



**REPORT C6485A/GRA  
JULY 2016**

**HAZARDOUS GROUND GAS RISK ASSESSMENT REPORT**

**For land at  
OUGHTIBRIDGE MILL**

**prepared for  
COMMERCIAL ESTATES GROUP**



<b>REPORT NUMBER:</b>	C6485A/GRA	<b>REPORT STATUS:</b>	FINAL
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<b>SITE:</b>	OUGHTIBRIDGE MILL		
<b>PREPARED FOR:</b>	COMMERCIAL ESTATES GROUP		
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**HAZARDOUS GROUND GAS RISK ASSESSMENT****for land at****OUGHTIBRIDGE MILL****Prepared for****COMMERCIAL ESTATES GROUP****CONTENTS**

<b>1. INTRODUCTION.....</b>	<b>5</b>
<b>2. SITE DETAILS AND DESCRIPTION.....</b>	<b>7</b>
<b>3. ENVIRONMENTAL SETTING .....</b>	<b>8</b>
3.1. Introduction.....	8
3.2. Site History .....	8
3.3. Published Geological Information .....	8
3.4. Hydrology .....	8
3.5. Landfilling and Waste Management .....	9
3.6. Radon Risk.....	9
<b>4. PREVIOUS INVESTIGATION FINDINGS.....</b>	<b>10</b>
<b>5. GROUND GAS CONCEPTUAL SITE MODEL.....</b>	<b>18</b>
<b>6. GROUND GAS AND GROUNDWATER MONITORING DATA.....</b>	<b>21</b>
6.1. Third Party Gas Monitoring Results, 2014-2015.....	21
6.2. Sirius Gas Monitoring Results, 2016 .....	22
<b>7. GROUND GAS RISK ASSESSMENT .....</b>	<b>23</b>
7.1. General.....	23
7.2. Ground Gas Sources.....	23
7.3. Ground Gas Risk Assessments per Zone .....	24
<b>8. CONCLUSIONS AND RECOMMENDATIONS.....</b>	<b>46</b>
8.1. Assessment of Ground Gas Regime .....	46
8.2. Recommended Ground Gas Protection Measures .....	46
8.3. Further Considerations .....	50
<b>9. REGULATORY AND OTHER APPROVALS.....</b>	<b>51</b>

## APPENDICES

### APPENDIX A FIGURES AND DRAWINGS

Drawing No.	Title	Scale
C6485A/GRA/01	Site Location Plan	1:50,000
C6485A/GRA/02	Site Features Plan	1:1,000
C6485A/GRA/03	Combined Exploratory Hole Location Plan	1:1,000
C6485A/GRA/04A	Conceptual Site Model - Former Landfill Area	NTS
C6485A/GRA/04B	Conceptual Site Model - Former Mill Area	NTS
C6485A/GRA/04C	Conceptual Site Model - South Western Area	NTS
C6485A/GRA/04D	Conceptual Site Model - North Western Area	NTS
C6485A/GRA/05A / B	Geological Cross-Sections	As stated
C6485A/GRA/06	Indicative Gas Zoning Plan	NTS

NTS: Not to Scale

### APPENDIX B EXPLORATORY HOLE LOGS

### APPENDIX C GROUND GAS AND GROUNDWATER MONITORING RESULTS

## EXECUTIVE SUMMARY

<b>Introduction</b>	<p>Sirius Geotechnical and Environmental Ltd (Sirius) was commissioned by Commercial Estates Group (CEG) to undertake a gas risk assessment of land at Oughtibridge Mill, Oughtibridge, Sheffield (the "site"). This gas risk assessment supplements a Geoenvironmental Appraisal report for the site, dated March 2016 (Sirius report ref. C6485A). The planned period of ground gas monitoring at the site is now complete. This gas risk assessment presents the results of that monitoring and an assessment of the risk posed by hazardous ground gases and vapours to the proposed development.</p> <p>Based on the development plan available at the time of preparing this report, it is understood that the proposed development will comprise up to 320 typically low-rise residential dwellings, with residential apartment blocks proposed within the south western site area.</p>
<b>Site Details</b>	<p>The site is irregular in shape, covering an area of approximately 13.8 hectares. For the purposes of clarity, the site has been designated into 4 individual zones. The site comprises a number of existing and recently demolished structures, associated with the former Oughtibridge Paper Mill (i.e. the 'mill zone'), including a former landfill located within the north east of the site (i.e. the 'landfill zone'). A former Mill Race, reservoirs and ponds were historically present within the north west of the site (i.e. the 'north western zone'), and a number of recently demolished buildings were located within the south western area of the site (i.e. the 'south western zone'). The River Don runs centrally through the site, bisecting it into two portions.</p>
<b>Fieldworks and Gas Monitoring</b>	<p>Sirius intrusive investigation took place between November 2015 and January 2016. The fieldworks were undertaken across the site as a whole and included a number of window sample boreholes, cable percussion boreholes, trial holes and hand dug pits.</p> <p>Gas and groundwater monitoring wells were installed within selected boreholes across the site (excluding the woodland areas). These were in addition to previously installed gas and groundwater monitoring wells as part of earlier investigations undertaken by third parties. Twelve subsequent gas and groundwater monitoring visits were completed by Sirius between January 2016 and June 2016. These monitoring visits supplemented the results of 5 monitoring visits previously undertaken by WSP between December 2014 and February 2015, and 4 monitoring visits undertaken by Arcadis between December 2014 and January 2015, within their own monitoring installations.</p>
<b>Ground Conditions</b>	<p>The previous investigation undertaken by Sirius revealed the site to be underlain by variable depths and compositions of made ground. Potentially degradable, putrescible materials were locally recorded within recently placed made ground soils within the landfill and north western site area. Made ground depths within the south western and mill areas ranged between 0.35m and &gt;6.0m, with granular ash rich / demolition rubble materials generally predominating within these areas.</p> <p>Made ground soils were found to be underlain by partly organic alluvial soils (locally underlain by granular alluvial soils), in turn underlain by residual Millstone Grit soils.</p>
<b>Ground Gas Sources</b>	<p>Localised hydrocarbon-impacted made ground soils that were considered to pose a potential risk to site end users via inhalation pathways, were identified within the south western area of the site as part of the Geoenvironmental Appraisal. This area of the site was recommended to undergo remediation.</p> <p>The slow biodegradability of organic matter types encountered across the majority of the site do not represent a significant source of biogenic hazardous ground gases in terms of gas generation rate. Small amounts of localised relatively biodegradable materials (such as paper pulp) were encountered however within the landfill.</p> <p>Localised naturally occurring organic-rich alluvial soils were found to be associated with high concentrations of methane and carbon dioxide in monitoring wells, with</p>

	usually negligible, or very little, gas generation, giving rise to relatively high concentrations of gas locally but very low (steady state) flow rates.
<b>Recommended Gas Precautions</b>	<p><u>Landfill Zone and Southern Mill Zone</u></p> <p>These zones been assessed as being Characteristic Situation 3 (CS3). Assuming a 'Type A' building (such as low-rise private residential housing) and based upon a recommended CS3 classification, a gas protection score of 4.5 is required for new development in this zone. This could be achieved, for example, by the incorporation of a precast suspended segmental subfloor and a passive sub-floor dispersal layer, achieving a 'very good performance' as defined in Annex B of BS8485:2015, together with the installation and verification of a gas-resistant membrane meeting the criteria specified in Table 7 of BS8485:2015.</p> <p><u>Northern / Central Mill Zone and South Western Zone</u></p> <p>These zones been assessed as being Characteristic Situation 2 (CS2). Assuming a 'Type A' building such as low-rise private residential housing, (and / or 'Type B' buildings such as managed residential apartments within the south western zone) and based upon a recommended CS2 classification, a gas protection score of 3.5 is required for new development in these zones. These conditions require a minimum gas protection score of 3.5, which may be achieved, for example, by a passive sub-floor void of suitable design and installation of a suitable gas resistant membrane, installed and verified in accordance with the requirements of BS8485:2015.</p> <p>The proposed classification for the south western zone has been set conservatively given the small number of boreholes in this zone and is likely influenced by the presence of localised 'hotspots' of hydrocarbon contamination. It may be possible to reduce this classification by undertaking further ground gas monitoring following the completion of hydrocarbon remediation.</p> <p><u>North Western Zone</u></p> <p>This zone has been assessed as being Characteristic Situation 1 (CS1). Table 4 of BS8485:2015 indicates that CS1 conditions do not require the installation of specific gas protection measures.</p> <p>An indicative gas zoning plan is presented as Drawing No. C6485A/GRA/06 in Appendix A.</p>
<b>Regulatory Approvals</b>	The proposed detailed design of gas protection measures will need to be agreed with the local authority and if applicable, the NHBC or other insurer, together with an appropriate strategy for verification prior to undertaking any construction on site.

**The executive summary is an overview of the key findings and conclusions of the report. There may be other information contained in the body of the report which puts into context the findings of the executive summary. No reliance should be placed on the executive summary in isolation, particularly when deriving design detail/abnormal costs.**

## 1. INTRODUCTION

Sirius Geotechnical and Environmental Ltd (“Sirius”) was commissioned by Commercial Estates Group (“CEG”) to undertake a gas risk assessment of land at Oughtibridge Mill, Oughtibridge, Sheffield (the “site”). This gas risk assessment supplements a Geoenvironmental Appraisal report for the site, dated March 2016 (Sirius report ref. C6485A).

The planned period of ground gas monitoring at the site is now complete. This gas risk assessment presents the results of that monitoring and an assessment of the risk posed by hazardous ground gases and vapours to the proposed development. Whilst this report discusses pertinent findings of the investigation, it must be read in conjunction with the aforementioned Geoenvironmental Appraisal report, which presents in detail the site setting and the findings of previous investigations.

In undertaking this assessment, we have taken account of current best practice guidance in the assessment risk posed by hazardous permanent ground gases, including:

- BS8485:2015 “Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings”;
- BS8576:2013 “Guidance on Investigations for Ground Gas – Permanent Gases and Volatile Organic Compounds (VOCs)”;
- CIRIA “Assessing Risks Posed by Hazardous Ground Gases to Buildings”, report C665, 2007;
- CIRIA “The VOCs Handbook. Investigating, Assessing and Managing Risks from Inhalation of VOCs at Land Affected by Contamination”, report C682, 2009;
- CL:AIRE “A Pragmatic Approach to Ground Gas Risk Assessment”, report ref. RB17, November 2012;
- NHBC “Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present”, report version 04, March 2007.

Based on the development plan available at the time of preparing this report, it is understood that the proposed development will comprise up to 320 typically low-rise residential dwellings. Residential apartment blocks with communal gardens / soft landscaping are presently proposed within the south western site area. A drawing showing the proposed development layout has been

provided by the client to Sirius (Drawing Ref.: Parameter Plan 1526:10, dated March 2016, by STEN Architecture) and is reproduced within Appendix A of this report.

For the purposes of ground gas risk assessment, unless specifically stated otherwise, the majority of the proposed development is considered to be characterised as comprising Type A buildings, as defined in Table 3 of BS 8485:2015.

Preliminary proposed remediated levels have been derived, undertaken as part of an initial cut/fill balance assessment. Final remediated levels are currently proposed to be raised by approximately 1.0m - 2.0m across the majority of the north western and south western site areas, and between approximately 0.5m - 1.0m within the landfill area. Only minimal volumes of cut are proposed within the landfill. Significant raising of levels are currently proposed between the north western and south western site areas, to accommodate a new proposed access road. Minor cut and fill earthworks are proposed across the mill area, to provide a suitable development plateau.

The comments and opinions presented in this report are based on the findings of the desk study, ground conditions encountered during intrusive investigation works performed by Sirius and the results of tests carried out within one or more laboratories. There may be other conditions prevailing on the site which have not been revealed by this investigation and which have not been taken into account by this report. Responsibility cannot be accepted for any conditions not revealed by this investigation. Any diagram or opinion on the possible configuration of strata, contamination or other spatially variable features between or beyond investigation positions is conjectural and given for guidance only. Confirmation of ground conditions between exploratory holes should be undertaken if deemed necessary. Evaluation of ground gas and groundwater is based on observations made at the time of the investigation and monitoring visits. It should be noted that ground gas and groundwater levels and quality may vary due to seasonal and other effects.

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## 2. SITE DETAILS AND DESCRIPTION

**Table 2.1. Current Site Overview**

<b>Location</b>	The site is located off Main Road and Langsett Road North, Oughtibridge, approximately 10km north west of Sheffield City Centre. A site location plan is included as Drawing No. C6485A/GRA/01 within Appendix A.
<b>National Grid Reference (NGR)</b>	430223mE, 393975mN.
<b>Topography and Features</b>	<p>The site is irregular in shape, with approximate dimensions of 900m in length and 200m in width, and comprises a number of existing and recently demolished structures and features associated with the former Oughtibridge Paper Mill, including a former landfill located within the north east of the site. The southern boundary of the site runs approximately north west-south east, parallel to the road.</p> <p>The River Don runs through the site, bisecting it into two portions. The river flows towards the south east. A Mill Race, reservoirs and ponds were historically present within the north west of the site.</p> <p>For the purposes of this report, the site has been zoned into four distinct areas, as indicated on Drawing No. C6485A/GRA/02 included within Appendix A of this report.</p>
<b>Approximate Site Area</b>	13.8 hectares.
<b>Site Boundaries</b>	The site is bordered by woodland to the north and east, Main Road / Langsett Road North to the south and residential properties and a public house to the north / north west.
<b>Current Land Use</b>	Disused.
<b>Adjacent Land Uses</b>	Residential and woodland. A pub (Wharncliffe Arms) is located adjacent to the north west of the site.

The main site features are shown on Drawing No. C6485A/GRA/02 within Appendix A.

### **3. ENVIRONMENTAL SETTING**

#### **3.1. Introduction**

Published environmental, geological and historical data relating to the site were reviewed as part of the Sirius Geoenvironmental Appraisal report. A brief synopsis of information relevant to this ground gas risk assessment is provided below.

#### **3.2. Site History**

The site was shown to be developed with a small, centrally located building, denoted as Spring Grove Paper Mill, on the earliest available Ordnance Survey (OS) map (dated 1855). The paper mill was shown on historical plans to have significantly expanded from 1894 until at least 2006, with the construction of a Mill Race, reservoirs, effluent tanks and on-site landfill all shown. Demolition and clearance works commenced at the site in 2014.

#### **3.3. Published Geological Information**

A summary of available published geological information indicates that the central area of site is underlain by alluvium, described by the BGS as comprising “*Normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present*”.

The solid geology is recorded as comprising Carboniferous Millstone Grit Formation, described by the BGS as comprising “*fine- to very coarse-grained feldspathic sandstones, interbedded with grey siltstones and mudstones, with subordinate marine shaly mudstone, claystone, coals and seatearths*”. An un-named sandstone unit (within the Millstone Grit Formation unit) is shown to be present beneath the north west of the site. An approximate east-west orientated fault is conjectured within the south of the site.

The Coal Authority mining report for the site states that: “*The property is not within the zone of likely physical influence on the surface from past underground workings*”.

#### **3.4. Hydrology**

The River Don runs through the site, and was classified by the EA in 2000 as River Quality B (good) under the GQA grading system.

### 3.5. Landfilling and Waste Management

Information provided by the Envirocheck report and the Environment Agency indicates that there are two historical landfills within approximately 1km. The landfills are registered as Delph Hill Quarry, located approximately 350m to the south west of the site (recorded as operating between 1982 and 1991), and Church Street, located approximately 650m to the south east of the site (recorded as operating between 1978 and 1980). Recorded wastes included inert and commercial.

Delph Hill Quarry is also recorded within the Envirocheck report as a registered landfill site, with the licence lapsed / cancelled in 1982.

A registered waste transfer site is recorded on site, licensed to British Tissues Ltd. The licence is currently lapsed / cancelled, and last dated November 1977. Authorised wastes included industrial non-hazardous wastes, scrap metals and wooden pallets. Prohibited wastes included 'any type of asbestos'.

Desk study information indicates the north eastern area of the site used for landfilling prior to 1969 up until approximately 1992.

### 3.6. Radon Risk

The BGS and HPA "Indicative Atlas of Radon in England and Wales" and the assessment contained within the Envirocheck Report, indicate that the site lies within an area in which **no radon protective measures are required**.

## 4. PREVIOUS INVESTIGATION FINDINGS

Previous investigations have been undertaken by Sirius and other parties within the site, as listed below. Salient points associated with ground gas investigations are summarised below.

A combined site investigation exploratory hole location plan, is included within Appendix A of this report as Drawing No. C6485A/GRA/03. Copies of each referenced third party report are reproduced within the Sirius Geoenvironmental Appraisal report (report ref. C6485A, dated March 2016).

### ***Report on Ground Investigation dated March 2001, prepared by Structural Soils Limited.***

A ground investigation was undertaken by Structural Soils Limited on behalf of Ove Arup and Partners at the site in January 2001. Fieldworks comprised seven cable percussion boreholes (ref. BH101 to BH104, BH106, BH106A and BH106B), five window sample boreholes (WS101 to WS104 and WS109) and nine machine-excavated trial pits.

Ground gas monitoring was undertaken on four occasions within three boreholes (BH101, BH102 and BH104) only. The report refers to gas monitoring installations within previous boreholes undertaken at the site (reference BH1, 6, 11 and 13), however no records appear to be available for these. The results of gas monitoring indicated no detectable concentrations of methane and concentrations of carbon dioxide of up to 8.9% v/v within previously installed borehole reference BH6. No gas flow rates were recorded.

The exploratory hole logs indicate hydrocarbon odours within BH101 to a depth of 1.0m below ground level (bgl), TP102 below a depth of 1.2m bgl, and TP105 to a depth of 1.6m bgl. Chemical analysis of a soil sample retrieved from TP102 at a depth of 1.2m bgl recorded a concentration of diesel range organics (DRO) of 196mg/kg.

### ***Findings of Diethanolamine Dye Investigation dated 22<sup>nd</sup> December 2010, prepared by URS.***

URS were commissioned in 2010 to undertake targeted ground and groundwater investigation at the site, within an area formerly occupied by a banded dye store located within a warehouse.

URS undertook intrusive investigation in December 2010, comprising the drilling of three window sample boreholes (MW101 to MW103) to a maximum depth of 7.0m bgl completed as groundwater monitoring wells.

No visual or olfactory evidence of potential contamination was noted by URS, and PID readings were recorded as 'non-detect'.

***Geoenvironmental Assessment dated April 2015, prepared by WSP UK Ltd.***

WSP was instructed by Capita to undertake an intrusive ground investigation at the site. Fieldworks were undertaken between November 2014 and February 2015. In total, investigation works comprised nine rotary boreholes (BH201, BH202, BH202A and BH203 to BH208), nine machine-excavated trial holes and two hand dug pits. Ten ground gas and groundwater monitoring wells were installed within selected boreholes.

Four rounds of ground gas monitoring were undertaken between December 2014 and January 2015. Elevated concentrations of methane (up to 14% v/v) and carbon dioxide (up to 7.6% v/v), were recorded within two boreholes (BH206 and BH208).

The WSP exploratory hole logs indicate hydrocarbon and/or 'coal tar' odours within exploratory holes BH202A, BH203, BH204, TP204, TP205 and TP207.

***Factual Environmental Ground Investigation Report - Retained Land, dated February 2015, prepared by Arcadis EC Harris.***

Arcadis was commissioned by Georgia-Pacific LLP to undertake a geoenvironmental ground investigation within the disused landfill area. The landfill was reported by Arcadis to have received mixed industrial wastes from the operation of the Oughtibridge Mill.

Fieldworks were undertaken in November 2014 and comprised the drilling of four cable percussion boreholes (BH101, B102A, BH103 and BH104) to a maximum depth of 8.0m bgl, all of which were completed as monitoring wells, and the excavation of nine trial pits. Following site works, four monitoring visits were undertaken, over a 2-month period.

The results of the gas monitoring undertaken by Arcadis indicated maximum concentrations of methane of 49.8% v/v and carbon dioxide of 10.6% v/v, both within BH101 (shallow installation). Maximum flow rates were recorded to be between -1.0 and +4.1 litres/hour in BH103 (shallow installation). Other recorded flow rates were non-detectable or very low.

Ground conditions within the landfill area were recorded to comprise made ground to depths of between 0.9m and 5.15m bgl, including gravelly sand, sandy gravel and sandy gravelly clay with cobbles and boulder-sized materials, which included concrete, bricks, ash, clinker and plastics. In addition to the general waste, a white jelly-like substance with a 'strong chemical odour' was

encountered at 1.0m bgl in TP101 and a 'large amount of compressed paper' was identified at 2.0m bgl in TP104. A hydrocarbon odour was noted at 0.75m bgl in BH101 and 0.7m bgl in BH102A.

***Geoenvironmental Appraisal dated March 2016, prepared by Sirius.***

The intrusive investigation was supervised by a Sirius Geoenvironmental Engineer, and took place between November 2015 and January 2016, comprising the:

- Mechanical excavation of 42 trial pits (STP01 to STP37 and STP40, STP42 to STP43, STP45 and STP49) to a maximum depth of 3.50m bgl.
- Drilling of 49 window sample boreholes (SWS01 to SWS24, SWS26 to SWS31, SWS33 to SWS35, SWS38, SWS41 to SWS45, inclusive SWS02A, SWS08A, SWS15A, SWS27A-B, SWS30A and SWS31A-D) to a maximum depth of 9.00m bgl.
- Drilling of 17 cable percussive boreholes (SBH01 to SBH16, inclusive of SBH12A) to a maximum depth of 11.20m bgl.

Permanent monitoring installations for both groundwater and ground gas monitoring were installed within 14 selected cable percussive boreholes (SBH01, SBH03 to SBH11 and SBH13 to SBH16) and 25 selected window sample boreholes (SWS01, SWS02A, SWS07, SWS08A, SWS09, SWS11, SWS13, SWS14, SWS19 to SWS22, SWS26, SWS27B to SWS29, SWS30A, SWS33 to SWS35, SWS38 and SWS41 to SWS44) across the site.

In addition, during our intrusive investigations a number of previous monitoring wells installed by WSP, Arcadis and URS were located, inferred (from previous exploratory hole locations plans). These comprised borehole references BH202A, BH204, BH205, BH207, and BH208 (WSP), BH101 and BH103 (Arcadis), and MW101 (URS).

Thirty nine monitoring wells installed as part of the Sirius ground investigation, along with eight wells previously installed by WSP and Arcadis, were monitored by Sirius on two occasions prior to preparation of the March 2016 Geoenvironmental Appraisal report. Nineteen of the monitoring wells were screened within the made ground, 24 in alluvium and / or bedrock, and four across both made ground and natural soils.

The report included the findings of a targeted site investigation undertaken by Sirius in June 2015, which comprised the mechanical excavation of nine trial pits (ref. TPA to TPI) to a maximum depth of 4.40m bgl, within the north western site area.

### ***Summary of Ground Conditions***

The ground conditions summarised below are salient to the ground gas risk assessment.

A detailed description of made ground and natural soils encountered within each area of the site are included within the exploratory hole logs (incorporated within Appendix B of this report). A detailed visual assessment of soils included the approximation of organic content of soils, together with fragments of coarser potentially degradable materials such as wood, plant matter, cloth and paper. In addition, the laboratory testing undertaken on selected soils included an assessment of the total organic carbon (TOC) content of soils. It should be noted however that the TOC content is not always reflective of the potential biodegradability of organic matter within the soils when a high proportion of ash, clinker and similar materials containing recalcitrant organic matter is present.

A fully detailed summary of ground conditions and TOC content within each zone across the site is included within the Geoenvironmental Appraisal report.

#### *Landfill Area*

Made ground was recorded across the landfill area, to variable depths of between 0.60m and 5.60m bgl, comprising both cohesive and granular soils. Cohesive made ground soils typically comprised soft, sandy gravelly clay including occasional wood and charcoal fragments. Reworked alluvial soils were locally encountered within the northern portion of the former landfill area, comprising sandy clay including localised peat and/or organic debris. SWS28 also identified decayed paper between 1.00m and 3.00m bgl. The granular fill was recorded to generally comprise sandy gravel / gravelly sand with rare fragments of wood. No rapidly putrescible organic matter (for example, food wastes or organic sludges) were evident within the landfill wastes.

TOC was recorded at concentrations of between 0.3 and 8.1 w/w% within granular and cohesive made ground soil samples.

Cohesive alluvial soils were recorded underlying made ground soils across the majority of the former landfill area, generally comprising sandy clay / silt with localised organic debris and peat. Where encountered, granular alluvial soils were recorded to comprise sandy gravels of sandstone. Alluvial soils were underlain by residual and / or competent bedrock at variable depths.

#### *Former Mill Area*

Granular made ground predominated across this area, typically comprising sand and gravels of ash, clinker, concrete, brick and locally wood. Cohesive fill was recorded to typically comprise

sandy gravelly clay with brick, concrete, sandstone and locally wood fragments. A reworked alluvial soil was locally encountered comprising gravelly sandy clay with occasional organic inclusions.

TOC was recorded at concentrations between 0.4 and 4.9%, the maximum concentrations being within two samples of granular made ground containing ash and clinker.

Natural cohesive alluvial soils generally comprised sandy clay / silt with gravel sized fragments of sandstone. Locally the alluvial soils (within the south eastern and central portions of the mill area) were noted to contain organic inclusions (including peat) at depths between 0.55m and >4.00m bgl. Granular alluvial soils were recorded to comprise gravelly sand or silty gravel of sandstone. Alluvial soils were absent within the north eastern extent of the mill area.

Natural residual soils, were found below either the granular and / or the cohesive alluvial soils within the majority of the exploratory hole locations across the site. Residual Millstone Grit Formation soils were found immediately below the made ground within the north east of the mill area.

#### *South West Area*

The granular fill within the south western site area was generally described as silty sandy gravel, typically described as demolition rubble fill. The demolition fill comprised sandy gravel and cobbles of brick, concrete, metal and locally wood. Cohesive fill comprised sandy clays with sandstone, brick and concrete.

TOC was recorded at concentrations between 1.6 and 6.5%, with the maximum concentration being within a sample of granular made ground, which was noted to contain ash and clinker.

Underlying natural cohesive alluvial soils were recorded to comprise sandy gravelly clays.

#### *North West Area*

Made ground soils were recorded to variable depths of between approximately 0.5m and 6.3m bgl, typically comprising sandy clay/silty clay with occasional gravel sized fragments of wood. Granular fill was also encountered comprising clayey sands and gravel, of ash, clinker, concrete, brick and sandstone. TOC was recorded at concentrations between 0.6 and 6.6%, with the maximum being within a granular made ground sample noted to partly comprise ash.

A band of soft slightly organic sandy silt, with reeds was recorded at depths of between 2.50m and 2.80m bgl, whilst a gravelly sandy silt/clay with organic and wood inclusions was encountered at

depths of between 2.00m and 3.30m bgl within the areas of the former reservoirs. These materials were considered representative of basal sediment deposits and / or a reworked alluvial soil associated with the former reservoirs.

Natural cohesive alluvial soils were recorded within a number of the exploratory holes comprising sandy clay with gravels of sandstone and mudstone. Gravel sized inclusions of organic debris were locally encountered. The granular alluvial soils comprised clayey sandy / silty gravels of sandstone. Natural residual soils were found either directly below the made ground soils and / or the granular / cohesive alluvial soils.

### **Groundwater**

Monitoring of the standpipes installed within the selected cable percussive and window sample boreholes revealed perched water or groundwater, where present, to be standing at depths of between 0.15m and 8.95m bgl. Many of the response zones installed within natural strata were found to be flooded either intermittently or continuously throughout the monitoring programme.

Where a high groundwater table is present, the groundwater has the potential to rise in the solid part of the well causing an increase in pressure that is released on opening, giving a misleading peak gas flow rate. It is considered that groundwater level variation has the potential to influence the ground gas regime at the site, particularly given that the winter of 2015-2016 was abnormally wet and gave rise to high groundwater levels.

### **Chemical Contamination that could Influence Ground Gas Composition**

Table 4.1 below summarises visual and olfactory evidence of contamination encountered during the fieldworks undertaken by Sirius.

**Table 4.1 Visual and/or Olfactory Evidence of Organic Contamination (Soils)**

<b>Exploratory Hole Ref.</b>	<b>Depths (m bgl)</b>	<b>Observation</b>	<b>PID Reading ppm (Depth m bgl)</b>
<b>Former Landfill Area</b>			
STP32	1.40	Suspect paper pulp in cohesive made ground.	NA
SWS21	4.50 - 5.80	Possible hydrocarbon sheen to granular made ground soils and groundwater.	8.2ppm (5.00m bgl)
SWS28	1.00 - 3.00	Inclusions of partially decayed paper within the cohesive made ground - possible reworked Alluvium.	NA
SWS29	3.00 - 4.00	Inclusions of black gelatinous substances within the cohesive made ground – possible	0.4ppm (3.60m bgl)

Exploratory Hole Ref.	Depths (m bgl)	Observation	PID Reading ppm (Depth m bgl)
		paper pulp.	
<b>South West Area – Former Building / Engine House / Machinery</b>			
SBH11	0.45 - 4.10	Strong hydrocarbon odour and slight sheen to the granular made ground soils and perched groundwater.	0.0ppm (3.20-3.70m & 4.60m bgl)
STP42	2.10 - 2.50 (base of pit)	Black staining and hydrocarbon odour and sheen to cohesive made ground soils.	7.0ppm (2.40m bgl)
STP49	2.30 - 2.80	Black staining and hydrocarbon odour and sheen to cohesive made ground soils.	0.5ppm (2.60m bgl)
SWS30A	0.50 - 0.60	Faint hydrocarbon odour to cohesive made ground.	0.0ppm (0.50-0.60m bgl)
<b>North West Area – Former Effluent Tanks / Reservoirs / Mill Race</b>			
SWS38	3.90	Faint natural organic odour to cohesive made ground.	NA

NA – Non Applicable

Other selected soil samples, which did not identify visual / olfactory evidence of contamination were also screened using the Photo-Ionisation Detector (PID) for the presence of volatile organic compounds (VOCs) in the soils, with all results returning concentrations below the Limit of Detection (LoD) of the meter.

During the initial groundwater monitoring visit on 6<sup>th</sup> and 7<sup>th</sup> January 2016, visual and olfactory observations were made of groundwater purged from each of the installed wells. Table 4.2 provides a summary of any evidence of contamination.

**Table 4.2 Visual and/or Olfactory Evidence of Organic Contamination (Groundwater)**

Exploratory Hole Ref.	Groundwater Depth (m bgl)	Observation	Free-product Thickness (mm)
<b>Former Landfill Area</b>			
SWS27B	3.32	Slight hydrocarbon odour, no sheen.	NA
SWS43	0.36	Hydrocarbon odour to dip tape, no sheen	NA
<b>Former Mill Area</b>			
SWS07	1.67	Hydrocarbon odour to dip tape, no sheen	NA
SBH01	2.23	Slight hydrocarbon odour, no sheen.	NA
BH208 (WSP)	1.65	Slight sheen, no odour.	NA
<b>South West Area – Former Building / Engine House / Machinery</b>			
SBH11	2.18	Slight hydrocarbon odour; free-product at surface of water (brown in colour)	30

Exploratory Hole Ref.	Groundwater Depth (m bgl)	Observation	Free-product Thickness (mm)
<b>North West Area – Former Effluent Tanks / Reservoirs / Mill Race</b>			
SBH13	1.22	No odour, slight sheen.	NA

NA – Not Applicable, no free-product present.

Elevated concentrations of hydrocarbons recorded within groundwater samples obtained indicated that contamination is typically limited to localised hydrocarbon hotspots, generally associated with both visual / olfactory evidence of hydrocarbons within the soils.

The biodegradation of hydrocarbons in the immediate vicinity of a borehole installation can result in depleted oxygen and elevated concentrations of methane and carbon dioxide. The degradation process can result in small volumes of methane and carbon dioxide that can appear as high gas concentrations in the well headspace. These high gas concentrations may not be reflective of the overall gas regime.

## 5. GROUND GAS CONCEPTUAL SITE MODEL

Based on the desk study information and the results of intrusive investigations undertaken at the site, a combined preliminary ground gas conceptual site model (CSM) has been developed for the proposed future land use (typically low-rise residential). This summarises the understanding of surface and sub-surface features, the potential hazardous ground gas sources, transport pathways and receptors to assess potential linkages.

It is assumed that ground levels will not change significantly from those described in this report. If these are not the case, then amendments to the CSM may be required.

The CSM has been sub-divided into four distinct zones on the basis of recorded ground conditions, namely the former landfill area, the mill area, the south western area (former buildings/machinery/engine house) and the north western area (former effluent tanks and reservoirs) as shown on Drawing No. C6485A/GRA/02 within Appendix A. Areas of existing woodland within the site boundary, which will remain undeveloped, are excluded from further assessment.

### Former Landfill Area

The conceptual site model is presented in schematic form in Drawing No. C6485A/GRA/04A within Appendix A. In summary, the CSM has identified the following potential hazardous ground gas linkages, which could result in an unacceptable risk to the proposed end-use if unmitigated:

- Inhalation of locally elevated concentrations of hydrocarbons detected within shallow made ground encountered (<1.0m bgl) in the vicinity of Arcadis borehole BH101 and within perched groundwater encountered within SWS21, posing a **low to moderate** risk to future residential end-users and adjacent site users and a **moderate** risk to construction workers.
- Hazardous ground gases arising from putrescible organic materials locally present within the landfill and underlying natural alluvial soils (as further detailed below), posing a **moderate to high** risk to human health receptors and future buildings.
  - Deep granular and cohesive made ground with localised fragments of putrescible materials including wood and paper pulp / decaying waste paper (specifically within exploratory hole locations SWS28, SWS29 and STP32).

- Localised reworked cohesive alluvial soils noted within the landfill site area, including occasional peat lenses and organic debris fragments.
- Natural cohesive alluvial soils with localised organic content and peat lenses (specifically within exploratory holes STP27 and SWS23).

### Mill Area

The preliminary conceptual site model is presented in schematic form in Drawing No. C6485A/GRA/04B (Appendix A). In summary, the CSM has identified the following potential hazardous ground gas linkages, which could result in an unacceptable risk to the proposed end-use if unmitigated:

- Inhalation of locally elevated concentrations of hydrocarbons detected within shallow made ground (<1.0m bgl) in the vicinity of WSP exploratory hole references BH205 and TP211, and within perched groundwater encountered within SWS07 and SWS08, posing a **low to moderate** risk to future residential end-users and adjacent site users and a **moderate** risk to construction workers.
- Hazardous ground gas sourced from the underlying alluvial soils and deep made ground (as further detailed below), posing a **moderate** risk to human health receptors and future buildings.
  - Deep granular and cohesive made ground with localised fragments of putrescible materials including wood.
  - Localised reworked cohesive alluvial soils, including occasional organic debris fragments.
  - Natural cohesive alluvial soils with localised elevated organic content and peat lenses (specifically within exploratory holes STP01, STP10, STP17, STP40, SWS02A, SWS11, WSP exploratory holes BH206 and BH208 and Structural Soils exploratory hole TP108).

### South West Area (Former Building / Engine House / Machinery)

The preliminary conceptual site model is presented in schematic form in Drawing No. C6485A/GRA/04C (Appendix A). In summary, the CSM has identified the following potential

hazardous ground gas linkages, which could result in an unacceptable risk to the proposed end-use if unmitigated:

- Inhalation of locally elevated concentrations of hydrocarbons detected within shallow made ground encountered (<1.0m bgl) (more specifically within the vicinity of WSP exploratory hole reference TP209), and within groundwater encountered within SBH11, posing a **low to moderate** risk to future residential end-users and adjacent site users and a **moderate** risk to construction workers.
- Hazardous ground gas sourced from locally deep made ground and underlying alluvial soils (as further detailed below), posing a **low to moderate** risk to human health receptors and future buildings.
  - Deep granular made ground with localised fragments of putrescible materials including wood.
  - Natural cohesive alluvial soils with localised elevated organic content (specifically within exploratory hole STP49).

### **North West Area (Former Effluent Tanks / Reservoirs)**

The preliminary conceptual site model is presented in schematic form in Drawing No. C6485A/GRA/04D in Appendix A. In summary, the CSM has identified the following potential hazardous ground gas linkages, which could result in an unacceptable risk to the proposed end-use if unmitigated:

- Hazardous ground gas sourced from the underlying deep made ground and alluvial soils, posing a **low to moderate** risk to human health receptors and future buildings.
  - Deep granular and cohesive made ground with localised fragments of putrescible materials including wood.
  - Localised reworked cohesive alluvial soils (with inclusions of organic debris) and / or basal sediment deposits with reeds, associated with base of former reservoirs.
  - Natural cohesive alluvial soils with localised elevated organic content (specifically within exploratory hole SWS34).

## 6. GROUND GAS AND GROUNDWATER MONITORING DATA

### 6.1. Third Party Gas Monitoring Results, 2014-2015

Five rounds of gas monitoring were undertaken by WSP between December 2014 and February 2015 of their BH202A, BH205, BH206, BH207 and BH208, of which BH205, BH206 and BH208 had been completed as dual shallow and deep monitoring installations. WSP noted that several response zones were flooded.

Four rounds of monitoring were undertaken between December 2014 and January 2015 by Arcadis within their BH101, BH102, BH103 and BH104, all of which had been completed as dual shallow and deep monitoring installations.

A summary of the gas results reported by WSP and Arcadis are summarised below in Table 6.1; the full monitoring results are reproduced within Appendix C.

**Table 6.1 Summary of Gas Monitoring (WSP and Arcadis)**

	Locations	Well	Methane (range) %v/v	Carbon Dioxide (range) %v/v	Oxygen (range) %v/v	Flow (range) l/hr	
WSP December 2014 to February 2015	NW area	BH202A	0.1 - 0.3	1.3	20.2 - 21.1	0.1	
	Mill area	BH205S	ND	ND - 0.5	14.9 - 19.9	ND - 1.0	
		BH205D	ND	ND - 0.4	15.2 - 19.8	ND	
		BH206S	ND	2.0 - 2.4	8.8 - 12.1	ND	
		BH206D	6.3 - 14.0	ND - 0.9	0.2 - 5.5	ND	
		BH207	ND	0.1 - 0.7	18.7 - 19.8	ND	
		BH208S	3.0 - 14.3	0.2 - 7.6	ND - 8.5	ND - 0.1	
		BH208D	2.4 - 5.1	2.8 - 7.6	12.0 - 18.0	ND - 0.3	
	Arcadis December 2014 to January 2015	Landfill area	BH204S	ND	0.2 - 1.5	ND - 7.9	0.1 - 1.0
			BH204D	ND	0.1 - 1.2	11.8 - 13.7	ND - 2.0
BH101S			40.0 - 49.8	9.9 - 10.6	ND - 1.5	-0.1 - 0.1	
BH101D			3.0 - 37.1	1.0 - 10.3	1.5 - 19.7	-0.3 - 0.1	
BH102S			ND - 0.2	0.1 - 0.9	0.3 - 21.4	ND - 1.5	
BH102D			ND - 0.1	0.2 - 5.5	2.5 - 20.6	-0.2 - ND	
BH103S			ND	0.1 - 1.0	19.3 - 21.8	-0.1 - 4.1	
BH103D			ND	0.2 - 4.6	16.7 - 21.8	ND	
		BH104S	ND	3.6 - 4.3	1.6 - 17.3	ND - 0.2	

		BH104D	ND	1.9 - 4.5	16.5 - 19.8	ND
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ND Not Detected

## 6.2. Sirius Gas Monitoring Results, 2016

Based upon a moderate source potential and high sensitivity end use, a ground gas monitoring programme comprising 12 visits over a period of six months was specified, in accordance with guidance provided in CIRIA C665. The rationale for the wells selected for monitoring are described in Section 6.4 of the Geoenvironmental Appraisal report for the site.

A summary of the monitoring data obtained is presented in Appendix C. The monitoring events covered atmospheric pressure conditions of 981 to 1018mbar, and included periods of falling, steady and rising pressure. The monitoring was carried out over 12 occasions between 6<sup>th</sup> January and 7<sup>th</sup> June 2016.

Where the response zone was flooded, attempts were made to monitor boreholes both before and after groundwater purging, where possible. Gas concentrations were often found to reduce when monitored post-purging. However, in some instances the shallow groundwater table and rapid recharge has meant this had limited beneficial effect in allowing the water level to be kept below the response zone of the well. Further details are provided in Section 7.3 below.

The full results of the Sirius gas and groundwater monitoring are presented as Appendix C to this report and a summary given in Table 6.2. It should be noted that the summary of results below is 'worst-case', and do not take into consideration any possible unrepresentative data such as peak instantaneous flows or spatial or elevation differences between individual boreholes. The dataset for each zone is discussed in further detail in Section 7.3 below.

**Table 6.2 Summary of Gas Monitoring (Sirius, January - June 2016)**

Area	CH <sub>4</sub> % v/v		CO <sub>2</sub> % v/v		O <sub>2</sub> %		Flow litre/hr		VOC
	Max	Steady	Max	Steady	Max	Min	Max	Steady	ppm
<b>Former Landfill Area</b>	56.3	56.3	39.2	39.2	22.1	ND	23.0	20.0	5.3
<b>Former Mill Area</b>	42.0	40.7	8.3	8.0	21.4	ND	10.0	10.0	312
<b>South West Area</b>	0.7	0.7	8.3	8.3	21.0	3.5	3.2	3.2	0.9
<b>North West Area</b>	0.7	0.2	7.7	1.5	20.6	2.0	11.8	11.8	312

## **7. GROUND GAS RISK ASSESSMENT**

### **7.1. General**

This gas risk assessment has been performed for land at the former Oughtibridge Mill.

It has been assumed in the production of this report that the site is to be redeveloped for a generally low-rise residential end use and that site levels will change in general accordance with those detailed in Section 1.0. If these are not the case, then amendments to the interpretation and conclusions in this report may be required.

### **7.2. Ground Gas Sources**

Localised hydrocarbon-impacted made ground soils that were considered to pose a potential risk to site end users via inhalation pathways, were identified within the south western area of the site as part of the Geoenvironmental Appraisal. Hydrocarbon impacted soils encountered at depths of less than 1m bgl were also encountered within several other localities within the landfill and mill areas, although the hydrocarbon fractions recorded were typically of low volatility and considered unlikely to pose a significant risk to human health under normal occupancy. These areas were therefore considered to pose a low risk to site end users, not requiring further specific consideration.

Localised, discrete, elevated concentrations of TPH were recorded elsewhere within groundwater, specifically within SWS07, SWS08A and SWS21. Based upon the results of investigations undertaken at the site (as reported within Sirius letter report ref. C6485A/GH/7423, dated 25<sup>th</sup> July 2016), it was considered that no specific remedial works are required to protect site end users as a result of the minor and localised hydrocarbon contamination detected within these boreholes.

Elevated concentrations of TOC within the landfill are likely to be representative of both small volumes of relatively biodegradable materials, such as paper pulp, and poorly degradable materials, including wood. A detailed visual assessment of the made ground soils within the landfill indicated that potential biodegradable anthropogenic materials that could represent sources of ground gas were not widespread and were limited in both volume and lateral / horizontal extent. On the basis of the site investigation undertaken, the majority of the made ground soils within the landfill, with the exception of small amounts of localised relatively biodegradable materials, are not considered to represent a major source of hazardous ground gas in terms of gas generation rate.

Recorded elevated concentrations of TOC within made ground soils across the remainder of the site are attributable to localised poorly degradable or recalcitrant organic materials, including wood fragments and ash / clinker. The slow biodegradability of these organic matter types means that the majority of made ground soils across the site as a whole do not represent a significant source of biogenic hazardous ground gases in terms of gas generation rate.

Lenses of potentially putrescible naturally occurring organic materials were locally noted within made ground / reworked alluvial soils, in addition to naturally occurring cohesive alluvial soils, across the landfill and the mill areas. These were often recorded as comprising 'organic inclusions' and lenses of peat. Localised organic sandy silts and evidence of reed beds were locally noted within the north western site area, associated with the former reservoirs.

Organic-rich alluvial soils and peat are often associated with high concentrations of methane and carbon dioxide in monitoring wells, present as a result of gas becoming trapped in pore spaces within lower permeability soils. There is usually negligible, or very little, gas generation, giving rise to relatively high concentrations of gas locally but very low (steady state) flow rates.

There are no known or suspected sources of mines gas on or in the vicinity of the site. Given their location and local ground conditions, the recorded off-site landfills are not considered to represent a viable source of ground gas that could impact the site.

In general, no significant concentrations of hydrogen sulphide or carbon monoxide were recorded. A peak concentration of carbon monoxide of 24ppm was recorded within SWS30 (within the mill area) on one monitoring occasion. The recorded concentration is inconsistent within the findings on other monitoring visits within the borehole and is considered to be anomalous.

### **7.3. Ground Gas Risk Assessments per Zone**

Twelve gas monitoring visits were completed at the site by Sirius in 2016, supplementing four previous monitoring visits by Arcadis and five by WSP undertaken in 2014-2015. These covered a wide range of atmospheric pressure conditions, including periods of falling pressure. Summaries of the gas results within each area of the site are provided below. The results include an assessment of the previous WSP and Arcadis monitoring results.

We have calculated the quantity of hazardous gas ( $Q_{hg}$ ) values for methane on the basis of peak flows and concentrations to reflect the fact that the risk posed by this gas is the production of an explosive mixture with air. For carbon dioxide, steady state concentrations and flows have been

used to calculate  $Q_{hg}$  to reflect the fact that the risk posed is the long-term accumulation of this suffocating gas in confined spaces.

For those boreholes that were flooded, no significant concentrations of methane or carbon dioxide were recorded and purging did not change these findings, indicating that groundwater does not act as a viable transport pathway by which dissolved ground gases can enter the shallow soil gas phase. Further, the nature of the shallow natural geology means that a significant drop in groundwater levels cannot occur to an extent that would create new flow paths for ground gas from saturated alluvial deposits.

### Former Landfill

Monitoring results within specific boreholes in the landfill area that exhibited significantly elevated gas concentrations and / or flow rates are summarised in Table 7.1, below. These numbered ten gas monitoring installations out of the twenty installations monitored. The worst-credible  $Q_{hg}$  values per borehole for both methane and carbon dioxide have been assessed. Other boreholes within the landfill area did not record any significant flow rates or elevated concentrations of hazardous ground gases.

Individual boreholes within the landfill area are discussed in further detail below.

**Table 7.1 Summary of Gas Monitoring, Landfill Area**

Borehole Installation	CH <sub>4</sub> % v/v		CO <sub>2</sub> % v/v		O <sub>2</sub> % v/v		Flow litre/hr		Worst credible $Q_{hg}$ (l/hr) per borehole	
	Max	Steady	Max	Steady	Min	Max	Max	Steady	CH <sub>4</sub>	CO <sub>2</sub>
SWS19	26.0	26.0	2.3	2.3	1.5	21.5	-4.8	-3.5	1.248	0.0805
SWS21	0.7	ND	3.0	3.0	16.8	20.9	-12.1	-12.1	0.0847	0.363
SWS27B	5.6	5.6	5.8	5.2	ND	18.4	0.8	0.4	0.0448	0.0208
SWS28	56.3	56.3	39.2	39.2	8.1	15.7	1.1	1.1	0.6193	0.4312
SWS42	0.1	ND	7.5	7.2	ND	21.8	-1.1	-1.1	0.0011	0.0792
SBH09	1.5	0.2	0.5	0.5	14.2	21.4	-1.3	0.9	0.0195	0.0045
BH101S	55.0	55.0	13.0	13.0	ND	21.3	0.5	0.5	0.275	0.065
BH101D	52.0	50.0	13.5	13.5	ND	21.4	2.3	2.3	1.196	0.3105
BH204S	ND	ND	1.1	1.1	7.4	21.4	6.0	6.0	0.006	0.066
BH204D	1.5	ND	2.6	2.2	7.7	21.6	2.3	2.3	0.0345	0.0506

ND = Not Detected.

### SWS19

The response zone within SWS19 is within cohesive made ground including fragments of ash and clinker, at a depth of between 1-3m. Standing groundwater was recorded generally at depths of between 1.5-2.5m bgl, below the top of the response zone.

Maximum peak methane concentrations of 26% v/v were recorded within SWS19 (on 3<sup>rd</sup> February 2016), with steady state carbon dioxide concentrations of 2.3% v/v (on 15<sup>th</sup> March 2016). No associated detectable steady flows were recorded within SWS19 on either monitoring visit. A maximum peak and steady flow rate of 2.5 litre/hour was recorded within the borehole on 12<sup>th</sup> April 2016, whilst maximum negative peak and steady state flows of -4.8 litre/hour and -3.5 litre/hour were recorded on 1<sup>st</sup> March 2016 (visit no.5) and 10<sup>th</sup> May 2016 (visit no.10), respectively.

Based on the monitoring results within this borehole, and assuming that the maximum negative flows could be realised as positive flows (a reasonable assumption given that at least part of the response zone remained unflooded),  $Q_{hg}$  values of 1.248 litre/hour for methane and 0.0805 litre/hour for carbon dioxide have been calculated. The results are indicative of a moderate hazard potential, characterised as CS3, based on Table 2 presented within BS8485:2015.

### SWS21

The response zone within SWS21 is placed within granular made ground of ash and clinker, at a depth of between 1-5m. Evidence of hydrocarbon contamination (a slight oily sheen) was noted at a depth of 4.5m bgl during drilling. Standing groundwater was recorded generally at depths of between 4.2-4.5m bgl, below the top of the response zone.

A maximum peak methane concentration of 0.7% v/v reducing to non-detect were recorded within SWS21 (on visit no.1, dated 6<sup>th</sup> January 2016), with steady state carbon dioxide concentrations of 3.0% v/v (on visit no.6, dated 15<sup>th</sup> March 2016). No associated detectable steady flows were recorded within SWS21 on either monitoring visit. A maximum negative peak and steady flow rate of -12.1 litre/hour was recorded within the borehole on 12<sup>th</sup> April 2016 (visit no. 8).

Based on the monitoring results within this borehole, and assuming that the maximum negative flows could be realised as positive flows,  $Q_{hg}$  values of 0.0847 litre/hour for methane and 0.363 litre/hour for carbon dioxide have been calculated. The results are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

### *SWS27B*

The response zone within SWS27B is placed within granular and cohesive made ground including fragments of ash and clinker, at a depth of between 1-4m. The cohesive made ground is recorded as possible reworked alluvial deposits, and comprised fragments of organic materials / speckling. Standing groundwater was recorded generally at depths of between 3.3-3.6m bgl.

Maximum peak methane concentrations of 5.6% v/v within SWS27B (on visit no.7, dated 29<sup>th</sup> March 2016) and steady state carbon dioxide concentrations of 5.2% v/v (on visit no.1, dated 6<sup>th</sup> January 2016) were recorded. Maximum peak and steady flow rates of 0.8 litre/hour and 0.4 litre/hour were recorded within the borehole on 24<sup>th</sup> May 2016 (visit no.11) and 26<sup>th</sup> April 2016 (visit no.9), respectively.

Based on the monitoring results within this borehole,  $Q_{hg}$  values of 0.0448 litre/hour for methane and 0.0208 litre/hour for carbon dioxide have been calculated. Given the maximum concentrations of methane and carbon dioxide recorded exceed 1% and 5%, respectively, the results are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

### *SWS28*

The response zone within SWS28 is placed within reworked cohesive alluvial deposits (at a depth between 1-4m), with frequent inclusions of 'partially decayed paper and rare organic debris' recorded within the made ground. Standing groundwater was recorded generally at depths of between 2-3m bgl, which is below the top of the response zone.

Maximum peak methane concentrations of 56.3% v/v and steady state carbon dioxide concentrations of 39.2% v/v were recorded within SWS28 (on 29<sup>th</sup> March 2016). No detectable flows were recorded within SWS28 on that monitoring visit. A maximum peak and steady flow rate of 1.1 litre/hour was recorded within the borehole on 7<sup>th</sup> June 2016.

Based on the monitoring results within this borehole,  $Q_{hg}$  values of 0.6193 litre/hour for methane and 0.4312 litre/hour for carbon dioxide have been calculated. The results are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

The elevated concentrations and low flows recorded are considered to be attributable to the decaying paper recorded within the fill, decomposition of which can often lead to high concentrations of hazardous ground gas but with limited production and flow rates.

### *SWS42*

The response zone within SWS42 is within granular made ground (comprising concrete and brick sub-base materials) and natural cohesive alluvial soils, at a depth of between 0.5-3.6m. Standing groundwater was recorded generally at a depth of approximately 2.5m bgl.

A maximum steady state carbon dioxide concentration of 7.2% v/v was recorded on the first visit, dated 6<sup>th</sup> January 2016 but only negligible concentrations of methane were detected. A maximum positive peak and steady flow rate of 1.0 litre/hour was recorded within the borehole on 20<sup>th</sup> January 2016, whilst a maximum negative peak and steady state flow of -1.1 litre/hour was recorded on 16<sup>th</sup> February 2016.

Based on the monitoring results within this borehole, and assuming that the maximum negative flows recorded could be realised as positive flows,  $Q_{hg}$  values of 0.0011 litre/hour for methane and 0.0792 litre/hour for carbon dioxide have been calculated. This is indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

### *SBH09*

The response zone within SBH09 is within both cohesive and granular natural alluvial soils and residual Millstone Grit strata at a depth of between 4.5-9.3m bgl. Standing groundwater was recorded at a depth of approximately 2.0m bgl, therefore flooding the response zone. The well was monitored both pre and post purge on several occasions, with minimal difference in gas concentration or flow rate noted. The effects of the flooded response zone could have potentially lead to artificially elevated flow rates due to a build-up of pressure caused by rising groundwater or suction caused by falling groundwater.

Maximum peak methane concentrations of 1.5% v/v and steady state carbon dioxide concentrations of 0.5% v/v were recorded within SBH09 on 6<sup>th</sup> January 2016, with associated negative peak and steady state flows of -1.3 and -0.3 litre/hour, respectively. A maximum steady flow rate of 0.9 litre/hour was recorded within the borehole on 7<sup>th</sup> June 2016.

Based on the monitoring results within this borehole and assuming the maximum negative flow recorded is representative of the gassing regime within the borehole,  $Q_{hg}$  values of 0.0195 litre/hour for methane and 0.00405 litre/hour for carbon dioxide have been calculated. However, given that the maximum concentration of methane recorded exceeds 1%, an increased classification of CS2 has been assigned.

*BH101S / BH101D (Arcadis Boreholes)*

These are two installations completed within different strata in the same borehole. The response zone in BH101S is at a depth of 1-2m bgl within reworked alluvial soils, overlying natural alluvial soils with organic content (including plant remains). No standing groundwater was encountered within the installation. A weak hydrocarbon odour was recorded at a depth of 0.75m by Arcadis, directly above the shallow installation. The response zone in BH101D is at a depth of 4-8m bgl within natural alluvial soils with organic content (including plant remains) and possible residual Millstone Grit strata. A groundwater strike was recorded at a depth of 4.5m bgl, with standing groundwater at depths of between approximately 4.4m to 4.7m bgl. The installation was monitored pre- and post-purging on several occasions.

Maximum peak methane concentrations of 55% v/v and 52% v/v and steady state carbon dioxide concentrations of 13.0% and 13.5% v/v were recorded by Sirius within BH101S and BH101D, respectively, on 6<sup>th</sup> January 2016. No detectable flows were recorded within either installation on this monitoring visit. However, a maximum peak and steady flow rate of 0.5 litre/hour was recorded within BH101S on 26<sup>th</sup> April 2016, whilst a maximum peak and steady flow rate of 2.3 litre/hour was recorded within BH101D on 24<sup>th</sup> May 2016.

Arcadis recorded comparable peak concentrations of 49.8% v/v and 37.1% v/v of methane and steady state carbon dioxide concentrations of 10.6% v/v and 10.3% v/v within BH101S and BH101D, respectively, with maximum peak and steady state flows of -0.3 litre/hour.

Based on the monitoring results within BH101S only,  $Q_{hg}$  values of 0.275 litre/hour for methane and 0.065 litre/hour for carbon dioxide have been calculated for this borehole. The results are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

Based on the monitoring results within BH101D only,  $Q_{hg}$  values of 1.196 litre/hour for methane and 0.3105 litre/hour for carbon dioxide have been calculated for this borehole. The results are indicative of a moderate hazard potential, characterised as CS3, based on Table 2 presented within BS8485:2015.

*BH204S / BH204D (WSP borehole)*

These are two installations completed within different strata in the same borehole. The response zone in BH204S is at a depth of 1.2-2.2m bgl within reworked alluvial soils, with gravels of brick and coal. Organic-rich bands were noted at a depth of 2.9m bgl, below the response zone.

Groundwater was encountered at the base of the installation only. The response zone in BH204D is at 3.7-6.7m bgl within possible granular alluvial deposits and / or residual Millstone Grit strata. Standing groundwater levels were at depths of between approximately 2.5m and 3.1m bgl. The installation could not be successfully purged because of rapid recharge of groundwater.

Maximum peak methane concentrations of <0.1% and 1.5% v/v and steady state carbon dioxide concentrations of 1.1% and 2.2% v/v were recorded by Sirius within BH204S and BH204D on 6<sup>th</sup> January 2016 and 1<sup>st</sup> March 2016, respectively. No detectable flows were recorded within either installation on these monitoring visits.

A maximum peak flow of 23.0 litre/hour was recorded by Sirius within BH204D on the first monitoring visit (6<sup>th</sup> January 2016), which reduced to non-detect after a period of approximately 30 seconds. This peak flow is considered to be the result of borehole pressurisation by rising groundwater and considered an unrealistic representation of the gas regime within the vadose zone soil. Maximum peak and steady state negative flows of -5.2 litre/hour and -3.1 litre/hour were recorded within BH204D on 3<sup>rd</sup> February 2016. These maximum peak negative flows coincided with a decrease in groundwater levels (from a depth of approximately 2.55m to 3.17m bgl), potentially causing low pressure within the sealed borehole. On this basis, it is considered that the peak negative flow rates recorded within BH204D are not representative of an unsealed system and are not considered further.

A maximum peak and steady positive flow rate of 6.0 litre/hour was recorded by Sirius within BH204S on 20<sup>th</sup> January 2016, whilst a maximum positive peak and steady flow rate of 2.3 litre/hour was recorded within BH204D on 24<sup>th</sup> May 2016. The flow rates within BH204S are considered representative of subsurface conditions of the shallow vadose zone soils in the vicinity of the borehole, given that groundwater is not flooding the response zone within this installation. BH204D was found to be consistently flooded, and therefore the gas flows recorded within this installation are not representative of the gassing regime. The remainder of the gas flows recorded within BH204D (other than those detailed above) were low or negligible; on this basis, the peak and steady flow rate of 2.3 litre/hour has been used in this assessment for BH204D.

Arcadis recorded no detectable concentrations of methane within these boreholes and steady state carbon dioxide concentrations of 1.5% v/v and 1.2% v/v, and maximum peak and steady state flows of 2.0 litre/hour and 0.1 litre/hour within BH204S and BH204D, respectively. The results are comparable to those recorded by Sirius following the removal of the unrealistic flow rates for BH204D.

Based on the monitoring results within BH204S, a  $Q_{hg}$  value of 0.066 litre/hour for carbon dioxide has been calculated for this borehole. A  $Q_{hg}$  value of 0.006 litre/hour for methane has been calculated. These results are indicative of a very low hazard potential, characterised as CS1, based on Table 2 presented within BS8485:2015.

Based on the monitoring results within BH204D,  $Q_{hg}$  values of 0.0345 litre/hour for methane and 0.0506 litre/hour for carbon dioxide have been calculated. Based on a peak concentration of methane of 1.5% v/v, the gas data are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

### ***Sensitivity Evaluation***

In accordance with the requirements of BS8485:2015, the plausible worst-case condition has been calculated for each hazardous gas below, as a 'worst-case' check. In accordance with the guidance, adopting the worst case  $Q_{hg}$  as the Gas Screening Value (GSV) for the site zone should be undertaken only when considered prudent and reasonable to do so.

A maximum peak methane concentration of 56.3% v/v and steady state carbon dioxide concentration of 39.2% v/v was recorded within the landfill area within borehole SWS28 on 29<sup>th</sup> March 2016. The made ground within SWS28 was noted to include biodegradable materials, including paper waste and disturbed natural organic matter. Methane and carbon dioxide concentrations were recorded to be consistently high within this monitoring installation, although no significant associated gas flows were recorded, which is consistent with the slow decomposition rate of the organic matter observed.

Maximum peak and steady flow rates of 20.0 litre/hour were recorded within SBH08 on 20<sup>th</sup> January 2016. The peak flow is considered unrepresentative given that it is inconsistent with other results within this borehole and was associated with a flooded response zone that is likely to have caused a build-up of pressure caused by rising water within a sealed system. On this basis, this maximum flow rate of 20.0 litre/hour is considered to be unrepresentative, and will be disregarded.

A maximum peak flow of 23.0 litre/hour was recorded within BH204D (deep borehole installation) on the first monitoring visit (6<sup>th</sup> January 2016), which reduced to non-detect after a period of approximately 30 seconds. WSP recorded maximum peak flow rates of 2.0 litre/hour within BH204D over 5 monitoring visits, in 2014-2015. That maximum peak flow rate recorded by Sirius within BH204D is considered attributable to gas pressurisation by groundwater within the flooded well, which quickly equilibrated after the gas tap was opened. Subsequent visits by Sirius recorded

low / negligible flow rates within BH204D, with the exception of a peak and steady flow of 2.3 litre/hour on 24<sup>th</sup> May 2016.

Peak and steady negative flow rates of -7.4 and -7.3 litre/hour were recorded within SWS22 on 6<sup>th</sup> January 2016, and of -12.1 litre/hour within SWS21 on 12<sup>th</sup> April 2016. Significant negative or positive flow rates were not recorded on other monitoring occasions within either borehole. The peak and steady negative flows of -7.4/-7.3 litre/hour recorded within SWS22 on 6<sup>th</sup> January 2016 coincides with groundwater infiltrating and flooding the borehole after drilling and these data are therefore disregarded, and not considered further. The peak and steady negative flows of -12.1 litre/hour recorded within SWS21 could potentially reverse to a positive value, and although the elevated flows were recorded on one monitoring visit only, they have been used as part of the assessment below.

Peak and steady state positive flows of between non-detect and 6.0 litre/hour were recorded within borehole installations within the landfill area on all other monitoring visits.

The worst-possible conditions in the landfill zone have been assessed for both methane and carbon dioxide by using the maximum recorded flow in any borehole and the maximum gas concentrations within any borehole but discounting any peak instantaneous flows and negative flows that have been judged to be unrealistic. In this case, these are based on a measured maximum methane concentration of 56.3% (SWS28) and carbon dioxide concentration of 39.2% (SWS28) and peak and steady gas flow rates of -12.1 litres/hour (SWS21).

On this basis, worst-possible  $Q_{hg}$  values of 6.81 litre/hour for methane and 4.74 litre/hour for carbon dioxide have been calculated for the landfill zone, indicative of a moderate to high hazard potential, characterised as Characteristic Situation 4 (CS4) as defined in Table 2 of BS8485:2015.

However, these 'worst-case' calculations assume that the maximum recorded negative flow of -12.1 litres/hour recorded within SWS21 on one monitoring occasion could potentially reverse to a positive flow and also be representative of the overall gas flow regime. Guidance provided within BS8485:2015 indicates that adopting a GSV based on  $Q_{hg}$  calculated from peak flow measurements might result in a disproportionately high gas hazard prediction, and assignment of an over-precautionary Characteristic Situation.

We consider that the overall dataset collected for the landfill area is representative and comprehensive given that the visits were carried out over a prolonged period that allowed for seasonal variation and covered periods of low and falling atmospheric pressures. Further, there is significant spatial variability in ground conditions and groundwater levels that contribute to

differences in ground gas generation potential and rate, as discussed above, which makes the combination of data between boreholes conceptually unsound. We therefore conclude that the application of a GSV for this zone derived by using worst-case concentrations and flows derived from disparate boreholes is unrepresentative and excessively conservative and that the GSV should be based on worst plausible values calculated on a per borehole basis.

### **Representative Gas Screening Value for Landfill Area**

The derived  $Q_{hg}$  values for methane and carbon dioxide based on data obtained within individual boreholes indicate that the worst-plausible gas screening value for methane within the landfill area is 1.248 litre/hour, recorded within SWS19, whilst the equivalent  $Q_{hg}$  value for carbon dioxide is 0.4312 litre/hour recorded within SWS28. These representative  $Q_{hg}$  values may be used as representative GSVs for the landfill zone and indicate CS3 conditions for methane and CS2 for carbon dioxide.

These values are based on a methane concentration of 26.0% and associated maximum peak flow of -4.8 litre/hour within SWS19, and a carbon dioxide concentration of 39.2% and associated maximum peak flow of 1.1 litre/hour within SWS28.

The landfill area is therefore classified as **Characteristic Situation 3** for hazardous ground gas.

### **Former Mill Area**

Monitoring results within specific boreholes within the mill area, with notable elevated gas concentrations and / or gas flow rates, are summarised in Table 7.2 below. These numbered nine gas monitoring installations out of the nineteen installations monitored. The worst-credible  $Q_{hg}$  values per borehole for both methane and carbon dioxide have been added.

Other boreholes within the mill area did not record any significant gas concentrations or flow rates, either pre or post purge of groundwater for those boreholes where response zones were found to be flooded. Individual boreholes within the mill area are discussed in further detail below.

**Table 7.2 Summary of Gas Monitoring, Mill Area**

Borehole Installation	CH <sub>4</sub> % v/v		CO <sub>2</sub> % v/v		O <sub>2</sub> % v/v		Flow litre/hr		Worst credible $Q_{hg}$ (l/hr) per borehole	
	Max	Steady	Max	Steady	Min	Max	Max	Steady	CH <sub>4</sub>	CO <sub>2</sub>
SWS02A	0.2	0.2	7.0	7.0	11.1	20.7	2.0	1.4	0.004	0.098

Borehole Installation	CH <sub>4</sub> % v/v		CO <sub>2</sub> % v/v		O <sub>2</sub> % v/v		Flow litre/hr		Worst credible Q <sub>hg</sub> (l/hr) per borehole	
	Max	Steady	Max	Steady	Min	Max	Max	Steady	CH <sub>4</sub>	CO <sub>2</sub>
<b>SWS08A</b>	0.6	0.5	5.9	5.9	11.9	20.4	1.4	1.4	0.0084	0.0826
<b>SWS14</b>	ND	ND	1.0	1.0	17.7	21.1	6.5	6.5	0.0065	0.065
<b>BH205S</b>	0.2	ND	0.4	0.4	15.7	21.4	-0.7	-0.7	0.0014	0.0028
<b>BH205D</b>	ND	ND	0.7	0.7	16.1	21.4	0.4	0.4	0.0004	0.0028
<b>BH206S*</b>	ND	ND	2.4	2.0	8.8	12.1	ND	ND	0.0001	0.002
<b>BH206D*</b>	14.0	6.3	0.9	ND	0.2	5.5	ND	ND	0.014	0.0001
<b>BH208S</b>	42.0	40.7	8.3	8.0	ND	20.6	5.0	3.0	2.1	0.24
<b>BH208D</b>	22.4 <sup>^</sup> / 2.5	2.5	1.5	1.3	16.8	21.2	1.3	1.3	0.0325	0.0169

\* Borehole BH206S / BH206D not located or monitored by Sirius. Results taken from WSP report.

<sup>^</sup>Peak instantaneous methane concentration considered unrepresentative in this instance.

ND = Not Detected

### SWS02A

The response zone within SWS02A is within natural cohesive alluvial soils comprising 'occasional black organic speckling', at a depth of between 1.5-3.5m. Standing groundwater was recorded at depths of between 1-2m bgl. The response zone within the borehole was found to be flooded on the majority of monitoring visits, and so was monitored both pre and post purging where possible.

A maximum steady state carbon dioxide concentration of 7.0% v/v was recorded within SWS02A on 29<sup>th</sup> March 2016. Negligible / non-detectable concentrations of methane were recorded within SWS02A throughout the monitoring period. A peak flow of 2.0 litre/hour was recorded within the borehole on 29<sup>th</sup> March 2016, although this quickly reduced to non-detectable steady flows. A maximum peak and steady flow rate of 1.4 litre/hour was recorded within the borehole on 26<sup>th</sup> April 2016, whilst a maximum negative peak and steady state flow of -1.2 litre/hour was recorded on 12<sup>th</sup> April 2016.

Based on the monitoring results within SWS02A only, Q<sub>hg</sub> values of 0.004 litre/hour for methane and 0.098 litre/hour for carbon dioxide have been calculated for this borehole. These results are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

The borehole installation location was obscured by a stockpile of soils on the last two monitoring visits. Given the generally consistent dataset obtained for SWS02A, no further visits are considered necessary to supplement the ten monitoring visits undertaken.

#### *SWS08A*

The response zone within SWS08A is placed within both granular and cohesive made ground, and natural cohesive alluvial soils, at a depth of between 1-4m. No organic material was observed within the soils. Standing groundwater was recorded at depths of between 2.2-3.6m bgl, below the top of the response zone.

A maximum peak methane concentration of 0.6% v/v was recorded within SWS08A on 6<sup>th</sup> January 2016. A maximum steady state carbon dioxide concentration of 5.9% v/v was recorded on 15<sup>th</sup> March 2016. No detectable flows were recorded within SWS08A on either visit. A maximum peak and steady flow rate of 1.4 litre/hour was recorded within the borehole on 26<sup>th</sup> April 2016.

Based on the monitoring results within SWS08A,  $Q_{hg}$  values of 0.0084 litre/hour for methane and 0.0826 litre/hour for carbon dioxide have been calculated for this borehole. These results are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

#### *SWS14*

The response zone within SWS14 is placed within granular made ground comprising sand and gravel of clinker and ash, at a depth of between 0.5-2m. No organic material was observed within soils. The borehole installation was generally recorded to be dry during the monitoring period.

No detectable concentrations of methane were recorded within SWS14 during the monitoring period. A maximum steady state carbon dioxide concentration of 1.0% v/v was recorded on 6<sup>th</sup> January 2016. A maximum peak and steady flow rate of 6.5 litre/hour was recorded on 3<sup>rd</sup> February 2016.

Based on the monitoring results within SWS14,  $Q_{hg}$  values of 0.0065litre/hour for methane and 0.065 litre/hour for carbon dioxide have been calculated for this borehole. These results are indicative of a very low hazard potential, characterised as CS1, based on Table 2 presented within BS8485:2015.

#### *BH205S / BH205D (WSP boreholes)*

BH205S and BH205D represent two installations within one borehole. The response zone in BH205S (at a depth between 0.5-1.0m), comprised granular made ground with gravels of concrete and brick. The borehole remained generally dry.

The response zone in BH205D (at a depth between 2.0-4.0m), comprised natural cohesive alluvial deposits and residual Millstone Grit strata. The cohesive soils were recorded as being organic-rich in nature. A groundwater strike was recorded at a depth of 1.80m bgl, with standing groundwater at depths of between approximately 1.0-1.5m bgl, flooding the response zone. The installation was unsuccessfully purged on several occasions because of rapid recharge of groundwater. The effects of the flooded response zone could have potentially lead to artificially elevated peak flows due to a build-up of pressure caused by rising groundwater.

Negligible / non-detectable concentrations of methane were recorded within BH205S and BH205D, whilst steady state carbon dioxide concentrations of 0.4% and 0.7% v/v were recorded within BH205S (3<sup>rd</sup> February 2016) and BH205D (20<sup>th</sup> January 2016), respectively.

Maximum peak and steady flow rates of 10.0 litre/hour were recorded within BH205D on 26<sup>th</sup> April 2016. This maximum recorded flow is considered unlikely to be representative in this instance because of its associated flooded response zone and given that the remainder of the monitoring visits recorded low / negligible flow rates. Maximum peak and steady flow rates of -0.7 litre/hour and 0.4 litre/hour, were recorded within BH204S on 16<sup>th</sup> February 2016 and within BH204D on dated 24<sup>th</sup> May 2016, respectively. WSP recorded no detectable concentrations of methane and steady state carbon dioxide concentrations of 0.5% v/v and 0.4% v/v within BH205S and BH205D, respectively, with maximum peak flows of 1.0 litre/hour and non-detect, respectively. The results are considered comparable to those recorded as part of the Sirius gas monitoring period, excluding the censored flow data point.

Based on the monitoring results, a  $Q_{hg}$  value of 0.0028 litre/hour for carbon dioxide has been calculated for both monitoring installations.  $Q_{hg}$  values of 0.0014 litre/hour and 0.0004 litre/hour for methane have been calculated for BH204S and BH204D respectively. These results are indicative of a very low hazard potential, characterised as CS1, based on Table 2 presented within BS8485:2015.

#### *BH206S / BH206D (WSP borehole)*

BH206S and BH206D represent two installations within one borehole. Sirius was unable to locate this monitoring point and the discussion below is based on results provided within WSP's Geoenvironmental Appraisal report only.

The response zone in BH206S (at a depth between 0.3-0.7m), comprised granular made ground with gravels of sandstone and brick. The borehole remained generally dry. The response zone in BH206D (at a depth between 2.0-5.0m), comprised natural cohesive alluvial deposits and residual Millstone Grit strata. A groundwater strike was recorded at a depth of 2.0m bgl, with standing groundwater at a depth of 2.2m bgl, flooding the response zone. No mention is made by WSP whether monitoring was undertaken post-purging of groundwater. On this basis, it is unclear if the gas data from BH206D are reliable.

WSP recorded no detectable concentrations of methane and steady state carbon dioxide concentrations of 2.0% v/v within BH206S, with no detectable flow rates. Maximum peak and steady state methane concentrations of 6.3% v/v and 14.0% v/v were recorded within BH206D, whilst peak and steady state carbon dioxide concentrations of 0.9% v/v and non-detect, respectively were recorded. No detectable flow rates were recorded within BH206D.

Based on the monitoring results within BH206S only, a  $Q_{hg}$  value of 0.002 litre/hour for carbon dioxide has been calculated for this borehole. A  $Q_{hg}$  value of 0.0001 litre/hour has been calculated for methane. The result is indicative of a very low hazard potential, characterised as CS1, based on Table 2 presented within BS8485:2015.

Based on the monitoring results within BH206D only,  $Q_{hg}$  value of 0.014 litre/hour for methane has been calculated. A  $Q_{hg}$  value of 0.0001 litre/hour has been calculated for carbon dioxide. Taking account of the peak concentration of methane recorded (14% v/v), the gas data are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

#### *BH208S / BH208D (WSP borehole)*

BH208S and BH208D are two installations placed within one borehole. The response zone in BH208S (at a depth of between 0.5-1.0m), comprised natural cohesive deposits (possibly alluvial deposits). The installation within BH208S remained generally dry. No significant organic matter was identified through the depth of the shallow borehole response zone.

The response zone in BH208D (at a depth between 1.0-5.0m), comprised natural cohesive deposits with organic content (assumed to be alluvial deposits), underlain by residual Millstone Grit strata. A groundwater strike was recorded at a depth of 3.0m bgl, with standing groundwater at depths of between approximately 1.3m-1.8m bgl, below the top of the response zone.

Maximum peak and steady state methane concentrations of 42.0% v/v and 40.0% v/v and steady state carbon dioxide concentrations of 8.0% v/v were recorded within BH208S on 29<sup>th</sup> March 2016.

An associated peak flow of 2.0 litre/hour was recorded within the monitoring installation decreasing to non-detect after a few seconds. A maximum peak positive flow rate of 5.0 litre/hour was recorded within this borehole on 12<sup>th</sup> April 2016, decreasing to a steady state flow of 1.5 litre/hour.

WSP recorded maximum peak and steady state methane concentrations of 14.3% v/v and 3.0% v/v and maximum peak and steady state carbon dioxide concentrations of 7.6% v/v and 0.2% v/v, respectively within BH208S with a maximum flow of 0.1 litre/hour.

Maximum peak and steady state methane concentrations of 22.4% v/v and 2.5% v/v were recorded by Sirius within the deep installation (BH208D). The maximum peak concentration of 22.4% v/v reduced to non-detect on the first monitoring visit (on 6<sup>th</sup> January 2016), and is likely to be attributable to the release of a build-up of gas within the installation over the period since it was last monitored by WSP. No associated flows were recorded on that occasion, however. The concentrations of methane within BH208D were typically below detection level for the remainder of the monitoring period other than a peak and steady state concentration of 2.5% v/v recorded on the final Sirius visit. On this basis, the one-off peak instantaneous concentration of 22.4% v/v is considered unrepresentative and has been disregarded.

A maximum peak and steady state flow rate of 1.3 litre/hour was recorded within BH208D on 26<sup>th</sup> April 2016.

WSP recorded maximum peak and steady state methane concentrations of 5.1% v/v and 2.4% v/v and maximum peak and steady state carbon dioxide concentrations of 7.6% v/v and 2.8% v/v, respectively within BH208D, with a maximum flow of 0.3 litre/hour.

Based on the monitoring results within BH208S only,  $Q_{hg}$  values of 2.1 litre/hour for methane and 0.24 litre/hour for carbon dioxide has been calculated. The result is indicative of a moderate hazard potential, characterised as CS3 as defined in Table 2 of BS8485:2015.

Based on the monitoring results within BH208D only,  $Q_{hg}$  values of 0.0325 litre/hour for methane and 0.0169 litre/hour for carbon dioxide have been calculated. Adopting 2.5% v/v as the representative peak concentration of methane (as discussed above), this borehole has been characterised as exhibiting CS2 conditions.

### ***Sensitivity Evaluation***

In summary, maximum peak methane concentrations of 42.0% v/v and steady state carbon dioxide concentrations of 8.0% v/v have been recorded within the mill area, both within the same borehole

and monitoring event (BH208S, 29<sup>th</sup> March 2016). An associated peak flow of 2.0 litre/hour was recorded within the borehole installation on this visit, which reduced to non-detect after several seconds. These results are consistent with the presence of organic-rich alluvial deposits underlying the response zone of this borehole in that elevated methane and carbon dioxide concentrations are present but that flow rates are low.

Although maximum peak and steady flow rates of 10.0 litre/hour were recorded within BH205D on one occasion, this maximum recorded flow is not representative in this instance of the ground gas regime being associated with a flooded response zone and no other similarly elevated flows being recorded in this borehole or others within this zone.

Peak and steady negative flow rates of -1.2 litre/hour were recorded within SWS02A on 12<sup>th</sup> April 2016, whilst maximum positive peak and steady state flow rates of 6.5 litre/hour were recorded within SWS14 on 3<sup>rd</sup> February 2016. Peak and steady state positive flows of between non-detect and 5.0 litre/hour were recorded within borehole installations within the mill area on all other monitoring visits.

The possible worst-case conditions in the mill zone have been assessed for both methane and carbon dioxide by using the maximum recorded flow along with the maximum gas concentrations, but discounting any peak instantaneous flows and negative flows that have been judged to be unrepresentative of true conditions. In this case, these are based on a measured maximum methane concentration of 42.0% (BH208S) and carbon dioxide concentration of 8.0% (BH208S) and peak and steady gas flow rates of 6.5 litres/hour (SWS14).

On this basis, worst-case  $Q_{hg}$  values of 2.73 litre/hour for methane and 0.52 litre/hour for carbon dioxide have been calculated, indicative of a moderate hazard potential, characterised as CS3 as defined in Table 2 of BS8485:2015.

We consider that the overall dataset collected for the mill area is representative and comprehensive. As with the landfill zone, there is significant spatial variability in ground conditions and groundwater levels that contribute to differences in ground gas generation potential and rate, which makes the combination of data between these conceptually unsound. We therefore conclude that the application of a GSV for this zone derived by using worst-case concentrations and flows derived from disparate boreholes is unrepresentative and excessively conservative and that the GSV should be based on worst plausible values calculated on a per borehole basis.

In addition, it is considered appropriate to further zone the mill area given its geological variability, and the presence of localised 'pockets' of organic-rich alluvial deposits which are only prevalent in close proximity to the river. This is discussed further below.

### ***Representative Gas Screening Value for Mill Area***

Based on the presence of organic-rich alluvial soils which are the principal source of elevated hazardous ground gases, the Mill Area can be zoned into the Southern Mill Area (incorporating BH206, BH208, SWS02A and SWS08A, which all demonstrated elevated methane and / or carbon dioxide concentrations) and the Central and Northern Mill Area (incorporating all other monitoring installations). Geological cross-sections indicating the localities of the organic rich soils that underpin the justification for this sub-division of the zone are provided as Drawing Nos. C6485A/GRA/05A and 05B, which are included within Appendix A.

The derived  $Q_{hg}$  values for methane and carbon dioxide based on data obtained within individual boreholes indicate that the highest  $Q_{hg}$  values for the Southern Mill Area are within BH208S, being 2.1 litre/hour for methane and 0.24 litre/hour for carbon dioxide. These results are indicative of a moderate hazard potential, characterised as CS3, based on Table 2 presented within BS8485:2015.

Elsewhere within the Southern Mill Area, the highest  $Q_{hg}$  for methane is 0.014 litre/hour (BH206D) and for carbon dioxide 0.098 litre/hour (SWS02A). Both of these boreholes are located along the southern-most boundary of the zone. These results are indicative of a low hazard potential, characterised as CS2, based on Table 2 presented within BS8485:2015.

It is evident that BH208S exhibits the highest  $Q_{hg}$  values within the Southern Mill Area, where naturally occurring alluvial soils with high natural organic matter content were predominantly located. A reasonable conservative assumption has been made that the gassing regime identified within BH208S could be encountered locally where similar alluvial soils are present along the southern boundary of this zone. Consequently, the highest  $Q_{hg}$  values calculated for boreholes situated in the Southern Mill Area (i.e. 2.1 litre/hour for methane and 0.24 litre/hour for carbon dioxide) are applied as the appropriate GSVs for this zone. The **Southern Mill Area** is therefore classified as **Characteristic Situation 3**.

The derived  $Q_{hg}$  values for methane and carbon dioxide based on data obtained within individual boreholes within the Central and Northern Mill Area indicate that the highest  $Q_{hg}$  for methane is 0.0014 litre/hour (BH205S), whilst the highest  $Q_{hg}$  for carbon dioxide is 0.065 litre/hour (SWS14). These results are adopted as the GSV for this sub-zone and are indicative of a very low hazard

potential, characterised as CS1, based on Table 2 presented within BS8485:2015. However, given the presence of the landfill at the northern boundary of this zone and the possibility that localised pockets of organic-rich alluvial soils could be encountered, we recommend the classification of the **Central and Northern Mill Area** as **Characteristic Situation 2**.

### South Western Site Area

The site investigation within the south western area was limited in extent, as a result of access restrictions associated with stockpiles of demolition rubble and numerous sub-structures posing obstructions to intrusive investigation. Two installations were placed within the south western site area (SBH11 and SWS30A), and these are discussed in further detail below.

The response zone within SBH11 is placed within granular made ground comprising concrete and brick at a depth of between 1.0-4.0m. A strong hydrocarbon odour and sheen was noted within soils and groundwater. Standing groundwater was recorded generally at depths of between approximately 2-3m bgl, with an associated layer of free-product. The response zone within SWS30A is placed within cohesive made ground (partly reworked alluvial deposits) at a depth of between 0.5-2.0m bgl. A faint hydrocarbon odour was noted between 0.6-0.8m bgl. The borehole was recorded as dry on subsequent groundwater monitoring visits.

In summary, maximum peak methane concentrations of 0.7% v/v and steady state carbon dioxide concentrations of 8.3% v/v have been recorded within the south western area within the same borehole installation (SBH11 on 12<sup>th</sup> and 26<sup>th</sup> April 2016, respectively). Peak and steady flows of 2.1 litre/hour were recorded within SBH11 on 12<sup>th</sup> April 2016, and peak and steady flow rates of 1.8 litre/hour and 1.6 litre/hour were recorded on 26<sup>th</sup> April 2016. Flows rates within SBH11 were to be negligible during the remainder of the monitoring period.

Maximum peak and steady state flow rates of 3.2 litre/hour were recorded within SWS30A on 7<sup>th</sup> June 2016.

Taking the maximum concentrations and flows recorded in both boreholes, worst-case  $Q_{ng}$  values of 0.0224 litre/hour for methane and 0.2656 litre/hour for carbon dioxide have been calculated. These indicate a low hazard potential, characterised as **Characteristic Situation 2** as defined in Table 2 of BS8485:2015. The use of these very conservative  $Q_{ng}$  values as GSVs is considered appropriate in this instance given the small number of borehole installations.

It is acknowledged that remedial works are proposed within the south western site area to deal with hydrocarbon-contaminated soils and groundwater. The remedial works may affect the current

gassing regime, by effectively removing a likely ground gas source, namely slowly biodegradable contamination. Post-remediation gas monitoring and re-assessment may allow a lower GSV to be adopted for the south western site area.

### North Western Site Area

Monitoring results within specific boreholes within the north western site area that recorded notably elevated gas concentrations and / or gas flow rates, are summarised in Table 7.3 below. These include 3 installations from a total of ten across the north western site area. The worst-credible  $Q_{hg}$  values per borehole for both methane and carbon dioxide are also shown.

The majority of the installations within the north western site area were noted to be flooded on a number of monitoring occasions. The groundwater was purged to below the response zone depth, where possible, and re-monitored. Groundwater was often found to recharge quickly where response zones are placed within natural alluvial and residual bedrock strata, indicative of the naturally high groundwater table within the north western site area.

**Table 7.3 Summary of Gas Monitoring, North Western Site Area**

Borehole Installation	CH <sub>4</sub> % v/v		CO <sub>2</sub> % v/v		O <sub>2</sub> % v/v		Flow litre/hr		Worst credible $Q_{hg}$ (l/hr) per borehole	
	Max	Steady	Max	Steady	Min	Max	Max	Steady	CH <sub>4</sub>	CO <sub>2</sub>
SWS33	0.8	0.2	7.7	0.9	6.5	21.0	2.6	2.6	0.0208	0.0234
SWS34	0.7	ND	1.5	1.5	19.3	20.7	4.2	4.2	0.0294	0.063
BH202A	ND	ND	1.5	1.5	19.0	21.0	1.1	1.1	0.0011	0.0165

ND = Not Detected

#### SWS33

The response zone within SWS33 is at a depth of between 2.5-4.5m within cohesive made ground, described as possible reworked alluvial soils with occasional inclusions of organic materials. Standing groundwater was recorded at depths of between 2.6 and 3.6m bgl, generally below the top of the response zone. On occasion, where groundwater was found to be flooding the borehole, this was purged and subsequently re-monitored.

The borehole was located in close proximity to potentially biodegradable materials (including reeds associated with the former reservoir base) encountered within exploratory hole reference TPB as

part of the June 2015 investigation (detailed further within the Sirius Geoenvironmental Appraisal report, ref. C6485A, dated March 2016).

A maximum peak methane concentration of 0.8% v/v, reducing to non-detect, was recorded within SWS33 on 10<sup>th</sup> May 2016. A maximum peak and steady state carbon dioxide concentration of 7.7% v/v and 0.9% v/v, respectively, was recorded on 6<sup>th</sup> January 2016. No detectable flows were recorded within SWS08A on either visit. A maximum peak and steady flow rate of 2.6 litre/hour was recorded within the borehole on 16<sup>th</sup> February 2016.

Based on the monitoring results within SWS33,  $Q_{hg}$  values of 0.0208 litre/hour for methane and 0.0234 litre/hour for carbon dioxide have been calculated. These results are indicative of a very low hazard potential, characterised as CS1, based on Table 2 presented within BS8485:2015.

#### SWS34

The response zone within SWS34 is at a depth of between 2.5 and 5.0m within natural cohesive alluvial soils with occasional organic inclusions. Standing groundwater was recorded at depths of between approximately 0.8 and 1.4m bgl, effectively flooding the response zone. The groundwater was purged as far as possible and subsequently re-monitored. SWS34 is located in close proximity to backfilled former reservoirs with localised natural organic content noted.

A maximum peak methane concentration of 0.7% v/v reducing to non-detect was recorded within SWS34 on 6<sup>th</sup> January 2016, although it is noted that the installation was flooded and was not purged and re-monitored on that occasion. A maximum steady state carbon dioxide concentration of 1.5% v/v was recorded on 15<sup>th</sup> March 2016, with an associated maximum peak and steady flow rate of 2.5 litre/hour. The borehole was purged and re-monitored on this occasion with flows subsequently recorded as non-detect.

Peak and steady flow rates of 11.8 litre/hour were recorded within SWS34 on 1<sup>st</sup> March 2016 but this was associated with a flooded response zone and so believed to be due to pressurisation of the sealed borehole. Following purging of groundwater from the borehole, peak and steady flows of 4.2 litre/hour were recorded, which are used for calculation of the  $Q_{hg}$  values detailed below.

Based on the monitoring results within SWS34, worst possible  $Q_{hg}$  values of 0.0294 litre/hour for methane and 0.063 litre/hour for carbon dioxide have been calculated. These results are indicative of a very low hazard potential, characterised as CS1, based on Table 2 presented within BS8485:2015.

*BH202A*

The response zone within BH202A is placed within both granular and cohesive made ground, at a depth of between 1-5m. Occasional organic material (including rootlets) was recorded within the exploratory hole location by WSP. Standing groundwater was recorded at depths of between 1.7-2.5m bgl, below the top of the response zone. The groundwater was purged and re-monitored on occasion.

Maximum peak and steady state carbon dioxide concentrations of 1.5 % v/v were recorded within BH202A on 29<sup>th</sup> March 2016, although no associated detectable flows were recorded on the visit within the borehole. No detectable methane was recorded within the borehole during the monitoring period. A peak and steady state flow of 1.1 litre/hour recorded within the borehole on dated 7<sup>th</sup> June 2016.

Within this borehole, WSP recorded maximum peak and steady state methane concentrations of 0.3% v/v and 0.1% v/v and maximum peak and steady state carbon dioxide concentrations of 1.3% v/v, respectively, with a maximum flow of 0.1 litre/hour.

Based on the monitoring results within BH202A, a  $Q_{hg}$  value of 0.0165 litre/hour carbon dioxide has been calculated. A  $Q_{hg}$  of 0.0011 litre/hour has been calculated for methane. These results are indicative of a very low hazard potential, characterised as CS1, based on Table 2 presented within BS8485:2015.

***Sensitivity Evaluation***

Maximum peak methane concentrations of 0.8% v/v and steady state carbon dioxide concentrations of 1.5% v/v were recorded within SWS33 on 10<sup>th</sup> May 2016 and SWS34 on 15<sup>th</sup> March 2016, respectively.

Peak and steady flow rates of 11.8 litre/hour were recorded within SWS34 on 1<sup>st</sup> March 2016 but this was associated with a flooded response zone and so believed to be due to pressurisation of the sealed borehole. Following purging of groundwater from the borehole, peak and steady flows of 4.2 litre/hour were recorded, which are likely to represent reliable gas flow rates. Peak and steady state flows of 4.2 litre/hour are therefore considered representative for the zone for the purposes of calculating  $Q_{hg}$  values.

The worst-case  $Q_{hg}$  values of 0.0336 litre/hour for methane and 0.063 litre/hour for carbon dioxide have been calculated for this zone. As with the per borehole values, these are indicative of a very low hazard potential, characterised as CS1 as defined in Table 2 of BS8485:2015.

***Representative Gas Screening Values for North Western Area***

$Q_{hg}$  values of 0.0336 litre/hour for methane and 0.063 litre/hour for carbon dioxide have been calculated and adopted as the GSVs for this zone. These are indicative of a very low hazard potential, assessed to indicate **Characteristic Situation 1** as defined in Table 2 of BS8485:2015.

## 8. CONCLUSIONS AND RECOMMENDATIONS

### 8.1. Assessment of Ground Gas Regime

The monitoring results obtained indicate that ground gas conditions at the site do not preclude residential development, subject to the adoption of appropriate protection within the design.

A summary of the site zones and their Characteristic Situation classifications for ground gas is presented below in Table 8.1

**Table 8.1 Summary of Hazardous Ground Gas Assessment**

Site Zone		Gas Screening Value (l/hr)		Characteristic Situation (CS) <sup>1</sup>	Minimum Gas Protection Score <sup>2</sup>
		CH <sub>4</sub>	CO <sub>2</sub>		
Landfill		1.248	0.4312	CS3	4.5
Mill Area	Southern	2.1	0.24	CS3	4.5
	Central and Northern	0.014	0.098	CS2	3.5
South West		0.0224	0.2656	CS2	3.5
North West		0.0336	0.063	CS1	0

1. Taken from Table 2 of BS8485:2015

2. Table 4 of BS8485:2015, assuming a high risk 'Type A' building (i.e. private ownership with no building management controls such as low-rise private housing) (assumes 'Type A' and / or 'Type B' building for the south western site zone).

Drawing No. C6485A/GRA/06 (within Appendix A) presents the indicative gas zoning plan based upon the 'parameter plan' provided by the client. This zoning plan should be applied to the proposed development layout, once available, and approved by the local authority prior to development commencing.

### 8.2. Recommended Ground Gas Protection Measures

#### Landfill Area

Assessment of the hazardous gas results obtained within the landfill area for both made ground soils and natural alluvial deposits indicates that gas precaution measures within new dwellings are necessary.

Assuming a 'Type A' building (such as low-rise private residential housing) and based upon a recommended **CS3 classification** for the landfill area, a **gas protection score of 4.5** is required for new development in this zone. This could be achieved, for example, by the incorporation of a precast suspended segmental subfloor (i.e. 'block and beam') and a passive sub-floor dispersal layer (e.g. clear void, proprietary void former blanket or 'no fines' gravel layer) achieving a 'very good performance' as defined in Annex B of BS8485, together with the installation and verification of a gas-resistant membrane meeting the criteria specified in Table 7 of BS8485:2015.

Many housing developments have suspended floor slabs with a ventilated underfloor void; which construction method has been recommended for geotechnical purposes across the majority of this site, as recommended within the Sirius Geoenvironmental Appraisal report, dated March 2016 (ref. C6485A). Ventilated voids provide good protection against ground gas ingress and, when designed and constructed correctly, have the ability to dilute hazardous ground gases to acceptable levels. Good construction also requires the cavity wall below ground level to be filled with concrete, again limiting the potential for gas ingress. Therefore, many buildings will have an inherent level of gas protection provided in their construction, which will meet or can readily be made to meet the requirements given within BS8485:2015.

A passive sub-floor of 'very good' performance, as detailed within Annex B of BS8485:2015, is necessary to achieve CS3 requirements. This could be achieved, for example, by the use of a clear void dispersal layer, with a minimum area of side ventilation of 1 500mm<sup>2</sup>/m run of wall on at least two opposite sides (assuming a small to medium width building, up to 15m wide).

Although hydrocarbon vapour ingress is not a risk-driver in this site zone, we note that the dilution potential of a sub-floor void would also significantly reduce the ingress of vapours into the completed properties.

Given the risks associated with ongoing ground settlement of fill materials within the recently infilled landfill area, consideration of ground improvement/treatment is currently underway to assist design of the proposed development. The most effective method of ground improvement will be dependent on a number of factors including the proposed development layout and levels, and the underlying soil profile and groundwater regime.

The proposed development within the landfill area is likely to be founded on piles (as detailed within the Sirius Geoenvironmental Appraisal report, dated March 2016, ref. C6485A), taken through the made ground and soft alluvial soils into the underlying competent bedrock. The use of piles within gassing landfilled wastes can create preferential gas flow pathways when they

penetrate through low permeability strata that confine the movement of gas. In this case, there is no impermeable stratum confining gas within the landfill surface and the gassing sources are distributed locally throughout relatively permeable fill materials. Therefore, piling will not have the potential to create new flow pathways or significantly increase the rate of flow through existing pathways and will not result in significant incremental risk.

It is acknowledged that alteration of the near-surface landfill materials through compaction and partial re-engineering may have the potential to alter the gassing regime by changing gas generation rate or altering the properties of migration pathways. Given that a large proportion of the landfill waste is granular and will remain close to its existing depth, the permeability of the soils through compaction is unlikely to be significantly changed and therefore the ground gas migration pathways will not change significantly. Any re-engineering of shallow soils would potentially mitigate the ground gas regime, as this would include the removal of geotechnically 'unsuitable' materials such as paper waste and wood fragments, which are the principal sources of the localised elevated gas concentrations within the made ground. On the basis that gas precautions will be constructed, installed and verified within this zone and the adjacent mill area in accordance with the recommendations made in this report and in accordance with BS8485:2015 and other applicable guidance, then the risk posed by hazardous ground gases in the post-development case will be low.

### **Mill Area**

Concentrations of methane and carbon dioxide across the mill area, and the associated level of ground gas risk were variable across this zone. Elevated concentrations of these gases were recorded within the southern portion of the area, although flow rates were generally low. In contrast, the central and northern portions of the mill area generally recorded negligible to low ground gas concentrations. The elevated gas concentrations within the southern part of this area coincided with the presence of natural organic alluvial soils adjacent to the River Don, which are less significant or absent in the central and northern parts (see Drawing Nos. C6485A/GRA/05A and 05B within Appendix A).

Consequently, the mill area has been sub-divided into two zones with regard to ground gas risk and mitigation as shown on Drawing No. C6485A/GRA/06 within Appendix A.

### ***Southern Mill Area***

Assuming a 'Type A' building (such as low-rise private residential housing) and based upon a recommended **CS3 classification**, a **gas protection score of 4.5** is required for new

development in this zone. As described above for the landfill area, this could be achieved, for example, by the incorporation of a precast suspended segmental subfloor (i.e. 'block and beam') and a passive sub-floor dispersal layer (e.g. clear void, proprietary void former blanket or 'no fines' gravel layer) achieving a 'very good performance' as defined in Annex B of BS8485, together with the installation and verification of a gas-resistant membrane meeting the criteria specified in Table 7 of BS8485:2015.

### **Central and Northern Mill Area**

Assuming a 'Type A' building (such as low-rise private residential housing) and based upon a recommended **CS2 classification**, a **gas protection score of 3.5** is required for new development in this zone. These conditions require a minimum gas protection score of 3.5, which may be achieved, for example, by a passive sub-floor void of suitable design and installation of a suitable gas resistant membrane, installed and verified in accordance with the requirements of BS8485:2015.

### **South Western Area**

Assuming either a 'Type A' building (such as low-rise private residential housing) and / or a 'Type B' building (such as managed residential apartment blocks) and based upon a recommended **CS2 classification**, a **gas protection score of 3.5** is required for new development in this zone. These conditions require a minimum gas protection score of 3.5, which may be achieved within a low-rise private residential house, for example, by a passive sub-floor void of suitable design and installation of a suitable gas resistant membrane, installed and verified in accordance with the requirements of BS8485:2015. Reference to BS8485:2015 should be made for design of gas measures within any proposed 'Type B' buildings.

The proposed classification for this zone has been set conservatively given the small number of boreholes in this zone and is likely influenced by the presence of localised 'hotspots' of hydrocarbon contamination. It may be possible to reduce this classification by undertaking further ground gas monitoring following the completion of hydrocarbon remediation.

### **North Western Area**

This zone has been assessed as being **Characteristic Situation 1**. Table 4 of BS8485:2015 indicates that CS1 conditions **do not require the installation of specific gas protection measures**.

### 8.3. Further Considerations

Design and verification of the ground gas protection measures shall be undertaken in accordance with BS8485:2015, CIRIA C735 'Good Practice on the Verification and Testing of Protection Systems of Buildings against Hazardous Ground Gases', dated 2014, and other relevant guidance that may apply to the specific measures implemented and current at the time these works are performed. In addition, verification of the gas protection measures shall be undertaken in accordance with Sheffield City Council's Environmental Protection Service 'Verification of Gas Protection Measures', dated February 2009 (or as amended).

Should the land use or proposed building type(s) change from those assumed in the preparation of this report, then re-evaluation of the conclusions and recommendations will be required.

The site is located within an area where no additional gas protection measures are required for protection of proposed new buildings from the ingress of radon gas.

Elevated concentrations of hazardous ground gases and depleted oxygen levels (<18% v/v) have been recorded at the site. During groundworks and construction, gas monitoring of all excavations and/or underground spaces should be carried out prior to personnel entry with continuous monitoring throughout the period of working. Gas monitoring by way of example should include as a minimum: methane, carbon dioxide, carbon monoxide and oxygen. Gas monitor(s) shall emit both audible and visual warnings. Alarm levels should be set with due regard to the relevant Occupational Exposure Limits given in HSE EH40/2005, and for low oxygen concentrations. If any anomalous or significantly elevated/depleted gas concentrations are detected, then all personnel should immediately evacuate the area and the advice of an appropriate specialist be obtained before work continues.

## **9. REGULATORY AND OTHER APPROVALS**

The conclusions and recommendations presented above are considered reasonable based on the findings of the site investigation. However, these cannot be guaranteed to gain regulatory approval and, therefore, the report should be passed to the appropriate regulatory authorities and/or other relevant organisations for their comment and approval prior to undertaking any works on site.

The proposed detailed design of gas protection measures will need to be agreed with the local authority and if applicable, the NHBC or other insurer, together with an appropriate strategy for verification prior to undertaking any construction on site.



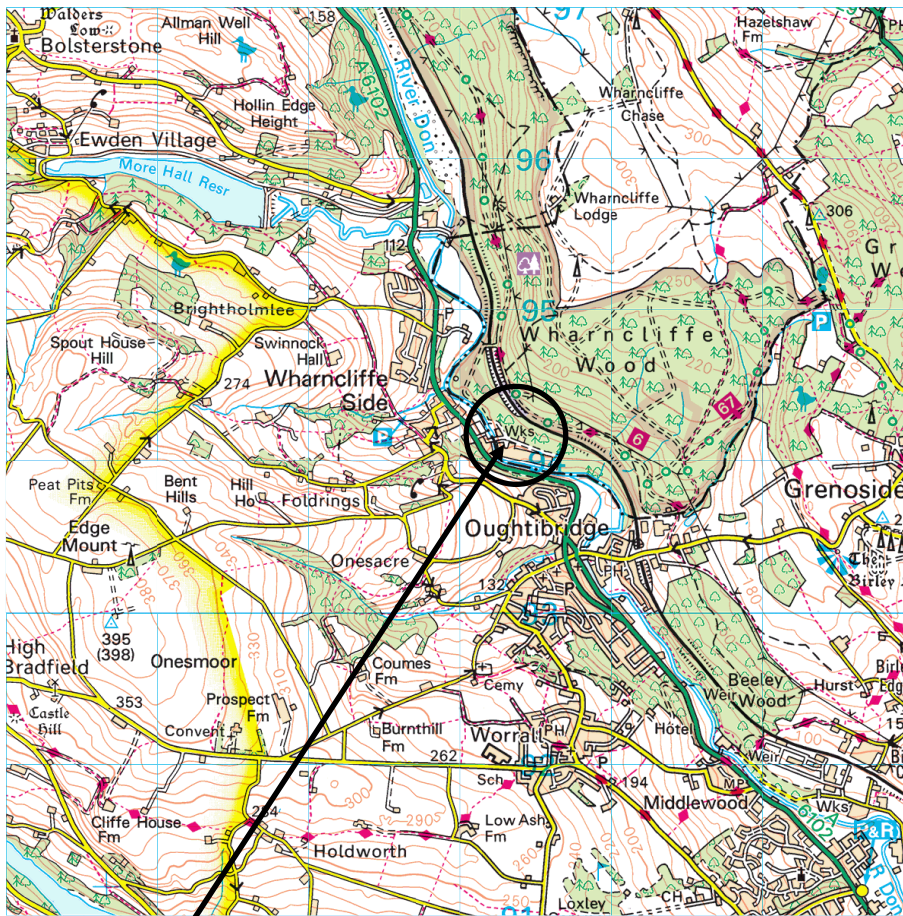
# APPENDIX A

## DRAWINGS



# Site Location Plan

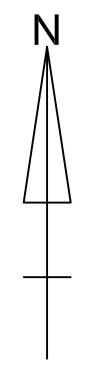
Contract Number	C6485A/GRA
Contract	Oughtibridge Mill
Client	CEG



**THE SITE**

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Scale	1:50,000	
Drawn by	SH	Approved JF
Drawing Number	C6485A/GRA/01	



**NOTES**

**Existing Site Features**

- Above Ground Storage Tank (AST)
- Electrical Sub-Station
- Weigh Bridge
- Flow Direction
- Oil Interceptors
- Assumed Route of Culverted Drain c. 4.00 mbgl (as Annotated From Arcadis Drawing 3178910005-CAD Dated 06/01/15)

**Historical Site Features**

- Former Boiler House
- Approximate Location of Former Diethandamine Bund / Tank c.3x3m
- Former Effluent Tanks
- Former Reservoirs
- Unknown Features
- Former Mill Race
- Former Railway Line / Sidings
- Former Chimneys
- Former Oil Store
- Former Mill Building / Engine / Machinery House Dated Between 1894-2015

**Site Zones**

- Site Boundary
- North West Area - Former Effluent Tanks / Reservoirs
- Woodland Areas
- Former Landfill Area (Approximate Location)
- South West Area - Former Buildings Machinery / Engine House
- Mill Area

**REVISION**

0	>>
A	>>
B	>>
C	>>

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**CLIENT**

**CEG**

**SITE**

**Oughtibridge Mill**

**DRAWING TITLE**

**Site Features & Zoning Plan**

<b>DRAWING NO.</b> C6485A/GRA/02	<b>REVISION NO.</b> 0
<b>DRAWN BY</b> DT	<b>APPROVED BY</b> GH
<b>DATE</b> July 2016	<b>SCALE</b> 1:1000
	<b>PAPER SIZE</b> A0