

Earth Science Partnership

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Dowlais Primary School, Merthyr Tydfil
Proposed Flying Start
Geo-Environmental and Geotechnical Report
Report Reference: ESP.7485d.3402

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Dowlais Primary School, Merthyr Tydfil Proposed Flying Start Geo-Environmental and Geotechnical Report

Prepared for:
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Report Reference: ESP.7485d.3402

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Contents

1	Introduction	1
1.1	Background	1
1.2	Objective and Scope of Works.....	1
1.3	Report Format	1
1.4	Limitations of Report	2
2	Desk Study and Field Reconnaissance Visit	3
2.1	Site Location and Description	3
2.2	Site History	4
2.3	Previous Investigations and Assessments	5
2.4	Contact with Regulatory Bodies & Local Information Sources.....	6
2.5	Hydrology	6
2.6	Flooding	6
2.7	Geology	7
2.8	Hydrogeology	8
2.9	Environmental Setting	9
2.10	Preliminary Geotechnical Risk Register.....	11
2.11	Radon Hazard.....	13
3	Preliminary Geo-Environmental Risk Assessment	15
3.1	Phase One Conceptual Site Model	15
3.2	Preliminary Risk Evaluation & Plausible Pollutant Linkages.....	17
4	Exploratory Investigation	19
4.1	Investigation Points.....	19
4.2	Instrumentation.....	22
4.3	Sampling Strategy	23
4.4	Evidence of Site Contamination Found During Site Works	23
4.5	Geotechnical Laboratory Testing.....	23
4.6	Geo-environmental Laboratory Testing.....	24
5	Development of the Revised Conceptual Model	25
5.1	Conceptual Ground Model - Geology	25
5.2	Conceptual Ground Model - Hydrogeology	26
5.3	Site Instability	26
5.4	Chronic Risks to Human Health – Generic Assessment of Risks	27
5.5	Hazardous Ground Gas.....	32
5.6	Sulphate Attack	32
6	Phase Two Geo-Environmental Risk Assessment	34
6.1	Discussion on Occurrence of Contamination and Distribution	34

6.2	Revised Risk Evaluation & Relevant Pollutant Linkages	34
7	Remedial Strategy for Contamination Risks	36
7.1	Risks to Health	36
7.2	Risks to Controlled Waters	37
7.3	Risks from Ground Gas.....	37
7.4	Risks to Property	38
7.5	Re-Use of Materials/Disposal of Excess Arisings.....	39
8	Geotechnical Comments	41
8.1	Site Preparation and Earthworks	41
8.2	Geotechnical Risk Register.....	41
8.3	Foundation Design and Construction	42
8.4	Floor Slab Foundations.....	43
8.5	Retaining Wall Design.....	43
8.6	Pavement Design	43
8.7	Excavation and Dewatering.....	44
8.8	Soakaway Drainage	45
9	Recommendations	48
10	References	49

Plates

Figure 1 – Investigation Point Plan

Appendix A	Risk Evaluation Methodology
Appendix B	Extracts from Historical Maps
Appendix C	Environmental and Geological Data Report
Appendix D	Correspondence with Merthyr Tydfil County Borough Council
Appendix E	Coal Authority Mining Report
Appendix F	Preliminary UXO Risk Assessment (Zetica, 2020)
Appendix G	Trial Pit Records
Appendix H	Rotary Drillhole Records
Appendix I	Results of Spot Gas and Groundwater Monitoring
Appendix J	Results of Soakaway Infiltration Testing
Appendix K	Results of Dynamic Cone Penetrometer (DCP) Testing
Appendix L	Geotechnical Laboratory Test Results
Appendix M	Geo-environmental Laboratory Test Results - Soils

General Notes

General Construction Advice

Executive Summary

Merthyr Tydfil County Borough Council are proposing to develop the subject site as a new Flying Start for the primary school. ESP have undertaken a geo-environmental and geotechnical assessment and 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 a grassed field which forms a playground for an existing primary school.
	Identified Ground Conditions. (Section 5.1)	-	Made Ground (MG) to a max. depth of around 1.2m followed by fine grained glacial soils with cobbles and boulders overlying Lower Coal Measures (LCM) bedrock. An intact coal seam (the Garw) and ironstones have been encountered to 40m.
	Groundwater Conditions. (Section 5.2)	-	The glacial deposits are classified as a Secondary Undifferentiated Aquifer and the LCM as a Secondary A Aquifer. Shallow perched water was identified between 1.7m and 2.2m bgl. Monitoring has recorded anomalously shallow levels in BH2 and BH3.
	Historical Land Use. (Section 2.2)	-	No obvious evidence of any prior development or former contaminative use has been identified, however the surrounding area has been heavily industrialised. Earthworks are indicated to have occurred on-site associated with a tennis court and the school.
Geo-environmental	Potential Contamination Sources (Section 3.1.2)	Low	No obvious sources of contamination were identified, however the surrounding area has been heavily industrialised.
	Chronic Risks to Human Health (Section 7.1)	Low	The levels are not considered to pose a risk to future site users. No remedial measures are considered necessary. If contaminated soils are identified, further specialist advice should be sought.
	Risks to Controlled Waters (Section 7.2)	Low	We consider that the risk to controlled waters is likely to be low and no further assessment is warranted.
	Hazardous Ground Gas (Section 7.3)	Moderate	The site has been characterised as CS-2. The building classification in accordance with BS8485 requires confirmation once the design is known and the gas protection measures should be incorporated accordingly based on the required point score. No radon protection measures are required.
	Spontaneous Combustion (Section 7.4.1)	Moderate	MG at the site could be locally potentially combustible. We recommend the carbonaceous MG is removed from beneath the footprint of the development area, and all underground services within the carbonaceous MG are placed in trenches filled with inert granular fill.
Geotechnical	Abandoned Mine Workings and/or Old Mine Entries (Section 8.2.2)	Low	Shallow ironstone workings are indicated by the Coal Authority, however 6no. rotary boreholes in the footprint did not record any obvious evidence of them. The subsidence risk is therefore considered low, and risk mitigation measures are not necessary. We recommend reinforcement is incorporated into the foundations as a precautionary measure. In any area of past mining the existence of unrecorded mine entries or workings cannot be discounted.
	Weak/Compressible Ground, requiring non-traditional foundations (Section 8.3 and Section 8.4)	Low to Moderate	Reinforced concrete spread foundations could be used, constructed in the firm glacial soils (depths of around 1.5m bgl). The glacial soils contain cobbles and boulders and the founding strata may need to be varied in response to the local conditions.
	Shrinkage or Swelling (Section 8.2.3)	Low to Moderate	The fine-grained glacial soils are of very low to moderate shrinkage/swelling potential. The foundation depth would need to be designed in accordance with NHBC/BRE guidelines.
	Sulphate Attack on Buried Concrete (Section 7.4.2)	Moderate	We consider that the Made Ground soils would be classified as DS-2 and AC-3z. If the above elevated classification has significant cost implication, further testing could be pursued to attempt to reduce it.
	Soakaway Feasibility (Section 8.8)	-	Soakaway drainage is feasible in the shallow glacial soils (above depths of around 1.6m to 1.8m), however the results are not definitive and are variable with depth. Design development is required, followed by further confirmatory testing.
	Other Hazards (Section 8.7)	High	For shallow excavations where there is a potential danger to life, support of excavation sides is likely to be necessary. No significant groundwater ingress is anticipated above 1m depth. However, groundwater monitoring in BH2 and BH3 has recorded very shallow levels, which are not obviously explainable at this stage. Management of surface water run-off may be required during construction.
Others	UXO (Section 2.10.6)	-	A specialist assessment concludes that 'a detailed desk study, whilst always prudent, is not considered essential in this instance'.
	Flooding (Section 2.6)	Low	A low flood risk from rivers and surface water has been identified.
	Invasive Plants (Section 8.1.2)	-	No invasive plants was identified during the works. However, their growth is seasonal and therefore their presence cannot be discounted.
	Further Investigation Required?	No	See Section 9.

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

1 Introduction

1.1 Background

Merthyr Tydfil County Borough Council (hereafter known as the Client) are proposing to develop the subject site as a new Flying Start for the primary school. The Earth Science Partnership Ltd (ESP), Consulting Engineers, Geologists and Environmental Scientists, were instructed by Blaenau Gwent County Borough Council, 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 in Section 2.1.

The proposed development will comprise a single story classroom with external hardstanding and landscaping. No detailed plans of the development layout are currently available.

The proposed development layout is presented as Insert 1.

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

1.2 Objective and Scope of Works

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 mutually developed with the Client by ESP within an agreed budget, 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 trial pits, rotary drillholes, soakaway infiltration testing, measurement of in-situ CBR values (using DCP equipment), geotechnical and geo-environmental laboratory testing, assessment 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 proposals of the 4th March and 17th June 2020 (ref: ESP7425d.It1 and ESP7425d.02.It1 respectively).

The initial investigation was undertaken in May 2015 with supplementary soakaway testing and assessment being undertaken in July and August 2020.

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.

This report is issued as a digital version only.

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 above. 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.

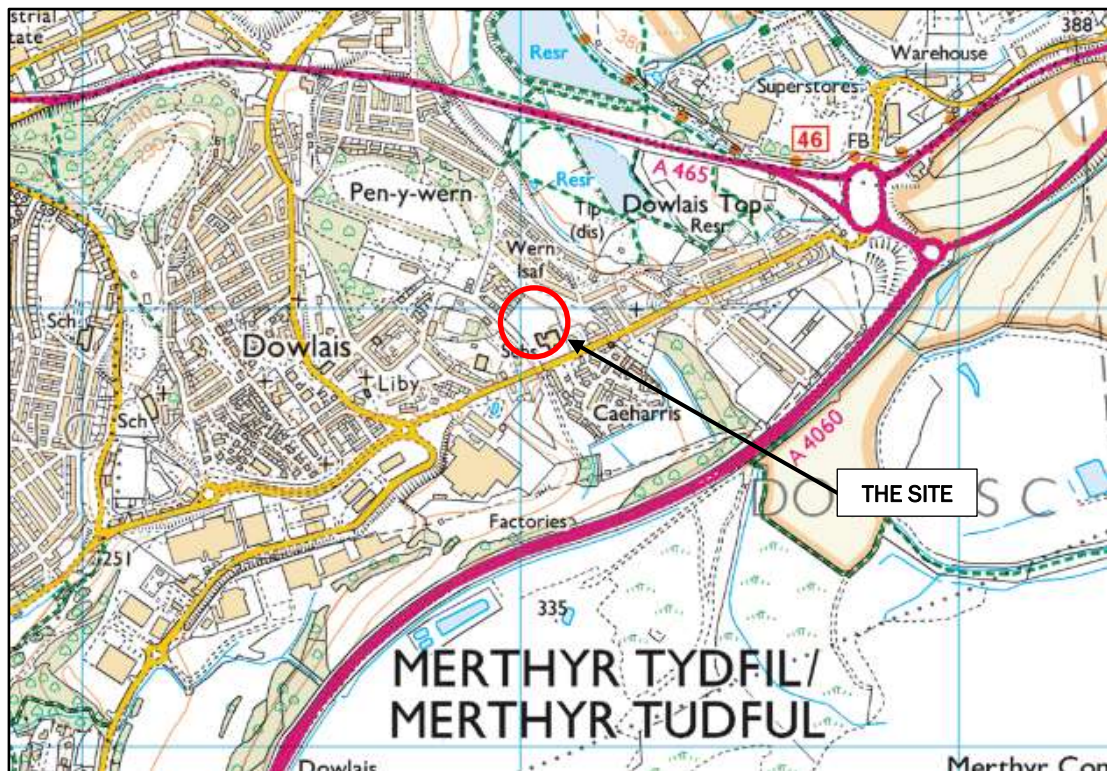
2 Desk Study and Field Reconnaissance Visit

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps, an environmental data report, a geological data report, information on a previous investigation at the site, and a mining report obtained from the Coal Authority. 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 during the fieldworks in May and July 2020 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 on the east side of Gwernllwyn Road, within Dowlais Primary School on the north east margins of Merthyr Tydfil. The National Grid Reference of the centre of the site is (SO) 307026 207975 and the postcode is CF48 3HB. A Site Location Plan is presented as Insert 1 below.

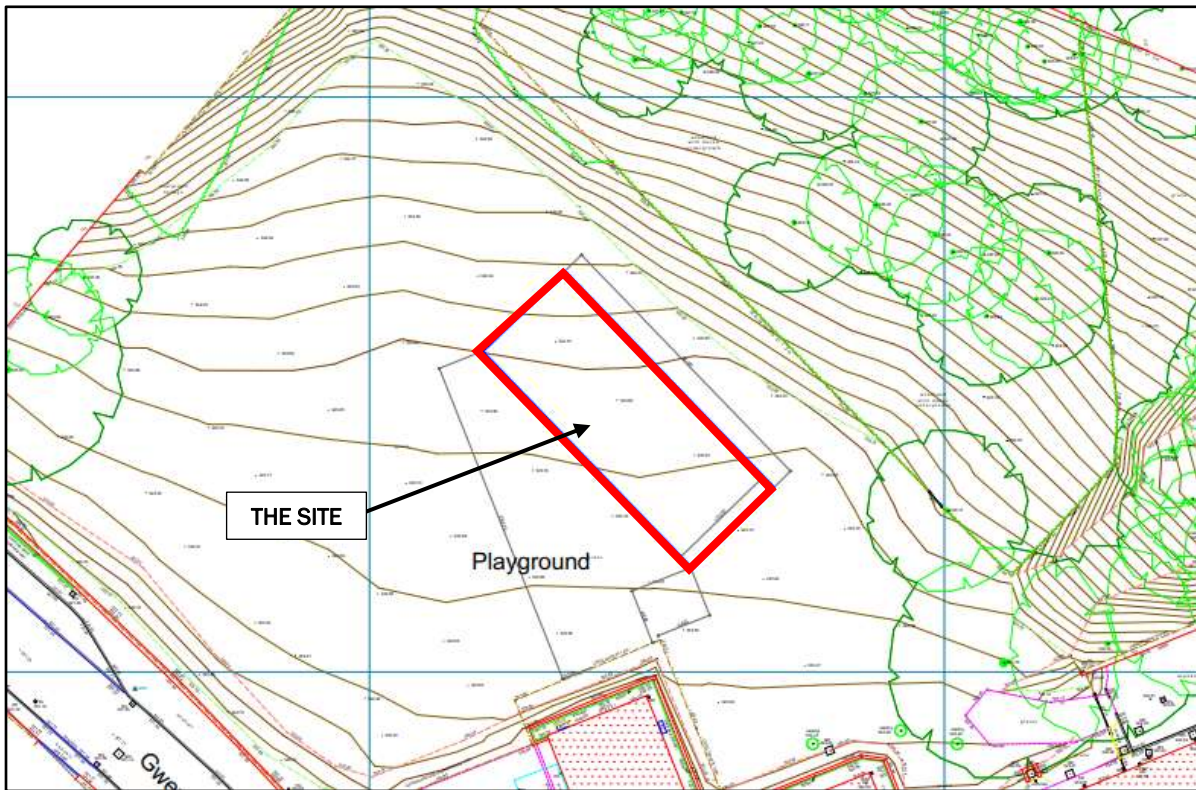


Insert 1 - Site Location Plan from Ordnance Survey 1:25,000 scale map.
Reproduced with permission (OS License No.: AL100015788).

The site comprises a rectangular shaped parcel of land of around 27m length (north west to south east) and 10m width (north east to south west), occupying an area of less than 0.1ha. It is presently occupied by a grassed field used as an external play area in a primary school.

It is bounded by:

- To the north: by residential developments and open fields.
- To the east: by woodland followed by residential developments.
- To the south: the existing primary school buildings.
- To the west: by the remainder of the field followed by Gwernllwyn Road.



Insert 2 - Site Location Plan and Topographic Survey (Provided by the Client)

Vehicular access to the site is currently gained via a gate in the south east corner of the field. The boundaries are open with the site located within the field.

We are not aware of a tree survey having been undertaken at this stage, but from site observations we identified dense woodland to the north east of the proposed building location. A tree survey should be considered by a specialist arboriculturist prior to development.

The general topography in the area slopes to the south/south east. A topographic survey provided by the Client for the site (see Insert 2), indicates the area of the proposed building slopes around 0.5m to the south and is generally at an elevation of around 324m AOD.

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 not crossed by any recorded services.

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 the table below.

Table 1: Review of Historical Maps

Date	On-Site	In Vicinity of Site
1875 - 1948	The site forms the central part of a larger parcel of seemingly undeveloped land.	Significant residential and industrial development is located in the surrounding area and occurs through this period. A tramway is located approximately 40m north east of the site trending north west to south east. Further railway lines are located a similar distance to the south west extending from the large 'Dowlais Ivor Iron Works' located from 130m north west. A smithy is noted 110m to the south east. An old ironstone shaft is noted approximately 140m north east with earthworks in it's vicinity. Brick kilns, further iron works and collieries are shown approximately 240m to the south which are linked to the Ivor works via the rail network. The iron works, collieries and works and associated infrastructure expand during this period.
1955-1958	The area of the site is now indicated to be a playground and the subject site is occupied by earthworks associated with a tennis court.	The ironworks to the north west has been redeveloped with a new layout and multiple tanks and a substation. Numerous railway lines have been dismantled and some buildings demolished. An additional substation is noted 150m to the east. The previously identified old mine shaft, smithy, railway and brick kilns are no longer shown, as the majority of the surrounding area has been redeveloped, primarily with residential dwellings. The site of the previous brick kilns has a tank and a chimney noted. Ruins are noted in the general area possibly associated with bombing during WW2.
1961-1966	No significant changes indicated.	The iron works is now indicated as an engineering works on the 1:2,500, however it remains an iron works on the 1:10,000. Further modifications have occurred (e.g. some tanks have been removed). Further dismantling of the railway networks and demolition of historical industrial infrastructure in the area has occurred. A refuse tip is indicated around 230m to the north east.
1973 - 1982	The tennis court is no longer shown as the site has been redeveloped into the existing school site.	School buildings are now indicated to the south. Additional tanks are indicated associated with the works. The temporary housing to the north east has been demolished and replaced with new residences.
1987-1995	No significant changes indicated.	A pond is shown approximately 30 m east of the site. The railway/tramlines to the east and west have been dismantled. The majority of the buildings related the site of the former iron works are no longer shown with some tanks and substation still present.
1995-present	No significant changes indicated.	The tanks at the site of the former iron works are no longer shown.
Notes: 1. Extracts from historical maps presented in Appendix B. 2. Features may have been present on site between the dates of the individual mapping, and it should be appreciated that these cannot be identified from the map review. 3. The map dated 1988 contradicts the continuity of the mapping data, however the 1988 map is shown to have been surveyed in 1958.		

The site appears to have remained undeveloped until the 1950s when a tennis court with associated earthworks was developed, which was later removed during the construction of the school in the 1970s. No earthworks are indicated once the school has been built therefore some re-profiling may have occurred.

2.3 Previous Investigations and Assessments

We are not aware of any previous geotechnical or geo-environmental investigations or assessments at the site.

ESP have undertaken numerous investigations in the Dowlais area including the RFC, the former St John's church and at Pengarnddu Industrial Estate. The site specific findings are not directly relevant,

however at the RFC and Pengarnddu Industrial Estate ironstone mine workings were encountered in the Lower Coal Measures strata.

2.4 Contact with Regulatory Bodies & Local Information Sources

The Local Authority have been contacted for additional information on the site.

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

There are no major surface water features within 150m of the site. Minor surface water features are indicated around 180m to the south west and north east flowing south east.

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.

2.6 Flooding

2.6.1 Rivers and Seas

From a review of topographical plans and flooding maps presented in the environmental data report and on the Natural Resources Wales (NRW)/Environment Agency (EA) website (EA, 2019), the site is located in Flood Zone 1 and not indicated to be at risk flooding from rivers (fluvial) or seas (tidal). Flood Zone 1 is defined as an area during any given year that has less than 0.1% (1 in 1000) of flooding from rivers (fluvial) or seas (tidal).

The potential for flooding from rivers or seas has not been addressed further in this report.

2.6.2 Surface Water

Surface water flooding happens when rainwater does not drain away through the normal drainage systems or soak into the ground but lies on or flows over the ground instead. This type of flooding can be difficult to predict, much more so than river or sea flooding as it is hard to forecast exactly where or how much rain will fall in any storm. The information available depends on available records including ground levels and drainage.

From a review of information available on the Natural Resources Wales (NRW) /Environment Agency (EA) website (2019), the site is indicated to be outside areas at risk of surface water flooding and is described at Negligible Risk, defined as an area that in any given year has less than 0.1% (1 in 1000) chance of surface water flooding.

2.6.3 Groundwater

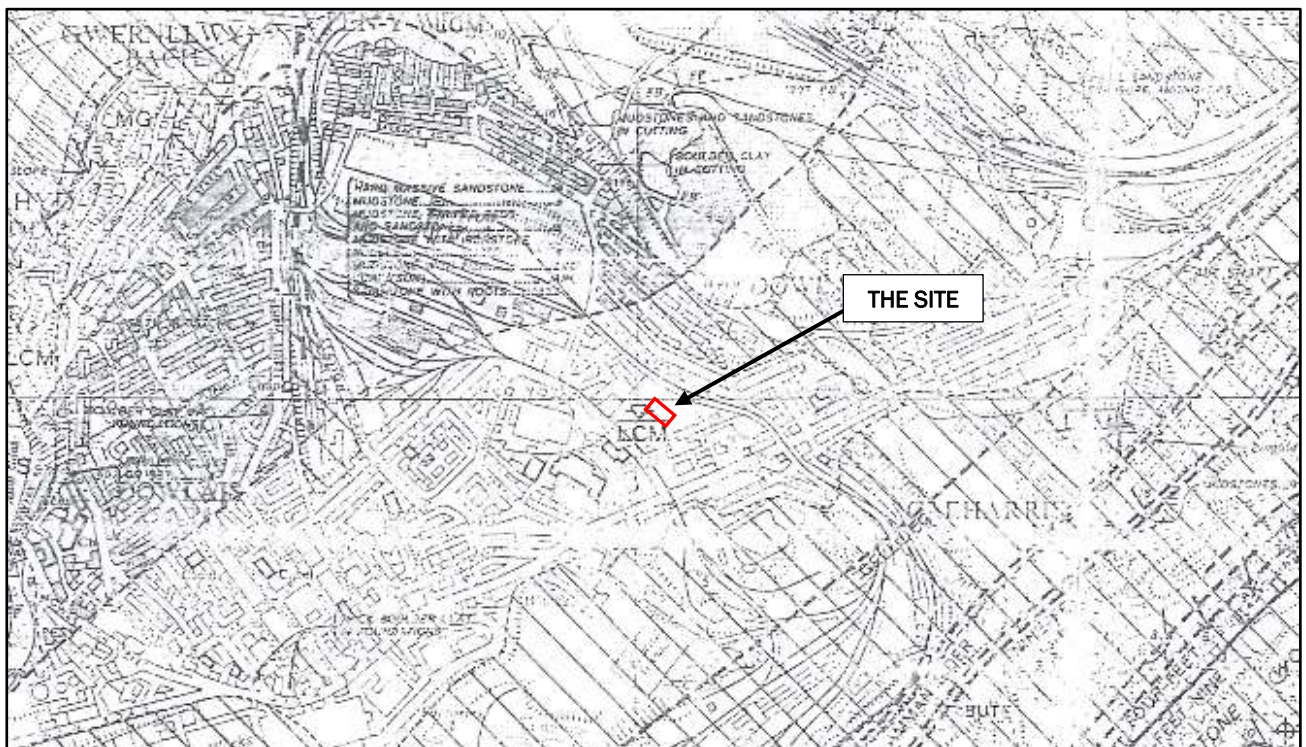
Groundwater flooding is defined as the emergence of groundwater at the ground surface away from river valleys or the rising of groundwater into man-made ground under conditions where the

'normal' range of groundwater levels and groundwater flows is exceeded and predicted risk from groundwater flooding aims to identify locations where this form of groundwater flooding could happen. It does not incorporate anomalous discharge from springs leading to groundwater flooding down the topographic slope or flooding associated with urban groundwater rebound, mine water discharge, urban drainage, or any other flooding associated with changes in the engineered environment.

The environmental and geological report in Appendix C indicates that the site is at a potential moderate risk at surface from groundwater flooding.

2.7 Geology

2.7.1 Published Geology



Insert 3 - Extract from BGS Geological Map Sheet SS00NE, original 1:10,560 scale.
Reproduced with permission (BGS licence number: C15/05 CSL)

The published 1:10,560 scale geological map for the area (Sheet SO 00 NE) indicates the site to be underlain by Boulder Clay (now known as Diamicton/Glacial Till) overlying South Wales Lower Coal Measures Formation. Reference to the up-to date mapping available on the website of the British Geological Survey (BGS, 2020) indicates a similar succession.

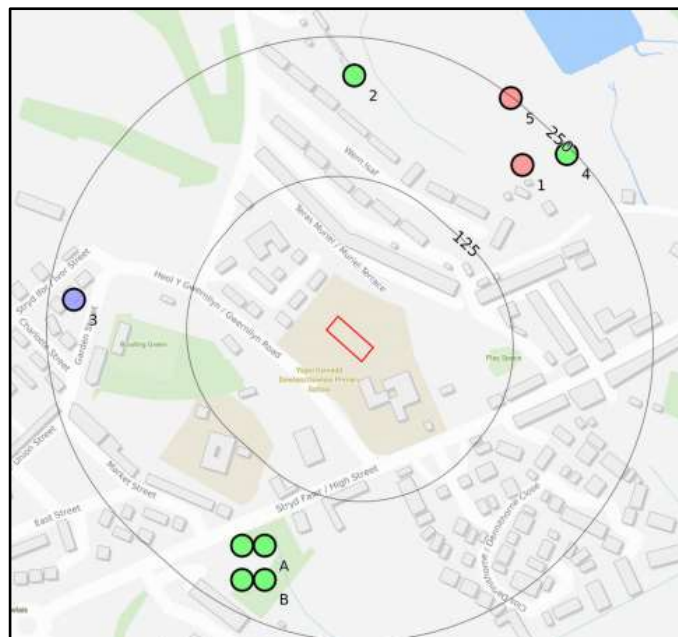
The Diamicton superficial strata would be expected to be a heterogeneous mix of clays, silts, sands and gravels with occasional cobbles and boulders. The Lower Coal Measures bedrock comprises an interbedded succession of sandstone, siltstones and mudstone, with coal seams and associated seat earths.

Widespread Made Ground associated with the extensive historic industrial activity is indicated in the area, however none beneath the site itself.

The bedrock in the area is shown to dip between 5° to 16° to the south. The 1:10,560 geological map shows the Gellideg coal seam outcropping around 330m south east of the site and the Farewell Rock (a distinctive sandstone band at the base of the coal measures) approximately 142m north of the site.

The stratigraphic sequence for the area indicates that the Garw coal seam (1 foot) and the underlying Rosser Ironstone Veins are present between the Gellideg seam and the Farewell Rock. The geological map does not show the outcrop of either of these seams and considering the regional dip they would underlie the site. In addition, we are aware of ironstones also being present beneath the Gellideg coal seam and therefore these would be present at shallow depth or outcropping on-site. See section 2.10.1 for further discussion.

2.7.2 Available BGS Borehole Records



Insert 4 - Map of BGS boreholes in the vicinity of the site.

There are no BGS boreholes within 150m of the site.

Boreholes roughly located between 210m to 250m to the north east, confirm the presence of ironstones generally between 10 and 20m bgl. A coal seam was encountered beneath the ironstones with a thickness of around 0.5m. Localised mine workings were encountered with a maximum thickness of around 1.6m.

2.8 Hydrogeology

Reference to the aquifer maps published in the environmental data report (Appendix C) indicates that the superficial deposits beneath the site (Glacial Diamicton) are classed as Secondary Undifferentiated Aquifer, whilst the bedrock (Lower Coal Measures) is classed as Secondary A Aquifer.

Secondary Undifferentiated Aquifers are assigned by the Environment Agency where it has not been possible to categorise an aquifer in either Secondary A or B. In most cases this is attributable to a unit being classified as both minor and non-aquifers in different locations due to the variable characteristics of the rock type. These strata can be 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.

2.8.1 Anticipated Groundwater Bodies

Based on the available information, we consider that the shallowest main groundwater body is likely to be located within the Lower Coal Measures. However, localised perched waterbodies within any Made Ground or Diamicton cannot be discounted.

2.8.2 Abstractions and Groundwater Vulnerability

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

2.8.3 Groundwater Movement

Groundwater movement within the Made Ground or Glacial Diamicton will be controlled by intergranular flow, whilst in the Lower Coal Measures bedrock, fracture flow is likely to be dominant.

It is anticipated that due to the topography and dip of bedrock, groundwater movement will flow southward. It should be appreciated in former mining areas, such as this, groundwater conditions may still be changing in response to the cessation or reduction in pumping from underground mine workings (See Section 2.10.2).

2.9 Environmental Setting

2.9.1 Summary of Environmental Data

The site exists in a historically industrial/urban, and now an urban setting.

An environmental data report has been obtained for the site and is presented in Appendix C, and the relevant data therein is summarised in the table below. The report should be consulted for further detail.

Table 2 - Summary of Environmental Data

Feature	On the Site	In the Immediate Vicinity
Environmentally Sensitive Sites ^{2,3}	None identified.	None recorded within 500m of the site.
Potentially Contaminative Land Use	Railway sidings are indicated on-site, however based on the historical mapping data (see Section 2.2) this is incorrect.	Numerous recorded within 250m of the site, including railway land and sidings, iron works, refuse heaps, mining features and works.
Historical Tanks, PFS, Garages, Energy Facilities	None identified.	A historic tank (likely water) is located 34m to the south east in 1875. No other features are recorded within 100m of the site.
Potentially Infilled Land	None identified. Earthworks are indicated to have occurred on-site associated with the former tennis court and re-development as a school.	Made Ground and extensive filling has occurred in the general area associated with historic industrial activity.
IPPC Authorisations	None identified.	None recorded within 500m of the site.
Discharge Consents	None identified.	None recorded within 200m of the site.
List 1 and 2 Dangerous Substances Sites	None identified.	None recorded within 400m 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.	4no. recorded within 100m of the site. However, none are considered significant in the context of the site. See Appendix C for details.
Contaminated Land under Part 2A EPA 1990.	None identified.	None recorded within 500m of the site.
Waste Management Facilities	None identified.	A historic refuse tip was indicated on mapping data around 230m to the north east. No further features are indicated, however there are numerous waste exemptions for nearby farms.
Current Industrial/Commercial Sites	None identified.	None recorded within 100m of the site.
Notes: 1. Full details of features presented in environmental data report (Appendix C). 2. 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. 3. Nitrate vulnerable areas relate to the agricultural use of fertilizers and are not considered further in this assessment.		

2.9.2 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.

2.9.3 On-Site Bulk Materials and Waste Storage

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

2.10 Preliminary Geotechnical Risk Register

The potential for various geotechnical and geomorphological hazards at the site is provided in the combined environmental data and geological data report (Appendix C). The potential hazards, as defined by the British Geological Survey (BGS) and reported in the above report, along with any salient further information has been considered in the preparation of this report.

Where a potential geotechnical hazard has been identified, it is discussed further in subsequent sections.

2.10.1 Past Coal and Ironstone Mining

As discussed in Section 0, the site is underlain by bedrock of the Lower Coal Measures, which contains several seams of coal (and bands of ironstone).

2.10.1.1 Historical and Geological Information

Historical information indicates that extensive mining has occurred in the general area and an ironstone mine shaft was located around 140m to the north east. Ironstone workings are extensively indicated on the 1:10,560 geological map.

The Gellideg coal seam is indicated to outcrop around 330m south east of the site, with the farewell rock to the north west. The stratigraphic sequence and literature for the area indicates ironstones are present beneath the Gellideg coal seam, followed by the Garw coal seam (1 foot) and then further ironstone veins (Rosser) followed by the Farewell Rock.

The geological map does not show the outcrop of either the Garw or the ironstones, however considering the regional dip they would likely underlie the site at shallow depth or possibly outcrop within the boundary.

Localised mine workings were encountered within BGS boreholes within the same stratigraphy to the north east with a maximum thickness of around 1.6m.

2.10.1.2 Coal Authority Website

Reference to the Coal Authority website (CA, 2020) provides the following salient information:

- The outcrop of an unnamed coal seam is shown to cross the site in an north east to south west direction. Reference to the published geology (Section 2.7.1) suggests that this could be the Garw coal seam. The resolution for the coal seam position is poor, therefore it's exact location relative to the site cannot be determined.
- No past surface hazard or surface mining is identified in the vicinity of the site.
- Past shallow coal mine workings are indicated beneath the site.
- No mine entries are shown within the site boundary.
- The site lies within a 'Development High Risk Area'.

2.10.1.3 Coal Authority Mining Report

A consultants mining report has also been obtained from the Coal Authority and is presented in Appendix E. This indicates that, based on the available Coal Authority records:

- There are recorded workings in two ironstones beneath the site, at depths of 26 and 32m. The workings are indicated to be in the Rosser and Bottom Vein with extraction thicknesses of around 1.3m and 1.0m respectively. These workings were abandoned in 1878.
- The Garw Coal seam is indicated to outcrop adjacent to the north boundary and the Coal Authority indicate it is workable.
- There are no recorded mine entries within 100m of the site.
- There are no recorded geological faults or fissures recorded beneath the site.
- There are no recorded damage notices or claims for the subject property, or any property within 50m of the site boundary, since 31st October 1994.
- There is no record of any request having been made to carry out preventive works before coal is worked under section 33 of the Coal Mining Subsidence Act 1991.
- No mine gas emission has been recorded within 500m of the property.
- There is no proposed future mining or licensing proposed.
- No notices have been given under Section 46 of the Coal Mining Subsidence Act 1991 stating that the land is at risk of subsidence.

2.10.1.4 Preliminary Coal Mining Risk Assessment

Geological mapping data and nearby BGS boreholes indicated the likelihood of the Garw coal seam and ironstones at shallow depth beneath the site.

Coal Authority information indicates the Garw seam outcrops adjacent to the north boundary and there are recorded ironstone workings at depths of between 26m and 32m. Whilst no workings are recorded in the Garw, the Coal Authority indicate it is workable and considering it's shallow depth in the area it would also be accessible for extraction. We therefore cannot discount unrecorded workings within this coal seam also.

Based on the available information, there is a potential significant subsidence risk from coal and ironstone mine workings and intrusive investigation is required to determine the risk posed and any mitigation measures required.

It should be appreciated that the Coal Authority records are known to be incomplete, partly because there was no statutory and mandatory requirement on colliery owners to survey and submit records of the extent of their mine workings to the Secretary of State until the Coal Mine Regulation Act of 1872. Therefore, given the potential age of the workings, the actual extent of mine workings may extend further than shown on the abandonment plans.

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

2.10.2 Shrinkable and Swelling Soils

From our experience, the fine grained glacial soils anticipated at shallow depth beneath the site commonly are susceptible to volume change with changes in moisture content (shrinkage and swelling). In addition, trees may be planted as part of the development.

We consider that the potential for shrinkable/swelling soils at the site is **Moderate**.

2.10.3 Compressible Ground

Any Made Ground soils beneath the site could be potentially compressible, particularly where containing organic materials, which could lead to settlement at the surface. The glacial soils and any weathered bedrock at shallow depth are unlikely to be significantly compressible.

We consider that the potential for compressible ground at the site is **Low to Moderate**.

2.10.4 Volumetrically Unstable Slag Materials

The potential for volumetrically unstable slag material to be present on the site is not considered in the environmental data report. Slag was a waste product from iron and steel manufacture, and varies chemically depending on the manufacturing process involved. There are three main types of slag, blast furnace slag, basic steel slag and acid steel slag, along with further associated refractory products. Some forms of slags, such as fresh blast furnace slag and acid steel slag, are generally volumetrically stable but, depending on their chemistry, some such as basic steel slags and weathered blast furnace slags can be extremely unstable when hydrated, which can lead to significant heave at the surface and damage to buildings and hard surfaces.

Considering the proximity of former iron works, there is a potential for slag materials to be present within any Made Ground.

2.10.5 Pyritic Ground

The environmental data report does not consider the potential risk from sulphate rich or pyritic ground.

The Made Ground, Glacial and weathered bedrock underlying the may contain elevated levels of pyrite, which could oxidise to sulphates.

Given the above, we consider that the potential for sulphate/pyrite attack on buried concrete would be **Low to Moderate**.

2.10.6 Unexploded Ordnance

A Preliminary (Pre-Desk Study) 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 F (Zetica, 2020).

The assessment concludes that '*a detailed desk study, whilst always prudent, is not considered essential in this instance*'.

2.11 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 <1% of properties above the action level.

Reference to the UK radon maps published by Public Health England (PHE, 2020) indicates that the site lies in an area classified as a maximum radon potential of less than 1%

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.

Given the currently available information, the risk from radon is considered **Low**.

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 (both contamination and hazardous gas), the receptors at risk (both human and non-human), and any feasible pathways between the two. These are discussed in the following sections.

3.1.2 Potential Soil Contamination Sources

The desk study review has identified no evidence of any prior development or former contaminative use on the site. Therefore, we have not established the presence of any potential sources of contamination. Notwithstanding this, considering the significant industrial development that has occurred in neighbouring areas and the earthworks undertaken on-site, the presence of Made Ground, which could contain elevated levels of soil contaminants cannot be fully discounted.

3.1.3 Potential Contaminants Present

No obvious contaminant sources have been identified. However, based on guidance of the contaminants typically found on brownfield sites in the UK 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;
- 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 is discussed in Section 0

3.1.4 Potential Sources of Hazardous Ground Gas

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

- General Made Ground – on site source.
- Extensive Made Ground, tips and reclaimed land in neighbouring areas associated with historic industrial activity – off-site sources.
- Former refuse tip approximately 240m to the north east – off-site source.
- Mine gasses in shallow coal and ironstone workings – on and off-site source.

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 very low to moderate gas generation potential.

3.1.5 Potential Receptors

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

- Future employees, pupils and site visitors, the critical receptors being employees outside during their break periods.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The groundwater within the Coal Measures strata and potentially the overlying glacial soils beneath the site.
- No surface water features have been identified in neighbouring areas.

As discussed in Section 1.1, the proposed development will comprise a new primary school. The most vulnerable human receptors with regards to any soil contamination present will be staff and pupils of the school. The children's attendance will be limited and periodic, and the most significant risks are considered to be associated with teachers and caretakers who will have the longest potential exposure to contaminants. Therefore, the school staff (adults) are considered the critical human receptor.

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 garden areas.
- Ingestion of soils and inhalation of dust in landscaping areas.
- Ingestion of edible plants and dust associated with such plants (if planting is proposed).
- Dermal contact with contaminated soils.
- Exposure to asbestos containing materials within the shallow soils.
- Potential explosive risk from flammable ground gas/vapours from on-site sources.
- Potential risk from toxic ground gas/vapours from on-site sources.
- Potential exposure to flammable or toxic ground gas/vapours originating from off-site sources – fine grained glacial soils will limit migration.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the shallow soils.
- 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.
- Potential explosive risk from flammable or toxic ground gas/vapours from off-site sources.

Groundwater:

- Leaching of mobile contaminants into the water-bearing strata within the bedrock. Fine grained glacial soils will limit vertical migration.

Nearby Surface Water Courses:

- 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.

Any soakaways constructed for the development have the potential to leach contaminants from the infiltration strata, which could then impact on the groundwater beneath the site.

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 general 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 by ESP 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 3 in Section 3.2.2 below.

3.2.2 Tabulated Preliminary Risk Evaluation & Plausible Pollutant Linkages

Table 3: 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	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 /Potable Water	Medium – site lies on Secondary Aquifers	Likely ²	Moderate Risk	Sampling of near-surface soils to confirm levels of leachable contamination present.
	Leaching of soil contaminants	Impact on Surface Water Features around 180m from the site.	Medium – surface waters are likely sensitive.	Low likelihood ²	Moderate/Low Risk	
Asbestos in shallow soils	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Likely ³	Moderate Risk	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Likely ⁴	Moderate/ Low 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.	Likely ⁵	High Risk	Install and monitor gas wells.
	Damage through explosion.	Building/Property	Severe – acute risk.		High Risk	
	Asphyxiation/poisoning. Injury due to explosion.	Construction and Maintenance Workers.	Severe – acute risk.		High Risk	
Radon gas	Migration into Buildings	Site Users	Medium – potential for chronic levels	Unlikely ⁶	Low Risk	See Section 0

Notes:

1. Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1.
2. The presence of Made Ground or contamination has not yet been confirmed on site. However, significant industrial activity has occurred in neighbouring areas. See Section 3.1.
3. No obvious sources of asbestos have been identified. However, it's presence in any shallow Made Ground soils cannot be discounted. See Section 3.1.
4. The Made Ground, glacial soils and weathered bedrock strata can potentially contain sulphates/pyrite. See Section 2.10.5.
5. Numerous on and off-site potential sources of hazardous ground gas/vapours have been identified. See Section 3.1.4.
6. Radon risk identified in environmental data report. See Section 0.
7. The above risk evaluation is updated following the intrusive investigation and testing in Section 6.2.

4 Exploratory Investigation

4.1 Investigation Points

4.1.1 Introduction

The intrusive investigation was undertaken in two phases; between 19th to 28th May and 20th to the 27th of July 2020. The investigation was undertaken in accordance with BS5930:2015 and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Section 2). It comprised trial pitting, rotary open hole drilling, rotary coring, 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, BS EN ISO 14688-1:2002, BS EN ISO 14688-2:2018, and BS EN ISO 14689:2018, along with published weathering schemes.

The investigation point positions are shown on Figure 1.

The ground levels indicated on the investigation point records are approximate only and have been interpolated from the topographical survey provided by the Client. The coordinates shown on the investigation point records are approximate only and are for the centre of the site only.

4.1.2 Investigation Strategy

No specific potential contaminant sources were identified in the desk study (see Section 3.1.2), however a potential significant geotechnical hazard in the form of shallow mine workings have been indicated to be present beneath the development area. The investigation points were spread across the site to obtain a general overview of the ground conditions present, particularly at the proposed structure locations.

The investigation point locations were positioned to maximise the information that could be obtained. Notwithstanding the above constraints, we consider that the investigation undertaken has been sufficient to identify the key ground issues at the site.

The supplementary works were required as during the initial phase poor temporary stability prevented repeat fills within the soakaway test pits. We therefore re-mobilised at a later date and adapted our testing procedures to ensure the tests could be undertaken as required.

4.1.3 Trial Pits

4no. trial pits (TP101 to TP104) were excavated across the site on 20th May 2020 with a further 2no. pits excavated on the 20th of July 2020 using a wheeled, backacting hydraulic excavator. The trial pits were excavated to a maximum depth of 2.8m. The trial pit records are presented as Appendix G, and their positions are shown on Figure 1.

Disturbed samples were collected from the trial pits for laboratory testing as shown on the trial pit records.

On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket, and the Topsoil reinstated on the surface. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

4.1.4 Rotary Drillholes

7no. rotary drillholes (BH1 to BH6 and BH4a), were constructed to a maximum depth of 40.0m. The borehole records are presented as Appendix H, and their positions are shown on Figure 1.

All the boreholes were located in the footprint of the building, constructed with the objective of locating the rock-head profile and the depth to coal seams or possible abandoned workings.

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. The ODEX 115 system of simultaneous drilling and casing was used in the superficial deposits, and the depth of casing in each drillhole is shown on the drillhole records.

A combination of dynamic sampling and rotary openholing were used in the superficial deposits within 3no. boreholes (BH1 to BH3) to allow progression to bedrock and the collection of samples for testing and identification purposes. Openholing only was undertaken in BH4, BH4a, BH5 and BH6 to achieve progression to bedrock. BH4a was constructed as coring within the bedrock in BH4 was not achievable due to the inability to progress the casing system to rockhead due to the boulders in the superficial deposits.

Where dynamic sampling was used (BH1 to BH3), the soils were recovered using windowless sampling techniques, whereby the soil was collected within plastic lined sampling tubes, which were then split to allow sampling and logging. Disturbed samples were obtained throughout the boreholes for identification and laboratory testing purposes, as shown on the borehole records. The windowless sampling provided generally poor recovery, due to very dense cobbles and boulders preventing progression within the superficial glacial soils.

Given that the objective of the drillholes was to intercept coal seams/workings, they were constructed under license to the Coal Authority (Permit ref. 19874). Where openholing was undertaken, in accordance with Coal Authority requirements, given the proximity to occupied properties, water was used as a flushing medium to keep the drill bits cool and return chippings to the surface, and the levels of ground gas were recorded at the drillhole during the works. During the drilling process, the rock chippings returned to the surface were described by the driller and the rate of progress monitored. It should be noted that, although adequate for identification purposes, the nature of the drilling method does not permit an accurate description of the strata.

Once bedrock was encountered in BH4a, to provide detailed resolution on the stratigraphy, cores were recovered in plastic liners using a triple tube barrel system, over runs of nominal 1.5m length. Where recovery was poor, the core length was reduced for the next run to maximise the chances of good recovery. The recovered cores were sealed in the plastic liners and placed in solid core boxes to prevent disturbance and swelling before logging. The plastic liners were only cut immediately prior to logging and sampling. In addition to the nature of the rock material, the identified fractures within the rock mass were also logged in accordance with BS5930:2015 and BS EN ISO 14689:2:2018. The Rock Quality Designation (RQD) recorded was for rock core 100mm or greater in length, unless otherwise stated. The fracture state of the recovered cores (in terms of number of fractures per metre run) is presented on the drillhole records.

Standard Penetration Tests (SPT) were carried out in the Made Ground and Glacial Deposits in BH1, BH2 and BH3 using a split spoon/solid cone in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2015) to assess the relative density of the coarse-grained soils encountered in the borehole and to provide a correlated assessment of the likely undrained shear strength of fine-grained soils using relationships published by Stroud (1975). As required in BS5930:2015, the SPT N-

values shown on the borehole records are the direct, uncorrected results obtained in the field. 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. Many of the SPT 'N' values are over 50, however this may be due to the common cobbles and boulders in the glacial soils and not its actual strength/density.

Caution must be applied when using in-situ data collected using a solid cone: Much of the existing correlations using N-values obtained from Standard Penetration Tests rely on the energy imposed on a split-spoon sampler (SPT) and not a solid cone (SPT-C). The solid cone has a greater surface area and, therefore, imparts a lower energy per blow than the split-spoon sampler, and can result in an over-estimation of the true SPT N-value. Based on the relationship of energy inputs at the point of penetration (Thorburn 1986), it can be inferred that the equivalent SPT N-value for a test using a cone (SPT-C) is equal to:

$$\text{SPT N-value} = \frac{\text{SPT-C}}{1.869}$$

On completion, instrumentation was installed in boreholes as detailed in Section 0. Below the instrumentation, the drillhole was backfilled with bentonite/cement as required by the Coal Authority.

4.1.5 Soakaway Infiltration Testing

The use of Sustainable Drainage (SUDs) systems in Wales, is now regulated and implemented by Statutory Approval Bodies (SABs) within the Local Authority. Applications for SuDS will be reviewed by the relevant SAB which will establish if the application is feasible, suitable for its intended use and is acceptable for adoption and maintenance by the SAB. All testing is required to be undertaken in strict accordance with BRE Digest 365 (2016) to gain SAB approval.

Soakaway infiltration tests were undertaken in 4no selected trial pits across the site (TP101, TP102, TP201 and TP202). The results of the infiltration testing, and the calculated infiltration rates, are presented in Appendix J. The positions of the test pits are shown on Figure 1.

At each position, the test pit was excavated to a depth which was anticipated to be a possible depth for the soakaway given the ground conditions identified and taking into account any proposed change in ground levels. Clean water was added from a large capacity bowser/tanker 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.

Due to poor temporary stability infilling the pit during testing, only one test was undertaken in TP101 and TP102 (May 2020). In TP201 and TP202 (July 2020), gravel was used to maintain temporary stability within the pit which enabled repeat testing to be undertaken (a total of three fills).

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

4.1.6 Dynamic Cone Penetration (DCP) Testing

CBR testing using the TRL approved dynamic cone penetrometer (DCP) was undertaken at six positions (DCP1 to DCP6) on 24th August 2020. The testing was undertaken generally across the site. At some positions, where the penetration depth was low, the test was repeated at a close by location (DCP-01). The test positions are shown on Figure 1, and test results are presented in Appendix K.

The DCP testing was undertaken from the existing ground surface with no service pit excavated. Appropriate precautions were taken during the testing to ensure the safety of ESP operatives.

The DCP test involves the fall of a fixed weight over a fixed height to force a 20mm diameter, 60° cone into the near surface soils. The depth of penetration for varying numbers of blows is recorded and is then converted to a CBR value using well established empirical correlations (Highways Agency, 2008). In general, the tests were undertaken between the existing ground surface and 0.9m below ground level, thus providing a profile of correlated CBR values within the near-surface soils. No water was added to the soils prior to testing, so they were in their natural condition. The correlated CBR values are also shown on the test result sheets in Appendix K.

4.2 Instrumentation

4.2.1 Gas Well Installations

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

Table 4: Gas Well Installations

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum	Rationale
BH1	20/05/2020	1.0 – 5.0m	Glacial Diamicton	Note 2
BH2	21/05/2020	0.5 – 4.8m	Made Ground and Glacial Diamicton	Note 2
BH3	22/05/2020	0.5 – 5.0m		Note 2
Notes: 1. Details of each monitoring well are presented on the individual borehole records (Appendix H). 2. Well installed in shallow Made Ground and Glacial Diamicton to asses the ground gas risk to the development from the identified sources (see Section 3.1.4).				

4.2.2 ‘Spot’ 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 sources on and in the vicinity of the site in terms of gas risk are classified as being of very low to moderate gas generation potential. The proposed development of a school is classified as of low to moderate sensitivity in terms of gas risk. Therefore, based on the guidelines in CIRIA C665, a minimum of 6no. monitoring visits are required over a three month period.

The installed wells have been monitored for levels of groundwater and ground gas on 6no. occasions between 19th June and 26th August 2020. The results of the 'spot' gas and groundwater monitoring undertaken to date are presented in Appendix I.

During each visit, Gas Data LMSxi G3.18e portable monitoring equipment was used to measure 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 (CH₄) and carbon dioxide (CO₂) 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 dipmeter from the site surface.

4.3 Sampling Strategy

4.3.1 Soil Sampling

Soil samples were collected from the exploratory holes as discussed in the previous sections. The sampling procedures were selected on the basis of the suitability for the laboratory testing proposed (see Section 4.6).

A non-targeted, random sampling strategy was used to obtain representative information on soil contamination across the site as a whole.

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

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

4.4 Evidence of Site Contamination Found During Site Works

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

4.5 Geotechnical Laboratory Testing

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

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

- Natural moisture content.
- Atterberg limits.
- Particle size analysis.
- Loss on Ignition; and
- Calorific value.

Selected samples were also analysed for soil sulphate and pH value in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005). Due to the potential presence of pyrite in the soils, these samples were also analysed to determine the levels of total sulphur, acid soluble sulphate in accordance with the analytical methods specified in BRE Special Digest SD1 (BRE, 2005).

The results of the sulphate testing are included with the geo-environmental test results in Appendix X

4.6 Geo-environmental Laboratory Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of soil recovered during the investigation.

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 Sections 5.4).

The Preliminary Risk Assessment (Section 3) did not identify any particular contaminants of concern at the site. However, given the identified presence of Made Ground in the exploratory holes, in order to allow an assessment of the potential chronic risks posed to human health, a total of 5no selected samples of the Made Ground (including the existing Topsoil) have been analysed for contaminants typically found on brownfield sites in the UK.

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

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

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

5 Development of the Revised Conceptual Model

5.1 Conceptual Ground Model - Geology

The exploratory holes have identified the site to be generally underlain by Made Ground, fine-grained Glacial Diamicton and Coal Measures bedrock. These strata are discussed in more detail in the following sections.

Made Ground: encountered to a maximum depth of 1.2m as a layer of Topsoil with rootlets followed by a probably loose, black, silty, gravelly, sand with rare cobbles.

The Made Ground was locally rich in carbonaceous material with man materials including glass, pottery and metal pipe also being recorded.

Glacial Diamicton: encountered beneath the Made Ground to a maximum depth of 9.8m generally as a soft to firm, sandy, gravelly, clay with a low to medium cobble and boulder content. Sandstone boulders up to around 0.8m in length were encountered.

Where openholing was undertaken, the driller generally described the glacial soils as silty, sandy, gravels with cobbles and boulders.

Laboratory testing within the fine-grained Diamicton indicated liquid limits between 25 and 45%, plasticity indices between 12 and 23%, and natural moisture contents between 8 and 24%. The modified plasticity indices (after the coarse-grained particles have been removed) suggest that the soils are generally of very low to medium shrinkage and swelling potential and would be generally classified as clays of low to intermediate plasticity (CL/CI).

Particle size analyses within the laboratory have indicated the coarse-grained glacial soils to comprise between 19 and 31% gravel, between 25 and 31% sand and between 30 and 45% silt and clay. Two tests recorded 14 and 23% cobbles. Based on our observations on site, these proportions are broadly representative for the matrix, however due to sampling bias the amount of cobbles and boulders are likely greater.

Field SPT N-values within the glacial soils varied between 4 and in excess of 50 where cobbles and boulders were present. The results were generally in excess of 40, however due to the proportion of larger material it is not clear whether this is representative of the in-situ strength of the soils. Due to the presence of cobbles and boulders a solid cone had to be used for all testing.

Lower Coal Measures Bedrock: encountered in the rotary drillholes generally as interbedded sandstone, mudstone, coal and ironstone to a depth of 40m.

Where coring was undertaken in BH4a, the mudstone was described as weak, dark grey, generally very thinly to thinly bedded (locally medium thickness), and fresh grade I to moderately weathered grade III (generally in the upper portions). No sandstones were encountered in the cored borehole, however the ironstone was described as strong to very strong and orange and it's weathering grade was I, fresh.

A 0.4m to 0.9m thick coal seam was identified in the drillholes at depths of between 20.5 and 20.9m – this is considered to probably be the Garw coal seam. No evidence of workings was encountered in the coal seam.

Generally between 33m and 40m, ironstones were noted by the driller ranging with a thickness of around 4 to 5m being noted. In the cored drillhole, the ironstone was only recored to be around 0.5m. No evidence of workings was encountered in the ironstones.

Further assessment of mining risk is presented in Section 8.2.2.

5.2 Conceptual Ground Model - Hydrogeology

The groundwater conditions identified in the investigation are summarised in the table below.

Table 5 - Summary of Groundwater Ingress in the Investigation

Hole ID	Stratum	Comment on groundwater encountered
BH1	Glacial Diamicton and Lower Coal Measures	Waterstrikes were recorded by the driller at depths of 9.5m and 13.0m in the bedrock. Monitoring has recorded groundwater levels of between 4.73m and 4.93m bgl in the glacial soils.
BH2	Glacial Diamicton	No waterstrikes were recorded during the drilling of the borehole. Groundwater monitoring has recorded levels of between 0.01m and 0.97m bgl.
BH3	Glacial Diamicton and Lower Coal Measures	The driller noted a sandstone horizon between 11.4m and 12.2m to be damp. Groundwater monitoring has recorded levels of between 0.01m and 0.99m bgl.
TP101, TP102, TP103 and TP201	Glacial Diamicton	Groundwater seepages were recorded between depths of 1.7m and 2.2m.
TP104 and TP202	Made Ground and Glacial Diamicton	No groundwater encountered.
Notes: 1. Full details of groundwater ingress presented on exploratory hole records in Appendices G and H.		

Near surface groundwater levels have been monitored in BH2 and BH3, however no waterstrikes were noted during the construction of these boreholes. It is not considered the seepages recorded in the glacial soils would be substantial enough to result in the conditions monitored unless, poor permeability has resulted in the well filling up. Surface water ponding and run off was noted during the monitoring period therefore this could be another potential surface of the shallow water levels recorded. The levels in BH01 were also significantly higher during the final visit after a period of heavy rain. Alternatively, artesian conditions in a bedrock groundwater body, may be causing the shallow levels noted, however, this would indicate the seal in the boreholes has been compromised.

Based on the above findings and the Conceptual Ground Model, we consider that a perched groundwater body is present in the glacial soils around 2m depth with a deeper groundwater body in the Lower Coal Measures bedrock around 10m bgl.

5.3 Site Instability

5.3.1 Global Site Stability

No evidence was identified of potential landslides or unstable ground in the Preliminary Geotechnical Risk Register (Section 2.10) and we identified no evidence of any global instability issues on the site.

5.3.2 Excavation Stability

During the excavation of the trial pits, instability and collapse was experienced in the pit walls. In many pits this was due to the unravelling of rounded cobbles and boulders from depths of 1.0m to 1.5m.

5.3.3 Mining Hazard

Whilst a coal seam and ironstones were consistently encountered, 6no. rotary drillholes constructed to 40m within the footprint of the proposed building have not identified obvious evidence of abandoned coal or ironstone workings. Further discussion is presented in Section 8.2.2.

5.4 Chronic Risks to Human Health – Generic Assessment of Risks

5.4.1 Assessment Methodology

The long-term risks to health have been assessed using methodologies and frameworks determined by the Environment Agency within documents SR2, SR3, SR4 and the CLEA Technical Review published to support the Contaminated Land Exposure Assessment Model (CLEA). Where applicable, reference has been made to the supporting toxicological reports (TOX Series) and the Soil Guideline Value reports (SGV Series). It is assumed that the reader is familiar with the above documents and it is not intended to repeat these described methodologies in detail, for further information, please refer directly to the specific documents.

In order to provide an initial 'screen' to identify elevated levels of contaminants, a Generic Quantitative Risk Assessment (GQRA) has been undertaken using the most appropriate Generic Assessment Criteria (GAC) determined by assessment of exposure frequency/duration relevant to the critical receptor.

5.4.2 Assessment Criteria

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

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

generic screening levels on residential developments in England and Wales (NHBC, 2014). Given this, where available and applicable, the C4SL have been adopted as the Generic Assessment Criteria in this assessment.

Where no C4SL is currently available, the Suitable For Use Levels (S4ULs) published in January 2015 by the Chartered Institute of Environmental Health (CIEH) and Land Quality Management (LQM) (Nathanail et al, 2015) have been adopted. These assessment criteria adopt updated toxicological data and exposure models, and the same 'minimal level' of risk as the SGV (i.e. unlike the C4SL). The S4ULs have been published for a large number of contaminants typically found on brownfield sites in the UK, and for the same range of land uses as the C4SL, i.e. including public open space scenarios.

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

For more exotic, predominantly organic, compounds no SGV, S4UL or C4SL assessment criteria have been published. In this instance, GAC published by CL:AIRE and the Environmental Industries Commission (CL:AIRE/EIC, 2010) have been adopted. These GAC have also been developed using the CLEA UK software based on a 'minimal level' of risk and for the same land use scenarios as the SGVs (i.e. not public open space).

Details of the Generic Assessment Criteria (GAC) adopted for each contaminant are presented on the assessment tables in the following section.

The proposed development comprises the construction of a new primary school building with associated areas of hardstanding and landscaping. There are currently no GAC published for such an end use. As discussed in Section 3.1.5, the critical receptors for a primary school are considered to be the staff (teachers and caretakers). Given this, we consider that the exposure scenarios adopted in the generation of the published GAC for a 'commercial' end use would be similar to those at the proposed development. Therefore, for the purposes of this generic assessment, the GAC for commercial use have been adopted primarily. An assessment against the GAC for public open space around residential properties has also been undertaken to assess the risks to school children. However, as the exposure frequency/durations are different for this use, using these GAC is considered a conservative approach and an exceedance does not necessarily indicate an unacceptable risk.

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 5.7 to 18%. 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 five samples of Made Ground (including the existing Topsoil). 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 5.4.4.

The results of the Generic Quantitative Risk Assessment for the proposed development are presented in the table below. It should be appreciated that if the development were to change, the following assessment should be reviewed and, if necessary, updated.

Table 6 - Generic Assessment of Human Health Risks (Commercial Use)

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	17 - 36mg/kg	640mg/kg	C4SL ²	None of 5
Barium	94 - 520mg/kg	22,000mg/kg	CL:AIRE/EIC ⁵	None of 5
Beryllium	0.6 - 1.4mg/kg	12mg/kg	S4UL ⁴	None of 5
Boron	0.3 - 0.7mg/kg	240,000mg/kg	S4UL ⁴	None of 5
Cadmium	0.1 - 0.3mg/kg	410mg/kg	C4SL ²	None of 5
Chromium (total) ⁶	14 - 18mg/kg	8,600mg/kg	S4UL ⁴	None of 5
Chromium (hexavalent)	<1.0mg/kg	49mg/kg	C4SL ²	None of 5
Copper	17 - 520mg/kg	68,000mg/kg	S4UL ⁴	None of 5
Lead	20 - 360mg/kg	2,330mg/kg	C4SL ²	None of 5
Mercury ⁷	0.06 - 0.94mg/kg	3,600mg/kg	S4UL ⁴	None of 5
Nickel	5.4 - 32mg/kg	1,800mg/kg	S4UL ⁴	None of 5
Selenium	<0.5 - 1.1mg/kg	12,000mg/kg	S4UL ⁴	None of 5
Vanadium	26 - 37mg/kg	9,000mg/kg	S4UL ⁴	None of 5
Zinc	38 - 220mg/kg	730,000mg/kg	S4UL ⁴	None of 5
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03mg/kg	84,000mg/kg*	S4UL ^{4,9}	None of 5
Acenaphthylene	<0.03mg/kg	83,000mg/kg*	S4UL ^{4,9}	None of 5
Anthracene	<0.03 - 0.04mg/kg	520,000mg/kg	S4UL ^{4,9}	None of 5
Benzo(a)anthracene	0.04 - 0.24mg/kg	170mg/kg	S4UL ^{4,9}	None of 5
Benzo(a)pyrene	0.03 - 0.23mg/kg	76mg/kg	C4SL ^{2,9}	None of 5
Benzo(b)fluoranthene	0.11 - 0.48mg/kg	44mg/kg	S4UL ^{4,9}	None of 5
Benzo(ghi)perylene	0.05 - 0.17mg/kg	3,900mg/kg	S4UL ^{4,9}	None of 5
Benzo(k)fluoranthene	0.03 - 0.15mg/kg	1,200mg/kg	S4UL ^{4,9}	None of 5
Chrysene	0.1 - 0.4mg/kg	350mg/kg	S4UL ^{4,9}	None of 5
Dibenzo(a,h)anthracene	<0.03 - 0.05mg/kg	3.5mg/kg	S4UL ^{4,9}	None of 5
Fluoranthene	0.07 - 0.52mg/kg	23,000mg/kg	S4UL ^{4,9}	None of 5
Fluorene	<0.03mg/kg	63,000mg/kg*	S4UL ^{4,9}	None of 5
Indeno(123-cd)pyrene	0.04 - 0.16mg/kg	500mg/kg	S4UL ^{4,9}	None of 5
Naphthalene	<0.03mg/kg	190mg/kg*	S4UL ^{4,9}	None of 5
Phenanthrene	0.06 - 0.27mg/kg	22,000mg/kg	S4UL ^{4,9}	None of 5
Pyrene	0.05 - 0.39mg/kg	54,000mg/kg	S4UL ^{4,9}	None of 5
Other Organic Compounds				
Phenol	<0.3 - 2.2mg/kg	760mg/kg	S4UL ^{4,9}	None of 5
Notes: - Assessment for commercial/industrial land use. - C4SL: Category 4 Screening Level, published by CL:AIRE. - SGV: Soil Guideline Value published by Environment Agency. - S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved. - CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission. - GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers. - In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted. - GAC for inorganic mercury adopted. - GAC for organic compounds based on 1% soil organic content. - Exceedances highlighted in red and bold. - Laboratory results presented in Appendix M. * GAC exceeds solubility or vapour saturation limit.				

Table 7 - Generic Assessment of Human Health Risks (Public open space near residential properties)

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	17 - 36mg/kg	170mg/kg	C4SL ²	None of 5
Barium	94 - 520mg/kg	1,300mg/kg	CL:AIRE/EIC ⁵	None of 5
Beryllium	0.6 - 1.4mg/kg	63mg/kg	S4UL ⁴	None of 5
Boron	0.3 - 0.7mg/kg	290mg/kg	S4UL ⁴	None of 5
Cadmium	0.1 - 0.3mg/kg	555mg/kg	C4SL ²	None of 5
Chromium (total) ⁶	14 - 18mg/kg	33,000mg/kg	S4UL ⁴	None of 5
Chromium (hexavalent)	<1.0mg/kg	220mg/kg	C4SL ²	None of 5
Copper	17 - 520mg/kg	44,000mg/kg	S4UL ⁴	None of 5
Lead	20 - 360mg/kg	1,300mg/kg	C4SL ²	None of 5
Mercury ⁷	0.06 - 0.94mg/kg	240mg/kg	S4UL ⁴	None of 5
Nickel	5.4 - 32mg/kg	800mg/kg	S4UL ⁴	None of 5
Selenium	<0.5 - 1.1mg/kg	1,800mg/kg	S4UL ⁴	None of 5
Vanadium	26 - 37mg/kg	410mg/kg	S4UL ⁴	None of 5
Zinc	38 - 220mg/kg	170,000mg/kg	S4UL ⁴	None of 5
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03mg/kg	29,000mg/kg	S4UL ^{4,9}	None of 5
Acenaphthylene	<0.03mg/kg	29,000mg/kg	S4UL ^{4,9}	None of 5
Anthracene	<0.03 - 0.04mg/kg	150,000mg/kg	S4UL ^{4,9}	None of 5
Benzo(a)anthracene	0.04 - 0.24mg/kg	49mg/kg	S4UL ^{4,9}	None of 5
Benzo(a)pyrene	0.03 - 0.23mg/kg	11mg/kg	C4SL ^{2,9}	None of 5
Benzo(b)fluoranthene	0.11 - 0.48mg/kg	13mg/kg	S4UL ^{4,9}	None of 5
Benzo(ghi)perylene	0.05 - 0.17mg/kg	1,400mg/kg	S4UL ^{4,9}	None of 5
Benzo(k)fluoranthene	0.03 - 0.15mg/kg	370mg/kg	S4UL ^{4,9}	None of 5
Chrysene	0.1 - 0.4mg/kg	93mg/kg	S4UL ^{4,9}	None of 5
Dibenzo(a,h)anthracene	<0.03 - 0.05mg/kg	1.1mg/kg	S4UL ^{4,9}	None of 5
Fluoranthene	0.07 - 0.52mg/kg	6,300mg/kg	S4UL ^{4,9}	None of 5
Fluorene	<0.03mg/kg	20,000mg/kg	S4UL ^{4,9}	None of 5
Indeno(123-cd)pyrene	0.04 - 0.16mg/kg	150mg/kg	S4UL ^{4,9}	None of 5
Naphthalene	<0.03mg/kg	1,200mg/kg*	S4UL ^{4,9}	None of 5
Phenanthrene	0.06 - 0.27mg/kg	6,200mg/kg	S4UL ^{4,9}	None of 5
Pyrene	0.05 - 0.39mg/kg	15,000mg/kg	S4UL ^{4,9}	None of 5
Other Organic Compounds				
Phenol	<0.3 - 2.2mg/kg	280mg/kg	S4UL ^{4,9}	None of 5
Notes: 1. Assessment for public open space near residential properties. 2. C4SL: Category 4 Screening Level, published by CL:AIRE. 3. SGV: Soil Guideline Value published by Environment Agency. 4. S4ULs Suitable 4 Use Levels. Copyright Land Quality Management Limited, reproduced with permission; Publication No. S4UL3156. All Rights Reserved. 5. CL:AIRE/EIC GAC published by CL:AIRE and Environment Industries Commission. 6. GAC for barium for residential use without plant uptake. No GAC published for plant uptake risk drivers. 7. In the absence of Chromium VI, all chromium present likely to be Chromium III. GAC for Chromium III adopted. 8. GAC for inorganic mercury adopted. 9. GAC for organic compounds based on 1% soil organic content. 10. Exceedances highlighted in red and bold. 11. Laboratory results presented in Appendix M. * GAC exceeds solubility or vapour saturation limit.				

All the determinands analysed were below their respective GAC for both exposure scenarios. No further statistical analysis is warranted.

5.4.4 Asbestos

No evidence of asbestos was identified in the samples analysed.

5.5 Hazardous Ground Gas

5.5.1 Degradation of Organic Materials

The installed gas wells have been monitored for hazardous gases on six occasions over a 10 week period to date, i.e. the scheduled preliminary monitoring period has been completed. The monitoring results are presented in Appendix I and are summarised in the table below:

Table 8 - Summary of Gas Monitoring Data (Visits 1 to 6)

Well	Response Zone Depth ¹ (m)	No visits	Maximum Methane (%)	Maximum Carbon dioxide (%)	Minimum Oxygen (%)	Maximum Gas Flow (L/hr)	Shallowest Water depth (m)	Atmospheric pressure
BH1	1.0 – 5.0m	6	ND	1.5	16.7	ND	1.61	966 - 1013
BH2	0.5 – 4.8m	4	ND	1.4	3.4	ND	0.02	966 - 1013
BH3	0.5 – 5.0m	3	ND	5.5	8.9	ND	0.01	966 - 1013
Notes: 1. Well installed in shallow Made Ground and Glacial Diamicton to assess the ground gas risk to the development from the identified sources 2. nd – none detected with instrument (<0.2% for methane, <0.1% for carbon dioxide). 3. Full monitoring results presented in Appendix I. 4. Groundwater levels were top of well in BH2 and BH3 during two and three visits respectively, so no meaningful gas measurement could be undertaken.								

The monitoring to date has indicated levels of methane between below the limit of detection (0.2%), carbon dioxide levels between below detection limit (0.1%) and 5.5%. Oxygen was depleted where the levels of methane and carbon dioxide were elevated.

No gas flows rates were recorded during the monitoring.

5.5.2 Gas Screening Values

The results of monitoring undertaken to date (six visits) have been used to calculate Gas Screening Values (GSV) appropriate for the site using the methodology published in CIRIA C665 (Wilson et al, 2007). As no positive flow rates were recorded during the monitoring, we have adopted a conservative approach where we have used a low level flow (0.5l/hr) that may be realised in the future. This allows a GSV to be calculated.

The calculated GSV for the site are presented in the table below.

Table 9 - Gas Screening Values (based on six visits)

	Maximum Recorded Level (%)	Maximum Gas Flow Rate (L/hr) ²	GSV (L/hr)
Methane	ND	0.5	-
Carbon dioxide	5.5	0.5	0.0275
Notes: 1. GSV calculated using method derived in CIRIA 665 (2007). 2. No flows recorded during the monitoring therefore a flow of 0.5l/hr has been assumed as a conservative approach.			

On the basis of the above calculated GSV, we consider that the site would be classified as Characteristic Situation CS-1 for a residential development (CIRIA C665:2007). However, the maximum value of carbon dioxide (CO₂) in BH2 of 5.5% exceeds the normal upper limit for CS-1 of

5.0%. Whilst no other visit was above 5%, to visits did record levels above 4% and there are numerous potential sources in the surrounding area e.g. industrial development and ironstone workings.

To ensure a protective approach, we therefore recommend the gas protection should be designed on the basis of Characteristic Situation CS-2.

5.6 Sulphate Attack

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

5.6.1 Classification of Site

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

5.6.2 Groundwater Setting

Groundwater was encountered in the exploratory holes and in some of the installed wells. Whilst likely deeper than the depth to which buried concrete will be placed, groundwater has been considered as mobile in this assessment to ensure a conservative approach.

5.6.3 Sulphate Levels

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the Made Ground and Glacial soils to be between <10 and 27mg/l. As levels of water soluble sulphate are less than 3,000mg/l, there is no need to consider the levels of magnesium present in the soils. Levels of acid soluble sulphate varied between 0.01 and 0.25% and total sulphur between less than 0.01 and 0.11%. From these results, the calculated levels of total potential sulphate are between 0.03 and 0.33%, and oxidisable sulphides are between 0.01 and 0.08%. As the levels of oxidisable sulphide are well below 0.3%, pyrite is unlikely to be present.

pH values in the Made Ground and natural soils varied between 5.9 and 8.6, indicating slightly alkaline to acidic soil conditions to exist.

5.6.4 Foundation Concrete Design:

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

Water soluble sulphate:	26mg/l;
Total potential sulphate:	0.26%;
pH value:	5.95

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

The desk study review has identified no obvious evidence of any prior development or former contaminative use on the site, however the surrounding area has been heavily industrialised. Earthworks are indicated to have occurred on-site, associated with the development of a tennis court and then subsequently the school.

The investigation identified a covering of Made Ground up to a maximum thickness of 1.2m, which was carbonaceous and included other man materials including glass and china. No obvious visual or olfactory evidence of contamination was noted.

Laboratory testing has recorded low levels of contamination below the general acceptance criteria adopted for the assessment. No asbestos was identified in the samples tested.

Ground gas monitoring has recorded levels of carbon dioxide above 5%, with non detectable levels of methane.

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 3, Section 3.2.2) have been updated and revised in Table 8 following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 10 - 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 shallow soils	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users	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	Likely ²	Low Risk	See Section 7.1.4 for further discussion.
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Medium – site lies on Secondary Aquifers	Low likelihood ²	Moderate/Low Risk	See Section 7.2 for further discussion.
	Leaching of soil contaminants	Impact on Surface Water Features around 180m from the site.	Medium – surface waters are likely sensitive.	Unlikely ²	Low Risk	
Asbestos in shallow soils	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Low likelihood ³	Moderate/Low Risk	See Section 7.1.1 for further discussion.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	Likely ⁴	Moderate/ Low Risk	See Section 0 for further discussion.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Low likelihood ⁵	Moderate Risk	See Section 7.3 for further discussion.
	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	Medium – potential for chronic levels	Unlikely ⁶	Low Risk	See Section 0 for further discussion.
Notes: - This table updates Table 3 in Section 3.2.2 using results of the investigation. Methodology and details of risk consequence, probability and category presented in Appendix A. - Made Ground has been encountered, however the recorded levels of contamination are below the adopted general acceptance criteria. - No obvious sources of asbestos have been identified and no asbestos has been identified in the samples of Made Ground tested. However, it's presence in any shallow Made Ground soils cannot be discounted. - Potentially elevated levels of sulphates have been identified in the Made Ground soils. See Section 2.10.5. - On and off-site potential sources of hazardous ground gas/vapours have been identified and elevated levels of carbon dioxide have been recorded. - Radon risk identified in environmental data report (Appendix C).						

7 Remedial Strategy for Contamination Risks

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

7.1 Risks to Health

7.1.1 Asbestos

No evidence of asbestos was detected at the site. Although no evidence has been identified in the investigation, where Made Ground is present, it cannot be discounted that asbestos containing materials (ACM) may have been included in the backfill materials.

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.

7.1.2 Site End Users

Assuming an end use of a new classroom, the identified levels of soil contamination at the site are not considered to pose a risk to future site users. Therefore, no specific remedial measures are considered necessary for the development.

Notwithstanding the above, If any evidence of Made Ground or other contaminated soils is identified during development, 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.

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

The site lies within a school whose occupants (children) would be particularly sensitive to any dust created during development. We recommend strict dust control measures during development.

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.

- No past contaminative use has been identified at the site. However, the surrounding area has been heavily industrialised. Some earthworks are indicated to have occurred on-site.
- Made Ground has been identified on the site, however no visual or olfactory evidence of contamination has been identified.
- The levels of soil contaminants are low, well below the GAC adopted.
- Soakaways are being considered for the development.
- The site is underlain by fine and coarse grained glacial soils
- The bedrock beneath the site is classified as a Secondary A aquifer. The glacial soils are defined as Secondary Undifferentiated.
- Perched groundwater has been recorded within the glacial deposits and a deeper body proven within the Lower Coal Measures bedrock.
- There are no surface water features in close proximity to the site.

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 8.8 for further discussion.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

On the basis of the above calculated GSV, we consider that the site would be classified as Characteristic Situation 2 for a commercial development (CIRIA C665:2007).

The requirements for gas protection have been assessed in accordance with BS8485:2019, which considers gas protection in terms of a ranking 'score' for various types of property.

The proposed development comprises a school building with small room sizes. Schools can be classified as both Type B and C buildings in accordance with BS8485:2019.

Based on Characteristic Situation CS-2, and the worst case building classification of a Type B Building, the required gas protection score would be 3.5. This may be made up of a number of elements included within the structure whose individual 'scores' add up to the required total. The best combination of elements will depend to a large degree on the design of the building.

If it can be demonstrated that the development would conform with Type C, then the required score could be lowered to 2.5. Further advice can be provided by this office once the design of the buildings has been finalised.

7.3.2 Risk to the Development – Radon

As discussed in Section 2.11, no radon protection is required.

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

The Made Ground has been identified to contain a notable fraction of coal. This has the potential to combust, given the correct environment (including a heat source and oxygen).

Laboratory testing has indicated soil organic contents between 5.7 and 18%, calorific values of between 3.2 and 8.9MJ/kg, and values of loss on ignition between 8.8 and 20%. The levels of soil organic matter indicate that the Made Ground contains a quantity of organic material which could be available to burn should combustion be initiated.

The potential for combustion within soils is not a well-established science and only general guidelines are available relating to availability of source material for combustion. Soils with a calorific value (CV) in excess of 10MJ/kg are considered almost certainly combustible, whilst those with a CV of less than 2MJ/kg are unlikely to burn, with some authors considering soils with a CV in excess of 7MJ/kg to be potentially combustible, usually by smouldering (ICRCL, 1986). On this basis, the Made Ground at the site must be considered potentially combustible.

Mass loss on ignition (LOI) has also been used as an indicator of combustibility and a value of 25% LOI is commonly considered to be the lower bound for potentially combustible soils (Richard et al, 1993). The loss on ignition percentages reported at the site are all below this level.

We consider that the Made Ground at the site could be locally potentially combustible and suitable precautions taken to mitigate the risk. The carbonaceous Made Ground could ignite spontaneously due to a prolonged heating caused by its proximity to buried electrical cables, and this would be more likely to occur in loosely compacted soils with a high proportion of air voids in which oxygen (which drives the combustion) could be present.

We recommend that the carbonaceous Made Ground is removed from beneath the footprint of the development area, and that all underground services within the carbonaceous Made Ground are placed in trenches filled with inert granular fill, thus isolating them from potentially combustible materials. We consider that this is likely to be sufficient to mitigate the risk of combustion at the development.

7.4.2 Sulphate Attack on Buried Concrete

The following characteristic values are applicable for the shallow soils at the site (all as SO₄):

Water soluble sulphate:	26mg/l;
Total potential sulphate:	0.26%;
pH value:	5.95

Based on these characteristic values, we consider that the Made Ground soils would be classified as Design Sulphate Class DS-2 (due to the total potential sulphate) and Aggressive Chemical Environment for Concrete Class AC-3z, allowing for mobile groundwater.

The proposed foundation will be located within the Made Ground. If the above elevated classification has significant cost implication, further testing could be pursued to attempt to reduce it.

7.5 Re-Use of Materials/Disposal of Excess Arisings

7.5.1 General Comments on Re-use/Disposal

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

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

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

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

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

In Scenario 3, management of soils could be undertaken via an Environmental Permit or Exemption. However, these can take time and are costly to arrange. Therefore, in certain circumstances, it is permissible to use the protocols laid down in the CL:AIRE Definition of Waste, Development Industry Code of Practice (DoWCoP, Duckworth, 2011) to classify the arisings and put a management plan in place to control the use. This involves approval of the proposals by a Qualified Person and is generally more efficient (in terms of time and cost) to implement.

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

7.5.2 Imported Materials

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

8 Geotechnical Comments

8.1 Site Preparation and Earthworks

8.1.1 Unexploded Ordnance

As discussed in Section 0, a specialist preliminary assessment has concluded that *'a detailed desk study, whilst always prudent, is not considered essential in this instance'*. Although no special precautions are considered necessary, a careful watch should be maintained during all excavation and any suspected ordnance identified should be investigated further by specialists. Ordnance awareness is recommended during site inductions.

8.1.2 Invasive Plants

No evidence of invasive plants such as Japanese Knotweed/Himalayan Balsam etc. was identified on the site during the site works. However, their growth is seasonal and therefore their presence cannot be discounted.

8.1.3 Existing Foundations and Services

No evidence of old foundations and underground structures have been identified in the investigation and are not anticipated beneath the site. However, if any are discovered then they should be grubbed up as part of the site preparation works.

There are no known live services present within the vicinity of the site.

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

8.1.4 New Services

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

8.1.5 Earthworks

We have not been advised that the development requires any significant earthworks. The site is relatively flat and, therefore, no such earthworks are anticipated.

8.2 Geotechnical Risk Register

8.2.1 Updated Geotechnical Risk Register

Following the site investigation the potential geotechnical hazards have been re-assessed as described in the following section. This includes construction risks identified by the intrusive investigation.

For risk associated with poor temporary stability of excavations and groundwater ingress see Section 8.7. For risks associated with sulphate attack see Section 0.

8.2.2 Coal Mining Hazard

A 0.4 to 0.9m thick coal seam was identified beneath the site between depths of 20.5m and 20.9m in 5no. of the 6no. boreholes. No obvious evidence of mine workings were noted and none are recorded based on coal authority information. The seam is considered to represent the Garw coal seam.

Generally between 33m and 40m, ironstones were noted by the driller ranging with a thickness of around 4 to 5m being noted. In the cored drillhole, the ironstone was only recovered to be around 0.5m. As the cored boreholes indicated, it is likely that the ironstones are present as thinner bands within the larger sandstone horizon. The depth of the recorded ironstones are roughly around the depth that the Coal Authority indicate that workings are present beneath the site, however no evidence of workings was encountered in the ironstones beneath the development footprint.

Localised mine workings (probable ironstone) were encountered in BGS boreholes in similar stratigraphy to the north east with a maximum thickness of around 1.6m. Based on the well accepted 10T rule of thumb for assessing mining subsidence risk, even if a similar size working was present in the ironstones from around 33m, there would be sufficient rock cover above them to mitigate potential risks.

Based on the above, the risk from past mining is considered low, and risk mitigation measures are not considered necessary. We recommend reinforcement is incorporated into the foundations as a precautionary measure.

It should be appreciated that in any area of past mining activity the possibility of the existence of unrecorded mine entries cannot be discounted. During site clearance operations and all excavation, a careful watch should be maintained for any isolated pockets of loose fill, brickwork or other anomalous features which may be indicative of past mining operations. Any such features should be subject to further investigation.

8.2.3 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 low to intermediate plasticity and very low to moderate 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.

Once 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.

8.3 Foundation Design and Construction

We understand that the site is being considered for potential development of a new classroom and the comments and recommendations in this report assume that the development will involve the construction of typical single storey structure of conventional load-bearing brickwork construction.

On the basis of the available investigation information, we consider that reinforced mass concrete spread foundations could be used at the site, constructed in the firm glacial soils encountered from depths of around 1.5m beneath ground level. The glacial soils are variable containing a high proportion of cobbles and boulders and therefore the founding strata may need to be varied in response to the local conditions. Reinforcement is required to reduce differential performance across the foundation length.

We consider that for foundations placed in this stratum, a presumed bearing value of around 75kPa should maintain total and differential settlements within acceptable levels.

The founding stratum is fine-grained in composition and of very low to moderate shrinkage/swelling potential. Footings should be deepened within the zone of influence of planting and extend beneath the Made Ground, which may be locally thicker in some areas.

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.

Given the presence of groundwater within the shallow soils, 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.

If a raft foundation is preferred, this would also be feasible and design information can be provided on request.

8.4 Floor Slab Foundations

Due to the presence of over 600mm of Made Ground, potentially soft compressible soils and the potential ground gas risk at the site, we consider that a suspended floor slab would be best suited for the development.

As removal of carbonaceous Made Ground has been recommended beneath the footprint to mitigate potential combustion risks (see Section 7.4.1), replacement of these soils would be required (likely with a clean aggregate). Provided this was compacted to a specification, this may enable the use of a ground bearing slab. Further advice in this regard can be provided if necessary.

8.5 Retaining Wall Design

We are not aware of any retaining structures being required in the development.

8.6 Pavement Design

We understand that hardstanding is proposed at the site.

8.6.1 Design CBR Value

An assessment of the likely CBR values in areas of grade (no change in ground level) has been undertaken using a dynamic cone penetrometer (DCP). Testing was undertaken at six locations

concentrated along the proposed access roads. The results of the DCP testing are converted to CBR values using correlations published by the Highways Agency (2008).

The DCP results and the correlated CBR values are presented in Appendix K.

Based on the above testing, we consider that a Design CBR value of 5% would be suitable for preliminary design purposes. In areas of Made Ground, lower values may be achievable and excavation and replacement or re-compaction may be necessary.

Where the near-surface soils comprise natural coarse-grained materials we would not expect the Design CBR value to vary to any significant degree seasonally or in the long term.

In some areas, the near-surface glacial soils comprise fine-grained materials. The CBR value is particularly sensitive to changes in moisture content. Careful consideration should be given to whether in the long term, the existing moisture content at which the test was undertaken is appropriate. If the formation were to become wetter the long term Design CBR value would reduce, possibly dramatically. In accordance with the recommendations in IAN73/06 (Highways Agency, 2009a), we recommend that the sensitivity of the Design CBR value of the fine-grained soils to variations in moisture content be assessed by further laboratory testing.

The final sub-grade should be inspected by a qualified engineer, and any soft or loose material removed and replaced as necessary, to ensure that the Design CBR value is achieved. It is further recommended that the sub-grade be proof-rolled with a suitable roller prior to the placement of the sub-base materials. In order to improve the sub-base performance the use of a suitable geo-grid may be considered.

We consider that it would be prudent to re-measure the CBR values of the sub-grade on exposure to confirm that they are equal to or better than the values measured in this investigation (as recommended by the Highways Agency [HA, 2009a]). If the CBR values in the sub-grade are found to be lower than the Design CBR, the subgrade must be improved to achieve the Design CBR or the road pavement foundation redesigned.

The investigation has identified near surface groundwater (less than 0.1m depth) across the site, however it is not clear what the origin of the shallow levels are. Consideration on whether suitable drainage should be installed in the pavement to ensure that water is kept out of the sub-base is needed.

8.6.2 Susceptibility to Frost Action

The near surface fine grained/coarse grained soils are considered to be non-frost susceptible.

8.7 Excavation and Dewatering

It is anticipated that excavation throughout most of the site will be within the capabilities of conventional mechanical excavators.

For shallow excavations where there is a potential danger to life, support of excavation sides is likely 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 1m depth. However, groundwater monitoring in BH2 and BH3 has recorded

very shallow levels, which are not obviously explainable at this stage. Where water ingress occurs it is likely that pumping from screened sumps within shallow excavations will be adequate.

During the gas monitoring, surface water run-off/pooling has been noted, particularly in the area around BH3. Management of this will be required during the construction of the development.

8.8 Soakaway Drainage

8.8.1 Soakaway Design

Soakaway infiltration tests were undertaken in 4no. test pits excavated across the site (TP101, TP102, TP201 and TP202). The results of the testing are presented in Appendix J.

Only one fill was undertaken in TP101 and TP102 due to collapse of the test pit side walls (May 2020), however repeat testing was able to be undertaken in TP201 and TP202 by using gravel to support the excavations sides during the test (July 2020).

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

Table 11 - Summary of soakaway infiltration test results

Test Pit	Fill No.	Test depth	Measured Infiltration Rate ¹	Estimated Infiltration Rate to Depth of Reduced Infiltration ²	Estimated Infiltration Rate to 75% Original Fill Depth ²	Infiltration Soils
TP101	1	2.1m	-	-	3 x 10 ⁻⁶ m/s	Sandy gravelly CLAY with cobbles and boulders (GLACIAL DIAMICTON).
TP102	1	2.85m	-	Low levels of Infiltration recorded therefore an estimate cannot be calculated with suitable confidence ⁴		
TP201	1	2.7m	-	1 x 10 ⁻⁶ m/s	Not achievable as infiltration stopped below 1.8m bgl ⁴	
TP201	2		-	1 x 10 ⁻⁶ m/s		
TP202	1	2.1m	-	2 x 10 ⁻⁶ m/s	1 x 10 ⁻⁶ m/s	
TP202	2		-	1 x 10 ⁻⁶ m/s	7 x 10 ⁻⁷ m/s	
TP202	3		6.7 x 10 ⁻⁷ m/s	-	-	
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 relatively quickly to between 1.6m and 1.8m. An infiltration rate has been calculated based on the initial drop in water level to these depths. Results should be treated with caution. 3. 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. 4. Insufficient data was obtained to allow an effective extrapolation of the data. No infiltration rate can be calculated						

In TP101, collapse of the pit sides back to a depth above 75% of the original fill depth prevented an infiltration rate in strict accordance with BRE365 to be calculated. However, a rate has been projected based on the monitoring undertaken prior.

The infiltration rate in TP102 was slow and due to collapse of the sides, the test was not continued as the measured fall in water level would not be accurate due to the influx of material into the pit.

In the two supplementary tests (TP201 and TP202) undertaken with aggregate to maintain the stability of the pits sides, the water infiltrated the soils relatively quickly to around 1.6m to 1.8m depth, however after this point the rate reduced dramatically and in many cases the water did not drop to 75% of the fill depth after a notable period of time.

It is unclear why this reduction in infiltration is occurring, however it could be due to changes in the fines content of the glacial soils, their compaction or it may be due to the perched water body being encountered in some of the pits between 1.7m and 2.2m (see Section 5.2).

The results do indicate some soakaway drainage is feasible in the glacial soils, primarily above depths of around 1.6m to 1.8m, however the results are not definitive. Where faster infiltration is possible (above 1.6m to 1.8m based on the testing), we consider that 10^{-6} m/s is achievable, however below these depths this would then reduce to $10^{-7}/10^{-8}$ m/s with a base around 2.1m (e.g. TP202 – Fill 2) or none at all with a deeper base (e.g. 2.7m in TP201). The results indicate that whilst infiltration is possible in the glacial soils, it may not be achieved completely within a standard system and some attenuation would need to be accommodated. These findings can be tentatively used as an infiltration rate for preliminary design across the site.

Once the location is known, some further testing at shallow depth (around 1.6m) would be prudent to see if these tests do empty at a consistent rate to 75% the effective depth. This may allow the design of a shallower soakaway drainage system.

8.8.2 Location Considerations

Care should be taken in the siting of the soakaways, with in particular, soakaways should be constructed a minimum of 10m away from the crest of slopes.

Soakaways should not normally be constructed closer than 5 m to building foundations or sensitive structures.

We recommend that the soakaway discharge point is kept as high as possible within the ground to maximise the thickness of soils between the discharge point and the groundwater below, i.e. the attenuation potential of the soils is maximised. The base of the soakaway should be constructed a minimum of 1m above the shallowest groundwater level to ensure long term functionality.

8.8.3 Regulatory Considerations

8.8.3.1 *Natural Resources Wales*

The infiltration stratum at the site would be the glacial soils which is likely in continuity with the underlying Coal Measures bedrock, which is classed as a Secondary A aquifer and the groundwater within is vulnerable to pollution. We recommend that enquiries are made to Natural Resources Wales to identify whether they would allow such discharge at the site.

8.8.3.2 *Statutory Approval Bodies (SABs)*

The use of Sustainable Drainage (SUDs) systems, is now regulated and implemented by Statutory Approval Bodies (SABs) within the Local Authority. Applications for SuDS will be reviewed by the relevant SAB which will establish if the application is feasible, suitable for its intended use and is acceptable for adoption and maintenance by the SAB.

Whilst adoption and maintenance approval will be the final stage in the process, SAB's will require validation of the constructed SuDS and will utilise commuted sums to ensure the proposed vs as built construction. SAB's will also be tasked with enforcement action in the event SuDS applications are not submitted appropriately or are not constructed as per authorised details.

It should be noted that the SABs process can take up to seven weeks for a complete and properly filed application to be processed and approved, and, if not already made, the application timeline should be considered as part of an any development.

9 Recommendations

We consider that the specified investigation is sufficient to progress the design of the development.

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

Required Further Actions:

- Develop outline design for the drainage strategy and then undertake further soakaway testing in the actual location to confirm the design rates and infiltration characteristics provided as part of this investigation. We recommend that this is undertaken at shallower depth than previous testing, to attempt to successfully drain the test pit fully.
- The site has been characterised as CS-2 in terms of ground gas risk. Determine the building classification in accordance with BS8485 and design the gas protection measures accordingly based on the required point score.
- Any carbonaceous Made Ground should be removed from beneath the footprint of the development area, and that all underground services within the carbonaceous Made Ground are placed in trenches filled with inert granular fill, thus isolating them from potentially combustible materials. We consider that this is likely to be sufficient to mitigate the risk of combustion at the development.
- Foundations are to be reinforced to limit differential performance.
- For shallow excavations where there is a potential danger to life, support of excavation sides is likely to be necessary.
- During the gas monitoring, surface water run-off/pooling has been noted, particularly in the area around BH3. Management of this will be required during the construction of the development.
- The investigation has identified near surface groundwater (less than 0.1m depth) across the site, however it is not clear what the origin of the shallow levels are. Consideration on whether suitable drainage should be installed in the pavement to ensure that water is kept out of the sub-base is needed.

Recommended Further Actions:

- If any evidence of Made Ground or other contaminated soils is identified during development, further geo-environmental specialist advice should be sought.
- We consider that the Made Ground soils would be classified as DS-2 and AC-3z. If the elevated classification has significant cost implication, further testing could be pursued to attempt to reduce it.
- Re-measure CBR values at sub-grade prior to pavement construction.
- Enquiries to NRW/EA to confirm acceptance of soakaways and any risk mitigation measures required.
- Verification testing of any soils imported to site.
- WM3 assessment of soils to be disposed of off-site.
- Materials management plan for re-use of soils on site and WM3 assessment of soils to be disposed of/re-used off-site, followed by WAC testing if disposal to landfill.

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