.166	0.09	0.60	1.00E-03	6.00E-01
Tree fruit	0.157	0.04	0.27	1.00E-03	6.00E-01

Gardener type None

CLEA Software Version 1.071

Report generated	26.11.19
Report title	Vapour risk assessment for commercial development, [redacted] Airport Expai
Created by	[redacted]

RESULTS

Environment Agency

		Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?		Top Two applied?	Apply Top 2 Approach to Produce Group					
		oral	inhalation	combined	oral	inhalation	combined		Oral	Inhal		Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
1	Toluene	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	8.35E+02 (vap)	No	No	No	No	No	No	No	No	No
2	Xylene, o- (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	4.67E+02 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3	Xylene, m- (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	6.13E+02 (vap)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4	Xylene, p- (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	5.64E+02 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
5	Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	5.08E+02 (vap)	No	No	No	No	No	No	No	No	No
6	TPH - Aliphatic EC5-EC6	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	3.68E+02 (sol)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
7	TPH - Aliphatic >EC6-EC8	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	1.57E+02 (sol)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
8	TPH - Aliphatic >EC8-EC10	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	7.92E+01 (vap)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
9	TPH - Aliphatic >EC10-EC12	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	4.77E+01 (vap)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
10	TPH - Aromatic >EC5-EC7	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	1.11E+03 (sol)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
11	TPH - Aromatic >EC7-EC8	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	8.35E+02 (vap)	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
12	TPH - Aromatic >EC8-EC10	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	6.10E+02 (vap)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
13	TPH - Aromatic >EC10-EC12	0.00E+00	0.00E+00	0.00E+00	0.00	0.00	0.00	3.62E+02 (sol)	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
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Environment Agency

	Assessment Criterion (mg kg^{-1})			Ratio of ADE to HCV			Saturation Limit (mg kg^{-1})	50% rule?		Top Two applied?	Apply Top 2 Approach to Produce Group					
	oral	inhalation	combined	oral	inhalation	combined		Oral	Inhal		Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
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		Soil Distribution				Media Concentrations													
		Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
		%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
1	Toluene	85.6	14.4	0.0	100.0	7.95E+01	**2.06E+00**	NA	NA	NA	1.47E-05	NA	NA	NA	NA	NA	NA	NA	NA
2	Xylene, o- (Arup)	92.5	7.5	0.0	100.0	7.30E+02	**2.07E+00**	NA	NA	NA	1.44E-05	NA	NA	NA	NA	NA	NA	NA	NA
3	Xylene, m- (Arup)	93.4	6.6	0.0	100.0	2.91E+03	**1.01E+02**	NA	NA	NA	7.03E-04	NA	NA	NA	NA	NA	NA	NA	NA
4	Xylene, p- (Arup)	92.8	7.2	0.0	100.0	2.91E+03	**1.01E+02**	NA	NA	NA	7.03E-04	NA	NA	NA	NA	NA	NA	NA	NA
5	Ethylbenzene	92.8	7.2	0.0	100.0	9.04E+02	**5.33E+00**	NA	NA	NA	3.71E-05	NA	NA	NA	NA	NA	NA	NA	NA
6	TPH - Aliphatic EC5-EC6	97.8	2.0	0.2	100.0	7.07E+00	**6.22E+01**	NA	NA	NA	4.73E-04	NA	NA	NA	NA	NA	NA	NA	NA
7	TPH - Aliphatic >EC6-EC8	99.3	0.7	0.0	100.0	1.41E+02	**5.02E+01**	NA	NA	NA	3.82E-04	NA	NA	NA	NA	NA	NA	NA	NA
8	TPH - Aliphatic >EC8-EC10	99.9	0.1	0.0	100.0	2.32E+03	**7.16E+01**	NA	NA	NA	5.44E-04	NA	NA	NA	NA	NA	NA	NA	NA
9	TPH - Aliphatic >EC10-EC12	100.0	0.0	0.0	100.0	1.13E+03	**2.21E+01**	NA	NA	NA	1.68E-04	NA	NA	NA	NA	NA	NA	NA	NA
10	TPH - Aromatic >EC5-EC7	67.4	32.5	0.0	100.0	3.27E-01	**4.72E-01**	NA	NA	NA	3.48E-06	NA	NA	NA	NA	NA	NA	NA	NA
11	TPH - Aromatic >EC7-EC8	85.6	14.4	0.0	100.0	2.04E+02	**6.42E-01**	NA	NA	NA	4.60E-06	NA	NA	NA	NA	NA	NA	NA	NA
12	TPH - Aromatic >EC8-EC10	97.8	2.1	0.0	100.0	1.22E+01	**5.22E+00**	NA	NA	NA	3.97E-05	NA	NA	NA	NA	NA	NA	NA	NA
13	TPH - Aromatic >EC10-EC12	98.6	1.4	0.0	100.0	7.50E+02	**8.90E+00**	NA	NA	NA	6.77E-05	NA	NA	NA	NA	NA	NA	NA	NA
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Environment Agency

	Soil Distribution				Media Concentrations													
	Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
	%	%	%	%	mg kg^{-1}	mg m^{-3}	mg kg^{-1}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg m^{-3}	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW	mg kg^{-1} FW
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		Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
		Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
1	Toluene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	9.18E-07	1.43E-04	7.43E-03	0.00	0.00	0.00	0.00	0.01	0.00	1.89	98.10
2	Xylene, o- (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	8.97E-07	1.57E-04	1.49E-03	0.00	0.00	0.00	0.00	0.05	0.00	9.56	90.39
3	Xylene, m- (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.38E-05	1.57E-04	1.49E-03	0.00	0.00	0.00	0.00	2.60	0.00	9.32	88.09
4	Xylene, p- (Arup)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.38E-05	1.57E-04	1.49E-03	0.00	0.00	0.00	0.00	2.60	0.00	9.32	88.09
5	Ethylbenzene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.31E-06	7.14E-05	1.86E-03	0.00	0.00	0.00	0.00	0.12	0.00	3.70	96.18
6	TPH - Aliphatic EC5-EC6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.94E-05	1.43E+95	1.43E+95	0.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00
7	TPH - Aliphatic >EC6-EC8	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.38E-05	1.43E+95	1.43E+95	0.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00
8	TPH - Aliphatic >EC8-EC10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.39E-05	1.43E+95	1.43E+95	0.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00
9	TPH - Aliphatic >EC10-EC12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.05E-05	1.43E+95	1.43E+95	0.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00
10	TPH - Aromatic >EC5-EC7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.17E-07	4.29E-05	2.86E-03	0.00	0.00	0.00	0.00	0.01	0.00	1.48	98.51
11	TPH - Aromatic >EC7-EC8	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.86E-07	1.43E-04	7.43E-03	0.00	0.00	0.00	0.00	0.00	0.00	1.89	98.11
12	TPH - Aromatic >EC8-EC10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.47E-06	1.43E+95	1.43E+95	0.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00
13	TPH - Aromatic >EC10-EC12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.21E-06	1.43E+95	1.43E+95	0.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00
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	Average Daily Exposure (mg kg^{-1} bw day^{-1})							Distribution by Pathway (%)							
	Direct soil ingestion	Consumption of homegrown produce and attached soil	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour	Background (oral)	Background (inhalation)	Direct soil ingestion	Consumption of homegrown produce	Dermal contact with soil and dust	Inhalation of dust	Inhalation of vapour (indoor)	Inhalation of vapour (outdoor)	Background (oral)	Background (inhalation)
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Environment Agency

		Oral Health Criteria Value (µg kg^{-1} BW day^{-1})		Inhalation Health Criteria Value (µg kg^{-1} BW day^{-1})		Oral Mean Daily Intake (µg day^{-1})	Inhalation Mean Daily Intake (µg day^{-1})	Air-water partition coefficient (K_{aw}) (cm^3 cm^{-3})	Coefficient of Diffusion in Air (m^2 s^{-1})	Coefficient of Diffusion in Water (m^2 s^{-1})	log K_{oc} (cm^3 g^{-1})	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor (g g^{-1} DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
1	Toluene	TDI	223	TDI	1400	10	520	1.15E-01	7.78E-06	5.88E-10	2.31	2.73	0.1	0.5	10	1	1
2	Xylene, o- (Arup)	TDI	180	TDI	60	11	104	9.20E-02	7.01E-06	5.31E-10	2.63	3.12	0.1	0.5	10	1	1
3	Xylene, m- (Arup)	TDI	180	TDI	60	11	104	1.12E-01	7.03E-06	5.31E-10	2.69	3.2	0.1	0.5	10	1	1
4	Xylene, p- (Arup)	TDI	180	TDI	60	11	104	1.07E-01	7.04E-06	5.31E-10	2.65	3.15	0.1	0.5	10	1	1
5	Ethylbenzene	TDI	100	TDI	220	5	130	1.39E-01	7.04E-06	5.31E-10	2.65	3.15	0.1	0.5	10	1	1
6	TPH - Aliphatic EC5-EC6	TDI	5000	TDI	5000	9.99E+99	9.99E+99	2.10E+01	1.00E-05	1.00E-09	2.91	3.31	0.1	0.5	10	1	1
7	TPH - Aliphatic >EC6-EC8	TDI	5000	TDI	5000	9.99E+99	9.99E+99	2.73E+01	1.00E-05	1.00E-09	3.58	4.13	0.1	0.5	10	1	1
8	TPH - Aliphatic >EC8-EC10	TDI	100	TDI	290	9.99E+99	9.99E+99	4.15E+01	1.00E-05	1.00E-09	4.48	5.22	0.1	0.5	10	1	1
9	TPH - Aliphatic >EC10-EC12	TDI	100	TDI	290	9.99E+99	9.99E+99	6.44E+01	1.00E-05	1.00E-09	5.38	6.3	0.1	0.5	10	1	1
10	TPH - Aromatic >EC5-EC7	TDI	223	TDI	1400	3	200	1.16E-01	8.77E-06	6.64E-10	1.83	2.13	0.1	0.5	10	1	1
11	TPH - Aromatic >EC7-EC8	TDI	223	TDI	1400	10	520	1.15E-01	7.78E-06	5.88E-10	2.31	2.73	0.1	0.5	10	1	1
12	TPH - Aromatic >EC8-EC10	TDI	40	TDI	60	9.99E+99	9.99E+99	2.53E-01	1.00E-05	1.00E-09	3.2	3.69	0.1	0.5	10	1	1
13	TPH - Aromatic >EC10-EC12	TDI	40	TDI	60	9.99E+99	9.99E+99	7.22E-02	1.00E-05	1.00E-09	3.4	3.93	0.1	0.5	10	1	1
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	Oral Health Criteria Value ($\mu g\ kg^{-1}$ BW day^{-1})		Inhalation Health Criteria Value ($\mu g\ kg^{-1}$ BW day^{-1})		Oral Mean Daily Intake ($\mu g\ day^{-1}$)	Inhalation Mean Daily Intake ($\mu g\ day^{-1}$)	Air-water partition coefficient (K_{aw}) ($cm^3\ cm^{-3}$)	Coefficient of Diffusion in Air ($m^2\ s^{-1}$)	Coefficient of Diffusion in Water ($m^2\ s^{-1}$)	log K_{oc} ($cm^3\ g^{-1}$)	log K_{ow} (dimensionless)	Dermal Absorption Fraction (dimensionless)	Soil-to-dust transport factor ($g\ g^{-1}$ DW)	Sub-surface soil to indoor air correction factor (dimensionless)	Relative bioavailability via soil ingestion (unitless)	Relative bioavailability via dust inhalation (unitless)
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		Soil-to-water partition coefficient (cm^3 g^{-1})	Vapour pressure (Pa)	Water solubility (mg L^{-1})	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
1	Toluene	1.18E+00	1.73E+03	5.90E+02	model	model	model	0.00E+00	0.00E+00	model
2	Xylene, o- (Arup)	2.47E+00	3.86E+02	1.73E+02	model	model	model	model	model	model
3	Xylene, m- (Arup)	2.84E+00	4.95E+02	2.00E+02	model	model	model	model	model	model
4	Xylene, p- (Arup)	2.59E+00	4.75E+02	2.00E+02	model	model	model	model	model	model
5	Ethylbenzene	2.59E+00	5.53E+02	1.80E+02	model	model	model	0.00E+00	0.00E+00	model
6	TPH - Aliphatic EC5-EC6	4.71E+00	2.19E+04	3.59E+01	model	model	model	model	model	model
7	TPH - Aliphatic >EC6-EC8	2.21E+01	3.45E+03	5.37E+00	model	model	model	model	model	model
8	TPH - Aliphatic >EC8-EC10	1.75E+02	3.20E+02	4.27E-01	model	model	model	model	model	model
9	TPH - Aliphatic >EC10-EC12	1.39E+03	3.21E+01	3.39E-02	model	model	model	model	model	model
10	TPH - Aromatic >EC5-EC7	3.92E-01	6.24E+03	1.78E+03	model	model	model	model	model	model
11	TPH - Aromatic >EC7-EC8	1.18E+00	1.73E+03	5.90E+02	model	model	model	model	model	model
12	TPH - Aromatic >EC8-EC10	9.19E+00	3.20E+02	6.46E+01	model	model	model	model	model	model
13	TPH - Aromatic >EC10-EC12	1.46E+01	3.21E+01	2.45E+01	model	model	model	model	model	model
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	Soil-to-water partition coefficient ($cm^3 g^{-1}$)	Vapour pressure (Pa)	Water solubility ($mg L^{-1}$)	Soil-to-plant concentration factor for green vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for root vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tuber vegetables (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for herbaceous fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for shrub fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)	Soil-to-plant concentration factor for tree fruit (mg g^{-1} plant DW or FW basis over mg g^{-1} DW soil)
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Appendix E – VOC age and odour assessment

Appendix E - Vapour age and odour assessment

E1 Landfill age assessment

E1.1 Methodology

E1.1.1 The age assessment is based on the relative proportions of chemical groups found within the samples. These groups are: alkanes, aromatic compounds, cyclohexanes, alcohols and ketones, halogenated compounds, and terpenes (however, no terpenes were present and hence were not assessed further). Other chemicals were also measured, such as aldehydes and alkenes, however do not fit within any of the chemical groups and have also been excluded from the assessment.

E1.1.2 Studies carried out by The Environment Agency [1] found that:

- Young landfill waste is typified by high concentrations of alcohols and ketones, and halogenated compounds;
- Medium landfill waste has high concentrations of aromatic compounds; and
- Old landfill waste has high concentrations of alkanes.

E1.1.3 The age of landfill waste at each borehole locations was calculated by using the average concentration of each chemical group across all monitoring rounds. Two parallel assessments were undertaken:

1. Only data which exceeded the Limit of Detection (LOD) was incorporated in the assessment; and
2. All data was incorporated in the assessment. For recorded values less than the LOD, the LOD value was used as the data point.

E1.1.4 Ages are represented with a 1-5 scale, where 1 is the youngest and 5 is the oldest waste.

E1.2 Results

Assessment 1 - data greater than LOD

E1.2.1 Most samples were found to have a gas signature typical of old waste. Twelve locations were found to have chemical group proportions dominated by alkanes (>75%), and were therefore regarded as having derived from old waste. Seven samples had proportions of alkanes between 60%-75%, and where regarded as having derived from medium-old waste; Two locations were dominated by (>55%) aromatic compounds and were regarded as having derived from medium waste; and two samples were

100% halogenated compounds and were regarded as having derived from young-medium waste.

E1.2.2 Given that only values greater than LOD were used, the quantity of data per location varied significantly. Six locations were found to have less than 7% of data greater than the LOD and eight locations were found to have total chemical concentration less than 400 $\mu g/m^3$. It should be noted that due to an inadequate quantity of data, the results from these locations should be treated with caution.

E1.2.3 A summary of findings for the age assessment can be found in Table E1 and Figure E1 and Figure E2.

Table E1: Age assessment of sampled locations based on relative proportions of different chemical groups.

Location	Age [a]	Reasoning	No. > LOD [b]	% > LOD	Comment [c]
BH03	5	>75% alkanes	83 of 412	20.1	
BH05G	5	>75% alkanes	54 of 412	13.1	
BH06	5	>75% alkanes	97 of 412	23.5	
BH07	5	>75% alkanes	82 of 412	19.9	
BH08	5	>75% alkanes	76 of 412	18.4	
BH10GA	5	>75% alkanes	55 of 412	13.3	Low total concentration
BH12A	5	>75% alkanes	113 of 412	27.4	Low total concentration
BH201	4	60% - 75% alkanes	5 of 73	6.8	Low % > LOD
BH203	5	>75% alkanes	9 of 73	12.3	
BH204	4	60% - 75% alkanes	18 of 73	24.7	
BH207	4	60% - 75% alkanes	29 of 73	39.7	
BH213	4	60% - 75% alkanes	18 of 73	24.7	
BH219	4	60% - 75% alkanes	14 of 73	19.2	
BH220	4	60% - 75% alkanes	22 of 73	30.1	
BH226	3	>55% aromatic compounds	4 of 73	5.5	Low % > LOD and low total concentration
BHS203	-		0 of 73	0	Low % > LOD low total concentration
BWS213	-		0 of 73	0	Low % > LOD low total concentration

Location	Age [a]	Reasoning	No. > LOD [b]	% > LOD	Comment [c]
BWS216	2	100% halogenated compounds	1 of 73	1.4	Low % > LOD low total concentration
WS206	3	>55% aromatic compounds	16 of 73	21.9	
BH216	5	>75% alkanes	9 of 65	13.8	
BH222	4	60% - 75% alkanes	5 of 65	7.7	
BH223	5	>75% alkanes	8 of 65	12.3	
BH232	5	>75% alkanes	7 of 65	10.8	
BWS217	2	100% halogenated compounds	1 of 65	1.5	Low % > LOD low total concentration
WS224	5	>75% alkanes	23 of 65	35.4	

[a] Age: 1 – Young; 2 – Young-Medium; 3 – Medium; 4 – Medium-Old; 5 – Old
[b] Only included the chemicals which are part of a chemical groups used as part of this assessment
[c] Low % > LOD indicates and low total concentration (as seen in Figure 1) indicates an inadequate quantity of data available to make robust assessments

E1.2.4 The data in Table 1 is represented in the following figures.

Figure E1: Concentration of chemical groups per location.

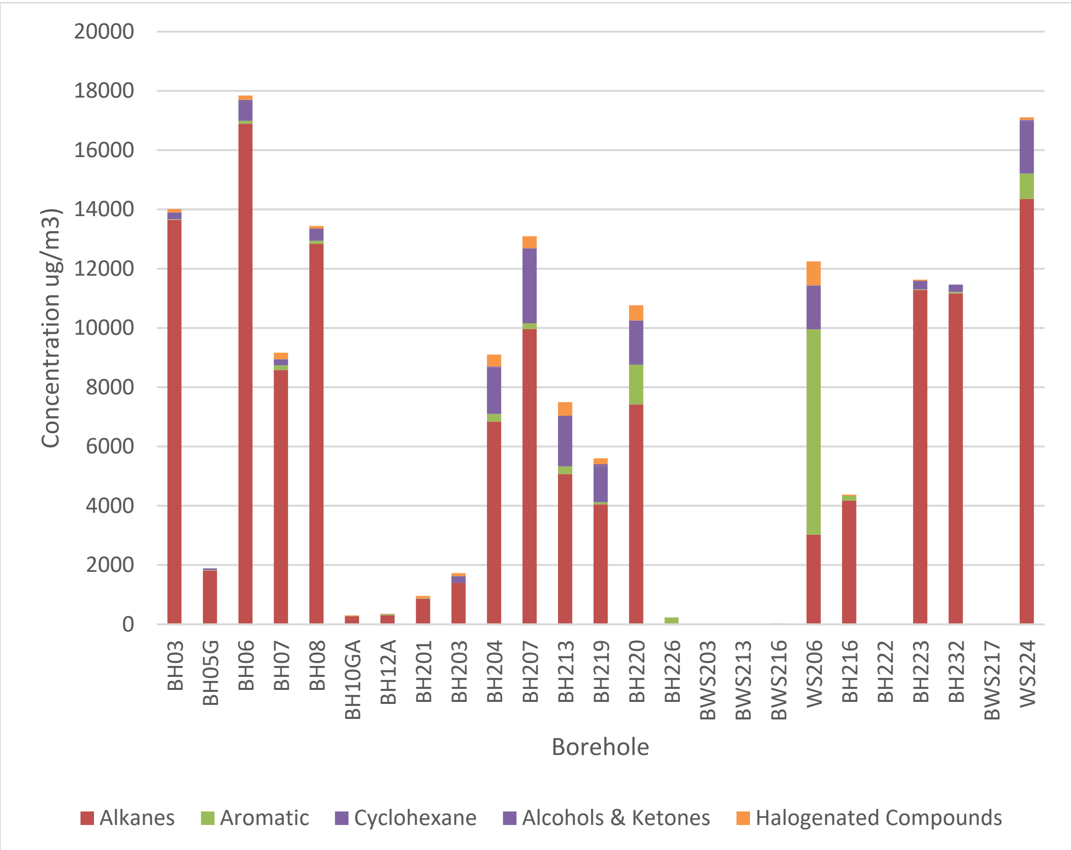


Figure E2: Relative proportions of chemical groups per location

E1.2.5 It can be seen that most locations are dominated by alkanes.

Assessment 2: LOD values used where the value is less than LOD

E1.2.6 A repeat assessment was also undertaken with a complete dataset including those values below the LOD. The results can be found in Figure E4.

E1.2.7 and Figure E3 & Figure E4.

Table E2: Age assessment using complete dataset including values at LOD

Exploratory Hole	Age	Reasoning	Exploratory Hole	Age	Reasoning
BH03	5	>75% alkanes	BH220	4	60% - 75% alkanes
BH05G	5	>75% alkanes	BH226	4	60% - 75% alkanes
BH06	5	>75% alkanes	BHS203	4	60% - 75% alkanes
BH07	5	>75% alkanes	BWS213	4	60% - 75% alkanes
BH08	5	>75% alkanes	BWS216	4	60% - 75% alkanes
BH10GA	5	>75% alkanes	WS206	3	>55% aromatic compounds
BH12A	5	>75% alkanes	BH216	5	>75% alkanes

Exploratory Hole	Age	Reasoning	Exploratory Hole	Age	Reasoning
BH201	5	>75% alkanes	BH222	5	>75% alkanes
BH203	5	>75% alkanes	BH223	5	>75% alkanes
BH204	4	60% - 75% alkanes	BH232	5	>75% alkanes
BH207	5	>75% alkanes	BWS217	5	>75% alkanes
BH213	4	60% - 75% alkanes	WS224	5	>75% alkanes
BH219	4	60% - 75% alkanes			

Figure E3: Concentration of chemical groups per location

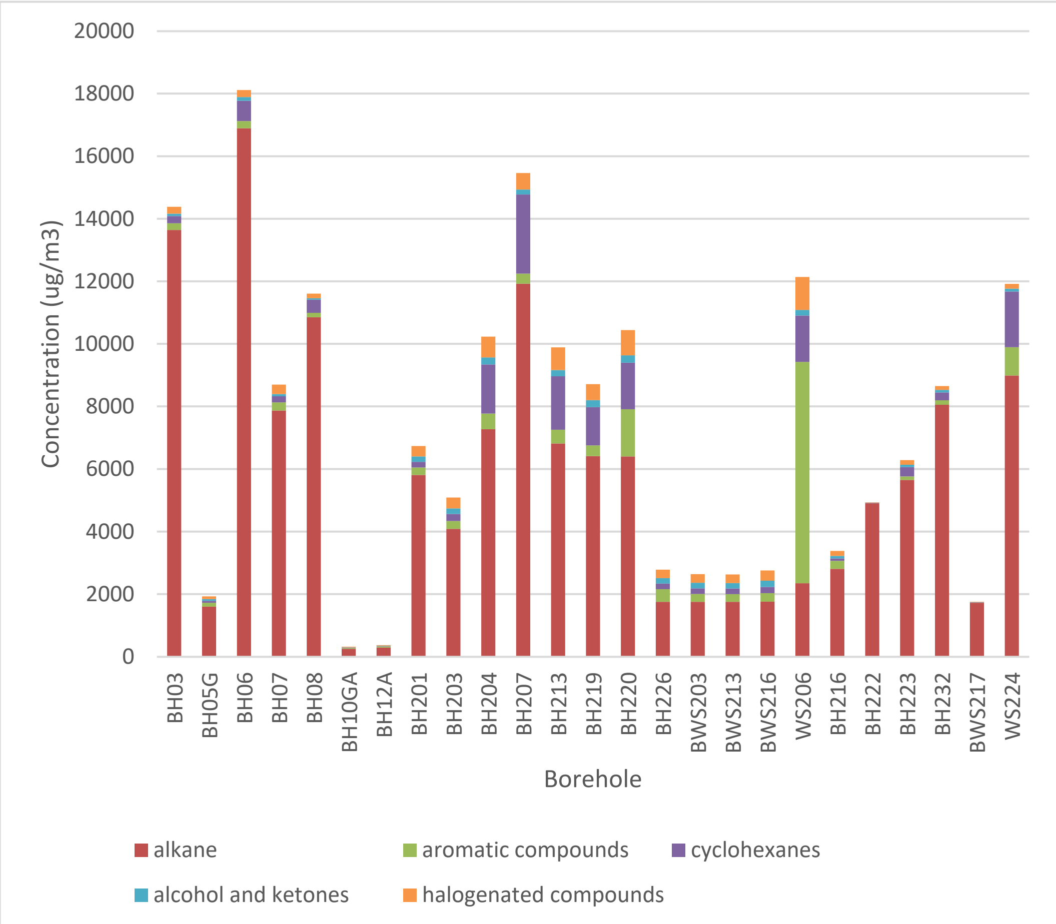
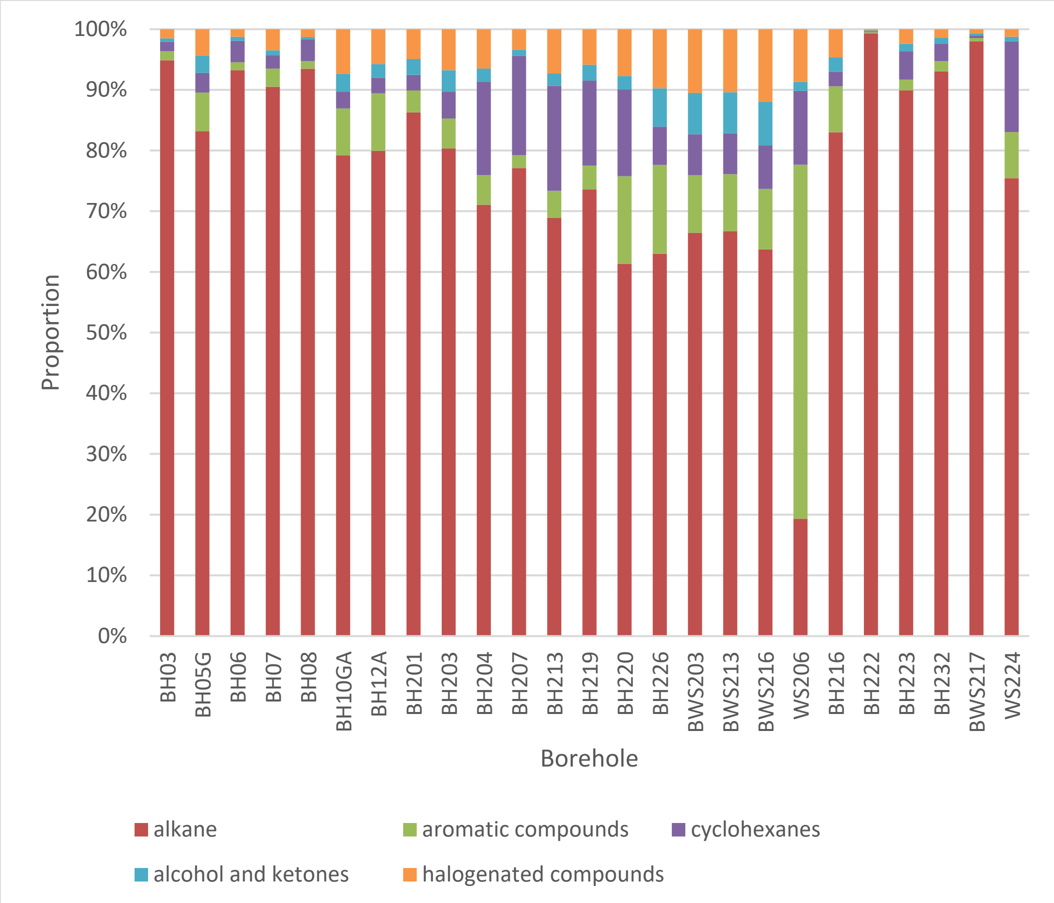


Figure E4: Relative proportion of chemical groups per location



E1.2.8 Again, all locations apart from WS206 are dominated by alkanes.

E1.3 Comparison between the two assessments

E1.3.1 The two age assessments were compared to see if there are any significant differences. It was found that between the two assessments there were only five instances where the LOD only assessment derived younger ages than the assessment which included the whole dataset. A comparison table can be found in Table E3.

Table E3: Age comparison between two data sets

	Data Set			Data Set	
	LOD Substitute	LOD Only		LOD Substitute	LOD Only
Location	**Age**	**Age**	**Location**	Age	Age
BH03	5	5	BH226	4	**3**
BH05G	5	5	BHS203	4	N/A
BH06	5	5	BWS213	4	N/A
BH07	5	5	BWS216	4	2

BH08	5	5	WS206	3	3
BH10GA	5	5	BH216	5	5
BH12A	5	5	BH222	5	**4**
BH201	5	**4**	BH223	5	5
BH203	5	5	BH232	5	5
BH204	4	4	BWS217	5	**2**
BH207	5	**4**	WS224	5	5
BH220	4	4			

E1.3.2 Locations BH201, BH207, BH226, BH222, BWS217 were assessed as younger within the LOD Only assessment. 'LOD Only' values in red are those which were found to infer a younger age of waste when compared to their 'LOD Substitute' counter-part.

E1.3.3 The conclusion drawn from the assessment is that at most exploratory hole locations the landfill waste is assessed as old due to the high proportion of alkanes contributing to the total vapour concentration.

E2 Odour assessment

E2.1 Methodology

E2.1.1 The data was compared to the odour threshold criteria which has been devised by EA [1].

E2.1.2 As part of the assessment the chemicals are given an odour ranking and a physical rank. The odour rank is based on the olfactory detection limit, as well as the smell strength. Values for this can be found in EA Technical Report [2]. The physical rank is defined by the chemical volatility relative to benzene. Chemicals with a Henry's law constant value lower than $5x10^{-3}$ atm.m^3/mol have a lower mobility than benzene and those with values greater than $5x10^{-3}$ atm.m^3/mol have a higher mobility. The odour importance is simply the odour rank multiplied by the physical rank.

E2.1.3 Unfortunately, most of the odour ranking data within the report P1-438/TR [1] is located on an external disk which is not digitally available, and hence some odour ranking values are missing resulting in an incomplete assessment. The assessment data is found in Table E5.

E2.2 Results

E2.2.1 Thirteen of the chemicals assessed were found to have odour threshold values. Fourteen samples were found to have concentrations greater than the odour detection limit. The odour exceedances and associated log descriptions are summarised below in Table E4.

Table E4: Chemicals with odour threshold values and concentrations which exceeded threshold values

Chemical	Odour Threshold	Units	Max Value	Location	No. exceeding threshold value
Carbon Disulfide	0.1	ug/m³	44.6	BH12A	1
Acetone + Propanal	1100	ug/m³	1300	BH08	1
2-Butanone (MEK)	737	ug/m³	2200	WS224	4
2-Pentanone	28000	ug/m³	-	-	0
Hydrogen sulfide	0.7	ug/m³	-	-	0
acetaldehyde	0.2	ug/m³	50	BH03	6
butyric acid	1	ug/m³	-	-	0
dimethyl disulfide	0.1	ug/m³	-	-	0
dimethyl sulfide	2.5	ug/m³	140	BH08	1
ethyl mercaptan	0.032	ug/m³	91	BH06	1
methyl mercaptan	0.04	ug/m³	-	-	0
propyl mercaptan	0.2	ug/m³	-	-	0
Formaldehyde	1320	ug/m³	-	-	0

E2.2.2 In Boreholes where recorded concentrations of 2-Butanone (MEK) were identified as exceeding the odour threshold, the associated odour descriptions in the borehole logs were described as putrid odour, no odour or a musk (pungent) and hydrocarbon (tar) odour with rating from 2 to 3 respectively which equates distinct but not strong odour and strong odour, respectively.

Table E5: Odour Assessment

Chemical	Henry's constant	physical rank	odour rank *	odour importance	No > Odour Detection limit
Carbon Disulfide	1.04E-02	2	3	6	1
Acetone + Propanal	1.17E-05	1	-		1
2-Butanone (MEK)	2.70E-05	1	-		4
2-Pentanone	1.38E-03	2	-		0
Hydrogen sulfide	1.00E-03	2	5	10	0

Chemical	Henry's constant	physical rank	odour rank *	odour importance	No > Odour Detection limit
acetaldehyde	6.67E-05	1	-		6
butyric acid	5.35E-07	1	5	5	0
dimethyl disulfide	1.21E-03	2	5	10	0
dimethyl sulfide	1.61E-03	2	4	8	1
ethyl mercaptan	4.53E-03	2	-		1
methyl mercaptan	1.23E-07	2	-		0
propyl mercaptan	4.08E-03	2	-		0
Formaldehyde	3.37E-07	1	-		0
* Odour rank data is derived from a EA guidance document [1]. Unfortunately, no digital record for some odour ranks were available.					

E2.2.3 Odour importance is based on physical rank (volatility relative to benzene) and odour rank (olfactory strength and detectability). Organic sulphide chemicals have the highest odour rank.

E2.2.4 Fourteen samples were found to exceed the odour detection limit. Of these, two chemicals (carbon disulfide and dimethyl sulphide) have an odour importance of 6 or greater. Unfortunately, no odour rank was available for the remaining chemical exceedances.

Limitations

E2.2.5 This assessment only incorporated data recorded as greater than the LOD. However, nine of the thirteen odorous compounds had odour thresholds lower than the LOD and therefore while samples were ignored for being less than the LOD, they may have exceeded the odour threshold.

E3 Waste type relationships

E3.1 Methodology

E3.1.1 A simple assessment on the total thickness of waste compared with total concentration of volatiles was undertaken to identify any correlations.

E3.1.2 The final assessment carried out attempts to highlight any correlations between the type of landfill waste present within each borehole and the chemical composition of the gas sampled. Landfill waste was categorised into five groups: Commercial, Construction, Industrial, Domestic Recent, and Domestic Old. Commercial waste includes paper and some plastics; construction waste included brick and rubble; industrial waste contains metal and rubble; and domestic waste contains paper, plastics and food.

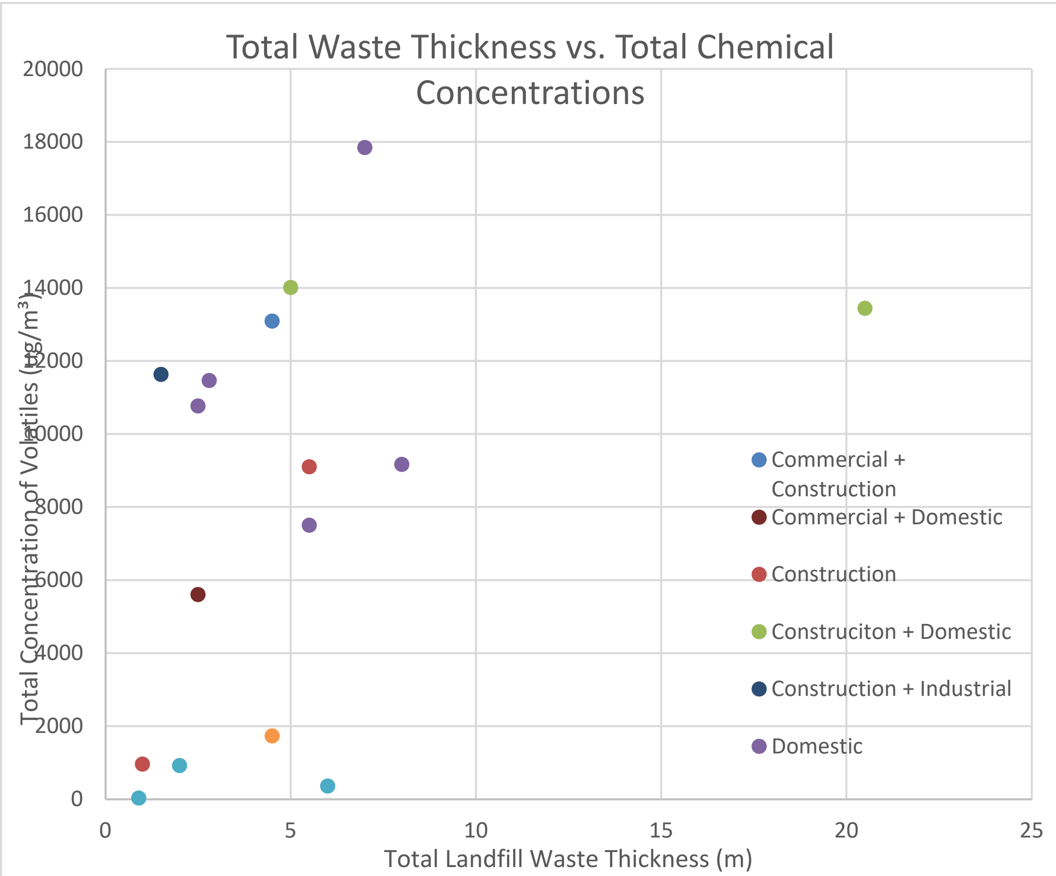
E3.1.3 Within each borehole the depth of each type of waste was logged and the borehole categorised into one of the groups or a mixture of two groups. These waste groups were then compared against the average concentration of the chemical groups: alkanes, aromatic compounds, cyclohexanes, alcohols and ketones, and halogenated compounds. The aim of this assessment was to identify chemical fingerprints with each type of waste type.

E3.2 Results

Depth of waste

E3.2.1 It was found that there is a positive correlation between landfill waste thickness and total concentration of volatiles. Some waste type groups, such as domestic waste, were also found to typically have high total concentrations. The findings are presented in Figure E5.

Figure E5: Total landfill thickness Vs. total concentration of volatiles



Chemical Fingerprint

E3.2.2 No obvious chemical fingerprint was found to represent each of the waste types, as shown in Figure E6 and E7

Figure E6: Type of waste and total vapour concentrations by borehole

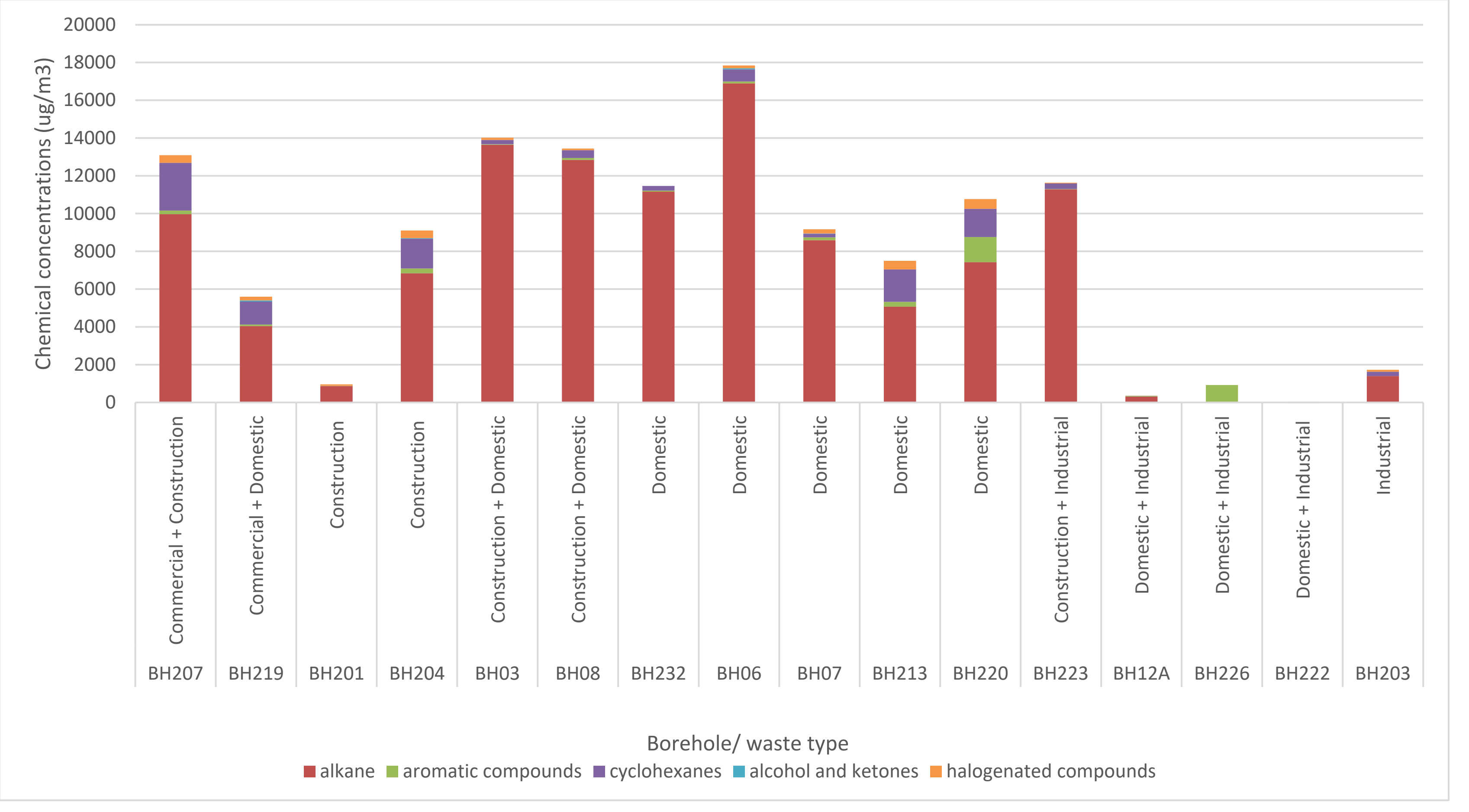
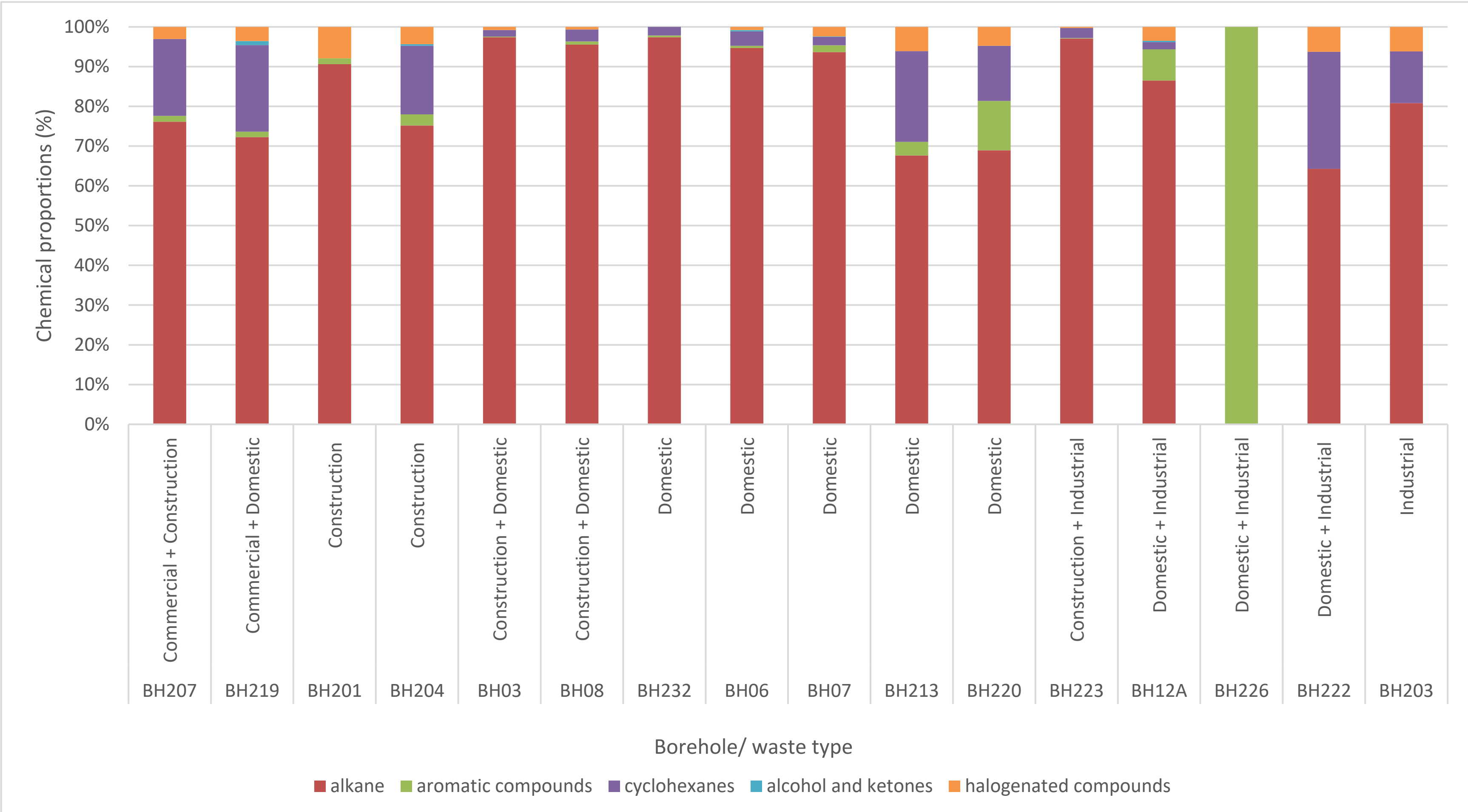


Figure E7: Type of waste and chemical proportions per borehole



E3.2.3 The lack of correlation between waste type and composition of the vapour may be due to the presence of alkanes, which dominate the dataset.

E4 Assessment limitations

E4.1.1 No clear hierarchy is present within the EA guidance documents [1] [2] with regards to assigning volatiles to each of the major chemical groups used for the assessment: alkanes, aromatic compounds, cyclohexanes, alcohols and ketones, and halogenated compounds. For instance, within this assessment it was decided that compounds which are both aromatic and halogenated are to be assigned to the aromatic compounds group and not the halogenated compounds group. The implication of which is that the assessment now considers a greater proportion of aromatic compounds compared to halogenated compounds. Given that aromatic compounds are found in medium-old waste and halogenated compound in young waste, this likely influent the interpretation of ages based on chemical group concentrations, skewing it toward older ages. However, the significance of this remains minimal as most samples were heavily dominated by alkanes. Given that aromatic and halogenated compound comprised significantly low proportions of each sample, they would only bring about minor impacts to any interpretations.

E4.1.2 Two age assessments were undertaken; one with a complete dataset where the LOD is assigned to values less than the LOD; and another which only included data greater than the LOD. The second assessment, with data greater than the LOD only, has some issues. Samples were collected over a six-month period, and therefore sent to laboratories at different dates. The LODs provided by laboratories varied across these dates. This means that while a concentration which is greater than LOD in one sample on one date might be less than LOD, and hence ignored, in another. Therefore, the data within this assessment should be considered in conjunction with the counter-part assessment which used LOD substitutes. Fortunately, both assessments evidenced similar ages.

E5 Summary

E5.1 Age assessment

E5.1.1 All but one sample (WS206) were found to be dominated, >60%, by alkanes indicating that the landfill waste on site is derived from medium-old to old waste.

E5.2 Odour assessment

E5.2.1 Fourteen odorous chemicals were found to exceed their odour threshold. Of these, two compounds, dimethyl sulphide and carbon disulphide, were also found to have an odour importance score greater than 6 out of 10. This indicates that there is a risk of strong odours to arise from any earthworks undertaken on site.

E5.3 Waste type assessment

E5.3.1 There is a positive correlation between landfill thickness and total concentration of volatiles. Some waste types, such as domestic waste, were also found to typically have high total volatile concentrations. No 'chemical fingerprint' was identified for each waste type.

E6 References

[1] Parker, T et al. 2002. Investigation of the composition and emissions of trace components in landfill gas. *Environment Agency, R&D Technical Report P1-438/TR.* [redacted]

[2] Parker, T et al. 2004. Quantification of trace components in landfill gas. Environment Agency, R&D Technical report P1-491/TR. [redacted]

[3] EPA. EPA on-line tools for site assessment calculations. [redacted]

[4] Strekowski, R.S. and George, C., 2005. Measurement of henry's law constants for acetone, 2-butanone, 2, 3-butanedione, and isobutyraldehyde using a horizontal flow reactor. *Journal of Chemical & Engineering Data*, *50*(3), pp.804-810. [redacted]

[5] California Air Resources Board. Methyl isobutyl ketone. [redacted]

[6] Sanders, R. 2015. Compilation of Henry's law constants (version 4.0) for water as solvent [redacted]