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Former Cowbridge Comprehensive School, Cowbridge

Geo-Environmental and Geotechnical Report

Report Reference: ESP.7052b.3120

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Former Cowbridge Comprehensive School, Cowbridge

Geo-Environmental and Geotechnical Report

Prepared for:

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Report Reference: **ESP.7052b.3120**

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Contents

Executive Summary

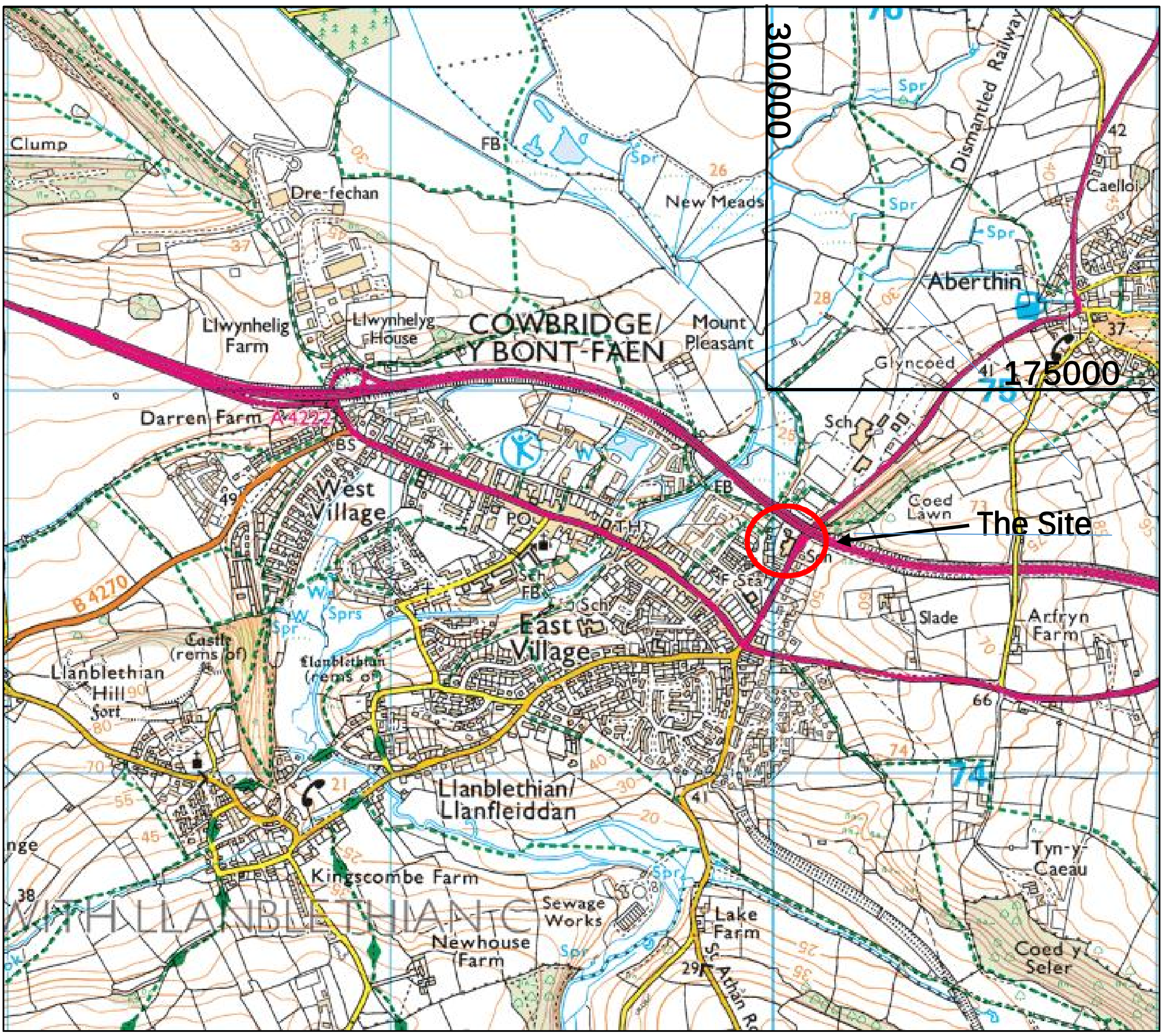
Hafod Housing Association is considering the subject site for redevelopment as a residential development. ESP have undertaken a geo-environmental and geotechnical assessment, comprising a desk study, intrusive investigation, laboratory testing and assessment of data. This report includes the Preliminary Risk Assessment and Generic Quantitative Risk Assessment (for human health and controlled waters) elements of CLR11. The key potential land quality issues identified by the assessment are summarised below:

	Potential Hazard	Anticipated Risk	Discussion
Site Setting	*Current Site Status. (Section 2.1)*	-	*The site is currently occupied by two buildings of the former Cowbridge Comprehensive School with areas of grass and hardstanding.*
	Identified Ground Conditions. (Section 5.1)	-	*The investigation has indicated the presence of Made Ground in the western portion of the site with weathered Mercia Mudstone encountered at shallow depths across the site.*
	Groundwater Conditions. (Section 5.2.1)	-	*The site is underlain by a Secondary A Aquifer overlying a Principal Aquifer. Groundwater is anticipated within 5m of the site surface.*
	Historical Land Use. (Table 1)	-	*The site remained undeveloped until 1897 when a school building is shown. In 1919 the building is extended and in 1969, additional buildings are shown on site and remains the same at the time of this report.*
Geo-environmental	*Potential Contamination Sources (Section 2.8)*	Moderate	*General Made Ground is anticipated across the site alongside Made Ground associated with unspecified ground workings in the north western portion.*
	Chronic Risks to Human Health (Section 5.7 and Section 5.8)	Low	*All determinands analysed fell below the adopted GAC and no asbestos was detected in laboratory testing.*
	Risks to Controlled Waters (Section 5.9)	Low	*The site lies approximately 150m west of the River Thaw. The underlying Glacio-fluvial deposits are classified as a Secondary A Aquifer with the underlying Mercia Mudstone classified as a Principal Aquifer.*
	Hazardous Ground Gas (Section 7.3)	High	*The site lies in an area where a maximum Radon potential of between 10 and 30% is recorded. Full radon protection measures are required for new buildings. Made Ground has been identified as a possible source of ground gas, however, monitoring to date has recorded low levels across the site.*
	Other Hazards (Section 3.1)	Moderate	*Given the age of construction of the school buildings (1969-1971) there is a possibility of ACMs within the building.*
Geotechnical	*Abandoned Mine Workings and/or Old Mine Entries (Section 8.3)*	-	*Not in an area that is likely to be affected by historic mining.*
	Weak/Compressible Ground, requiring non-traditional foundations (Section 8.3 and Section 8.4)	Moderate	*Made Ground was encountered on the site to a maximum depth of 1.1m overlying weathered Marginal Facies. Further investigation is required primarily in the areas of existing buildings.*
	Shrinkage or Swelling (Section 8.2.2)	Moderate	*Fine grained soils identified with moderate to high plasticity and medium shrinkage/swelling potential. Potential for shrinkage/swelling in the zone of influence of existing and new planting.*
	Sulphate Attack on Buried Concrete (Section 7.4.2)	Low	*Laboratory testing has indicated the site is classed as AC- 1 in terms of sulphate attack on buried concrete.*
	Soakaway Feasibility (Section 8.13)	-	Soakaway drainage is likely to be feasible subject to further consideration.
Others	*UXO (Section 2.11)*	Low	*UXO preliminary risk assessment identified the site to be of low risk.*
	Flooding (Section 2.5.3)	Moderate/ Low	*The site is not indicated to be located in an area at risk of flooding.*
	Invasive Plants (Section 8.1.1)	-	*No evidence of invasive plants were noted during the site works.*
	Further Investigation Required? (Section 9.0)	Yes	*See Section 9.0*

1 Introduction

1.1 Background

Hafod Housing Association (hereafter known as the Client) are proposing to redevelop the subject site for residential purposes. The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by CB3 Consult, acting on behalf of the Client, to undertake an integrated geotechnical and geo-environmental investigation and assessment to identify and evaluate potential ground hazards which could impact on the proposed development. The site location is shown on Insert 1.



Insert 1: Site Location Plan from Ordnance Survey 1:25,000 (OS License No.: AL100015788).

The proposed development will include the demolition of the former Cowbridge School currently occupying the site. It is understood the development will comprise 48no. dwellings (43no. flats and 5no. houses) with associated parking and landscaping. The buildings are understood to comprise a combination of three storey buildings for houses and a four storey building for flats.

We understand that there will be no significant changes to the current ground levels.

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

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.

We are not aware of any ground hazard related planning conditions relating to the development.

The scope of works for the investigation was designed by CB3 Consult and comprised a desk study review of available historical Ordnance Survey maps, environmental data, geological maps, memoirs and data, and further desk study information, a field reconnaissance visit, the supervision and direction of windowless sample boreholes, trial pits, soakaway infiltration testing, geotechnical and geo-environmental laboratory testing, assessment of foundation options, risks to human health and controlled waters, and reporting.

The contract was awarded on the basis of a competitive tender quotation. The terms of reference for the assessment are as laid down in the Earth Science Partnership proposal of 2nd November 2018 (ref: db/7052b.lt1). The investigation and assessment was undertaken in January and February 2019.

1.3 Report Format

This report includes the desk study and field reconnaissance reports (Section 2), and details of the investigation undertaken of Eurocode EC7 and BS5930:2015 (Section 4), along with the Preliminary Risk Assessment stage (Section 3) and Generic Quantitative Risk Assessment (Section 5) of CLR11. A preliminary evaluation of the resulting risks and any remedial measures potentially required to mitigate identified unacceptable risks from contamination and hazardous ground gas is included in Sections 6 and 7. However, it should be appreciated that this is a preliminary evaluation only, and will not generally meet the requirements of the Options Appraisal report of CLR11.

A preliminary risk register, identifying potential geotechnical hazards from the desk study review, is presented as Section 2.9, with a full assessment of the geotechnical conditions including foundation and floor slab options, the feasibility of soakaways, etc. in Section 8 – this complies the relevant elements of the Geotechnical Design Report of BS EN 1997-2 (Eurocode 7) and BS5930:2015. The geotechnical risk register is updated using the findings of the intrusive investigation and assessment in Section 8.2. The report concludes with a summary of any further surveys/ investigations/ assessments recommended (Section 9).

The assessment of the potential for hazardous substances (contamination) or conditions to exist on, at or near the site at levels or in a situation likely to warrant mitigation or consideration appropriate to the proposed end use has been undertaken using the guidance published by CIRIA (2001). This is discussed in more detail in Section 3.2.1 and in Appendix A.

1.4 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. 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.

1.5 Digital Copy of Report

This report is issued as a digital version only.

2 Desk Study and Field Reconnaissance Visit

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps (Appendix B), an environmental data report (Appendix C), information on a previous investigation at the site (Appendix E). Further desk study reports/data/records are included as subsequent appendices as referenced in the text.

The site description is largely based on a field reconnaissance and site inspection visit made at the site on 9th January 2019 during dry and sunny weather, and general views of the site are included as a series of photographs within the Plates section of this report.

2.1 Site Location and Description

The site is located at the former Cowbridge School off Aberthin Road, Cowbridge, Vale of Glamorgan. The National Grid Reference of the centre of the site is (ST) 300037 174614 and the postcode is CF71 7EN. A Site Location Plan is presented as Insert 1.

The site comprises a roughly rectangular shaped parcel of land of around 100 m length (north east to south west) and 50m width (east to west), occupying an area of around 0.52ha. The development fronting Aberthin road is currently occupied by the former Cowbridge Comprehensive School and grounds (Plate 1 and Plate 2).

It is bounded by:

- To the north: Cowbridge By-Pass (A48) which is elevated on a viaduct and the current Cowbridge Comprehensive School beyond (see Plate 3);
- To the east: Aberthin Road and New Forest View residential area. Beyond lie fields associated with Arfryn and Westmoor Farm;
- To the south: immediately by Slade Close, followed by private housing associated with East Village;
- To the west: immediately by private dwellings on Millfield Drive within the residential area of East Village

Vehicular access to the site is currently gained via a driveway on the south eastern boundary (Plate 4). The boundaries generally comprise of stone walls and iron fencing to the east and south and hedges to the west.

It is understood that a tree survey has been previously undertaken on the site. The survey indicated the presence of both mature and sapling trees across the site with species including, Ash, Lime, Yew, Hawthorn alongside various shrubs. The trees are predominantly located in the north western and south eastern portions of the site.

The general topography of the area is characterised by increases in elevation towards the east of the site reaching 120m at Stalling Down some 1500m away. The site itself is flat and level. A topographic survey has been undertaken and provided by the Client as drawing Layout_2019-01-21.dwg. The survey indicates site levels of approximately 32mOD with a marginal fall in elevation to the north with levels indicated to be 31mOD at the north boundary.

The Client has provided ESP with a series of plans showing the locations of recorded underground services in the vicinity of the site.

Site observations and the utility plans indicate that the site is crossed by the following services:

- Low Pressure Gas Pipes entering the building in the southern portion;
- BT Lines (Built) along the eastern boundary;
- Sewer and combined chambers in the north western portion.

2.2 Site History

2.2.1 Published Historical Maps

The site history has been assessed from a review of available historical Ordnance Survey County Series and National Grid maps. Extracts from the historical maps are presented in Appendix B and the salient features since the First Edition of the County Series maps are summarised in Table 1 below.

Table 1: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1875–1878	The site remains undeveloped.	Directly to the west of the site approximately 25m away the Taff Vale Railway and station are prominent features. A quarry and lime kiln exist 100m east of the site and a gasworks is present 400m to the west.
1897-1914	The former Cowbridge Comprehensive School is built in its current location in 1897. The 1914 map shows an area of embankment/land raising in the north portion.	The quarry to the east of the site is no longer present on historical mapping. The Taff Vale Railway is extended further enveloping the southern margins of the site. An 'old' quarry is recorded 500m to the south.
1919-1938	In 1919 the school building has been extended. The remainder of the site remains unchanged	The Gas works to the west of the site is no longer presented on historical mapping. The Taff Vale Railway is now referred to as the Great Western Railway.
1947-1964	The site appears to remain unchanged.	The quarry 500m to the south is no longer present.
1969-1974	The site appears to have expanded with additional outbuildings in 1969.	Aberthin and East Village have largely expanded, the railway station and tracks are now appearing to be dismantled. The Cowbridge By-Pass (A48) is built on the northern margins of the site and is visually noted to pass above the north boundary. Whilst not noted on the mapping, earthworks associated with the bypass are recorded in the area.
1986-1988	The site appears to remain unchanged.	New Forest View housing built directly to the east on Aberthin Road.
2002-2010	The site appears to remain unchanged.	The current Cowbridge Comprehensive School has expanded with the addition of sports fields and outbuildings. East and West Village residential areas have expanded further.
2014-present	The site appears to remain unchanged and is currently occupied by the former school building and associated infrastructure.	The site is in a primarily residential area with the current Cowbridge Comprehensive School located to the north. The A48 extends laterally across the site on the northern boundary.

2.2.2 Other Sources

No further relevant information on the site history has been identified as part of this assessment.

2.2.3 Archaeological Setting

A full archaeological assessment was not included within the brief; however, we have identified a archaeological record (accession no 20.435, find spot 6053) which indicates that an early bronze age knife or dagger was found in the vicinity of the site (Historic Wales, 2019). It is understood that an Archaeological and Heritage Assessment of the site has already been undertaken prior to this investigation, however, we have not been provided with this report.

2.2.4 Ecological Setting

It is understood that 2no. ecology surveys have been undertaken for the site, the first completed in September 2017 and an additional survey undertaken in December 2018, however, we have not been provided with this report.

2.3 Previous Investigations and Assessments

We are not aware of any previous geotechnical or geo-environmental investigations or assessments at the site. Earth Science Partnership (ESP) undertook a geotechnical and geo-environmental assessment some 1000m to the north east at Aberthin Village Hall in 2014 (ESP 5607s.2005) for a then proposed extension. The investigation included the following investigation points:

- 2no. hand excavated trial pits (HDP1 to HDP2) excavated across the site on 5th September 2014 to a maximum depth of 1.1m.
- 5no. windowless sample drill holes (WS1 to WS5) constructed on 5th September 2014 to a maximum depth of 2.8m.

2.4 Contact with Regulatory Bodies & Local Information Sources

Enquiries for information have been made to the Local Authority. At the time of issue of this report, we have not yet received a response from the consultees. Once received, any response will be forwarded under separate cover. It should be appreciated that their responses may contain salient information on the site which could not be taken into account during the preparation of this report.

2.5 Hydrology

2.5.1 Surface Water Features

The nearest major surface water feature to the site is the River Thaw some 150m west which flows from Llanharry in a generally south eastern direction through Cowbridge then southward to Breaksea point in the Bristol Channel.

The environmental data report (Appendix C) indicates that the latest data shows the water quality (in terms of biology) between the confluence of Aberthin Bk and Newton Bk with the River Thaw was classified as Grade B (good) between 2006 and 2007, improving to Grade A (very good) between 2008 and 2009. In terms of chemistry, the water quality over the same stretch of river was classed as Grade B (good) between 2005 and 2006, improving to Grade A (very good) between 2007 and 2008.

2.5.2 Surface Water Abstractions

The environmental data report (Appendix C) indicates that there are no surface water abstractions within 250m of the site.

2.5.3 Flooding (Rivers and Seas)

From a review of topographical plans and flooding maps presented in the environmental data report and NRW website, the site is not located within an area at risk from flooding by the River Thaw, however, areas of flooding are shown in close proximity to the site.

2.5.4 Flooding (Surface Water)

From a review of the information presented on the NRW website, the site is not indicated to be at risk from surface water flooding.

2.5.5 Flooding (Groundwater)

The environmental data report presented in Appendix C has identified a British Geological Survey (BGS) groundwater flooding susceptibility area within 50 m of the boundary of the study site. BGS has designated a confidence rating of low in the groundwater flooding susceptibility result.

The report has identified groundwater flooding susceptibility of Clearwater Flooding. Groundwater flooding may be associated with unconfined aquifers. Where a potential for groundwater flooding at the surface is identified given the geological conditions the groundwater flooding hazard should be considered in all land-use and planning decisions. It is recommended that other information such as flooding history, rainfall, property type and land drainage information is investigated in order to establish relative, but not absolute, risk of groundwater flooding.

2.6 Geology

2.6.1 Published Geology

The published 1:50,000 scale geological map for the area of the site (British Geological Survey, 2019) indicates the site to be underlain by glaciofluvial sand and gravels overlying bedrock of the Mercia Mudstone Group (Marginal Facies).

The Mercia Mudstone Group (Marginal Facies) is a variable lithological unit typically consisting of conglomerate and breccias often with clasts incorporated from rocks lying immediately below the unconformable base. The matrix generally consists of finer-grained rock fragments or, less commonly, siltstone, sandstone or limestones. Superficial glaciofluvial deposits can be anticipated to contain sand and gravel, locally with lenses of silt, clay or organic material.

2.6.2 Available BGS Borehole Records/Previous Investigation

Reference to the website of the British Geological Survey (BGS, 2019) indicates the available records of 3no. borehole records adjacent to the north of the site and 6no. trial hole records at the current Cowbridge Comprehensive School within 250m of the site. The BGS borehole records are displayed in Appendix D.

The BGS borehole record located at the A48 overpass comprises 3no borehole records which indicate the following:

- ST07SW/1 and ST07SW/2 (1959): superficial fine grained soils to a depth of approximately 18.0m overlying weathered bedrock to a proven depth of 30.0m
- ST07SW/3 (1963): ballast overlying shallow bedrock comprising sandstone, siltstones, limestone and dolostones. Groundwater was struck at approximately 20m depth and rose to over 4.5m above ground level.

The trial hole records at the Cowbridge Compressive School (ST07SW25, ST07SW26, ST07SW27, ST07SW28, ST07SW29, ST07SW30) indicate the following:

- The trial holes excavated in 1972 to a maximum 2m exposed a generalised succession of topsoil underlain by a reddish-brown sandy clay with occasional pockets of pebbles and very small rounded sandstone fragments. Groundwater levels are noted between 0.8m and 1.2m.

2.7 Hydrogeology

2.7.1 Aquifer Classification

Reference to the aquifer maps published on the environmental data report indicates that the superficial deposits beneath the site (Glaciofluvial Deposits) are classed as Secondary A, whilst the bedrock (Mercia Mudstone Group- Marginal Facies) is classed as Principal aquifer.

Principal Aquifers generally correspond with the previously classified major aquifers and are described by the Environment Agency as ‘rock or drift deposits that have high intergranular and/or fracture permeability’. They may support water supply and/or river base flow on a strategic scale. Principal Aquifers are particularly sensitive to pollution.

Secondary A Aquifers generally correspond with the previously classified minor aquifers, and comprise permeable layers capable of supporting water at a local, rather than strategic, scale and in some cases form an important base flow to rivers. Secondary A Aquifers are sensitive to pollution.

2.7.2 Anticipated Groundwater Bodies

Based on the available information, we consider that the shallowest main groundwater body is likely to be located within the Glaciofluvial Deposits strata. However, localised perched water bodies cannot be discounted. Deeper groundwater will be present in the Marginal Facies.

The previous investigation at the current Cowbridge Comprehensive School (Section 2.6,2) identified groundwater levels between a depth of 0.8m and 1.2m.

2.7.3 Abstractions and Groundwater Vulnerability

The environmental data report indicates that there are no groundwater abstractions or Source Protection Zones within 500m of the site.

The groundwater vulnerability is shown in the environmental data report to be a major aquifer high leaching potential.

2.7.4 Groundwater Movement

Groundwater movement within the Glaciofluvial Deposits will be controlled by intergranular flow whilst, in the Mercia Mudstone (Marginal Facies) bedrock, fracture flow is likely to be dominant.

Given the site setting, which consider that the groundwater within the Glaciofluvial Deposits aquifer may be providing base flow to the River Thaw.

2.8 Environmental Setting

2.8.1 Summary of Environmental Data

The site exists in a historically rural, and now a partly urban setting. An environmental data report has been obtained for the site and is presented in Appendix C, and the data therein is summarised in Table 2 below and, where salient, discussed in Section 2.8.2.

Table 2: Summary of Environmental Data

Item	On the Site	In the Immediate Vicinity
Environmentally Sensitive Sites [2]	None identified.	None recorded within 1000m of the site.
Potentially Contaminative Land Use	10no. recorded	68no. recorded within 250m of the site.
Historical Tanks, PFS, Garages, Energy Facilities	None identified.	2no. recorded within 250m of the site.
Potentially Infilled Land	6no. recorded	17no. recorded within 250m of the site.
IPPC Authorisations	None identified.	None recorded within 500m of the site.
Discharge Consents	None identified.	6no. recorded within 250m of the site.
List 1 and 2 Dangerous Substances Sites	None identified.	None recorded within 500m of the site.
Radioactive Substance Sites	None identified.	None recorded within 500m of the site.
Enforcements	None identified.	None recorded within 500m of the site.
Pollution Incidents	None identified.	3no. recorded within 500m of the site.
Contaminated Land under Part 2A EPA 1990.	None identified.	None recorded within 500m of the site.
Waste Management Facilities	None identified.	None recorded within 1km of the site.
Current Industrial Sites	None identified.	13no. recorded within 250m of the site.

Notes
1. Sensitive land uses include Sites of Special Scientific Interest, Nature Reserves, National Parks, Special Areas of Conservation, Special Protection Areas, Ramsar sites, World Heritage sites and Ancient Woodland.
2. Nitrate vulnerable areas relate to the agricultural use of fertilizers and are not considered further in this assessment.

2.8.2 Further Discussion on Salient Environmental Features

Potentially Contaminative Land Use

10no. records on site including railway sidings and unspecified groundworks. Reference to the historical maps indicate these are likely related to the nearby Taff Vale Railway some 25m to the east. 68no. records are identified within 250m of the site, these various land uses associated with the nearby railway line, railway station and goods station.

Historical Tanks

2no. records of historical tanks are held. 1no record is at 78m northeast dating 1989 and listed as an unspecified disused tank. Another record is held for an unspecified tank at 98m north east dating 1988.

Potentially Infilled Land

6no. records on site including unspecified ground workings dating between 1914 to 1947. Beyond the site, the nearest record is at 31m to the east, listed as an un unspecified quarry dating 1947.

Discharge Consents

6no. records within 250m of the site, the closest is at 170m northwest dating between 1978 to 1983 with unspecified effluent type recorded. The River Thaw is listed as the receiving water. The closest active consent is at 221m northwest dated 2003. The effluent type is listed as sewage discharges for a water company pumping station with the River Thaw is listed as the receiving water.

Pollution Incidents

3no. recorded within 500m of the site with the closes at 230m to the northwest dated 2003. The pollutant is listed at sewage materials and the record indicates the following impact categories; Water Impact: Category 3 (minor), both Land and Air Impact are listed as Category 4, (no impact).

Current Industrial Sites

13no. recorded within 250m of the site, the closest is at 41m north and is listed as a gas valve compound.

2.8.3 On-Site Bulk Liquid Storage

The historical maps and field reconnaissance visit have provided no evidence of any past or recent above ground or underground bulk liquid (e.g. fuels/oils) storage on site.

2.8.4 On-Site Bulk Materials and Waste Storage

The field reconnaissance visit indicated no evidence of recent materials or waste storage on the site.

2.9 Preliminary Geotechnical Risk Register

2.9.1 Summary of Potential Geotechnical and Geomorphological Hazards

The potential for various geotechnical and geomorphological hazards at the site is provided in the environmental data report (Appendix C). The potential hazards, as reported in these reports are listed in Table 3 below, along with any salient further information on the potential hazard identified by ESP in the preparation of this report. Where a potential hazard has been identified, it is discussed further in subsequent sections.

Table 3: Preliminary Geotechnical Risk Register

Ground Stability Hazard	Potential[1]	ESP Comment
Coal Mining	-	No further information identified to contradict data report.
Mining (non-coal)	-	No further information identified to contradict data report.
Shrinking or Swelling Clays	Negligible	See Section 2.9.2
Landslides	Very Low	No further information identified to contradict data report.
Ground Dissolution (Soluble Rocks)	Low	See Section 2.9.3
Compressible Ground	Negligible	See Section 2.9.4
Collapsible Ground	Very Low	No further information identified to contradict data report.
Running Sand	Very Low	No further information identified to contradict data report.
Sulphate/Pyritic Ground	Not reported.	See Section 2.9.5

Notes
1. Potential as reported in environmental data report (Appendix C)
2. Salient hazards discussed in following sections.
3. An updated Geotechnical Risk Register, following intrusive investigation of salient hazards, is presented as Table 8 in Section 8.2.1.

2.9.2 Shrinkable and Swelling Soils

Any weathered Marginal Facies that may be present at shallow depth beneath the site commonly have a moderate 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 at the site should be advanced from that reported in the environmental data report (Table 3, Negligible) to **Moderate**.

2.9.3 Ground Dissolution

The Marginal Facies that is anticipated to underlie the rock can be prone to dissolution leading to the formation of cavities that have the potential to migrate to the surface. Therefore, we consider that the potential for ground dissolution at the site should be advanced from that reported in the environmental data report (Table 3, Low) to **Moderate**.

2.9.4 Compressible Ground

The desk study assessment indicates the potential for infilled land on the site, the Made Ground soils anticipated beneath 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 should be advanced from that reported in the environmental data report (Table 3, Negligible) to **Moderate**.

2.9.5 Pyritic Ground

The environmental data report does not consider the potential risk from sulphate rich or pyritic ground. The Mercia Mudstone bedrock underlying the site are listed by the BRE (2005) as potentially containing elevated levels of pyrite, which may oxidise to sulphates and lead to aggressive attack on buried concrete. Depending on its origin, the Made Ground anticipated beneath the site may also contain elevated levels of pyrite. Given the above, we consider that the potential for sulphate/pyrite attack on buried concrete would be Moderate

2.10 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 (Appendix C) indicates that the site lies in a radon affected area as defined by the Health Protection Agency, with between 5 and 10% of properties above the action level.

Reference to the UK radon maps published by Public Health England (PHE, 2015) indicates that the site lies in an area classified as a maximum radon potential of between 10 and 30%.These maps indicate the worst level of radon potential, based on existing information gathered mainly from residential properties within the 1km square in which the site is located. It is designed as a preliminary evaluation only. Reference to BRE 211 (Scivyer, 2007) indicates that the site lies in a 1km square where the maximum requirements are for full radon protection measures in new buildings (domestic or non-domestic). Given the currently available information, the risk from radon is considered High.

2.11 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 rural area which is likely to have been targeted by the Luftwaffe during World War Two. Reference to UXO risk maps available on-line (Zetica, 2016) suggests that the site is located within a low risk region with regards to the risk from buried unexploded ordnance.

A Preliminary UXO Desk Study assessment of risk has been completed by a specialist Ordnance consultant in accordance with CIRIA guidelines (Stone et al, 2009) and is presented in Appendix E (Zetica, 2018). This indicates that the following strategic targets were located in the vicinity of the site during WWI and WWII:

- Transport infrastructure and public utilities
- Royal Air Force (RAF) Llandow

The assessment concludes that no readily available records have been found to indicate the site was bombed and that a detailed desk study, whilst always prudent, is not considered essential in this instance.

3 Preliminary Geo-Environmental Risk Assessment

3.1 Phase One Conceptual Site Model

3.1.1 Background

The Phase One Conceptual Site Model lists the potential sources of geo-environmental risk, the receptors at risk and the pathways between the two. These are discussed in the following sections.

3.1.2 Potential Contamination Sources

The site history has indicated that in 1919, after the development of the school, few further changes have occurred. Reference to the environmental data report indicates that there are 6no. records of potentially contaminative land use on site including unspecified ground workings and railway sidings. The historical maps indicate that in 1919, after the development of the school, unspecified earthworks have occurred in the north western portion of the site. From the available information, we consider that the following features on site could prove sources of diffuse and point source contamination that could impact on the development, environment or site users:

- Made Ground – general diffuse contamination;
- Made Ground – historic unspecified ground workings in north western portion as identified as earthworks on historical mapping;
- Made Ground – proximity to railway land;
- Asbestos – ACMs within additional school building built between 1969 - 1971.

3.1.3 Potential Contaminants Present

The potential contaminants associated with the above potential sources have been identified from various guidelines published by DEFRA, the Environment Agency and others. Based on this guidance and our experience, we consider that the following contaminants could be present on the site:

- heavy metals and semi-metals (arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, zinc);
- cyanide, sulphate, sulphide;
- polyaromatic hydrocarbon (PAH) compounds;
- petroleum hydrocarbons, including methyl-tert-butyl-ether (MTBE);
- phenols;
- asbestos.

No evidence has been identified from the desk study to suggest that radioactive substances may be present on the site. The potential presence of radon in discussed in Section 3.1.4.

3.1.4 Potential Sources of Hazardous Ground Gas and Radon

The site is not located within 250m of an existing or former recorded landfill. There are records of infilled land on site including unspecified ground workings and unspecified heaps. Depending on the nature of the backfill materials (which are currently unknown), they could represent a source of hazardous ground gas which could impact on the site.

Based on the available information, the following potential sources of hazardous ground gas have been identified on, or in close vicinity of, the site:

- General Made Ground – organic and other materials could generate combustible and noxious gases;
- Potentially Infilled land on site - unknown materials could generate combustible and noxious gases;
- Unspecified Quarry within 100m to the east- unknown backfilled materials could generate combustible and noxious gases;

Based on the guidelines presented by O'Riordan and Milloy (1995) and revised by Wilson et al (2009), the above potential gas sources would generally be classified as of low gas generation potential.

As discussed in Section 2.10, the site is located within an area where the maximum radon potential is between 10% (Environmental Report) and 30% (PHE 2015), with Radon protection measures required.

3.1.5 Potential Receptors

As discussed in Section 1.1, the details of the proposed development have not been provided at this stage, residential properties with landscaping and vehicle parking areas, but no private gardens. The site is located only 150m from the River Thaw above superficial soils classified as a Secondary A Aquifer and bedrock classified as a Principal Aquifer.

Given the above, we consider that the most vulnerable receptors with regards to any contamination or hazardous ground gas present are likely to be as follows.

- Future residents, the critical receptors being young children playing in landscaped areas.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The water quality in the River Thaw.
- The groundwater within the Mercia Mudstone strata beneath the site (classified as a Principal Aquifer)

3.1.6 Potential Migration Pathways

Based on the Conceptual Site Model discussed in the previous sections, the following are considered the most likely migration pathways with regard to any contamination or hazardous ground gas present beneath the site.

Site Users:

- Ingestion of soils and inhalation of dust in landscaping areas.
- Dermal contact with contaminated soils.
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential risk from toxic ground gas/vapours from on-site sources.
- Chronic (long term) exposure to unacceptable levels of radon.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the existing buildings.
- Ingestion of soils and inhalation of dust across site.

- Dermal contact with contaminated soils.
- Potential explosive risk from flammable or toxic ground gas/vapours from on-site sources.

Groundwater:

- Leaching of mobile contaminants into the water-bearing strata within the bedrock.

River Thaw:

- Leaching of mobile contaminants to the groundwater beneath the site, and then on to the nearby surface water course.

Buildings:

- Sulphate attack on buried concrete (foundations, drainage etc.).
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential explosive risk from flammable ground gas/vapours from off-site sources.

3.2 Preliminary Risk Evaluation & Plausible Pollutant Linkages

The land use history of the site and surrounding area, as established from the desk study and walkover, has identified a number of potential contamination linkages due to ground conditions or former operations either on, adjacent to, or in the vicinity of the site. Note that these potential linkages will need to be later assessed and re-established using actual site data obtained from an exploratory investigation.

3.2.1 Introduction to Risk Evaluation Methodology

The methodology set out in CIRIA C552 *Contaminated Land Risk Assessment – A Guide to Good Practice* (Rudland et al, 2001), has been used to assess whether or not risks are acceptable, and to determine the need for collating further information or remedial action.

Whilst at a later stage, this methodology may be informed by quantitative data (such as laboratory test results) the assessment is a qualitative method of interpreting findings to date and evaluating risk. The methodology requires the classification of:

- The magnitude of the potential consequence (severity) of risk occurring (Table A1 in Appendix A):
- The magnitude of the probability (likelihood) of risk occurring (Table A2 in Appendix A).

The classifications defined above are then compared to indicate the risk presented by each pollutant linkage, allowing evaluation of a risk category (Tables A3 and A4 in Appendix A). These tables have been revised slightly from those presented in CIRIA C552, to allow for the circumstances where no plausible linkage has been identified and, therefore, no risk would exist.

The methodology described above 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, using information known about the site, at this desk study stage. This is presented as Table 6 in Section 3.2.2 below.

3.2.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

Table 4: 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 shallow soils	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	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]	Low Risk	
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Secondary A Aquifer	Likely[2]	Moderate/Low Risk	Sampling of near-surface soils to confirm levels of leachable contamination present.
	Leaching of soil contaminants	Impact on River Thaw	Medium – site lies adjacent to river	Low likelihood[2]	Moderate Risk	
Asbestos in existing buildings	Ingestion of fibres	Demolition Workers/ Ground Workers	Medium – potential for chronic levels	Likely[3]	Moderate Risk	Asbestos survey of building
Asbestos in shallow soils	Ingestion of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Low Likelihood[3]	Moderate/Low Risk	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood[4]	Moderate Risk	Sampling of soils to confirm levels of sulphate, pH, and groundwater.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Low likelihood[5]	Moderate Risk	Install and monitor gas wells at request of client.
	Damage through explosion.	Building/Property	Severe – acute risk.		Moderate Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		Moderate Risk	
Radon gas	Migration into Buildings	Site Users (residents)	Medium – potential for chronic levels	High Likelihood[6]	High Risk	See Section 7.3.2

Notes:
1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. Although Made Ground is anticipated on the site, the presence of contamination has yet to be confirmed on site.
3. No obvious asbestos materials have been observed in the Made Ground soils. ACMs may be present within the school building on site.
4. The Mercia Mudstone can potentially contain sulphates/pyrite (Section 2.9.3)
5. Unknown Made Ground infill forms a potential source of hazardous ground gas/vapours at the site (Section 3.1.4).
6. Radon risk identified in environmental data report (Section 2.10).

4 Exploratory Investigation

4.1 Investigation Points

4.1.1 Introduction

The intrusive investigation was undertaken on 9th January 2019 in accordance with BS5930:2015 and BS10175:2013, and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Section 2). It comprised trial pitting, windowless sample boreholes, measurement of the correlated in-situ CBR value using DCP equipment, soakaway infiltration testing, gas and groundwater monitoring.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2015, along with published weathering schemes. Given the presence of Mercia Mudstone beneath the site, the weathering scheme published by Spink and Norbury (1993) has been adopted.

Descriptions and depths of the strata encountered are presented on the borehole and trial pit records in Appendix F and Appendix G. The results of the in-situ testing and monitoring are presented in Appendix H to Appendix J. The investigation point positions are shown on Figure 2.

The ground levels indicated on the investigation point records are approximate only and have been interpolated from the topographical survey provided by CB3 Consult (Layout_2019-01-21.dwg). The coordinates shown on the investigation point records are approximate only and have been interpolated from the topographical survey.

4.1.2 Investigation Strategy

The investigation strategy was generally designed in accordance with BS10175:2013, taking into account the additional potential for geotechnical hazards to be present. The desk study identified potential contaminant sources/geotechnical hazards predominantly in the north western portion of the site.

Due to access constraints and the presence of underground services, the investigation in this portion of the site was limited. The investigation points were spread across the site to obtain a general overview of the ground conditions present, particularly at the proposed structure locations. Notwithstanding the above constraints, we consider that the investigation undertaken has been sufficient to identify the key ground issues at the site.

4.2 Trial Pits

6no. trial pits (TP1 to TP3, TP3A, TP4 and TP5) were excavated across the site on 9th January 2019 using a wheeled excavator. The trial pits were excavated to a maximum depth of 3.5m. The trial pit records are presented as Appendix F.

Disturbed samples were collected from the trial pits for laboratory testing. On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket, and the Topsoil reinstated on the surface. In areas of hardstanding, the concrete/tarmacadam surface was not reinstated. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

4.3 Windowless Sampling

5no. windowless sample drillholes (WS1 to WS5) were constructed on 9th January 2019 to a maximum depth of 4.0m. 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. The windowless sampling provided generally good recovery to the depth of refusal and the borehole records are presented in Appendix G.

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. At borehole BH4, the tarmac was broken out using a hydraulic breaker.

Standard Penetration Tests (SPT) were carried out using a split spoon 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 an 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. Depending on the nature of the test undertaken and the soils subjected to testing, field SPT N-values may require correction before using in design.

On completion, boreholes WS2 and WS5 were backfilled with arisings with the topsoil reinstated at the surface. Monitoring instrumentation was installed in boreholes, WS1, WS3 and WS4 as detailed in Section 4.14.2.

4.4 Soakaway Infiltration Testing

Soakaway infiltration tests were undertaken in general accordance with BRE Digest 365 (2007) in 3no. selected trial pits across the site (TP1, TP2 and TP3A). The results of the infiltration testing, and the calculated infiltration rates, are presented in Appendix H.

At each position, the test pit was excavated to a depths of between 1.60 to 2.20m which was anticipated to be a possible depth for the soakaway given the ground conditions identified. 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.

Sufficient time and water was available to repeat the test (a total of two fills) in Test Pits TP1. However, due to the low infiltration rate, insufficient time was available to repeat the test in Test Pits TP2 and TP3A. 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.

4.5 Dynamic Cone Penetrometer Testing (DCP)

CBR testing using the TRL approved dynamic cone penetrometer (DCP) is due to be undertaken alongside the on-going as monitoring and will be provided under separate cover upon completion.

4.6 Instrumentation

4.6.1 Gas Well Installations

At the request of the client's designer, 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.

4.6.2 Gas Monitoring

Monitoring of the installed gas wells has been undertaken on a 'spot' monitoring basis (periodic visits to monitor gas levels at the time of the visit). CIRIA C665 (Wilson et al, 2007) provides guidance on the number and frequency of monitoring visits required for installed gas wells. These depend on the gas generation potential of the source and the sensitivity of the development to gas risk and are designed as a typical minimum only.

As discussed in Section 3.1.4, the most significant source in the vicinity of the site in terms of gas risk, the unspecified infill and general Made Ground, is classified as being of low gas generation potential. The proposed development comprises flat-type and conventional residential properties which are classified as of moderate/high sensitivity in terms of gas risk.

To date, the installed wells have been monitored for levels of groundwater and ground gas on two occasions. 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) 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.

Upon completion of all monitoring, a ground gas risk assessment will be provided as an addendum report.

4.7 Sampling Strategy

4.7.1 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.

A non-targeted, random sampling strategy was used to obtain representative information on soil contamination across the site as a whole. However, a number of constraints were imposed on the available sampling locations by existing buildings, access restraints and underground services and therefore a regular grid sampling pattern could not be adopted.

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.

4.7.2 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). Cutting relatively undisturbed block samples from trial pit walls provides Class 1 or 2 samples, provided that they are collected, preserved and transported in an appropriate manner.

The split spoon sample from a Standard Penetration Test (SPT) is usually considered a Class 5 sample however, it can be deemed Class 4 in homogeneous fine-grained soils. Disturbed sampling (bulk bags and small tubs) from boreholes is considered Class 3 (if dry), Class 4 (fine soil below the water table) or Class 5 (coarse soils from beneath the water table).

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.

4.8 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.

4.8.1 Site Stability

No evidence of geotechnical hazards were identified in the exploratory holes, however, thicker Made Ground has been identified in the north portion, where potential earthworks were identified on the historical mapping (TP5)

4.8.2 Site Evidence of Contamination

No direct visual/olfactory evidence of contamination was identified in the exploratory holes, however, Made Ground has been encountered during the investigation.

4.8.3 Services

During the investigation, a number of manhole covers were observed across the site and a clay drainage pipe was encountered in TP3, in the western portion of the site. It is understood that a drainage survey has been undertaken on the site, however, ESP have not been provided a copy of this to date.

4.9 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.

- Natural moisture content.
- Atterberg limits.
- Particle size analysis.

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). The results of the sulphate testing are included with the geo-environmental test results in Appendix K.

4.10 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil. 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 (see Section 4.1.1). The PRA (Section 3.1.2) did not identify any particular contaminants of concern at the site. However, given the presence of Made Ground and sensitive nature of the proposed development, in order to allow an assessment of the potential chronic risks posed to human health, a total of 6no. selected samples of the Made Ground and 2no. samples of the near-surface soils have been analysed for contaminants typically found on brownfield sites in the UK.

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

5 Development of the Revised Conceptual Model

5.1 Geology

The exploratory holes have identified the site to be underlain by Made Ground above weathered Marginal Facies (of the Mercia Mudstone) Bedrock with more competent bedrock encountered at greater depths. These strata are discussed in more detail in the following sections. No Glacio-fluvial superficial deposits were encountered during the investigation. Evidence of infilled ground in the north western portion was not encountered, however, due to access restraints, the coverage of this area was limited.

Made Ground: encountered to a maximum depth of 1.10m in TP3 as a slightly clayey, gravelly sand with concrete and brick rubble and metal pipes. The Made Ground in investigation points TP3A to TP5, WS2 and WS4 generally comprised grey hardcore gravel and reworked natural soils.

Glaciofluvial Deposits: not encountered during the investigation and anticipated to be absent from the site.

Weathered Mercia Mudstone Group (Marginal Facies) Bedrock: encountered beneath the Made Ground and Topsoil to a maximum depth of 4.0m generally comprising a silty gravelly clay with varying proportions of sand. The soils generally had a low to medium angular limestone cobble content. The weathered bedrock soils have been generally classed as Class D, destructed Mercia Mudstone as shallow depths with Class C, distinctly weathered bedrock encountered at greater depths.

Laboratory testing within the fine-grained weathered bedrock indicated liquid limits between 36 and 63%, plasticity indices between 21 and 28%, and natural moisture contents between 17 and 39%. The modified plasticity indices (after the coarse-grained particles have been removed) suggest that the soils are generally of medium shrinkage and swelling potential and would be generally classified as clays of intermediate plasticity (CI). In TP5, a thin band was encountered as a firm silty clay material with organic matter, laboratory indicated this to be a silt of high plasticity (MH).

Particle size analyses within the laboratory have indicated the more coarse-grained weathered bedrock to comprise between 2 and 47% gravel, predominantly fine to medium, between 18 and 37% sand, predominantly medium/coarse, and with 0% cobbles. Based on our observations on site, these proportions would appear generally representative of the in-situ soils.

Field SPT N-values within the weathered bedrock varied between 2 and in excess of 50 where cobbles, boulders and competent bedrock was present, with most results greater than 15.

5.2 Hydrogeology

5.2.1 Groundwater Bodies

The investigation did not identify any groundwater to a depth of 4.0m. However, the exploratory holes were completed within one working day and the near-surface soils were fine-grained in nature. Therefore, due to the soils low permeability, it is possible that groundwater may be present within the depth of investigation, but there was insufficient time for it to be recorded.

Monitoring for shallow groundwater is ongoing as part of ground gas monitoring and will be discussed further upon completion in our addendum report.

5.2.2 Hydraulic Gradient

Monitoring of groundwater is ongoing and will be reported under separate cover, however, based on the site setting and available information, we consider that the hydraulic gradient beneath the site is likely to be towards the north.

5.3 Site Instability

5.3.1 Site Stability

No evidence of significant geotechnical hazards were identified in the exploratory holes, however, thicker Made Ground has been identified in the north portion, where potential earthworks were identified on the historical mapping.

5.3.2 Localised Excavation Stability

During the excavation of the trial pits, some minor spalling of the pit walls was experienced, particularly within the upper weathered Mercia Mudstone (Marginal Facies) deposits at 0.80m in TP2.

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 2014, DEFRA published the Category 4 Screening Levels (C4SL) 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. They 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). However, 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). At the time of writing, the use of the C4SL in planning has not yet been accepted by many parties, including some regulators. The C4SL have also only been published for a limited number of contaminants. The C4SL have not been generally adopted in this assessment.

In this assessment, where available, the Soil Guideline Values (SGV) published by the Environment Agency have been adopted as the Generic Assessment Criteria (GAC) in the first instance. However, the SGV are only available for a limited number of contaminants for three proposed land uses (residential, commercial and allotments - not public open space). Where no SGV is available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) have been adopted (Nathanail et al, 2015). These assessment criteria adopt updated toxicological data and exposure models, but 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.

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).

At the time of writing there is no published SGV, S4UL or CL:AIRE/EIC assessment criteria for lead. For the purposes of this assessment, and in the absence of any other current authoritative guidance, the Category 4 Screening Level (C4SL) value published by DEFRA has been adopted.

Details of the source of the GAC adopted for each contaminant are presented on the assessment table below.

The proposed development comprises residential accommodation, without private gardens, but with external landscaping. No growing of edible plants is anticipated, therefore, the GAC appropriate for public open space around residential properties 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 0.5 to 3%. 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 comprised 5no. samples of Made Ground and 3no. samples of natural glacial soils. At this stage, all samples 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 risks from asbestos are considered further in Section 7.1.1.

The results of the Generic Quantitative Risk Assessment are presented in Table 5 below.

Table 5: Summary of Geo-environmental Soil Results

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	<0.2 – 16 mg/kg	79mg/kg	S4UL[2]	None of 8
Barium	<1.5 – 230 mg/kg	1,300mg/kg	CL:AIRE[3]	None of 8
Beryllium	<0.2 – 0.8 mg/kg	2.2mg/kg	S4UL[2]	None of 8
Boron	<0.2 – 0.4 mg/kg	21,000mg/kg	S4UL[2]	None of 8
Cadmium	<0.1 – 1.3 mg/kg	120mg/kg	S4UL[2]	None of 8
Chromium (total)[5]	<0.15 – 28 mg/kg	1,500mg/kg	S4UL[2]	None of 8
Chromium (hexavalent)	<0.1 mg/kg	7.7mg/kg	S4UL[2]	None of 8
Copper	<0.2 – 41 mg/kg	12,000mg/kg	S4UL[2]	None of 8
Lead	<0.3 – 190 mg/kg	630mg/kg	C4SL[4]	None of 8
Mercury[6]	<0.05 – 0.15 mg/kg	120mg/kg	S4UL[2]	None of 8
Nickel	<1.0 – 27 mg/kg	230mg/kg	S4UL[2]	None of 8
Selenium	<0.5 – 1.1 mg/kg	1,100mg/kg	S4UL[2]	None of 8
Vanadium	<0.8 – 39 mg/kg	2,000mg/kg	S4UL[2]	None of 8
Zinc	<1 – 230 mg/kg	81,000mg/kg	S4UL[2]	None of 8
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03 – 0.79 mg/kg	15,000mg/kg	S4UL[2,7]	None of 8
Acenaphthylene	<0.03 mg/kg	15,000mg/kg		None of 8
Anthracene	<0.03 – 0.73 mg/kg	74,000mg/kg		None of 8
Benzo(a)anthracene	<0.03 – 0.93 mg/kg	29mg/kg		None of 8
Benzo(a)pyrene	<0.03 – 0.32 mg/kg	5.7mg/kg		None of 8
Benzo(b)fluoranthene	<0.03 – 0.63 mg/kg	7.1mg/kg		None of 8
Benzo(ghi)perylene	<0.03 – 0.13 mg/kg	640mg/kg		None of 8
Benzo(k)fluoranthene	<0.03 – 0.23 mg/kg	190mg/kg		None of 8
Chrysene	<0.03 – 0.9 mg/kg	57mg/kg		None of 8
Dibenzo(a,h)anthracene	<0.03 – 0.04 mg/kg	0.57mg/kg		None of 8
Fluoranthene	<0.03 – 3.4 mg/kg	3,100mg/kg		None of 8
Fluorene	<0.03 – 0.72 mg/kg	9,900mg/kg		None of 8
Indeno(123-cd)pyrene	<0.03 – 0.14 mg/kg	82mg/kg		None of 8
Naphthalene	<0.03 – 0.1 mg/kg	4,900mg/kg		None of 8
Phenanthrene	<0.03 – 3.2 mg/kg	3,100mg/kg		None of 8
Pyrene	<0.03 – 2.2 mg/kg	7,400mg/kg		None of 8
Other Organic Compounds				
Phenol	< 0.03mg/kg	760mg/kg	S4UL[2,7]	None of 8

Notes
1. Assessment for public open space (landscaping around residential units, without growth of home-grown produce.
2. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved. No SGV published for this land use.
3. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission.
4. C4SL: Category 4 Screening Level. No current SGV, S4UL or CLAIRE/EIC assessment criteria for lead. Category 4 Screening Level adopted in assessment.
5. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted.
6. GAC for inorganic mercury adopted.
7. GAC for organic compounds based on 1% soil organic content.
8. ESP - Generic Assessment Criteria generated by ESP using CLEA software.
9. Exceedances highlighted in red and bold.
10. Laboratory results presented in Appendix L.

From Table 5, it is clear that all the determinands analysed were below their respective GAC. No further statistical analysis is warranted.

5.4.4 Asbestos

No evidence of asbestos was identified in the samples analysed.

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 25 below:

Table 6: Summary of Assessment Criteria for Planting

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	<0.2 – 16 mg/kg	250mg/kg	MAFF[1]	None
Cadmium	<0.1 – 1.3 mg/kg	3mg/kg	ICRCL[2]	None
Chromium (total)[6]	<0.15 – 28 mg/kg	400mg/kg	MAFF[1]	None
Copper	<0.2 – 41 mg/kg	200mg/kg (pH>7)	BS3882[3]	None
Lead	<0.3 – 190 mg/kg	300mg/kg	MAFF[1]	None
Mercury	<0.05 – 0.15 mg/kg	1mg/kg	MAFF[1]	None
Nickel	<1.0 – 27 mg/kg	110mg/kg (pH>7)	BS3882[3]	None
Zinc	<1 – 230 mg/kg	300mg/kg (pH>7)	BS3882[3]	None

Notes
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 Appendix L.

From Table 6, it can be seen that the levels of the potentially phytotoxic contaminants recorded were all below the respective assessment criteria.

5.6 Ground Gas

5.6.1 Degradation of Organic Materials

At the request of the client, 3no. ground gas monitoring wells have been installed and to date monitored for hazardous gases on 2no. occasions. The current monitoring has indicated levels of methane up to 0.2%, levels of carbon dioxide up to 2.5% and gas flow rates of non-detect. A full assessment of gas risks will be presented in a gas addendum report on completion of the monitoring.

5.6.2 Radon

As discussed in 2.10 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 1.1m of Made Ground comprising gravelly sand with hardcore, concrete and brick rubble and metal pipes on the site, we consider that it should be considered as 'brownfield' in terms of concrete classification.

5.7.2 Groundwater Setting

No groundwater was encountered in the exploratory holes to a depth of 4.0m. However, no long term monitoring (in excess of 24 hours) of groundwater levels has been undertaken. Therefore, in accordance with the BRE guidelines, we recommend that groundwater be considered as 'mobile' in terms of foundation concrete 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 10 and 29mg/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 0.02 and 0.07% and total sulphur between 0.01 and 0.06%. From these results, the calculated levels of total potential sulphate are between 0.03 and 0.18% and oxidisable sulphides are between 0.00 and 0.11%. As the levels of oxidisable sulphide are well below 0.3%, pyrite is unlikely to be present. pH values in the Made Ground varied between 7.9 and 9.7, indicating near neutral soil to slightly acidic 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.

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the upper weathered Mercia Mudstone (Marginal Facies) soils to be between 10 and 11mg/l. Levels of acid soluble sulphate varied between 0.02 and 0.06% and total sulphur between 0.01 and 0.02%. From these results, the calculated levels of total potential sulphate are between 0.03 and 0.06% and oxidisable sulphides are between 0.00 and 0.01%. As the levels of oxidisable sulphide are well below 0.3%, pyrite is unlikely to be present. pH values in the upper weathered Mercia Mudstone (Marginal Facies) varied between 7.8 and 8.2, indicating near neutral soil conditions to exist.

5.7.4 Foundation Concrete Design:

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

Water soluble sulphate:	29mg/l;
Total potential sulphate:	0.18%

pH value: 7.9

Using the above results, we consider that the following characteristic values are applicable for the upper weathered Mercia Mudstone (Marginal Facies) soils at the site (all as SO_4):

Water soluble sulphate:	11mg/l;
Total potential sulphate:	0.06%
pH value:	7.8

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

The investigation has identified a partial covering of Made Ground across the site. Made Ground was identified to very shallow depths in the western and northern portions of the site (TP3A to TP5, WS2 and WS4) generally comprising grey hardcore gravel and reworked natural soils. In TP3, Made Ground comprising gravelly sand with concrete and brick rubble and metal pipes was encountered to a depth of 1.1m. Groundwater was not encountered in the investigation points over the duration of the site works.

Geo-environmental laboratory testing has indicated that all the determinands tested fall well below the adopted GAC for public open space around residential properties. No evidence of asbestos was encountered on the site or in laboratory testing, however, the presence of asbestos within the existing buildings of site has yet to be confirmed.

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 4, Section 3.2.2) have been updated and revised in Table 7 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 7: 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	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Unlikely[2]	Low Risk	See Section 7.1.2 for further discussion.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Low likelihood[2]	Very Low Risk	
	Leaching of soil contaminants	Impact on Groundwater	Medium – site lies on Principal Aquifer	Likely[2]	Moderate Risk	See Section 7.2 for further discussion.
	Leaching of soil contaminants	Impact on River Thaw	Medium – site lies 150m west of river.	Low likelihood[2]	Moderate/Low Risk	
Soil sulphate	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Low likelihood[3]	Low Risk	See Section 7.4.2 for further discussion.
Asbestos in shallow soils	Ingestion of fibres	Demolition/ Construction Workers	Medium – potential for chronic levels	Unlikely[4]	Low Risk	See Section 7.1.4 for further discussion.
Asbestos in building and/or future demolition rubble.	Ingestion of fibres	Demolition/ Construction Workers	Medium – potential for chronic levels	Low Likelihood[4]	Moderate/Low Risk	See Section 7.1.4 for further discussion.
Radon Gas	Migration into Buildings	Site Users (residents)	Medium – potential for chronic levels	High Likelihood[5]	High Risk	See Section 7.3.2 for further discussion.
Ground gas generated in Made Ground	Asphyxiation/ poisoning, injury by explosion	Site Users / Visitors (residents)	Severe	Low Likelihood[6]	Moderate Risk	See Section 7.3 for further discussion.
	Damage through explosion	Buildings	Severe	Low Likelihood[6]	Moderate Risk	
	Asphyxiation/ poisoning, injury by explosion	Construction/ Maintenance Workers	Severe	Low Likelihood[6]	Moderate Risk	

Notes:

1. This table updates Table 4 in Section 3.2.2 using results of the investigation. Methodology and details of risk consequence, probability and category presented in Appendix A.
2. All determinands tested fell below the GAC guideline values- see Section 5.4
3. Low levels of sulphate were recorded in the samples analysed – see Section 5.7.
4. No asbestos identified in the samples analysed, however, ACMs may be present within the building on site – see Section 5.4.4
5. Radon risk identified in Groundsure report – see Section 3.1.4.
6. Monitoring of installed gas wells is ongoing at the request of the client.

7 Preliminary 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. Subsequent assessment will be required following the supplementary works recommended in Section 9.0. 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 at the site. However, it cannot be discounted that ACMs were used during the construction of newer school buildings in the early 1970's and that excess building materials could have been placed on the site.

An asbestos survey of the building should be undertaken and if any suspected asbestos containing materials (ACM) are identified during development, the advice of a suitably qualified specialist should be sought immediately. Any identified ACM would need to be removed from site by a licensed specialist contractor.

There is no clear UK guidance on what would constitute an acceptable concentration of asbestos in soil. Therefore, we recommend that all asbestos contaminated soils be removed from site prior to development. Working with asbestos (even within soils) is governed by the Control of Asbestos Regulations (2012). This requires that the excavation and removal of the asbestos contaminated soils musty be undertaken by a licensed contractor. Alternatively, an asbestos specialist may be employed to undertake further assessment of the risk from the asbestos present in the soils beneath the site with a view to investigating whether there would be an alternative risk mitigation method to prevent the expensive and non-sustainable removal and disposal of soils.

Prior to the demolition of the more recent school building on site, an asbestos survey should be undertaken and any asbestos materials found removed by a licensed contractor.

The following sections presume that any risks from asbestos materials at the site are mitigated.

7.1.2 Site End Users

Assuming an end use of residential the identified levels of soil contamination at the site are not considered to pose a risk to future site users. At present, no specific remedial measures are considered necessary for the development, however, supplementary assessment of areas not yet investigated are recommended as outlined in Section 9.0.

Notwithstanding the above, it cannot be discounted that former hollows in the site surface may have been infilled in the past with contaminated materials, particularly in the north portion where historic earthworks have been recorded. If during the recommended further works any evidence of significant Made Ground or soils that are markedly different from the current understanding are encountered, further geo-environmental specialist advice should be sought.

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 site has been developed as a school and areas of unspecified infill are recorded in the north western portion.
- Made Ground was encountered in some investigation points primarily in the western and northern portions of the site.
- The levels of soil contaminants are low, well below the GAC adopted.
- 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 oils and fuels from vehicle spills and leaks.
- Soakaways are being considered for the development.
- The site is underlain by fine grained soils, primarily comprising weathered bedrock which contains a high fine-grained fraction in its upper layers
- The bedrock beneath the site is classified as a Principal aquifer. Groundwater is anticipated within the weathered bedrock at depths below 10m.
- The River Thaw lies some 150m to the 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 and no further assessment is warranted. However, some risk mitigation is likely to be required where soakaways are used to dispose of surface water run-off – see Section 8.7 for further discussion.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

At the request of the client, 3no. ground gas monitoring wells have been installed and to date monitored for hazardous gases on 2no. occasions. The current monitoring has indicated levels of methane up to 0.2%, levels of carbon dioxide up to 2.5% and gas flow rates of non-detect. A full assessment of gas risks will be presented in a gas addendum report on completion of the monitoring.

7.3.2 Risk to the Development – Radon

As discussed in Section 3.1.4, the Preliminary Risk Assessment has indicated that radon protection is required and suitable enquiries should be made to ensure the appropriate application of these protection measures i.e. basic/full protection etc.

7.3.3 Risk to Construction and Maintenance Workers

Based on the above results we do not consider there is a particular risk to construction and maintenance workers, and there is no requirement to define shallow excavations as confined spaces. However, we recommend good site practice and all excavations should be considered potentially confined spaces. 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. If during construction any organic materials are encountered they should be excavated and replaced.

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.

7.4.2 Sulphate Attack on Buried Concrete

From Section 5.7.3, the following characteristic values are applicable for the shallow soils at the site (all as SO_4):

Water soluble sulphate:	29mg/l;
Total potential sulphate:	0.18%
pH value:	7.9

Based on these characteristic values, we consider that the site would be classified as Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-1, 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.

The stockpiles of demolition rubble/soil present on site would be initially classified as waste and cannot be managed under the DoWCoP protocols. If it can be demonstrated (by further testing and assessment) that the materials are compliant with the WRAP protocols, they may be de-classified as waste. Exemptions from the waste legislation may also be applicable.

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 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 prior to development.

8.1.2 Existing Foundations and Services

It is understood that the buildings currently occupying the site are to be demolished. Following demolition works, any old foundations of underground structures identified during development should be grubbed up within the zone of influence of the development as part of the site preparation works.

The following services are indicated on the service plans to be present within the site;

- Low Pressure Gas Pipes entering the building in the southern portion;
- BT Lines (Built) along the eastern boundary;
- Sewer and combined chambers in the north western portion.

During the investigation, a number of manhole covers were observed across the site and a clay drainage pipe was encountered in TP3, in the western portion of the site.

A network of land drains is likely to be present and may provide a seepage path into excavations. The land drains should be diverted where they enter foundation excavations.

8.1.3 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.

8.1.4 Earthworks

We have not been advised that the development requires any significant earthworks. The site is relatively flat and, therefore, no such earthworks are anticipated, however, we understand that historic earthworks may have been undertaken in the north portion and will require further consideration (see Section 9.0).

8.2 Geotechnical Risk Register

8.2.1 Updated Geotechnical Risk Register

The desk study (Section 2) identified the following potential geotechnical hazards at the site:

- Shrink/swell;
- Compressible ground;
- Ground dissolution; and
- Sulphate/pyrite.

This has been updated in Table 8 additional information on these and other potential geotechnical/construction risks identified by the intrusive investigation.

Table 8: Updated Geotechnical Risk Register

Hazard	Risk	Comments
Shrinkage and Swelling	Moderate	High plasticity soils identified – see Section 8.2.2
Ground Dissolution	Moderate	Marginal Facies are prone to weathering and creation of solution features.
Compressible Ground/ Settlement of Foundations	Moderate	Settlement of shallow footings could be excessive in areas of Made Ground – see Section 8.2.4
Sulphate Attack	Low	Concrete Class AC-1 required – see Section 8.2.3.

Notes
1. This table updates Table 3 in Section 2.9.1 using the results of the intrusive investigation.
2. Further discussion is presented in the following sections.

8.2.2 Shrinkage and Swelling

Laboratory testing has indicated, based on the modified plasticity index (which excludes the non-plastic coarser fraction within the soil), that the fine-grained soils at shallow (probable foundation) depth are of moderate to high plasticity and medium shrinkage/swelling potential. Based on this volume change potential, the minimum foundation depth would need to be 0.9m across the site, however this depth would need to be increased in accordance with NHBC/BRE guidelines within the zone of influence of recent, existing or future planting. It is essential that a tree survey (including current tree heights and species) is undertaken prior to any removal of trees in order to allow an assessment of the most economical foundation design.

A tree survey previously undertaken has indicated the presence of both mature and sapling trees across the site with species including, Ash, Lime, Yew, Hawthorn alongside various shrubs. The trees are predominantly located in the north western and south eastern portions of the site. Ash and lime are species of moderate water demand, and are could have an impact on the stability of the soils both laterally and vertically. Foundations in this area may have to be extended to at least 3.5m depth – see Section 8.2. Appropriately proportioned sub-floor voids would also be required beneath suspended floor slabs – see Section 8.4.

The use of trench fill foundations in these circumstances should be used with great caution as lateral swelling pressures on such large foundation surfaces can lead to rotation or other movement which could lead to failure of the foundation, and they may be subject to uplift forces from the soil swelling.

Swelling pressures can be reduced with the use of suitably dimensioned compressible layers, such as Clayboard or similar, on the sides of the foundations. BRE report 298 provides further guidance on other methods which may be adopted. In addition, the use of deep spread footings (strips or trench fill) can also initiate swelling in the fine-grained soils where roots are severed.

One the design proposals have been finalised, further advice can be provided by this office as to the required safe depth of foundations across the development.

It should be appreciated that the timing of construction will have an impact on the likelihood of shrinkage and swelling affecting the development. As such, consideration should be given to the proposed construction programme and then the need to carry out further testing and analysis of the potential and scale of movements.

8.2.3 Ground Dissolution

The site lies in an area susceptible to solution, through the weathering of the Marginal Facies. Therefore, following excavation, the formation should be very carefully inspected and any anomalous feature investigated further. In particular, areas of broken rock or clay infill alongside otherwise competent limestone should be excavated further to check the underlying materials. If in doubt, further geotechnical advice should be sought. Should any solution features be encountered in foundation excavations within the bedrock, the following treatment may be appropriate depending on the structural requirements:

Where a zone of broken ground crosses a foundation trench, they can be treated by removing the soft clay and fragmented rock infill to a depth of at least 500mm below foundation base level and then backfilling with concrete or designing the foundation to span such areas.Solution features such as cavities, pipes or channels should be treated by lining with a geotextile fabric and filling with free draining compacted suitable material.

These recommendations should be approved by a geotechnical engineer before the foundations are constructed. The above measures would only be practicable provided the size of the features does not exceed a nominal $3m^2$. If an individual feature does exceed $3m^2$ in size, then the most economical option may be to reposition the structure.

The location of soakaways should be carefully considered in areas where limestone solution is a risk – see Section 8.7.

8.2.4 Sulphate Attack

As discussed in Section 7.4, we consider that the site would be classified as Design Sulphate Class DS-1 and Aggressive Chemical Environment for Concrete Class AC-1.

8.2.5 Compressible Ground

The investigation identified Made Ground on the site with the deepest Made Ground encountered to 1.1m in TP3 in the western portion of the site. The Made Ground soils are potentially compressible. Furthermore, weak weathered upper portions of Mercia Mudstone Group (Marginal Facies) were encountered as soft to firm fine grained soils across the site to depths of up to 3.0m. The nature of these soils can be highly compressible and could results in settlement of foundations.

8.3 Preliminary Foundation Design and Construction

We understand that the site is being considered for potential development for residential purposes. It is understood the development will comprise three and four storey buildings. The comments and recommendations in this report are preliminary only at this stage and presume the structures to be conventional loadbearing brickwork construction. The following recommendations are preliminary only at this stage and should be reviewed upon completion of the supplementary works outlined in Section 9.0.

The site lies in an area susceptible to solution, through the weathering of the Marginal Facies. Therefore, following excavation, the formation should be very carefully inspected and any anomalous feature investigated further.

On the basis of the available investigation information, we consider that mass concrete spread foundations could be used at the site, constructed in the more competent weathered Mercia Mudstone (Marginal Facies) encountered from depths of 1.1. We consider that for foundations placed in this stratum, a presumed bearing value of around 100kPa should maintain total and differential settlements to less than 25mm. In some areas, including where more competent bedrock was not encountered, the foundations should be deepened. It cannot be discounted that areas of deeper bedrock may be present under the existing building footprint, as such further investigation is required post demolition.

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. We recommend that a blinding layer of concrete be placed on the formation after excavation and inspection in order to protect the formation against softening and disturbance.

Although groundwater was not encountered during the investigation, should groundwater be encountered at any point during excavation, to minimise the potential for excavation instability, we recommend that as short a time as possible is left between excavating the foundation trenches and pouring the concrete.

8.4 Floor Slab Foundations

The near-surface fine-grained soils at the site have a medium volume change potential. Therefore, all floor slabs constructed within the zone of influence of past, existing or future planting (including hedgerows) should be suspended with a suitably dimensioned sub-floor void to allow for any future movement in the soils.

8.5 Pavement Design

We understand that vehicle access roads and areas of parking are proposed at the site. CBR testing using the TRL approved dynamic cone penetrometer (DCP) is due to be undertaken alongside the on going as monitoring. The full results of the DCP testing will be provided alongside the gas addendum following completion of this report.

8.5.1 Susceptibility to Frost Action

Given their plasticity, the near surface fine grained soils are considered to be frost susceptible. A total thickness of 450mm non-frost susceptible pavement construction will be required to avoid frost heave.

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. The wheeled excavator used in the investigation failed to excavate below 2m to 3m within the weathered bedrock.

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 5m 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 (TP1, TP2 and TP3A). The results of the testing are presented in Appendix H.

Sufficient infiltration was achieved within the test to allow an infiltration rate to be calculated at only 1no. of the 3no. locations (TP1). At location TP1, 2no. fills were carried out, due to time constraints the second fill was abandoned, however, sufficient infiltration was experienced to allow for effective extrapolation of the data. At locations TP2 and TP3A, sufficient infiltration was experienced to allow an effective extrapolation of the test data to obtain an estimate of the likely infiltration rate had the required additional time been available to complete the test.

The calculated and extrapolated infiltration rates are presented in Table 9 below.

Table 9: Summary of soakaway infiltration test results

SA Test	Test Pit	Test depth	Measured Infiltration Rate[1]	Estimated Infiltration Rate[2]	Infiltration Soils
SA1 – Fill 1	TP1	1.6m	2.09×10^{-5} m/s	-	Silty gravelly CLAY
SA1 – Fill 2		1.52m	-	1.43×10^{-5} m/s	Silty gravelly CLAY
SA2	TP2	1.8m	-	7.5×10^{-6} m/s	Silty gravelly CLAY
SA3	TP3A	2.1m	-	*8.6* $\times 10^{-6}$ m/s	Silty gravelly CLAY

Notes:

1. Testing undertaken in accordance with BRE 365. Water level fell to 25% of fill depth.
2. Water level did not fall to 25% fill depth, but did fall beyond 75% fill depth, allowing extrapolation of data to 25% fill depth to provide an estimate of infiltration rate. Results should be treated with caution.

The soakaway infiltration rate is dependent on the fine fraction within the soils. In general, where the soils comprised a clay (albeit gravelly or sandy), the infiltration rate was low (e.g. TP2, TP3A). However, where the proportion of fine grained materials (silt and clay) was low and, therefore, the porosity of the soils was greater, the infiltration rate was found to be significantly higher, of the order of 10^{-4} or 10^{-5} m/s (e.g. TP1).

In general, we would recommend that 10^{-6} m/s be used as a typical infiltration rate for design across the site. However, it must be appreciated that where fine-grained soils are present, infiltration rates will be lower. As the infiltration stratum was weathered bedrock it should also be appreciated that cracks or faults will also significantly affect the obtained infiltration rates.

8.7.2 Soakaway Location

Care should be taken in the siting of the soakaways, with in particular, soakaways should be constructed a minimum of 5m from buildings and party walls and 10m away from the crest of slopes. Consideration will also have to be given to the creation of solution features through the use of soakaways.

8.7.3 Soakaway Discharge

The infiltration stratum at the site would be the Marginal Facies (Mercia Mudstone Group) bedrock, which is classed as a Principal aquifer and the groundwater within is vulnerable to pollution. The Environment Agency has a general policy that no direct discharge of surface run-off would be accepted in vulnerable groundwater aquifers. Given the shallow depth of the bedrock at the site, any soakaways would result in the direct discharge of surface water run-off into the aquifer. We recommend that enquiries are made to Natural Resources Wales (who have taken over the role of the Environment Agency) to identify whether they would object to such discharge at the site. As a minimum, risk mitigation measures such as oil interceptors are likely to be required.

9 Recommendations

We consider that the following further investigation and assessment would be required or prudent prior to development:

- Asbestos survey of existing building (Section 7.1.1);
- Further intrusive investigation in the areas currently occupied by the school buildings after demolition;
- Further intrusive investigation should be undertaken in the north portion where historic unspecified infilling has been recorded (Section 3).
- Enquiries to NRW/EA to confirm acceptance of soakaways and any risk mitigation measures required (Section 8.8.3);
- Careful design of soakaways, taking into account the potential for solution features;
- Review and confirmation of foundation recommendations based on investigation of currently non investigated areas;
- Watching brief and foundation inspections for Limestone Solution Features.

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