Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

Glanyrafon Court, Ebbw Vale
Proposed Residential Redevelopment
Geo-Environmental & Geotechnical Assessment

Report Reference: ESP.6566b.02.3275

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Glanyrafon Court, Ebbw Vale
Proposed Residential Redevelopment
Geo-Environmental & Geotechnical Assessment

Prepared for:
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Tai Calon
Community Housing

Report Reference: **ESP.6566b.02.3275**

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Notes:

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Contents

Executive Summary

Tai Calon Community Housing Ltd are proposing to redevelop the subject site for residential purposes. ESP have undertaken a geo-environmental and geotechnical assessment, comprising a desk study, intrusive investigation, laboratory testing and assessment of data. The key potential land quality issues identified by the assessment are summarised below:

	Potential Hazard	*Anticipated Risk*	*Discussion*
Site Setting	***Current Site Status.***	-	*The site is currently vacant with the former building demolished and located adjacent to a river. Steep slopes are present at the west and east boundaries.*
	Anticipated Ground Conditions.	-	*The anticipated ground conditions are likely to comprise a cover of Made Ground overlying Alluvium and bedrock of the Lower Coal Measures.*
	Groundwater Conditions.	-	*The site is underlain by a Secondary A Aquifer and groundwater has been encountered at shallow depth during monitoring.*
	Historical Land Use.	-	*The site has been previously developed with a residential property comprising several flats, constructed in the north of the site in the early 1970s. No obviously significant contaminating land uses have been identified.*
Geo-environmental	***Potential Contamination Sources***	*Low*	*No obviously significant contaminating land uses have been identified, but Made Ground encountered at the site.*
	Chronic Risks to Human Health	*Moderate*	*Presence of Beryllium recorded above guideline values with further consideration required.*
	Risks to Controlled Waters	*Low*	*Site is underlain by a Secondary A Aquifer, but low levels of contaminants identified and no contamination sources recorded.*
	Hazardous Ground Gas	*High*	*Potential for gas with monitoring ongoing and to be reported as an addendum.*
Geotechnical	***Abandoned Mine Workings and/or Old Mine Entries***	*High*	*As discussed in Section 2.9.2 and 2.9.3 of the desk study, there is a potential risk from underground workings beneath the site from historical mining of coal and ironstone. As coal seams are indicated to dip away from the site, ironstone is likely to be of highest concern.*
	Sulphate Attack on Buried Concrete	*Moderate*	*Potential for elevated levels of sulphate with an advanced concrete class required.*
Others	***UXO***	-	*UXO mapping identifies that a detailed assessment whilst prudent is not essential on this occasion.*
	Further Investigation Required? ***(Section 10.0)***		*See Section 10.0.*

Note: The above is intended to provide a brief summary of the conclusions of the assessment. It does not provide a definitive assessment and must not be referenced as a separate document. Refer to the main body of the report for details.

1 Introduction

1.1 Background

Tai Calon (hereafter known as the Client) are proposing a new residential development at the site. The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by the Client to undertake an exploratory ground investigation and assessment in order to identify and evaluate potential geotechnical and geoenvironmental hazards which could impact on the proposed development. The site location is shown on Insert 1 below.

The proposed development will comprise the construction of a number of two storey traditional residential buildings with associated areas of access, hardstanding, gardens and landscaping. We understand that the building will be tolerant to minor movement and that there will be no significant changes to the current ground levels and the proposed development layout is presented as Figure 1.

Based on the above, we understand that the proposed structures would be classified as Geotechnical Category 2 (BS5930:2015).

1.2 Objective and Scope of Works

This Phase 2 assessment follows a previous Desk Study assessment undertaken by ESP in March 2017 (Ref: 6566b.2743) and implements the intrusive investigation requirements recommended within that Desk Study, which is also provided in full in Appendix B.

The objective of the investigation was to obtain information on the geotechnical character and properties of the ground beneath the site, potential risks posed by contamination and ground gas, and to allow an assessment of these ground conditions with particular reference to the potential impact on the proposed development. In addition, the investigation was designed to identify potential geotechnical hazards at the site.

At this stage, we are not aware of any ground hazard related planning conditions relating to the development.

The scope of works for the investigation was mutually developed with the Client by ESP within an agreed budget and comprised a desk study review previously issued by ESP (6566b.2743 – March 2017), a field reconnaissance visit, the supervision of windowless sample boreholes, trial pits, soakaway infiltration testing, geotechnical and geo-environmental laboratory testing, risks to human health and controlled waters, and reporting.

1.3 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1 of the desk study(ESP.6566b.2743). The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site-specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

1.4 Digital Copy of Report

This report is issued as a digital version only.

2 Site Location and Description

The information presented in this section is a summary of the desk study previously undertaken and issued by ESP in March 2017 (6566b.2743). This report contains a summary of the salient information from the desk study only (See Section 2.1 to 2.6). For full content and context, it is recommended the previous assessment be read in conjunction with this report (see Appendix B).

2.1 Site Location

The site is located at Glan Yr Afon Court, in the Newtown area of Ebbw Vale, Blaenau Gwent. The National Grid Reference of the centre of the site is (SO) 316589, 211314 and the postcode is NP23 5NS. A Site Location Plan is presented as Insert 1, below.

Insert 1: *Approximate site boundary (Ordnance Survey License No.: AL100015788*).

2.2 Site Description

The site is roughly rectangular shape and aligned generally north west to south east. At its largest dimensions the site is approximately 170m in length by 60m wide and covers an area of 1.16ha. The site is comprised predominantly of grassed surface and footpaths along with the demolition rubble of the pre-existing Glanyafron Court in the north.

The site is constructed on a generally level plateau with a steep slope present at the west boundary rising sharply to Allotment Road, and another steep slope, falling sharply at the north boundary down to the river.

3 Summary of Desk Study Information

3.1 Site History

The site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps and is summarised in Table 1 below. Our full previous Desk Study should be referred to for full details.

Table 1: *Review of Historical Maps*

Date	On-Site	In Vicinity of Site
1880 – 1920	The site is indicated to be vacant, with a slope present along the north boundary, sloping down the River Ebbw and the south boundary rising to a tramway.	The River Ebbw is present at the north boundary of the site and trends north west to south east. Housing to the north of the river are annotated as River Row. A footbridge over the River Ebbw is indicated approximately 20m to the east. Beaufort Ironworks (disused) is indicated approximately 100m to the east. An old coal level is indicated approximately 150m to the north east. A series of fill slopes/earthworks are indicated 20m north of site extending northward, followed by residential housing. A tramway is indicated 20m to the south followed by open fields. A footpath is indicated to the south west and an old air shaft is indicated approximately 500m to the south west. Opencast mine workings are indicated to the west of the site.
1959 - 1960	No significant changes are shown.	A slope is indicated at the south boundary.
1969	No significant changes are shown.	Significant development to the south and west, comprising residential housing and educational facilities. The iron works, shafts and levels are no longer indicated. An outfall is indicated in the east portion.
1970 - 1994	Glanyrafon Court, now occupies the north portion of the site. The	The road at to the south is now annotated as Allotment Road. No other significant changes are shown.
2002 - 2014	No significant changes are shown.	No significant changes are shown.
Notes to Table 1: 1. Extracts from historical maps presented in Appendix B. 2. Features may have been present on site between the dates of the individual mapping, and it should be appreciated that these cannot be identified from the map review.		

3.2 Summary of Environmental Conditions

A Review of historical mapping and other environmental information obtained during the Desk Study (see ESP.6566b.2743) has identified the following main potential contaminative features.

The site is primarily recorded as vacant until the early 1970s when the previously present Glan Yr Afon Court was constructed. Other notable land uses, identified on the historical maps indicate slopes at the west and east boundaries. A series of earthworks are noted in the central portion during the 1970s and is anticipated to have occurred in tandem with the development of the site. A former tramway is recorded at the crest of the west boundary and shown until the 1920s.

3.3 Geology

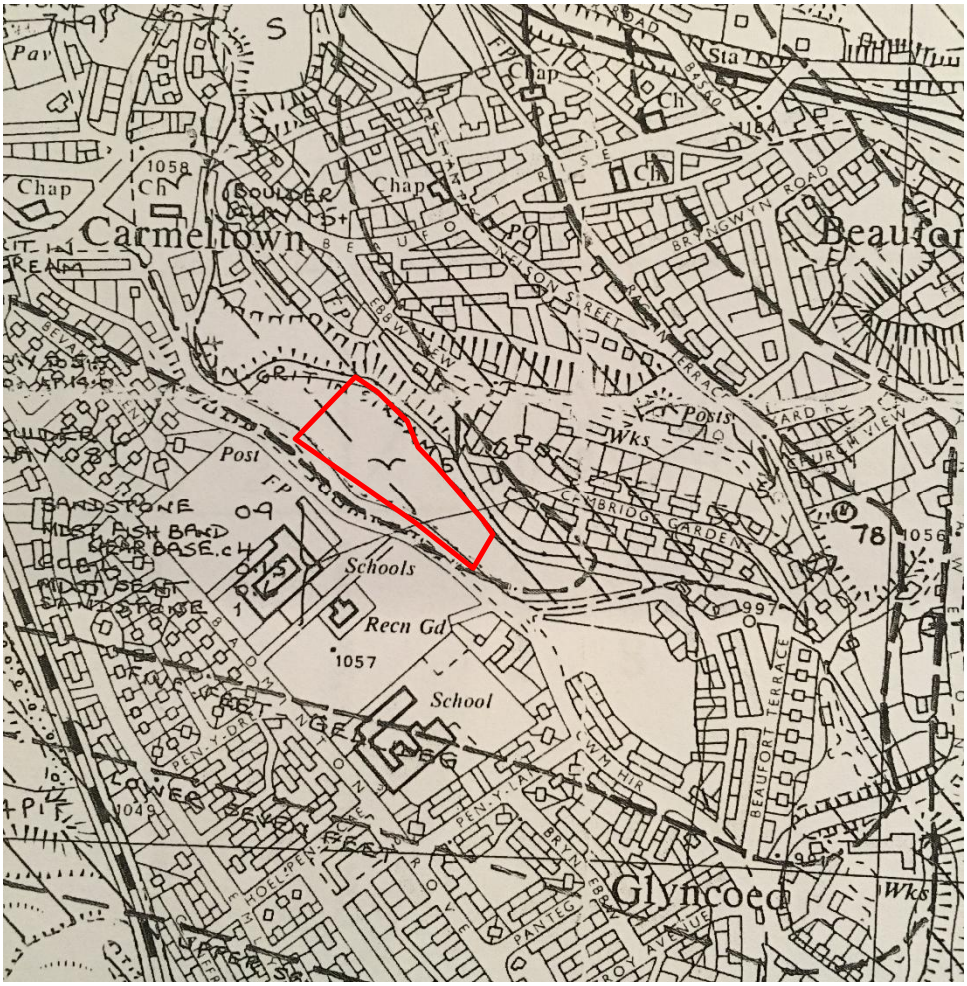
The published 1:10,560 scale geological map for the area of the site (Sheet SO 11 SE) indicates the site to be underlain by Alluvium overlying Rhondda Beds bedrock of the Upper Coal Measures, with an extract from the combined maps presented on Insert 3 below.

Reference to the up-to-date mapping available on the website of the British Geological Survey (BGS, 2019) indicates a similar succession. The Alluvial superficial strata would be expected to be fine-grained in nature with some gravel, and possibly cobbles and rare boulders. The Coal Measures bedrock comprises an interbedded succession of sandstone, siltstone and mudstone, with coal seams and associated seat earths.

Significant areas to west are noted as disturbed ground and is associated with recorded historic coal pit and opencast workings"

The Garw Coal seam is indicated to outcrop at the south boundary and also approximately 30m to the north, with the site situated below the level of these outcrops. As such it is likely that the Garw Seam has been eroded away during the formation of the valley, however, this will require confirmation.

Subsequent seams in the sequence such as the Gellideg, Upper and Lower Seven Feet and the Yard seam are all indicated to outcrop south of the site. Based on information presented on the BGS 1:50,000 scale map for the site (Sheet 232) these seams dip southward and do not underlie the site.



Insert 2: *Exract From Geological Map Sheets SO 11 SE (1:10,560) BGS licence number: C15/05 CSL*

3.4 Hydrogeology

Reference to the aquifer maps published within the environmental data report/ indicates that the superficial deposits beneath the site (Alluvium) are unclassified or classed as Unproductive Strata, whilst the bedrock (Coal Measures) is classed as Secondary A.

Based on the available information, we consider that the shallowest main groundwater body is likely to be located within the Coal Measures strata. There is the potential for perched water bodies within the overlying Made Ground and Alluvial deposits cannot be discounted.

The Groundsure Report (Appendix B) identifies the site as at risk of groundwater flooding from clearwater, which may potentially be present at the surface. A high confidence rating is provided in this assessment.

3.5 Hydrology

The nearest major surface water feature to the site is the Afon Ebwy (River Ebbw) classified as a Primary River which flows from north west to south east at the north-north east boundary.

From a review of topographical plans and flooding maps presented in the environmental data report/on the Natural Resources Wales website (NRW, 2019), the north and north west portions of the site are indicated to be at risk of flooding by rivers.

3.6 Preliminary Geotechnical Risk Register

The following geotechnical risks have been summarised from our Desk Study report (Ref: ESP.6566b.2743 – March 2017) and the previous assessment should be referred to for full content and context.

3.6.1 Past Coal Mining

The site is underlain by bedrock of the Upper Coal Measures, which contains several seams of coal (and bands of ironstone). The geological map indicates the conjectural outcrop of the Garw Seam to outcrop to the south and north, but at a higher elevation than the site and therefore likely to have been eroded away. Subsequent seams in the sequence such as the Gellidg, Upper and Lower Seven Feet and the Yard seam are all indicated to outcrop south of the site, dipping southward away from the site.

Reference to the Coal Authority website (CA, 2019) provides the following salient information:

- Seams outcrop to the south and north of the site, higher in the valley sides.
- Further outcrops noted to the south.
- These seams outcrop are identified as ‘Development High Risk Areas’, however, the site is not.

A Coal Authority Consultants Mining Report has also been obtained from the Coal Authority (CA) and is presented in Appendix C and indicates:

- The property is not in an area where underground mining is recorded, however, the site is indicated with be within the outcrop of the Garw Coal Seam.
- A mine entry (adit) is recorded approximately 80m to the east.

- Any ground movement from these coal workings should have stopped by now.
- The property is not within a surface area that could be affected by present underground mining.
- The property is not in an area where the Coal Authority has plans to grant a licence to remove coal using underground methods.
- The property is not in an area where a licence has been granted to remove or otherwise work coal using underground methods.
- The property is not in an area likely to be affected from any planned future underground coal mining. However, reserves of coal exist in the local area which could be worked at some time in the future.
- No notices have been given, under section 46 of the Coal Mining Subsidence Act 1991, stating that the land is at risk of subsidence.
- There may however be mine entries/additional mine entries in the local area which the Coal Authority has no knowledge of.
- The property is not within the boundary of an opencast site from which coal has been removed by opencast methods.
- The property does not lie within 200 metres of the boundary of an opencast site from which coal is being removed by opencast methods
- There are no licence requests outstanding to remove coal by opencast methods within 800 metres of the boundary
- The property is not within 800 metres of the boundary of an opencast site for which a licence to remove coal by opencast methods has been granted.
- The Coal Authority hold three mine entry (abandonment plans) for the seams below the site or interacting with the site boundary.

Based on available information, it is likely that coal seam dip south away from the site and ironstones present beneath the site, may pose a risk.

In any mining area such as this, the possibility of past unrecorded mine entries cannot never be totally discounted. Appropriate precautions should be taken during development, and any further anomalous features reported for further inspection and investigation by a geotechnical specialist.

It should be appreciated that all coal reserves, including abandoned workings are under the ownership of the Coal Authority, and their permission must be obtained before any investigation can be undertaken to intercept these features. .

3.6.2 Non Coal Including Past Ironstone Mining

We have identified information to suggest that ironstone mining may be a sub-surface hazard beneath the site with exploitation of the Ironstone present in the geological succession, common in the local area. Whilst not addressed directly by the Groundsure report, we consider the risk posed by mined Ironstones to be High.

3.6.3 Shrinkable and Swelling Soils

The Alluvial soils anticipated at shallow depth beneath the site commonly have an intermediate plasticity index and, hence, are often classified as of potential moderate volume change potential with changes in moisture content (shrinkage and swelling). Therefore, we consider that the potential for shrinkable/swelling soils is Moderate.

3.6.4 Landslips

Reference to the South Wales Landslip Survey (Conway et al, 1980) does not indicate any post-glacial landslips on or within 1km of the site, however, a number of small to large failures are noted to the south and east.

The topography surrounding the site slopes steeply at the south boundary into the site and at the north boundary down to the River Ebbw, with the site itself likely constructed on a cut/fill plateau. No obvious indications of slope movement or ground failure were noted during the walkover, however, a detailed geotechnical assessment was not required as part of this scope of works.

Based on the available evidence, we consider that the potential for landslips at the site to be Moderate.

3.6.5 Compressible Ground

Made Ground and weaker Alluvial soils that are anticipated at the site, are potentially compressible, particularly where containing organic materials are present, which could lead to significant settlement at the surface. Therefore, we consider that the potential for compressible ground at the site to be Moderate.

3.6.6 Collapsible Ground

The site has likely been filled as part of a cut/fill exercise to create a development platform and exists in an area where extensive opencast mineral extraction has occurred. Mudstone-rich colliery spoil when used as backfill can be susceptible to collapse when influenced by groundwater. The surrounding area is noted to have been extensively impacted by “disturbed ground” as a result of opencast workings and a potential for shallow groundwater within superficial deposits is also identified. Therefore, we consider that the potential for collapsible ground at the site to be Moderate.

3.6.7 Volumetrically Unstable Slag Materials

The potential for volumetrically unstable slag material to be present on the site is not considered in the environmental data report. There are a number of chemically different types of slag found on brownfield sites across the UK. Some forms of slags are volumetrically stable but, depending on their chemistry, some can be extremely unstable when hydrated, which can lead to significant heave at the surface and damage to buildings and hard surfaces. The site and surrounding area are noted to have been extensively impacted by “disturbed ground” from historic mining activities. Given the currently available information, the presence on site of slag within the shallow Made Ground cannot be discounted, and the risk from unstable slag is considered Moderate.

3.6.8 Pyritic Ground

The environmental data report does not consider the potential risk from sulphate rich or pyritic ground. Depending on its origin, the Made Ground and or Alluvial soils anticipated beneath the site may contain elevated levels of pyrite. Given the above, we consider that the potential for sulphate/pyrite attack on buried concrete would be Moderate.

3.6.9 Radon Hazard

Radon is a colourless, odourless, radioactive gas, which can pose a risk to human health. It originates in the bedrock beneath the site, where uranium and radium rich minerals are naturally present, and can move through fractures in the bedrock, and overlying superficial deposits, to collect in spaces within/beneath structures. The environmental data report obtained as part of the Desk Study indicates that the site lies in a radon affected area as defined by the Health Protection Agency, with less than 1% of properties above the action level. Given this, the risk from radon is considered Low. No radon protection measures are required.

3.6.10 Buried Unexploded Ordnance (UXO)

The environmental data report does not consider the potential risk from unexploded ordnance at the site. The site is located in a historical industrial area and these areas were routinely targeted during World War Two. Reference to UXO risk maps available on-line (Zetica, 2019) suggests that the site is located within a Low risk region with regards to the risk from buried unexploded ordnance.

A preliminary risk assessment obtained for the site supports this and indicates that whilst always prudent, a detailed assessment is not considered necessary in this instance.

3.7 Preliminary Risk Assessment

The methodology described in the Desk Study (see Appendix B) has been used to establish Plausible Pollutant Linkages (PPL) based on the Conceptual Site Model generated for the site and proposed development, and to evaluate the risks posed by those linkages, this is presented as Table 2 below.

Table 2: Preliminary Risk Evaluation & Plausible Pollutant Linkages (PPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in Made Ground on site from previous development including cut/fill plateau.	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users/Visitors	Medium – potential for chronic levels.	Likely[2]	Moderate Risk	Sampling of near-surface soils to confirm levels of total contamination present.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Likely[2]	Moderate/Low Risk	
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on a Secondary A Aquifer	Likely[2]	Moderate Risk	Sampling of near-surface soils to confirm levels of leachable contamination present.
	Leaching of soil contaminants	Impact on River Ebbw	Medium	Low Likelihood[2]	Moderate Risk	
Soil sulphate	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood[3]	Moderate Risk	Sampling of soils to confirm levels of sulphate and pH.
Asbestos	Ingestion of fibres	Demolition/ Construction Workers	Medium – potential for chronic levels	Low Likelihood[4]	Moderate Risk	Sampling of shallow soils.
Hazardous ground gas risk from on site Made Ground, and underlying alluvium.	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Likely[5]	High Risk	Install and monitor gas wells.
Radon gas	Migration into Buildings	Site Users (Full time employees)	Medium – potential for chronic levels	Low Likelhood[6]	Low Risk	Groundsure Report identifies low risk with no protection measures required.

Notes to Table 2:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001).
2. The presence of Made Ground or contamination has not yet been confirmed on site.
3. The underlying soils can potentially contain sulphates/pyrite.
4. Potential for asbestos containing materials in existing buildings and underlying Made Ground.
5. Potential source of hazardous ground gas/vapours at the site (see full desk study for further information).

4 Exploratory Investigation

4.1 Investigation Points

4.1.1 Introduction

The phased intrusive investigation was undertaken between the 11th and 20th September 2019 in accordance with BS5930:2015 and BS10175:2017 and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Appendix B). It comprised trial pitting, windowless sample boreholes, soakaway infiltration testing, gas and groundwater level monitoring.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015, BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2018, and BS EN ISO 14689:2018, along with published weathering schemes. Descriptions and depths of the strata encountered are presented on the trial pit and windowless sample records in Appendix D to Appendix E. The results of the in-situ testing and monitoring are presented in Appendix F. The investigation point positions are shown on Figure 1.

The coordinates shown on the investigation point records are approximate only and have been interpolated from recent Ordnance Survey maps.

It should be noted that subsequent to the investigation works, the planning application boundary for the site was augmented (as shown on Figure 1). Whilst the Desk Study data requests and investigation indicate the original larger boundary, the information discussed throughout this report refers to the boundary shown on Figure 1.

4.1.2 Investigation Strategy

The investigation strategy was generally designed in accordance with BS10175:2017, taking into account the additional potential for geotechnical hazards to be present.

The desk study identified a number of potential contaminant sources/geotechnical hazards at the site including:

- Potential Made Ground in the west;
- Potential past coal and ironstone mining;
- Potential landslips at the site;
- Potential collapsible ground at the site;
- Potentially shrinkable/swelling soils across the site;
- Possible expansive slag on the site;
- Possible pyritic ground at the site.

Therefore, the investigation points were selected to maximise the information obtained on these hazards, as well as obtaining a general overview of the general ground conditions present. The investigation point positions are shown on Figure 2.

4.1.3 Trial Pits

8no. trial pits (TP1 to TP8) were excavated across the site on 11th and 12th September 2019 using a wheeled excavator. The trial pits were excavated to depths of between 2.2 and 2.9m. The trial pit records are presented as Appendix D, and their positions are shown on Figure 2.

Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records. On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket, and the Topsoil reinstated on the surface.

4.1.4 Windowless Sampling

8no. windowless sample drillholes (WS1 to WS8) were constructed on 19th & 20th September 2019 to depths between 1 and 2.5m. The borehole records are presented as Appendix E, and their positions are shown on Figure 2.

A hydraulically powered rig was used to drive plastic lined sampling tubes into the ground, with the soil recovered within the tubes, which are then split to allow sampling and logging. Disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes, as shown on the borehole records. The windowless sampling provided generally good recovery to the depth of refusal.

At the commencement of each borehole, a square of the grass landscaping was cut and a service inspection pit excavated by hand to a depth of 1.2m.

Standard Penetration Tests (SPT) were carried out using a solid cone in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the coarse-grained soils encountered in the borehole and to provide a correlated assessment of the likely undrained shear strength of fine-grained soils using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field.

On completion, the boreholes were either backfilled with arisings/gravel, with the concrete/tarmacadam reinstated at the surface or, monitoring instrumentation was installed in the boreholes as detailed in Section 4.2.

4.1.5 Soakaway Infiltration Testing

Soakaway infiltration tests were undertaken in general accordance with BRE Digest 365 (2016) in 3no. selected trial pits across the site (TP1, TP2 and TP3). The results of the infiltration testing, and the calculated infiltration rates, are presented in Appendix F. The positions of the test pits are shown on Figure 2. At each position, the test pit was excavated to depth which was anticipated to be a possible depth for the soakaway given the ground conditions identified and taking into account any proposed change in ground levels. Clean water was added from a large capacity bowser and the water level monitored as it percolated into the soil

The infiltration rate was calculated from the time taken for the water to fall between the 75% and 25% full level. Where insufficient time was available for the water level to fall to the 25% full level, but a significant drop in water level was recorded, the infiltration rate can be estimated by extrapolating the test results. However, where the water level only dropped marginally during the available test period (e.g. not as far as the 75% full level), we consider that there is insufficient data to allow a valid extrapolation with any confidence and no infiltration rate can be estimated.

There was insufficient time available to repeat the test (a total of two/three fills) in Test Pit TP3 and due to the low infiltration rate, insufficient time was available to repeat the test in Test Pits TP1, TP2.

Fencing was erected around the test pits during the testing to protect site workers/ the general public. On completion of the testing in each pit, any remaining water was removed from the test pit and it was backfilled with the excavated arisings.

4.2 Instrumentation

4.2.1 Gas Well Installations

A 50mm diameter monitoring well was installed in selected boreholes in accordance with BS8576:2013 in order to allow monitoring of hazardous ground gases. The wells, comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seals above the response zone, and a lockable vandal proof cover, were installed as detailed on the borehole records and summarised in Table 3 below.

Table 3: *Gas Well Installations*

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum	Rationale
WS02	19/09/2019	0.5 – 1.6m	Estuarine Alluvium	2
WS05	20/09/2019	0.5 – 1.4m	Made Ground	3
WS07	20/09/2019	0.5 – 1.9m	Made Ground	3
WS08	20/09/2019	0.5 – 2.5m	Made Ground/ Estuarine Alluvium	2/3

Notes to Table 3
1. Details of each monitoring well are presented on the individual borehole records (Appendix E).
2. Well installed in organic Estuarine Alluvium.
3. Well installed in artificial Made Ground.

4.2.2 Ground Gas and Groundwater Level Monitoring

To date, the installed wells have been monitored for levels of groundwater and ground gas on 1no. occasions with a further 5no. visits scheduled. During each visit, Gas Data LMSxi G3.18e portable monitoring equipment was used to measures levels of the following ground gases within the airspace in the wells and the flow rates from the wells:

- Methane - total and percentage of Lower Explosive limit (LEL);
- Carbon dioxide;
- Oxygen; and
- Hydrogen sulphide.

The percentage of nitrogen is also calculated by difference. The equipment uses infra-red methane (CH_4) and carbon dioxide (CO_2) detectors, coupled with pressure (barometric and well), temperature and flow sensors. A photo-ionisation detector (PID) with a 10.6eV lamp was used during the monitoring to measure the levels of volatile organic compounds present in the well.

Following measurement of gas levels and flow rates, the well cap was removed, and groundwater levels were measured using a dip meter from the site surface. Monitoring is ongoing and will be reported as an addendum report upon completion.

4.3 Sampling Strategy

4.3.1 Soil Sampling

Soil samples were collected from the exploratory holes as discussed in the previous sections. The sampling procedures were selected on the basis of the suitability for the laboratory testing proposed. The sampling was focused on the contaminant sources identified in the desk study. Further soil samples were also taken randomly from non-targeted areas to provide a general indication of the variability in concentrations of possible diffuse source contamination across the site as a whole.

Environmental samples (denoted as ES on the exploratory holes records) were collected for possible geo-environmental laboratory testing and generally comprised a plastic tub, an amber glass jar and an amber glass vial. The sample containers provided clean by the testing laboratory appropriate for the proposed testing to be scheduled. Immediately after collection the samples were placed in sealed cool boxes with ice packs where they remained during storage and transport to the laboratory.

Samples for logging and geotechnical laboratory testing purposes were collected at regular intervals within the exploratory holes.

4.3.2 Soil Sample Quality

Samples of soil recovered from investigations are classified as Classes 1 to 5 in terms of quality and depend on the investigation and sampling method, the particle size of the strata sampled, and the presence of groundwater. Class 1 and 2 samples are those in which there has been no or only slight disturbance of the soil structure, with moisture contents and void ratios being similar to the in-situ soil. Class 3 and 4 samples contain all the constituents of the in-situ soil in their original proportions, and the soil has retained its original moisture content, but the structure of the soil has been disturbed. In Class 5 samples, the soil structure and original layering cannot be identified, and the water content may have changed from that in-situ. The category and class of samples are discussed further in BS EN ISO 22476:2006, EN 1997-2:2007 and BS5930:2015.

In general terms, disturbed samples recovered from trial pits (bulk bags and small tubs) are classed as Class 3 (if dry), Class 4 (fine soil below the water table), or Class 5 (coarse soils from beneath the water table). Disturbed sampling (bulk bags and small tubs) from boreholes is considered Class 3 (if dry). The samples recovered within the liner in windowless sampling are generally Class 3 in fine-grained soils with good recovery, becoming Class 2 in favourable circumstances, but Class 3 or 4 in coarse-grained soils.

4.4 Evidence of Site Hazards Found During Site Works

With regard to potential hazards identified in the desk study and Preliminary Risk Assessment, the following observations were made.

4.4.1 Site Stability

No evidence of geotechnical hazards was identified in the exploratory holes.

4.4.2 Site Evidence of Contamination

No direct visual/olfactory evidence of contamination was identified in the exploratory holes. However, Made Ground was present across the site which can contain elevated levels of contaminants such as metals and polyaromatic hydrocarbon (PAH) compounds.

4.5 Geotechnical Laboratory Testing

Geotechnical laboratory testing was undertaken on samples from the suitable quality classes recovered from the exploratory holes in order to obtain information on the geotechnical properties on the soils beneath the site.

The following tests were undertaken by a UKAS accredited laboratory on samples selected by ESP in accordance with the methodologies presented in BS1377:1990. The results are presented in Appendix G.

- Particle size analysis.
- Atterberg limits

Selected samples were also analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005). Due to the potential presence of pyrite in the soils, these samples were also analysed to determine the levels of total sulphur, acid soluble sulphate in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005). The results of the sulphate testing are included with the geo-environmental test results in Appendix H.

4.6 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil and leachate generated from shallow soils. The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment.

To allow an assessment of the potential chronic risks posed to human health samples of the near-surface natural soils have been analysed for the contaminants identified in the desk study, plus other determinands typically present on brownfield sites in the UK.

The general suite of geo-environmental laboratory testing undertaken comprised:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, chromium VI, copper, lead, mercury, nickel, selenium, vanadium, zinc;
- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols;
- Total cyanide, asbestos qualitative screen (presence or absence);
- Soil organic content, pH value.

The geo-environmental soil test results are presented in Appendix H.

5 Development of the Revised Conceptual Model

5.1 Conceptual Ground Model - Geology

The exploratory holes have identified the site to be generally underlain by Topsoil, significant areas of Made Ground and variable Alluvial deposits. These strata are discussed in more detail in the following sections, with the ground conditions separated into north and south portions of the site.

North Portion (WS04 to WSO8 & TP3 to TP05 and TP07 to TPO8)

Made Ground (associated with demolition): encountered to a depths of between 0.35m and 2.2m as a firm grey to brown gravelly clay with frequent gravel, brick and cobbles.

Alluvium: encountered beneath the Topsoil and Made Ground to a maximum depth of 2.9m as a grey mottled brown-orange, clayey, sandy gravel and cobbles.

South Portion (WS01 to WS03 and TP01, TP02 & TP06)

Placed Topsoil: encountered to a maximum depth of 0.1m to 0.2m as a brown gravelly slightly sandy clay with occasional anthropogenic material;

Alluvium: encountered beneath the Topsoil to a maximum depth of 2.7m as a grey mottled brown-orange, clayey, sandy gravel and cobbles.

Material Properties

Field SPT N-values within the Made Ground varied between 9 and 13. The field SPT results within the Alluvium where recorded between 33 and 50, however, these values are likely to have been where cobbles and boulders were present.

5.2 Conceptual Ground Model - Hydrogeology

5.2.1 Groundwater Bodies

Groundwater during the works, was only identified in the base of TP1 and not during the remaining exploratory holes. Based on the above findings and the Conceptual Ground Model, we consider that the main groundwater body beneath the site is within Coal Measures, however, perched water may also be present within the Made Ground and Alluvial soils.

An update on monitored (standing) groundwater levels recorded as part of the ongoing monitoring regime will be reported within our monitoring addendum report.

5.2.2 Hydraulic Gradient

Monitoring of groundwater levels is ongoing and will be addressed as part of our addendum report, however, based on the site setting and available information, we consider that the hydraulic gradient beneath the site is likely to be towards the south east.

5.3 Site Instability

During the excavation of the trial pits, spalling of the pit walls was noted within the majority of the trial pits.

Whilst a formal slope assessment was noted required, observations did not indicate any obvious evidence of failure in the steep slope that forms the west boundary of the site.

5.4 Chronic Risks to Human Health – Generic Assessment of Risks

5.4.1 Assessment Methodology

The long-term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents. In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

5.4.2 Assessment Criteria

In 2013, CL: AIRE published the Category 4 Screening Levels (C4SL – CL: AIRE, 2013) for use in Part 2A determinations. The C4SL are designed to be more pragmatic, but still strongly precautionary, assessment criteria compared to the previous assessment criteria (SGV – see below) used to assess chronic human health risks. The C4SL have been calculated for a limited number of contaminants at this stage, and range of land uses including residential, commercial and public open space, but are based on a 'low level' of risk rather than the 'minimal level' of risk adopted by the Environment Agency in preparing their Soil Guideline Values (SGV). The C4SL have also only been published for a limited number of contaminants commonly identified in contaminated land risk assessments at present (arsenic, cadmium, chromium VI, lead, benzene, benzo[a]pyrene). However, the C4SL have been published for a range of land uses, including residential, commercial, allotments and two types of public open space.

The C4SL are designed for use in deciding whether land is suitable for use and definitely not contaminated, and DEFRA and the Welsh Government have recommended that they be used in assessing human health risks during the planning regime (i.e. as part of standard development investigations). The Welsh Local Government Association and Natural Resources Wales (WLGA/NRW) have confirmed that, '*where the site conditions are applicable to the land use scenarios adopted in their calculation, the C4SL levels can be used as screening tools*' for development site risk assessments (WLGA/NRW, 2017). The C4SL have also been accepted by the NHBC for use as generic screening levels on residential developments in England and Wales (NHBC, 2014). Given this, where available and applicable, the C4SL have been adopted as the Generic Assessment Criteria in this assessment.

Where no C4SL is currently available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM)

(Nathanail et al, 2015) have been adopted. These assessment criteria adopt updated toxicological data and exposure models, and the same 'minimal level' of risk as the SGV (i.e. unlike the C4SL). The S4ULs have been published for a large number of contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e. including public open space scenarios.

Where no C4SL or S4UL is available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) – note several SGV have been withdrawn since originally published. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments – and not public open space).

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL: AIRE and the Environmental Industries Commission (CL: AIRE/EIC, 2010) have been adopted. These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e. not public open space). Details of the Generic Assessment Criteria (GAC) adopted for each contaminant are presented on the assessment tables in the following section. The proposed development comprises conventional residential properties with private gardens. Therefore, the GAC appropriate for the residential land use with plant uptake have been adopted in this assessment. The GAC for most organic compounds are dependent on the organic content of the soil. Analysis has shown that the soil organic content in the soils analysed ranged from 2.6 to 17%. Therefore, for the purposes of this assessment, GAC for a soil organic content of 1% has been adopted. This again is considered a conservative approach for the majority of the soils at the site.

5.4.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants have been considered across the site as one averaging area. If any exceedances are identified, a statistical analysis based on particular averaging areas may be undertaken to further assess the risks. The results of the Generic Quantitative Risk Assessment for the proposed development are presented in Table 4 below. It should be appreciated that if the development were to change, the following assessment should be reviewed.

Table 4: Generic Assessment of Human Health Risks

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	5.3 – 14 mg/kg	37mg/kg	C4SL[2]	None of 10
Barium[6]	38 – 380 mg/kg	1,300mg/kg	CL:AIRE/EIC[5]	None of 10
Beryllium	0.4 – 2.5 mg/kg	1.7mg/kg	S4UL[4]	2 of 10
Boron	0.4 – 1.9 mg/kg	290mg/kg	S4UL[4]	None of 10
Cadmium	<0.01 – 0.4 mg/kg	26mg/kg	C4SL[2]	None of 10
Chromium (total)[7]	7.1 – 16 mg/kg	910mg/kg	S4UL[4]	None of 10
Chromium (hexavalent)	< 1.0 mg/kg	21mg/kg	C4SL[2]	None of 10
Copper	12 – 25 mg/kg	2,400mg/kg	S4UL[4]	None of 10
Lead	13 – 41 mg/kg	200mg/kg	C4SL[2]	None of 10
Mercury[8]	<0.05 – 0.06 mg/kg	40mg/kg	S4UL[4]	None of 10
Nickel	5.3 – 15 mg/kg	130mg/kg	S4UL[4]	None of 10
Selenium	0.8 – 2.7 mg/kg	250mg/kg	S4UL[4]	None of 10
Vanadium	13 – 46 mg/kg	410mg/kg	S4UL[4]	None of 10
Zinc	26 – 78 mg/kg	3,700mg/kg	S4UL[4]	None of 10
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03mg/kg	210mg/kg	S4UL[4,9]	None of 10
Acenaphthylene	<0.03mg/kg	170mg/kg	S4UL[4,9]	None of 10
Anthracene	<0.03 – 0.06 mg/kg	2,400mg/kg	S4UL[4,9]	None of 10
Benzo(a)anthracene	<0.03 – 0.13 mg/kg	7.2mg/kg	S4UL[4,9]	None of 10
Benzo(a)pyrene	<0.03 – 0.11 mg/kg	5mg/kg	C4SL[2,9]	None of 10
Benzo(b)fluoranthene	<0.03 – .015 mg/kg	2.6mg/kg	S4UL[4,9]	None of 10

Benzo(ghi)perylene	<0.03 - 0.08mg/kg	320mg/kg	S4UL[4,9]	None of 10
Benzo(k)fluoranthene	<0.03 – 0.11mg/kg	77mg/kg	S4UL[4,9]	None of 10
Chrysene	<0.03 – 0.19mg/kg	15mg/kg	S4UL[4,9]	None of 10
Dibenzo(a,h)anthracene	<0.03mg/kg	0.24mg/kg	S4UL[4,9]	None of 10
Fluoranthene	<0.03 – 0.36mg/kg	280mg/kg	S4UL[4,9]	None of 10
Fluorene	<0.03mg/kg	170mg/kg	S4UL[4,9]	None of 10
Indeno(123-cd) pyrene	<0.03 – 0.07 mg/kg	27mg/kg	S4UL[4,9]	None of 10
Naphthalene	<0.03mg/kg	2.3mg/kg	S4UL[4,9]	None of 10
Phenanthrene	<0.03 – 0.26mg/kg	95mg/kg	S4UL[4,9]	None of 10
Pyrene	<0.03 – 0.26mg/kg	620mg/kg	S4UL[4,9]	None of 10
Other Organic Compounds				
Phenol	<0.03 – 0.5 mg/kg	280mg/kg	S4UL[4,9]	None of 10

Notes to Table 4:

1. Assessment for residential land use with home-grown produce uptake (apart from barium – see Note 6 below).
2. C4SL: Category 4 Screening Level, published by CL: AIRE.
3. SGV: Soil Guideline Value published by Environment Agency.
4. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved.
5. CL: AIRE/EIC GAC published by CL: AIRE and Environment Industries Commission.
6. GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers.
7. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
8. GAC for inorganic mercury adopted.
9. GAC for organic compounds based on 1% soil organic content.
10. Laboratory results presented in Appendix H.

The testing to date has indicated the presence of Beryllium in exceedance of the guideline value in one samples and at the guideline value in another. Both of these samples were obtained from WS08 in the north portion of the site.

5.4.4 Asbestos

No asbestos was detected in the sample submitted to the laboratory for testing.

5.5 New Planting

Soil contamination can have a deleterious impact on the health of new plants. Such 'phytotoxic' effects can include inhibited growth, nutrient deficiencies and discolouration of vegetation. However, the potential impact on planting is difficult to quantify partly due to differing abilities of various plants to tolerate different soil conditions.

Contaminants are taken up by plants in a number of ways, the principal mechanism being via root uptake, but also including adsorption to roots. The impact on contaminants on plant growth depends on a number of factors, including the plant species, the soil type, the soil pH, the availability of the contaminant, and the impact of other external stresses on the plant such as drought.

The British Standard for the provision of Topsoil (BS3882:2007) provides guidance on acceptable levels of copper, nickel and zinc within a growing medium, which vary with soil pH value. ICRCL 70/90 (1990) discussing the restoration of metalliferous mining sites also provides 'threshold trigger levels' for a number of metals and fluoride, below which there should be no impact on plant growth. Finally, MAFF (1998) provides assessment criteria for the assessment of the impact of a number of metals on the growth of plants. For the purposes of this assessment, we have adopted the BS3882 guidance values in the first instance, followed by the MAFF published guidelines, and finally the ICRCL 'trigger values.

The assessment along with the assessment criteria adopted are presented in Table 5 below:

Table 5: Assessment of Risks to Planting

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	5.3 – 14mg/kg	250mg/kg	MAFF[1]	None of 10
Cadmium	<0.01 – 0.4mg/kg	3mg/kg	ICRCL[2]	None of 10
Chromium (total)[6]	7.1 – 16mg/kg	400mg/kg	MAFF[1]	None of 10
Copper	12 – 25mg/kg	200mg/kg	BS3882[3]	None of 10
Lead	13 – 41mg/kg	300mg/kg	MAFF[1]	None of 10
Mercury	<0.05 – 0.06mg/kg	1mg/kg	MAFF[1]	None of 10
Nickel	5.3 – 15mg/kg	75mg/kg	BS3882[3]	None of 10
Zinc	26 – 78mg/kg	300mg/kg	BS3882[3]	None of 10

Notes to Table 5

1. MAFF: Ministry of Agriculture, Fisheries and Food guideline for maximum permissible concentrations in agricultural soils.
2. ICRCL: ICRCL 70/90.
3. BS3882:2007 – values dependent on soil pH values.
4. Laboratory test results presented in H.

5.6 Hazardous Ground Gas

5.6.1 Degradation of Organic Materials

Gas monitoring wells have been installed at the site and the results will be provided as an addendum upon completion, however, it should be noted that monitoring to date has indicated levels of methane below the limit of detection, levels of carbon dioxide up to 4.0% and gas flow rates up to 2.0L/hr. It is likely some ground gas protection measures will be required.

5.6.2 Radon

As previously discussed, no radon protection is required for the development.

5.7 Sulphate Attack

The assessment of the concrete protection against sulphate attack has been undertaken in accordance with BRE SD1 (2005).

5.7.1 Classification of Site

Due to the presence of Made Ground and the previous development history of the site, we consider that it should be considered as 'brownfield' in terms of concrete classification.

5.7.2 Groundwater Setting

Groundwater was encountered in the installed wells at depths of between 0.9m and 1.5m. This is likely to be close to the depth to which buried concrete will be placed. Therefore, groundwater has been considered as mobile in this assessment.

5.7.3 Sulphate Levels

Laboratory test results indicate the levels of water-soluble sulphate (as SO_4) in the Made Ground soils to be between 29 and 1800mg/l. As levels of water-soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. Levels of acid soluble sulphate varied between 0.01 and 1.3% and total sulphur between <0.01 and 0.53%.

From these results, the calculated levels of total potential sulphate are between 0.03 and 1.59%, and oxidisable sulphides are between 0.01 and 0.29%. As the level of oxidisable sulphides does not exceed 0.3%, pyrite is unlikely to be present.

pH values in the Made Ground varied between 7.3 and 9.7, indicating alkaline soil conditions to exist. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g. hydrochloric and nitric acids).

5.7.4 Foundation Concrete Design:

Using the above results, we consider that the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	1800mg/l;
Total potential sulphate:	1.59%;
pH value:	7.3

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

A historical Desk Study has identified that the site has been previously developed with residential properties since the early 1970s. Potentially contaminating former features of the site and surrounding area include the previous development, a tramway at the crest of the west boundary and earthworks which have been recorded in the centre of the site and likely associated with the site development.

Laboratory testing has identified the presence of Beryllium in soils. Whilst Beryllium can occur naturally through the breakdown of rocks and soils, it is mostly commonly encountered at brownfield sites as a result of the combustion of coal (i.e. burning).

The risks evaluated at the desk study stage of this report (Table 3, Section 3.6) have been updated and revised in Table 6 following information learned from the exploratory works and results of monitoring and laboratory testing.

6.2 Revised Risk Evaluation & Relevant Pollutant Linkages

As discussed in detail within Section 3.2.1, the methodology set out in CIRIA C552 (2001) has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

The risks evaluated at the desk study stage of this report (Table 2, Section 3.2.2) have been updated and revised in Table 6 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 6: Revised Risk Evaluation & Relevant Pollutant Linkages (RPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in Made Ground on site from previous development including cut/fill plateau.	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users/Visitors	Medium – potential for chronic levels.	Likely[2]	Moderate Risk	Generally low levels, however, presence of Beryllium has been recorded which will require further consideration.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Low Likelihood[2]	Moderate/Low Risk	
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on a Secondary A Aquifer	Low Likelihood[2]	Moderate/Low Risk	No point source contaminants identified and generally low levels recorded in laboratory results.
	Leaching of soil contaminants	Impact on River Ebbw	Medium	Low Likelihood[2]	Moderate/Low Risk	
Soil sulphate	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood[3]	Moderate Risk	Advanced concrete class required.
Asbestos	Ingestion of fibres	Demolition/ Construction Workers	Medium – potential for chronic levels	Low Likelihood	Moderate/Low Risk	No asbestos detected in samples submitted to laboratory.
Hazardous ground gas risk from on site Made Ground, and underlying alluvium.	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Likely[4]	High Risk	Continue monitoring of gas wells.
Radon gas	Migration into Buildings	Site Users (Full time employees)	Medium – potential for chronic levels	Low Likelihood	Low Risk	Groundsure Report identifies low risk with no protection measures required.

Notes to Table 4:

1. Table 6 updates Table 3 in Section 3.0.
2. General low levels of contaminants have been identified in laboratory testing to date, however, levels of Beryllium will need further consideration.
3. pH and sulphate levels will require further consideration.
4. Ground gas monitoring is ongoing, however, presence of Carbon Dioxide and positive flows have been recorded.

7 Remedial Strategy for Contamination Risks

The following recommendations are based on interpretations made from the relatively limited site investigation data obtained to-date, and do not form the full Options Appraisal stage of CLR11. If at any stage of the construction works, contamination or a potential for such contamination is identified that is different to that presented within this report, all of the following should be reviewed and the advice of a geo-environmental specialist sought immediately.

7.1 Risks to Health

7.1.1 Asbestos

No evidence of asbestos was detected within the samples tested from the site. However, as the site has been previously developed the presence of asbestos in the shallow Made Ground and any so-far unidentified backfilled pits cannot be discounted. We have assumed that an asbestos survey and any necessary removal works were undertaken prior to the demolition of the former buildings.

If any asbestos is identified during development, the advice of a suitable qualified asbestos specialist should be sought and the following sections assume risks from asbestos have been mitigated.

7.1.2 Site End Users

The undertaken to date have identified generally low levels of contaminants, however, occurrences of beryllium, elevated above the generic assessment criteria have been recorded.

Due to the limited investigation undertaken to date (based on site size) and the brownfield nature of the site, it is considered that there may be an unacceptable risk to end users.

Once the development layout is finalised, additional soil sampling could be undertaken in any garden, landscaping and external areas to enable a more detailed risk assessment based on a larger sample population. It should be noted that supplementary testing may only confirm the requirement for a clean capping layer.

Alternatively and based on the available information, appropriate measures would need to be taken to break the pollutant linkage and mitigate these risks in areas of soft surfacing (e.g. gardens, public landscaping etc.) such as a clean imported 600mm capping. In areas of hard surfacing (e.g. beneath structures, driveways, roads and other hardstanding), the hard surface would break the pollutant linkage and no further risk mitigation would be required in terms of risks to human health, however, discussions would need to be held with the local regulator to determine the thickness of clean fill required below areas of hardstanding.

7.1.3 New Service Connections

The current water industry guidance for the suitability of pipe materials on potentially contaminated sites (Blackmore et al, 2010) has onerous requirements and it is likely/possible, based on this guidance, that the levels of contaminants on site may prevent the use of plastic pipework. We recommend that enquiries are made to the local water authority to confirm their requirements for underground service materials for this development.

7.1.4 Risk to Construction and Maintenance Workers

Short term (acute) risks to construction and maintenance workers are generally poorly understood within the industry, certainly when compared to the volume of research undertaken on long term risks. However, we anticipate that the levels of contamination at the site are not likely to pose a severe acute risk to construction workers or future maintenance workers. Ground workers would need to undertake their own assessment of the risks to their workers.

Notwithstanding the above, we recommend that construction workers adopt careful handling of the potential contaminants and good standards of personal hygiene should be adopted to reduce the risk of possible ingestion and skin contact should any hotspots be encountered. The contractor should comply with the appropriate current Health and Safety at work legislation.

7.1.5 General Public/Neighbouring Properties

We do not anticipate any significant risks to the general public from the development of the site. However, careful dust control measures should be adopted during construction to minimise the risk (and nuisance) to the general public and neighbouring residents.

7.2 Risks to Controlled Waters

No specific assessment of the risks to controlled waters has been undertaken to date. However, the following points are considered salient.

- The proposed development comprises a conventional residential estate which will include areas of car parking which are anticipated to be hard surfaced – surface drainage from these areas could contain leached oils and fuels from vehicle spills and leaks.
- Some elevated levels of contaminants have been encountered.
- Soakaways are being considered for the development.
- The site is underlain by fine grained alluvial soils, and weathered bedrock which contains a high fine-grained fraction in its upper layers
- The bedrock beneath the site is classified as a Secondary A aquifer.
- The Ebbw River lies 10m east at its closest point.

Given the above, we consider that the overall risk to controlled waters from the development of the site is likely to be low.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

As discussed previously 4no. gas wells have been installed at the site and are being monitored. The levels of hazardous gas encountered during monitoring to date ranged between:

- methane: below detection;
- carbon dioxide up to 4.0%;
- Gas flow rates up to 2.0L/hr.

On completion of the remaining scheduled gas monitoring visits, we will prepare a gas assessment addendum report, detailing the monitoring results, the recommended characteristic situation and any gas protection required, assessed in accordance with BS8485:2015.

Risk to the Development – Radon

As discussed previously, the Preliminary Risk Assessment has indicated that no radon protection is required.

Risk to Construction and Maintenance Workers

The risk posed to workers by ground gas will be considered as part of our addendum. However, notwithstanding this, Carbon dioxide is a particular risk in Made Ground materials as it is commonly present and as it is heavier than air, it can displace it at the base of excavations, which can then lead to workers being at risk from asphyxiation. The presence of elevated levels of carbon dioxide in the Made Ground could pose a risk to construction workers, and lead to asphyxiation in confined spaces. All excavations should be treated as confined spaces and suitable precautions taken prior to man entry.

7.4 Risks to Property

7.4.1 Spontaneous Combustion

No evidence of combustible materials has been identified in the shallow soils. Therefore, the risk from spontaneous combustion is considered to be low. As the site has previously been developed, if during development any ground conditions are encountered that may indicate a potential for spontaneous combustion (coal, spoil etc.) then the advice of a suitable qualified specialist should be sought.

7.4.2 Sulphate Attack on Buried Concrete

The following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	1800mg/l;
Total potential sulphate:	1.59%;
pH value:	7.3

Based on these characteristic values, we consider that the site would be classified as Design Sulphate Class DS-4 and Aggressive Chemical Environment for Concrete Class AC-4, allowing for mobile groundwater.

7.5 Risks to New Planting

As discussed in Section 5.7, analysis of the shallow soils has indicated no levels of contaminants above the respective assessment criteria for general new planting. However, some species of plant have particular requirements and limitations and a landscaping specialist should be consulted with regards to future planting.

7.6 Re-Use of Materials/Disposal of Excess Arisings

7.6.1 General Comments on Re-use/Disposal

All soils or other materials excavated from any site are generally classified as waste under the Waste Framework Directive (European Union, 2008) and their re-use is controlled by this legislation.

If the soils are to be re-used on site (e.g. within the red-line planning boundary), provided that they are 'uncontaminated' or other naturally occurring deposits and they are certain to be used for the purposes of construction in their natural state on the site from which they are excavated, they may be excluded from waste regulation (Duckworth, 2011). A Materials Management Plan (MMP) may be required – further guidance can be provided by this office once proposals have been finalised. However, if they are man-made or contaminated materials, their use on the site may be limited.

If the soils are to be removed from site, they are automatically classified as waste, and they may only be:

- Disposed at a licensed landfill;
- Disposed at a licensed, permitted soil treatment centre; or
- Removed to a Receiver Site for beneficial re-use.

In Scenarios 1 and 2, the materials must be transferred by a licensed waste carrier and the waste producer (the developer) must ensure that the destination landfill or treatment centre is a legitimate operation (e.g. by requesting a copy of the Environmental Permit before releasing the soils). Prior to removal from site, the excavated arisings would need to be classified as either 'hazardous' or 'non-hazardous' waste based on the hazard that they pose– a WM3 assessment (note that this is a different assessment to the risk assessments reported on in earlier sections of this report). This can commonly be undertaken on the results of soils testing undertaken during the investigation, although further sampling and testing may be required. Only once the soils have been classified under the WM3 assessment, would Waste Acceptability Criteria (WAC) testing then be required to determine the type of landfill in which the arisings could be disposed in Scenario 1. Further testing and assessment may also be required by the soil treatment centre in Scenario 2.

In Scenario 3, management of soils could be undertaken via an Environmental Permit or Exemption. However, these can take time and are costly to arrange. Therefore, in certain circumstances, it is permissible to use the protocols laid down in the CL:AIRE Definition of Waste,

Development Industry Code of Practice (DoWCoP, Duckworth, 2011) to classify the arisings and put a management plan in place to control the use. This involves approval of the proposals by a Qualified Person and is generally more efficient (in terms of time and cost) to implement.

Further guidance on the legislative requirements of the re-use/disposal of materials generated by the development can be provided by this office once the development proposals have been finalised.

7.6.2 Imported Materials

Any soils or materials to be imported to site (including Topsoil) should be certified clean and inert, and suitable for use. An appropriate number of samples (depending on the volume of soils imported) should be analysed for an appropriate suite of contaminants, and verification certificates should be provided. Further guidance can be provided by this office if required.

8 Geotechnical Comments

8.1 Site Preparation and Earthworks

8.1.1 Unexploded Ordnance

As discussed in the desk study (Appendix B), maps published online (Zetica, 2019) indicate that the site is within an area where further consideration of UXO risk, whilst prudent, is not considered necessary.

8.1.2 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed/Himalayan Balsam etc. was identified on the site during the site works, however, the works were undertaken during the winter months and this should be confirmed by a specialist during the growth season.

8.1.3 Existing Foundations and Services

The site has been previously been developed as a residential development comprising flats and assisted living and old foundations and underground structures are anticipated beneath the site.

Any sub-structures identified during development should be grubbed up within the zone of influence of the development as part of the site preparation works.

8.1.4 New Services

For new services, flexible pipework and connections should be provided as a safeguard against potential settlements. Consideration could be given to increasing the gradients on sewage connections to mitigate against possible settlements.

8.1.5 Earthworks

We have not been advised that the development requires any significant earthworks. However, the west boundary of the site slopes steeply into the site and the east boundary adjoins the River Ebbw.

Any permanent cuttings or embankment surcharges associated with earthworks or landscaping within the site should be kept to a minimum to avoid any possible adverse effects on the existing stability of the site.

Any proposed changes to the topography or encroachment on the toe of the west slope or crest of the east slope should reviewed by a geotechnical engineer and if necessary subject to a slope stability assessment.

8.2 Geotechnical Risk Register

8.2.1 Updated Geotechnical Risk Register

Following the exploratory investigation, the following potential geotechnical hazards are considered to remain at, or have been reclassified at the site:

- Coal and ironstone mining;
- Compressible ground;
- Slope stability;

8.2.2 Coal Mining Hazard

The site is noted to be located within an outcrop of the Garw Coal Seam, which is recorded to outcrop to the north, east and west of the site. Due to the topography of the site and local area, it is possible that the Garw seam has been eroded, however, the stratigraphy will need to be proven to determine if the Garw is present/absent. In addition to this, a number of Ironstone bands are recorded in vertical succession to the Garw and may also be present beneath the site.

If present, these features, pose a subsidence risk to future development, therefore, we recommend further intrusive investigation to further define the risk. We recommended a series of initial rotary boreholes are undertaken to a nominal depth of 40m to confirm the geological succession.

Should the recommended investigation works identify shallow historic mine workings, it may be necessary to undertake a more detailed mining investigation and may still result in the requirement for ground stabilisation to reduce the mining hazard and subsidence risks.

8.2.3 Compressible Ground

The Made Ground and alluvial soils beneath the site are potentially compressible, particularly where containing organic materials, this could lead to significant settlement at the surface. Where structures are proposed, there is a potential for differential settlement and given the above, we consider that the potential for compressible ground at the site to be Moderate.

It is likely that windowless samples have terminated on cobbles/boulders within the alluvium and the in-situ strengths recorded are unlikely to be representative of the full alluvial sequence. It will be necessary to undertake boreholes to prove the thickness and strengths of this strata.

8.2.4 Slope Stability

We have not been advised that the development requires any significant earthworks. However, the west boundary of the site slopes steeply into the site and the east boundary adjoins the River Ebbw. Any permanent cuttings or embankment surcharges associated with earthworks or landscaping within the site should be kept to a minimum to avoid any possible adverse effects on the existing stability of the site.

Any permanent cuttings or embankment surcharges associated with earthworks or landscaping within the site should be kept to a minimum to avoid any possible adverse effects on the existing stability of the site. Any proposed changes to the topography should reviewed by a geotechnical engineer and if necessary, subject to a slope stability assessment.

8.3 Preliminary Foundation Design and Construction

A risk from shallow coal and ironstone seams and potentially variable alluvial soils has been identified and the recommendations below should be considered preliminary. Once this risk has been established, the determination foundation solutions and presumed bearing pressures can be determined.

We understand that the site is being considered for potential development for residential purposes and the comments and recommendations in this report assume that the development will involve the construction of typical two-storey structures of conventional load-bearing brickwork construction.

North Portion

On the basis of the available investigation information, we consider that well reinforced mass concrete spread foundations could be used at the site, constructed in the natural coarse alluvium deposits, encountered from depths of between 1m and 2.0m in the north portion. Presumed bearing pressures should be determined upon completion of the supplementary investigation. Alternatively, once in-situ strengths and potential for settlement are identified through the recommended deeper boreholes, consideration could be given to the use of raft foundations.

For all spread foundation options, the formations should be cleaned, and subsequently inspected by a suitably qualified engineer prior to placing concrete. Should any soft, compressible or otherwise unsuitable materials be encountered they should be removed and replaced by lean mix concrete or suitable compacted granular material.

South Portion

On the basis of the available investigation information, we consider that well reinforced mass concrete spread foundations could be used at the site, constructed in the natural coarse alluvium deposits, encountered from depths of between 0.3m and 0.4m in the south portion. Presumed bearing pressures should be determined upon completion of the supplementary investigation. Alternatively, once in-situ strengths and potential for settlement are identified through the recommended deeper boreholes, consideration could be given to the use of raft foundations.

8.4 Floor Slab Foundations

Due to the presence of over 600mm of Made Ground and shallow soft compressible soils at the site, we consider that ground bearing floor slabs would not be suitable for the development, and floor slabs should be suspended or incorporated into the raft design. Floor slabs will also have to allow for inclusion of ground gas protection measures, which will be recommended upon completion of the monitoring regime.

8.5 Pavement Design

We understand that vehicle access roads and areas hardstanding are proposed at the site. California Bearing Ratio (CBR) tests have not been carried out at the site, but based on

experience and published guidelines, a CBR value of <2% is considered appropriate for preliminary design purposes, for the near surface Made Ground, with higher values likely to be realised in the deeper alluvial deposits and may be improved in shallower soils through an excavate and replace exercise. Actual design values should be determined for designated areas as required. The near surface fine grained natural soils are not considered to be frost susceptible.

8.6 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators. Old foundations will require higher capacity machines for their removal.

For shallow excavations where there is no danger to life, support of excavation sides is unlikely to be necessary. Should any indication of excavation instability be noted at any depth, support should be provided as appropriate.

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 1.0m depth. Where water ingress occurs, it is likely that pumping from screened sumps within shallow excavations will be adequate.

8.7 Soakaway Drainage

8.7.1 Soakaway Design

Soakaway infiltration tests were undertaken in 3no. test pits excavated across the site (TP01, TP02 and TP03). The results of the testing are presented in Appendix F.

Sufficient infiltration was achieved within the test to allow an infiltration rate to be calculated at only one of the three locations (SA03/TP03). At the two other locations (TP02 and TP03, sufficient infiltration was not achieved to allow an effective extrapolation of the test data to obtain an estimate of the likely infiltration rate. The calculated infiltration rates are presented in Table 7 below.

***Table 7**: Summary of soakaway infiltration test results*

SA Test	Test Pit	Test depth	Measured Infiltration Rate[1]	Infiltration Soils
SA1	TP01	2.9m	Test Failed	Alluvium
SA2	TP02	2.2m	Test Failed	Alluvium
SA3	TP03	2.9m	1.68×10^{-5}m/s	Alluvium

Notes to Table 7
1. Testing undertaken in accordance with BRE 365. Water level fell to 25% of fill depth. Test was not repeated as infiltration was within Made Ground strata.
2. Water level did not fall to 25% fill depth.

Based on the results and ground conditions, it is unlikely that soakaways in this portion of the site will be suitable. Consideration could be given to utilising the existing local drainage network, however this would require discussion with the statutory bodies. Should sustainable drainage be essential to the scheme, consideration should be given to supplementary SAB compliant testing at other areas of the site within the natural coarse alluvial deposits.

9 Recommendations

Based on the available information, we consider that the following further investigation and assessment would be required or prudent prior to development:

- Completion of ground gas monitoring and provision of a ground gas addendum which has been allowed for within this current commission.
- Borehole investigation to determine deeper ground strengths within the alluvium below the proposed building footprints;
- Mining investigation including rotary open hole drilling and obtaining abandonment plans in order to confirm the presence/absence of coal and/or ironstone seams;
- Stability assessment as part of detailed design for the west and east boundaries of the site if the development is to encroach on the toe/crest respectively;
- Supplementary geoenvironmental testing of soils within garden areas to further assess risks posed by soil contaminants;
- Verification testing of any soils imported to site.
- WM3 assessment of soils to be disposed of off-site and/or Materials management plan for re-use of soils on site.

ESP are able to help progress the aspects above as part of detailed design, when required.

10 References

ALLEN D J, BREWERTON L J, COLEBY L M, GIBBS B R, LEWIS M A, MacDONALD A M, WAGSTAFF S J and WILLIAMS A T. 1997. The Physical Properties of Major Aquifers in England & Wales. BGS Technical Report WD/97/34 - EA R&D Publication 8. BGS and Environment Agency.

BRITISH GEOLOGICAL SURVEY (BGS). 2019. Website accessed 2019.

BRITISH STANDARDS INSTITUTION (BSI). 1990. Methods of Test for Soils for Civil Engineering Purposes. BS1377, Parts 1 to 9, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2002. Geotechnical Investigation and Testing: Identification and Classification of Soil, Part 1. Identification and Description. BS EN ISO 14688-1. HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2003. Geotechnical Investigation and Testing: Identification and Classification of Rock, Part 1. Identification and Description. BS EN ISO 14689-1. HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2004. Geotechnical Investigation and Testing: Identification and Classification of Soil, Part 2. Principles for Classification. BS EN ISO 14688-2. HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2004. Eurocode 7: Geotechnical Design – Part 1: General Rules. BS EN 1997-1:2004, HMSO, London. (including UK National Annex).

BRITISH STANDARDS INSTITUTION (BSI). 2005. Geotechnical Investigation and Testing – Field Testing, Part 2, Dynamic Probing. BS EN ISO 22476-2:2005. HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2005. Geotechnical Investigation and Testing – Field Testing, Part 3, Standard Penetration Test. BS EN ISO 22476-3:2005. HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2006. Geotechnical Investigation and Testing – Sampling Methods and Groundwater Measurements. Part 1, Technical Principles for Execution. BS EN ISO 22475-1:2006. 2007 reprint. HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2007. Eurocode 7: Geotechnical Design – Part 2: Ground Investigation and Testing. BS EN 1997-2:2007, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2007. Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments. BS8485, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2011. Investigation of Potentially Contaminated Sites – Code of Practice. BS10175, HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2013. Guidance on Investigations for Ground Gas – Permanent Gases and Volatile Organic Compounds (VOCs). BS8576:2013. HMSO, London.

BRITISH STANDARDS INSTITUTION (BSI). 2015. Code of Practice for Ground Investigation. BS5930:2015. HMSO, London.

BUILDING RESEARCH ESTABLISHMENT (BRE). 2001. Protective Measures for Housing on Gas Contaminated Land. BRE Digest 414. BRE Garston.

BUILDING RESEARCH ESTABLISHMENT (BRE). 2007. Radon: Guidance on Protective Measures for New Dwellings. BR211. BRE, Garston.

BUILDING RESEARCH ESTABLISHMENT (BRE). 2005. Concrete in Aggressive Ground. Third Edition. Special Digest 1 (SD1). BRE, Garston.

BUILDING RESEARCH ESTABLISHMENT (BRE). 2016. Soakaway Design. BRE Digest 365. BRE, Garston.

CONTAMINATED LAND APPLICATIONS IN REAL ENVIRONMENTS (CL:AIRE) and THE ENVIRONMENTAL INDUSTRIES COMMISSION. 2010. Soil Generic Assessment Criteria for Human Health Risk Assessment.

HEALTH & SAFETY EXECUTIVE. 1991. Protection of Workers and the General Public During the Development of Contaminated Land. HMSO, London.

NATHANAIL P, JONES A, OGDEN R, and ROBERTSON A. 2014. Asbestos in Soil and Made Ground. A Guide to Understanding and Managing Risks. CIRIA C733.

NATHANAIL P, McCAFFREY C, GILLETT A, OGDEN R and NATHANAIL J. 2015. The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, Nottingham.

NATIONAL HOUSE BUILDING COUNCIL (NHBC). 2016. NHBC Standards, Technical Guidance. Chapter 4.1, Land Quality.

NATIONAL HOUSE BUILDING COUNCIL (NHBC). 2016. NHBC Standards, Technical Guidance. Chapter 4.2, Building Near Trees.

NATIONAL HOUSE BUILDING COUNCIL (NHBC). 2016. NHBC Standards, Technical Guidance. Chapter 4.3, Spread Foundations.

O'RIORDAN N J and MILLOY C J. 1995. Risk Assessment for Methane and other Gases from the

RUDLAND D J, LANCEFIELD R M and MAYELL P N. 2001. Contaminated Land Risk Assessment. A Guide to Good Practice. Construction Industry Research and Information Association. CIRIA Report C552.

SCIVYER C. 2007. Radon: Guidance on Protective Measures for New Buildings. Building Research Establishment, BRE 211.

TOMLINSON, MJ. 2001. Foundation Design and Construction (7th edition). Prentice Hall

WILSON S, OLIVER S, MALLETT H, HUTCHINGS H and CARD G. 2007. Assessing Risks Posed by Hazardous Ground Gases to Buildings. Construction Industry Research and Information Association. CIRIA Report C665.

WILSON S, CARD G and HAINES S. 2009. Ground Gas Handbook. Whittles Publishing.