

Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

Ty Mawr, Pontardawe
Proposed Residential Development
Exploratory Investigation
Report Reference: ESP.8293.02.3827.

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Ty Mawr, Pontardawe Proposed Residential Development Exploratory Investigation

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Report Reference: **ESP.8293.02.3827**

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General Notes

General Construction Advice

Executive Summary

The Earth Science Partnership Ltd (ESP) were instructed by the Pobl Group (hereafter known as the Client) to undertake an integrated geo-environmental and geotechnical assessment of the key potential land quality issues identified by the assessment, which are summarised below:

	Potential Hazard	Anticipated Risk	Discussion
Site Setting	Current Site Status. (Section 2.1)	-	The site is currently partially occupied by a building with the proposed development area vacant.
	Identified Ground Conditions. (Section 5.1)	-	The investigation has indicated a thick cover of Made Ground (at least 2.0m deep). Natural deposits have not been proven.
	Groundwater Conditions. (Section 5.2)	-	The site is underlain by a Secondary Aquifer. No groundwater was encountered in exploratory holes however, groundwater level monitoring is ongoing.
	Historical Land Use. (Section 2.2)	-	Historical uses have been identified to include railway lines/sidings, embankments, buildings and areas of extensive disturbed/Made Ground.
Geo-environmental	Potential Contamination Sources (Section 3.1.2)	Moderate	Range of potential contaminants based on site history, including metals, PAHs and asbestos.
	Chronic Risks to Human Health (Section 7.1)	Moderate/ Low	Based on proposed end use, the levels of contamination encountered are acceptable, however, caution is recommended (see Section 7.0).
	Risks to Controlled Waters (Section 7.2)	Moderate	Leachate testing has identified the potential for some metals and PAH compounds. Whilst the development will actually reduce the area available for leachate generation, the use of sustainable drainage may not be acceptable and requires further assessment.
	Hazardous Ground Gas (Section 7.3)	High	Ground gas monitoring is ongoing. Radon protection measures (full) are required.
Geotechnical	Abandoned Mine Workings and/or Old Mine Entries (Section 8.2.2)	Low	Based on available evidence, considered to be low.
	Weak/Compressible Ground, requiring non-traditional foundations (Section 8.3 and Section 8.4)	High/ Moderate	Further information is required to provide a clear foundation design; however, it is likely options such as rafts, ground improvement or piled foundations will be required.
	Shrinkage or Swelling (Section 8.2.3)	Moderate	Natural alluvial soils were not encountered during the investigation and will require further assessment during recommended supplementary works.
	Sulphate Attack on Buried Concrete (Section 7.4.2)	Moderate/ Low	Laboratory testing has indicated the site is classed as AC-2/DS2 in terms of sulphate attack on buried concrete.
	Spontaneous Combustion	Moderate	Further assessment of this risk is required, via Loss on Ignition Testing.
	Volumetrically Unstable (Slag) Deposits	High/ Moderate	Requires further consideration. Some slag has been encountered with the site located in a wider area of slag impacted land.
	Soakaway Feasibility (Section 8.7)	-	The use of infiltration drainage in extensive Made Ground, alongside variable infiltration rates, requires further consideration if essential to the scheme.
Others	UXO (Section 2.10.6)	-	No further consideration required, outside good site practise.
	Flooding (Section 2.6)	Moderate	Area is identified as at risk of flooding during certain events. No further assessment of flooding has been undertaken.
	Invasive Plants (Section 8.1.2)	-	Not visually identified during site works.
	Further Investigation Required?	Yes	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

The Earth Science Partnership Ltd (ESP) were instructed by the Pobl Group (hereafter known as the Client) to undertake an integrated geo-environmental and geotechnical assessment of the site, comprising a Desk Study and intrusive investigation, to inform the proposed development.

ESP have previously undertaken a limited soakaway infiltration feasibility assessment in October 2022 (Ref: ESP.8293.3802). Where relevant, pertinent information from that assessment has been incorporated throughout this report, with the site records presented in Appendix G.

1.1 Background

The Client is proposing to redevelop the subject site for residential purposes. ESP, Consulting Engineers, Geologists and Environmental Scientists, were instructed by 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 in Section 2.1.

We understand that the proposed development will comprise the refurbishment of the existing detached building and extension to the south elevation. External development will include new access roads, car parking and soft landscaping. It is understood no private gardens are proposed. The development layout is presented as Insert 1 below and also presented on the appended Plates.

At present, the investigation and assessment works covered in this report, have focussed on the extension area only and not the wider site.



Insert 1 – Proposed development layout (provided by the Client)

Based on the above, we understand that the proposed structures would be classified as Geotechnical Category 2 (BS5930:2020).

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, nor have we been provided with 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, windowless sample boreholes, 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 proposal of 19th October 2022 (Ref: ESP.8239.02.It1.Proposal).

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 BS5930:2020 (Section 4), along with the Preliminary Risk Assessment stage (Section 3) and Generic Quantitative Risk Assessment (Section 5) of the land contamination risk management (LCRM) guidelines (formerly 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 LCRM guidelines.

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 BS5930:2020. The geotechnical risk register is updated using the findings of the intrusive investigation and assessment in Section 8.2. The report concludes with a summary of any further surveys/ investigations/ assessments recommended (Section 9).

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

1.4 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1 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.

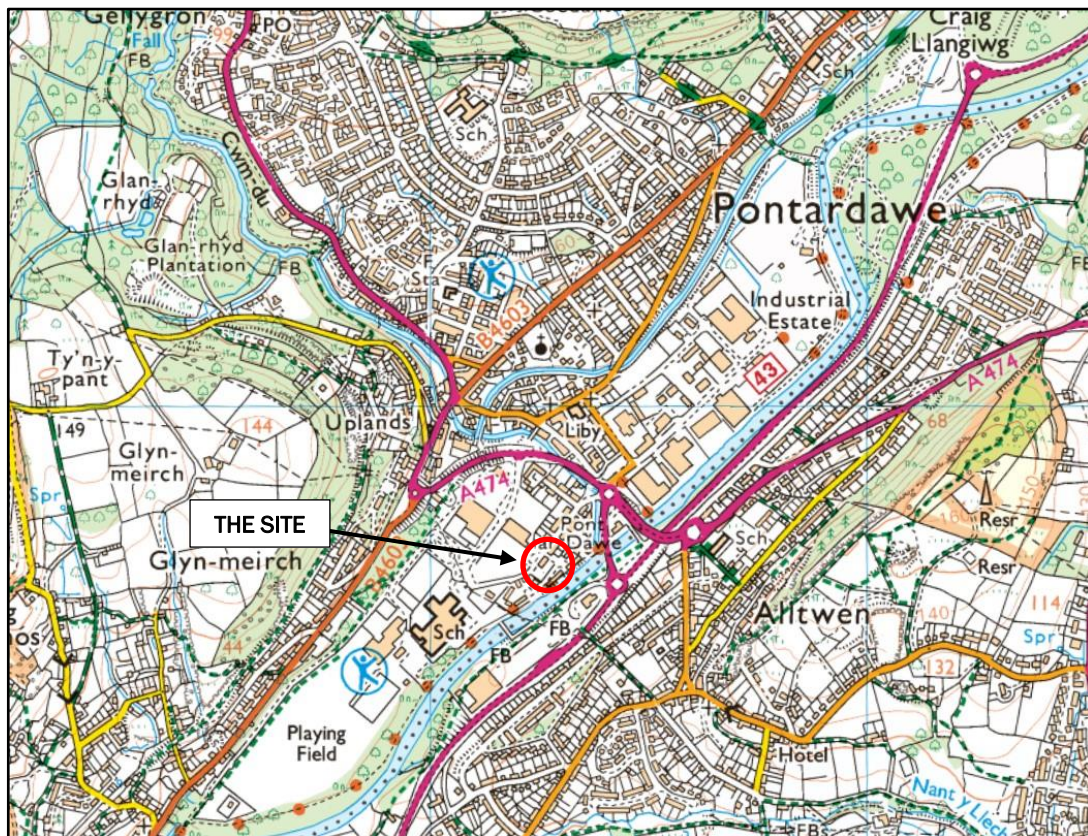
2 Desk Study and Field Reconnaissance Visit

The information presented in this section was obtained from desk-based research of sources detailed in the text, including historical maps, a combined environmental and 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 recent works on 1st December 2022 during cold, dry, and sunny weather. 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 southern side of Ynisderw Road in Pontardawe, Neath Port Talbot. The National Grid Reference of the centre of the site is (SN) 272270 203640 and the postcode is SA8 4HP. A Site Location Plan is presented as Insert 2 below.



Insert 2 - Site Location Plan from Ordnance Survey 1:25,000 scale map.
Reproduced with permission (OS License No.: AL100015788).

The development area comprises a roughly rectangular shaped parcel of land around 55m length (north-west to south-east) and 30m width (north-east to south-west), occupying an area of around 0.2ha. The site is currently partially occupied by the existing building, access road and car parking. The remainder of the site is grass-surfaced.

It is bounded by:

- To the north: Llys Glan Yr Afon road and Ynisderw Road, followed by residential properties.
- To the east: by residential properties, followed by the River Tawe some 40m east.
- To the south: by residential properties, followed by the River Tawe some 35m south.
- To the west: by Ynisderw Road, followed by residential properties.

We are not aware of a tree survey having been undertaken at this stage, but from site, there are two trees within the development footprint which are assumed will be removed to enable the proposed extension. The east and south boundaries are lined with a hedge. A tree survey should be completed by a specialist arboriculturist prior to development.

The general topography in the area is relatively flat, with the River Tawe some 35m to the south and the site itself is generally flat and level. A topographic survey has been provided by the Client (Ref: A311/A002) and indicates the level at the site to be in the order of 32m AOD. The survey plan is presented in Appendix J for reference.

The Client has provided ESP with a series of plans showing the locations of recorded underground services (water, sewerage and telecoms) in the vicinity of the site. As part of this assessment, ESP also obtained contemporary electric and gas plans from the utility companies for completeness.

Site observations and the utility plans indicate that the following service locations are pertinent to the investigation.

- Underground electric cables along the west boundary.
- Underground low-pressure gas on the south/southeast boundary.
- Underground mains water along the west boundary.
- Underground telecommunication cables along the west and north boundary.

Private services are also likely to be present which are not shown on the statutory plans, to provide amenities to the existing building.

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
1877 - 1881	The site forms part of a larger undeveloped parcel of land extending further to the north	The majority of the land to the north comprises undeveloped land parcels. The River Tawe is shown flowing from north east to south west approximately 50m to the south with a water wheel shown 20m to the west. Industrial features include Pontardawe Tin Plate Works 200m west, coke ovens 70m southwest, flour mill 100m south east, Pontardawe Chemical Works 100m south west, limekiln 250m north west. A network of rail lines are shown connecting these industrial features to the south and east of the site. An old coal level is shown approximately 100m south, across the River Tawe.
1897 - 1898	A rail line/siding trends south-west to north through the centre portion, with a second line/siding occupying the south corner. These rail features are indicated to have been constructed on fill slopes. Ynys-Derw Road (now Ynisderw Road) is shown along the northern boundary.	Residential developments are shown to the north. The tin plate works have expanded. The coke ovens, waterwheel, flour mill and limekiln no longer noted.
1913 - 1948	A building is now indicated in the north portion, with the south-west to north-east trending railway line/siding no longer indicated. Up until 1919, a small building is indicated to occupy the south portion and by 1941, two additional smaller buildings are shown in the southern portion.	The tin plate works (now steel and tin plate) has expanded further to within 50 m of the site and with additional rail lines. Additional residential development to the north. Areas to the east and south are shown to be occupied by "disturbed ground".
1962 - 1966	No significant changes indicated.	Part of the steel and tin plate works is marked as 'disused', one of the adjacent buildings is noted as a 'works'. The chemical works and a number of the former rail lines are no longer shown. Additional residential developments are shown to the southern side of the River Tawe.
1973 - 1984	No significant changes indicated.	The majority of the former infrastructure/buildings for the steel and tin plate works to the north are no longer shown. The site of the former chemical works to the south (across the river) is noted as a haulage contractors yard.
1989 - 2023	The two smaller buildings in the southern end of the site have been replaced by a single detached building.	The haulage contractors' yard is no longer noted. Residential developments are shown directly to the south. Commercial developments are shown at the site of the former steel and tin plate works.
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.		

2.2.2 Other Sources

A review of publicly available historical satellite imagery from Google Earth Pro© revealed no significant changes between 2006 (earliest available imagery) and 2021

2.3 Previous Investigations and Assessments

2.3.1 On Site Assessments

ESP undertook a limited infiltration investigation and assessment in 2022 (Ref: ESP.8293.3802). Three mechanically excavated trial pits were undertaken to allow soakaway infiltration testing. The trial pits encountered the following ground conditions

- TP01
 - 0.0 – 0.3 m - soft brown slightly sandy silty clay (Made Ground/Topsoil).
 - 0.3 – 2.0 m - Dark brown and black ashy slightly sandy slightly gravelly subangular slag cobbles and boulders (Made Ground).
- TP02
 - 0.0 – 0.2 m - soft dark brown slightly sandy clayey silt (Made Ground/Topsoil).
 - 0.2 – 0.4 m - Light brown slightly clayey sandy angular to subrounded fine to coarse brick and sandstone gravel (Made Ground).
 - 0.4 – 2.0 m - Dark brown and black ashy medium and coarse sand and angular to subrounded fine to coarse slag brick and sandstone gravel with medium sub-angular slag, brick and sandstone cobble and boulder content (Made Ground).
- TP03
 - 0.0 – 0.2 m - soft brown slightly sandy silty clay (Made Ground/Topsoil).
 - 0.2 – 0.6 m - Soft to firm light brown slightly sandy slightly gravelly clay. Gravel is angular to subrounded sandstone and mudstone (Made Ground).
 - 0.6 – 0.85 m - Dark brown and black ashy medium and coarse sand and angular to subrounded fine to coarse slag brick and sandstone gravel (Made Ground).

No groundwater was identified in any of the pits excavated. As part of the works four samples were tested for a suite of commonly occurring contaminants including screening for asbestos. No significantly elevated levels were identified, and no asbestos fibres were detected in the samples tested.

2.3.2 Adjacent Assessments

In addition to this ESP have undertaken a number of projects in Pontardawe and the surrounding area, with the following two projects undertaken in close proximity (20m – 180m) and within the same general geological/historical regime.

ESP – 5295e.2070 (2014)

A ground investigation and assessment was undertaken for a then proposed housing development, approximately 20m to the north-west and comprised a series of trial pits, trial trenches and light cable percussion boreholes.

These works identified Made Ground to depths of up to 3.2m comprising a large proportion of gravel and cobbles sized fragments of slag, brick rubble and concrete, in a coarse matrix. In some places this matrix was predominantly slag gravel and cobbles. The Made Ground contained a significant number of sub-structures including old floor slabs, foundations, a railway track and basements.

The Made Ground was identified to be underlain by low strength Alluvium and River Gravels. The more competent River Gravels were encountered below the Alluvium at depths of between 2.0m and 3.5m bgl and proven to depths of between 4.8m and 13.0m. The exploratory holes did not progress beyond the base of the River Gravels. A number of the exploratory holes had to be terminated at shallow depth and relocated due to the presence of obstructions, slag boulders and general insitu strength of the Made Ground.

Laboratory testing identified the potential for risks to site end users (health) and Controlled Waters, alongside the presence of asbestos which was identified in samples submitted to the laboratory. Monitored groundwater levels, identified a generally consistent groundwater body in the River Gravels.

Pertinent geotechnical hazards identified included, significant obstructions in the Made Ground, the presence of extensive slag deposits, potential for spontaneous combustion and low strength, fine (clay) alluvial deposits.

Foundation options for any development were recommended to comprise reinforced raft foundations (constructed on engineered fill), vibro-replacement or piled foundations.

ESP 7297d. Technical Note (2019)

ESP undertook a preliminary risk assessment and provision of outline technical advice for a proposed classroom, approximately 180m to the north west. Whilst a ground investigation was not undertaken a review of site history was included.

The review indicates that this area, as with the site addressed in this current report) was extensively occupied by historical industrial land uses, including steel works, tin works, railway lines and Made Ground. The location of this site corresponds with the extensive area of Made Ground that is identified on the geological mapping.

2.4 Contact with Regulatory Bodies & Local Information Sources

The following departments of the Local Authority (Neath Port Talbot Council) have been contacted as part of this assessment:

- Environmental Services/Health/Pollution Control.
- Building Control.
- Trading Standards (Petroleum Officer).

At the time of issue of this report, we have not yet received a response from the consultees. Once received, any response will be forwarded under separate cover. It should be appreciated that their responses may contain salient information on the site which could not be considered during the preparation of this report.

2.5 Hydrology

2.5.1 Surface Water Features

The nearest major surface water feature to the site is the River Tawe which flows from north east to south west approximately 35m to the south boundary at its closest point.

2.5.2 Surface Water Abstractions

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

2.6 Flooding

2.6.1 Rivers (Fluvial)

From a review of topographical plans and flooding maps presented in the data report and on the Natural Resources Wales (NRW) website (2023), the site is indicated to be at a low risk of flooding from rivers (fluvial). This usually corresponds with flooding associated with more extreme (0,1%) flood events. The NRW information also indicates that the site is located with a C1 flood zone, defined as “an area at risk of flooding, but served by significant infrastructure, including flood defences”.

The available information suggests, there may be a risk posed by flooding that will require future consideration. At present the potential for flooding has not been addressed further in this report and if/when required ESP are able to implement an appropriate Flood Consequences Assessment.

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) website (2023) parts of the site are indicated to be at a low risk of surface water flooding.

This is defined as “a chance of flooding between 1 in 1000 (0.1%) and 1 in 100 (1%)”. This type of flooding can be difficult to predict, as it is hard to forecast exactly where or how much rain will fall in any storm and this rating is based on the best information NRW have available, such as ground levels and drainage.

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.

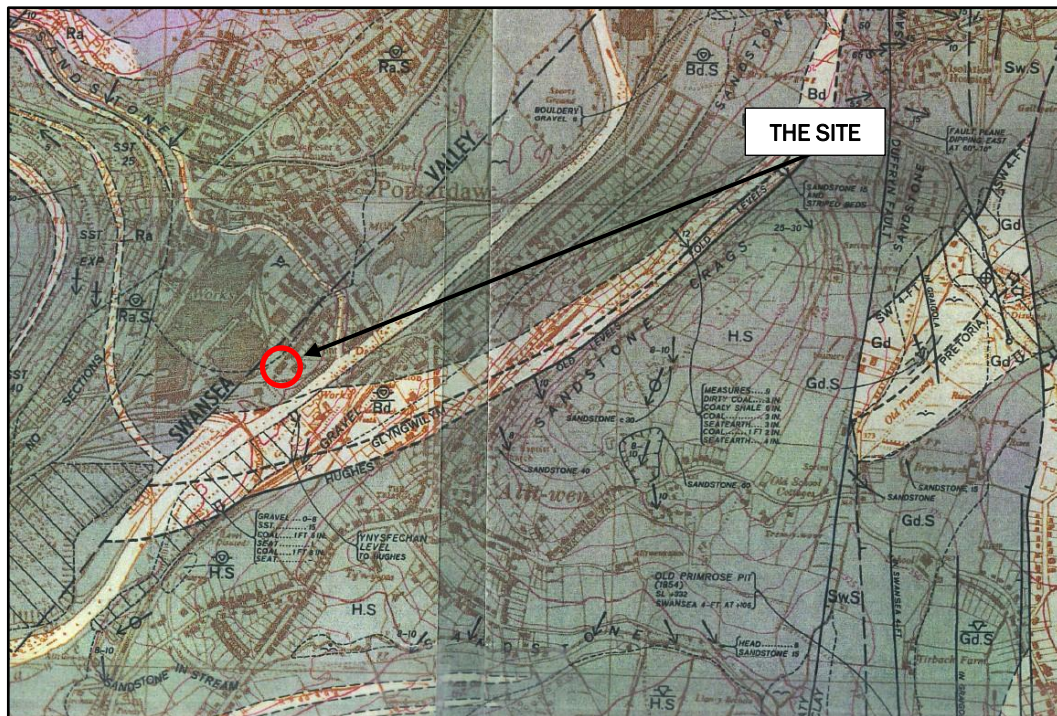
The environmental report in Appendix C indicates that the site is at a potential moderate/low risk of groundwater flooding.

2.7 Geology

2.7.1 Published Geology

The published 1:10,560 scale geological map for the area of the site (Sheet SN70SW, presented as Insert 3) indicates the site to be underlain by Alluvium overlying bedrock of the Brithdir Beds.

Reference to the up-to-date mapping available on the website of the British Geological Survey (BGS, 2023) indicates a similar succession, except the Brithdir Beds are renamed the Brithdir Member.



Insert 3 - Extract from BGS Geological Map Sheet SN70SW, original 1:10,560 scale.
Reproduced with permission (BGS licence number: C15/05 CSL)

The alluvium will likely comprise soft to firm consolidated compressible silty clay with layers of silt, sand, peat and basal gravels. The Brithdir Beds are anticipated to comprise green-grey sandstones with conglomerate lenses at the bases units and thin mudstone/siltstone/coal layers.

The geological map indicates the outcrop of a fault, the Swansea Valley Disturbance, to extend north east - south west approximately 50 m to the north. The map indicates general geological dips to the south between approximately 8 – 12 degrees. Two coal seams, the Glyngwilym and the Hughes, are indicated to outcrop to the south of the site, however, they are south of the River Tawe and anticipated to dip southwards and therefore not likely to underly the site. The risk from coal mining related subsidence is discussed further in Section 2.10.1.

2.7.2 Available BGS Borehole Records

Reference to the website of the British Geological Survey (BGS, 2023) indicates the available records for a number of boreholes approximately 100 – 150 m to the east (see Appendix D). Two of the deeper borehole records indicate the following:

SN70SW233: drilled in 1987 some 120m to the east of the site this borehole indicates

- 0.0 – 6.2 m – Sand and Gravel (Recovered as surrounded coarse gravel and cobbles of assorted siltstone and sandstone from 3.8 m depth)
- 6.2 – 11.25 m – Grey fine and medium grained thinly and thickly bedded slightly weathered slightly micaceous SANDSTONE, strong and very strong.

No comments on groundwater are provided

SN70SW112: drilled in 1985 some 140 m to the east of the site this borehole indicates

- 0.0 – 1.4 m – MADE GROUND – Black sand and gravel of ash, clinker and sandstone with occasional cobbles
- 1.4 – 1.9 m – Soft dark grey sandy SILT
- 1.9 – 3.0 m - Soft brown clayey sandy SILT with a little gravel
- 3.0 – 7.2 m – Dense brown coarse SAND and fine medium and coarse rounded GRAVEL with cobbles and occasional boulders
- 7.2 – 17.5 m – Loose grey brown fine sandy SILT, clayey in places.
- 17.5 – 18.5 m – Dark grey laminated to thinly bedded, SILTSTONE, moderately weak
- 18.5 – 23.5 m - Grey medium grained, medium bedded, with occasional carbonaceous lamination, fresh SANDSTONE, strong.

Groundwater struck at 3.0 m and 5.5 m depth, rising to 3.0 m after 20 minutes

2.8 Hydrogeology

2.8.1 Aquifer Classification

Reference to the aquifer maps published in the data report (Appendix C) indicates that both the superficial deposits beneath the site (Alluvium) and the bedrock (Brithdir Member) are classed as Secondary A Aquifers.

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.

2.8.2 Anticipated Groundwater Bodies

Based on the available information, we consider that the shallowest main groundwater body is likely to be located within the superficial (Alluvium) strata. However, localised perched water bodies within the overlying Made Ground cannot be discounted.

2.8.3 Abstractions and Groundwater Vulnerability

The data report (Appendix C) indicates that there are no groundwater abstractions or Source Protection Zones within 250m of the site.

2.8.4 Groundwater Movement

Groundwater movement within the superficial deposits will be controlled by intergranular flow whilst, in the bedrock, fracture flow is likely to be dominant. Given the site setting, which consider that the groundwater within the superficial aquifer may be providing base flow to the River Tawe directly to the south.

2.9 Environmental Setting

2.9.1 Summary of Environmental Data

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

A 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 250m of the site.
Potentially Contaminative Land Use	16no. recorded	76no. recorded within 250 m.
Historical Tanks, PFS, Garages, Energy Facilities	None identified.	18no. recorded within 250 m.
Potentially Infilled Land	1no. recorded	4no. recorded within 250 m.
Discharge Consents	None identified.	6no. recorded within 250 m.
List 1 and 2 Dangerous Substances Sites	None identified.	None recorded within 250m of the site.
Radioactive Substance Sites	None identified.	None recorded within 250m of the site.
Enforcements	None identified.	None recorded within 250m of the site.
Pollution Incidents	None identified.	9no. recorded within 250 m.
Contaminated Land under Part 2A EPA 1990.	None identified.	None recorded within 250m of the site.
Waste Management Facilities	None identified.	None recorded within 250m of the site.
Current Industrial/Commercial Sites	None identified.	4no. recorded within 250 m.
Notes: 1. Full details of features presented in the 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 Further Discussion on Salient Environmental Features

Potentially Contaminative Land Use:

The sixteen records on site relate to refuse/unspecified heaps (1897 -1966); steel and tin plate works (1913 – 1948); railway features (1897 – 1966); unspecified works (1964 – 1992) and industrial estates (1980).

The off-site records related to unspecified/refuse heaps; tramway/railway features; unspecified pits/ground workings; chemical works; unspecified works; coal level; flour/unspecified/sheet mill; chimney; electrical substation; goods shed; smithy; lime kiln and industrial estates.

The environmental report also identifies the site to be within an area of extensive Made Ground (see Appendix C – Section 14.1).

Historical Tanks, PFS, Garages, Energy Facilities:

14no. historical unspecified tanks are listed between 1877 – 1963 with the closest located 68 m northwest.

4no. electrical substations are noted between 1972 – 1998 located 61 m north, 128 m and 159 m west and 228 m southwest.

Potentially Infilled Land:

The site is located in an area of Made Ground (see Appendix C, Section 14.1) which extends further to the southwest, Additional areas of Made Ground (undivided) are also noted 61m south; 213 m north and 222 m northeast. An area of 'Worked Ground (undivided) is shown 154 m southeast.

Discharge Consents:

A licensed pollutant release is held at a Tesco Stores 110 m southeast relating to the unloading of petrol into storage.

5no. licensed discharge to controlled waters are held within 250 m of the site, the closest located 105 m east relating to an expired permit of unspecified effluent into the River Tawe.

Pollution Incidents:

The environmental report lists 9no. pollution incidents within 250 m, the closet is located 41 m south dated 2003 relating to 'metal waste' which had minor impact on water quality. None of the other pollution incidents are noted to be above having minor impact on land, water, or air quality.

Current Industrial/Commercial Sites:

The environmental report lists a Tesco store between 114 – 119 m to the southwest which includes a petrol station and two electrical substations located 157 m west and 227 m south west.

2.9.3 On-Site Bulk Liquid Storage

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

2.9.4 On-Site Bulk Materials and Waste Storage

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

2.10 Preliminary Geotechnical Risk Register

The potential for various geotechnical and geomorphological hazards at the site is provided in the 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 Mining

As discussed in Section 2.7, the site is underlain by bedrock of the Brithdir Member, which contains several seams of coal. The geological mapping identifies two coal seams, the Glyngwilym and the Hughes, outcropping approximately 200m and 250m to the south, respectively (and beyond the River Tawe).

Two mine adits are also shown approximately 110m and 30 m to the south presumed to target these two seams. This provides evidence that shallow coal mining is present in the local area, however, as the Glyngwilym and the Hughes seams outcrop to the south (beyond the River Tawe) and bedrock dips are recorded to the south, these coal seams are not anticipated to underly the site.

A large fault line, the Swansea Valley Disturbance, is shown extending northeast - southwest approximately 30m to the north. This will likely have caused large disturbance to the bedrock and displaced coal seams. No additional coal seams are shown to be present on the geological map between the Glyngwilym outcrop and the fault line.

The geological map shows two unnamed coal seams (noted as 'measures with thin coals' on the stratigraphic column) to outcrop approximately 600 and 750 m to the northwest. Sections of these outcrops are illustrated in solid lines indicating they are proven and potentially worked; however, these outcrops are not continuous and are likely to have been displaced by the fault line. Therefore, are unlikely to underly the site.

Reference to the Coal Authority website (CA, 2023) provides the following salient information:

- Coal outcrops are indicated approximately 300m south, 590m southwest, 900m north west and 1.2km to the north
- A number of mine entries are shown to the south and west, with the closest located approximately 110m to the south
- The site is not located in a 'Development High Risk Area'
- There are no areas surface mining (past and current); past shallow coal mine workings; probable shallow coal mine workings within the immediate vicinity.

A consultant's 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:

- No past underground mining is recorded
- No probable unrecorded shallow workings are noted
- No spine roadways are recorded at shallow depth
- Two mine entries (adits) are listed, located 80 and 100 m to the south. One of these adits is noted to have been investigated in 1987 and drainage works were undertaken as part of the treatment works.
- No abandoned mine plans are available

- No coal outcrops are recorded
- No geological faults, fissures and break lines are recorded
- No opencast mines or coal authority managed tips are present within 500 m
- No records of coal mining related subsidence are held within 50 m
- No mine gas or mine water treatment scheme are recorded within 500 m

Given the available information, the site is situated in an area of past shallow coal mining. However, the recorded workings are located either to the south, and due to the southerly dip of the bedrock these would not underly the site or are located on the northern site of the Swansea Valley Disturbance which would have caused displacement of the coal seams and prevented workings progressing beneath the site.

We have found no evidence to suggest that any potential coal seams could outcrop between the site and the fault line that may have been worked at shallow depth and the risk is anticipated to be low.

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.

2.10.2 Compressible Soils

Made Ground is likely to be present across the site and has been encountered during the previous investigation works. Made Ground, particularly organic material can be potentially compressible. Until further information on Made Ground is available, the risk posed by compressible soils is considered moderate.

2.10.3 Shrinkable and Swelling Soils

From our experience, the fine-grained alluvial soils anticipated at shallow depth beneath the site commonly are susceptible to volume change with changes in moisture content. During exceptionally dry periods or where the moisture is extracted by tree root activity, the clay can become desiccated and shrink in volume, and conversely swell again when the moisture content is restored. Therefore, we consider that the potential for shrinking or swelling of clays at the site should be considered moderate.

2.10.4 Pyritic Ground

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

2.10.5 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.

Based on available evidence and information available from adjacent sites, we cannot discount that the slag fragments identified during the Phase 1 works are not representative of a more extensive coverage of volumetrically unstable (slag) materials, and so we consider the potential risk should be considered High at this desk study stage.

2.10.6 Unexploded Ordnance

The data report does not consider the potential risk from unexploded ordnance at the site.

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, 2022).

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 data report (Appendix C) indicates that the site lies in a radon affected area as defined by the Health Protection Agency, with between 10 and 30% of properties above the action level which require full radon protection measures.

Reference to the UK radon maps published by Public Health England (PHE, 2015) indicates that the site lies in an area classified as a maximum radon potential of between 10 and 30%. These maps indicate the worst level of radon potential, based on existing information gathered mainly from residential properties within the 1km square in which the site is located. It is designed as a preliminary evaluation only.

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

From the available information, we consider that the following features on site could prove sources of diffuse and point source contamination that could impact on the development, environment or site users:

- Potentially extensive Made Ground;
- Former railway lines crossing the site;
- Former on site buildings;
- Alluvial soils – potentially contain pyrite
- Industrial activities – off-site source.
- Potential asbestos containing materials in shallow soils and existing building.

3.1.3 Potential Contaminants Present

The potential contaminants associated with the above potential sources have been identified from various guidelines published by DEFRA, the Environment Agency and others.

Based on this guidance and our experience, we consider that the following contaminants could be present on the site:

- heavy metals and semi-metals (arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, vanadium, zinc);
- cyanide, sulphate, sulphide;
- polyaromatic hydrocarbon (PAH) compounds;
- 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 2.11

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:

- Alluvial soils and peat – on site source.
- Made Ground – on site source.
- Potential leaks and spills of petroleum hydrocarbons from former rail line use.

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 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 residents, the critical receptors being young children playing in soft landscaped areas.
- Construction and maintenance workers.
- Buried concrete (foundations, drainage etc.).
- The water quality in the River Tawe.
- The groundwater within the alluvial and bedrock strata beneath the site.

3.1.6 Potential Migration Pathways

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

Site Users:

- Ingestion of soils and inhalation of dust in landscaping areas.
- Dermal contact with contaminated soils.
- 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.
- Chronic (long term) exposure to unacceptable levels of radon.

Construction and Maintenance Workers:

- Exposure to asbestos containing materials within the existing buildings.
- 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.

Groundwater:

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

River Tawe

- Leaching of mobile contaminants to the groundwater beneath the site, and then on to the nearby surface water course.
- Surface run-off of contaminated leachate to adjacent stream/river.

Buildings:

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

3.2 Preliminary Risk Evaluation & Plausible Pollutant Linkages

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

3.2.1 Introduction to Risk Evaluation Methodology

The 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 4 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 particularly anticipated Made Ground	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Low likelihood ²	Moderate Risk	Sampling of near-surface soils to confirm levels of total contamination present. If elevated levels are identified, then leachate testing may be required.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Low likelihood ²	Low Risk	
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Mild – site lies on Secondary Aquifer	Low likelihood ²	Low Risk	
	Leaching of soil contaminants	Impact on River Tawe	Medium – site lies adjacent to river	Low likelihood ²	Moderate Risk	
Asbestos in shallow soils	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Low Likelihood ³	Moderate Risk	Sampling of shallow soils for asbestos.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood ⁴	Moderate Risk	Sampling of soils to confirm levels of sulphate, pH, and groundwater.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	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 (residents)	Medium – potential for chronic levels	Likely ⁶	Moderate Risk	Risk identified in environmental report – see Appendix C.
Notes: - Methodology and details of risk consequence, probability and category based on CIRIA C552 (2001) and presented in Section 3.2.1. - The presence of Made Ground has been identified as part of the previous phase of works, however, elevated levels of contaminants was not identified in the samples tested. - No asbestos was identified in the samples tested as part of the previous phase of works - The alluvium can potentially contain sulphates/pyrite. See Section 2.10.4. - The Made Ground and alluvium forms a potential source of hazardous ground gas/vapours at the site. - Radon risk identified in data report. See Section 2.11 and Appendix C. - 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 on 1st December 2022 in accordance with BS5930:2020 and BS10175:2017, and was designed to investigate both geo-environmental and geotechnical hazards identified in the desk study (Section 2). The investigation comprised windowless sample boreholes, followed by the installation of gas and groundwater monitoring wells.

The exploratory holes were supervised and logged by an engineering geologist in general accordance with BS5930:2020, 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 of the investigation points have been interpolated from the topographical survey provided by the Client (see Appendix J), while the coordinates have been interpolated from available ordnance data.

4.1.2 Investigation Strategy

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

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

- Potential Made Ground across the site.
- Former railway line/sidings land use.
- Former buildings.

The investigation points were selected to obtain a general overview of the general ground conditions present in the area of the proposed extension, install ground gas wells and minimise disruption at the site.

4.1.3 Soakaway Test Pits (ESP, September 2022)

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.

Prior to the soakaway works, ESP were provided with a marked-up plan indicating the location and preferred depths of the soakaways. The drawing was provided by the Client after Hydrock (design Engineer). 3no. trial pits (TP1 to TP3) were excavated across the site on 14th September 2022 using a wheeled hydraulic excavator. The trial pits were excavated to depths of between 0.85m and 2.0m. The trial pit records are presented as Appendix G, and their positions are shown on Figure 1.

At each position, the test pit was excavated to the depth specified by the design engineer for the project, 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.

During the excavation of TP1 and TP2, Made Ground was encountered to the depths specified by the designer (0.75m for TP1 and 1-1.5m for TP2). ESP contacted the Client to relay the identified ground conditions and discuss deepening the soakaway test pits to attempt to locate the depth of natural soils; this was instructed by the Client and undertaken on site. Natural soils were not identified within the test pits, however no further excavation could be undertaken due to heavy spalling of the Made ground soils, creating instability at the surface.

ESP relayed this information to the Client and the soakaway tests were undertaken at the depths achieved, within the Made Ground. ESP also recommended that soil samples were collected for contamination testing (including leachate testing), which the Client subsequently instructed.

Due to the depth of TP1 and TP2, ESP undertook a third soakaway test (see Figure 1) at shallow depth, to obtain information on the shallow infiltration rates within the Made Ground.

The infiltration rate was calculated from the time taken for the water to fall between the 75% and 25% full level. In TP1 and TP2, no measurable head of water could be maintained due to the fast infiltration of the water into the Made Ground. An estimated 500-gallons of water was emptied into east test pit over one minute; however, this is approximate only and should not be used to inform any designs/calculations.

In TP03, the soakaway test could be measured, and the test was repeated three times (in accordance with the published guidance).

Herras fencing was erected around the test pits during the testing to protect site workers/ the general public. On completion, the trial pits were backfilled with arisings in layers compacted with the excavator bucket. The arisings were left slightly proud of the adjacent surface to allow for future settlement.

4.1.4 Windowless Sampling

3no. windowless sample drillholes (WS201 to WS203) were constructed on 1st December 2022 to depths between 1.4m and 1.9m. The borehole records are presented as Appendix H, and their positions are shown on Figure 1.

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

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

Standard Penetration Tests (SPT) were carried out using a solid cone in the boreholes in accordance with BS EN ISO 22476-3 (2005) and BS5930 (2020) to assess the relative density of the coarse-grained soils encountered in the borehole. As required in BS5930:2020, the SPT N-values shown on the borehole records are the direct, uncorrected results obtained in the field.

Depending on the nature of the test undertaken and the soils subjected to testing, field SPT N-values may require correction before using in design.

On completion, monitoring instrumentation was installed in the boreholes as detailed in Section 4.2. Below the instrumentation, the borehole was backfilled with arisings/gravel.

4.2 Instrumentation

4.2.1 Gas Well Installations

A 50mm diameter monitoring well was installed in selected boreholes in accordance with BS8576:2013 in order to allow monitoring of hazardous ground gases. The wells, comprising slotted plastic pipe with a gravel surround (the response zone), bentonite seals above the response zone, and a lockable vandal proof cover, were installed as detailed on the borehole records and summarised in the table below. At present, it has only been possible to install ground gas wells at shallow depth within the Made Ground.

Table 4: Gas Well Installations

Well ID	Date of Installation	Response Zone depth	Response Zone Stratum	Rationale
WS201	01/12/2022	0.5m – 1.7m	Made Ground	2
WS202	01/12/2022	0.5m – 1.7m	Made Ground	2
WS203	01/12/2022	0.5m – 1.4m	Made Ground	2
Notes: 1. Details of each monitoring well are presented on the individual borehole records (Appendix H). 2. Well installed in Made Ground to assess shallow ground gas risk.				

4.2.2 'Spot' Gas Monitoring

To date, the installed wells have been monitored for levels of groundwater and ground gas on two occasions with a total of 6no. visits programmed.

Given the limited data collected to date no formal assessment can be undertaken and this will be provided in an addendum report on completion of the monitoring, however, at present ground gas levels indicate no methane and low levels (<1%) of carbon dioxide. This will be updated as further information becomes available.

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) with a 10.6eV lamp was used during the monitoring to measure the levels of volatile organic compounds present in the well.

Following measurement of gas levels and flow rates, the well cap was removed, and groundwater levels were measured using a 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 investigation area, which can contain elevated levels of contaminants such as metals and polyaromatic hydrocarbon (PAH) compounds.

4.5 Geotechnical Laboratory Testing

As no Made Ground was encountered at the site and no natural soils identified, no general classification testing has been undertaken to date.

Selected samples were 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 (see Section 2.10.3), 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 I.

4.6 Geo-environmental Laboratory Testing

4.6.1 Soils 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 5.3).

To allow an assessment of the potential chronic risks posed to human health, a total of 8no. selected samples of the Made Ground (4no. from the previous soakaway works and 4no. from the recent borehole works) have been analysed for the contaminants identified in Section 3.1.3, plus other determinands typically present on brownfield sites in the UK.

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

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

The geo-environmental soil test results from both the soakaway assessment and the recent investigation are presented in Appendix I.

4.6.2 Leachate Samples

In order to allow an assessment of the potential pollution risks to controlled waters, samples of leachate have been generated from 8no. samples of Made Ground soil recovered from the exploratory holes. The leachate preparation was carried out in accordance with BS EN 12457, at a 10:1 eluate ratio. The resulting leachate was analysed for the following determinants:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc.
- US EPA 16 polycyclic aromatic hydrocarbon (PAH) compounds.
- Total monohydric phenols.
- Cyanide, soluble sulphate, pH value.

The results of the leachate tests are presented in Appendix I.

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 a potentially thick horizon of Made Ground. No obvious evidence for natural deposits was encountered, however, the Made Ground is anticipated to be underlain by Alluvial deposits and the Brithdir Member bedrock.

The Made Ground was encountered over two phase of work to depths of between 0.85m and 2.0m as a variable, generally clay becoming gravel material with frequent fragments of slag, clinker, brick, concrete and other anthropogenic fragments.

Field SPT N-values within the Made Ground indicate SPT 'N' values of 6-12 at a depth of around 1.2m, rising to 'N' values of 50+ in the base of the windowless sample holes (1.4m to 1.9m depth) where the exploratory positions were terminated due to lack of progress.

It is anticipated, based on the ground conditions encountered, that the windowless sample holes failed to progress based on the density of and obstructions within the Made Ground (see Plates) rather than the presence of competent natural soils. This is supported by the findings of the 2022 trial pit investigation, which progressed to depths of 2.0m in open excavation, remained within Made Ground and encountered large cobbles and other frequent anthropogenic materials.

5.2 Conceptual Ground Model - Hydrogeology

The investigation works (2022 and 2023) have not identified any groundwater to a depth of 2.0m during investigation works. However, groundwater levels are being recorded as part of the monitoring regime and will be reported upon completion.

5.3 Chronic Risks to Human Health – Generic Assessment of Risks

5.3.1 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.

5.3.2 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 an extension to an existing residential property with areas of landscaping. We understand that no areas of private gardens are proposed and therefore, the GAC appropriate for a flats/apartment/care homes type end use have been adopted in this assessment.

The GAC for most organic compounds are dependent on the organic content of the soil. Analysis has shown that the soil organic content in the soils analysed ranged from 2.9 to 8%.

5.3.3 Generic Quantitative Risk Assessment

The samples analysed for soil contaminants comprised eight samples of Made Ground collected during the 2022 and 2023 investigation works. 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 5.3.4.

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 4 - Generic Assessment of Human Health Risks

Determinand	Range Recorded	GAC	Source of GAC	Exceedances
Metals and Semi-metals				
Arsenic	14 - 43mg/kg	79mg/kg	C4SL ²	None of 8
Barium ⁶	62 - 920mg/kg	1,300mg/kg	CL:AIRE/EIC ⁵	None of 8
Beryllium	0.4 - 2.1mg/kg	2.2mg/kg	S4UL ⁴	None of 8
Boron	<0.2 - 0.6mg/kg	21,000mg/kg	S4UL ⁴	None of 8
Cadmium	0.3-1.2mg/kg	220mg/kg	C4SL ²	None of 8
Chromium (total) ⁷	14-130mg/kg	1,500mg/kg	S4UL ⁴	None of 8
Chromium (hexavalent)	<1.0mg/kg	23mg/kg	C4SL ²	None of 8
Copper	28-320mg/kg	12,000mg/kg	S4UL ⁴	None of 8
Lead	19-130mg/kg	630mg/kg	C4SL ²	None of 8
Mercury ⁸	<0.05-0.08mg/kg	120mg/kg	S4UL ⁴	None of 8
Nickel	20-54mg/kg	230mg/kg	S4UL ⁴	None of 8
Selenium	0.8-5.1mg/kg	1,100mg/kg	S4UL ⁴	None of 8
Vanadium	23-81mg/kg	2,000mg/kg	S4UL ⁴	None of 8
Zinc	88-410mg/kg	81,000mg/kg	S4UL ⁴	None of 8
Polyaromatic Hydrocarbons (PAH)				
Acenaphthene	<0.03 - 0.33mg/kg	15,000mg/kg	S4UL ^{4,9}	None of 8
Acenaphthylene	<0.03mg/kg	15,000mg/kg	S4UL ^{4,9}	None of 8
Anthracene	<0.03 - 0.41mg/kg	74,000mg/kg	S4UL ^{4,9}	None of 8
Benzo(a)anthracene	<0.03 - 1.4 mg/kg	29mg/kg	S4UL ^{4,9}	None of 8
Benzo(a)pyrene	<0.03 - 0.74mg/kg	10mg/kg	C4SL ^{2,9}	None of 8
Benzo(b)fluoranthene	<0.03 - 1.3 mg/kg	7.1mg/kg	S4UL ^{4,9}	None of 8
Benzo(ghi)perylene	<0.03 - 0.32mg/kg	640mg/kg	S4UL ^{4,9}	None of 8
Benzo(k)fluoranthene	<0.03 - 0.36 mg/kg	190mg/kg	S4UL ^{4,9}	None of 8
Chrysene	<0.03 - 1.6 mg/kg	57mg/kg	S4UL ^{4,9}	None of 8
Dibenzo(a,h)anthracene	<0.03-0.06mg/kg	0.57mg/kg	S4UL ^{4,9}	None of 8
Fluoranthene	<0.03 - 4.1 mg/kg	3,100mg/kg	S4UL ^{4,9}	None of 8
Fluorene	<0.03 - 0.23mg/kg	9,900mg/kg	S4UL ^{4,9}	None of 8
Indeno(123-cd)pyrene	<0.03 - 0.32mg/kg	82mg/kg	S4UL ^{4,9}	None of 8
Naphthalene	<0.03mg/kg	4,900mg/kg	S4UL ^{4,9}	None of 8
Phenanthrene	<0.03 - 2.7mg/kg	3,100mg/kg	S4UL ^{4,9}	None of 8
Pyrene	<0.03 - 3.0 mg/kg	7,400mg/kg	S4UL ^{4,9}	None of 8
Notes to Table:				
- Assessment for residential land use <u>with home-grown produce uptake</u> (apart from barium – see Note 6 below). - 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. - GAC for xylene based on p-xylene (lowest S4UL).				

The levels of determinands fall below the respective guideline values, for a land use associated with residential properties of a flat/apartment nature, as it understood no areas of private gardens are proposed.

5.3.4 Asbestos

No evidence of asbestos was identified in the samples analysed during the 2022 and 2023 works.

5.4 Risk to Controlled Waters - Level One Assessment

5.4.1 Methodology

As the use of infiltration drainage is being considered, and at the request of the Client/Design Team, ESP have implemented a preliminary assessment of the potential risks posed to Controlled Waters by leachable contaminants.

The potential impact of contamination originating at the site on controlled waters in the area of the site (i.e. groundwater and surface water) has been initially evaluated in line with the Environment Agency guidance (Carey et al, 2006). Levels of leachable contamination within the soil samples recovered at the site have been analysed, which represents a 'Level One' risk assessment (Carey et al, 2006).

5.4.2 Assessment Criteria

As for the assessment of human health risks above, the results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area. The Preliminary Risk Assessment (Section 3) has identified that the following controlled water receptors are potentially at risk from contamination originating at the site:

- The groundwater within the Coal Measures bedrock which is classified as a Secondary A aquifer, where the groundwater could be abstracted for potable use in the future.
- The water within the River Tawe, located some 35m to the south of the site. The groundwater within the shallow soils beneath the site may be in hydraulic connection with the river water.

Surface Water Receptors:

In order to assess the potential impact on the waters of the River Tawe, the levels of contaminants have been compared to the Environmental Quality Standards (EQS) published within the Water Framework Directive Directions (WFD, 2015). For the purposes of this assessment, the Annual Average (AA) or long term (mean) EQS have been adopted which represent the acceptable levels of a contaminant over an annual period. Given the most vulnerable receptor is considered to be the River Tawe, the EQS published for fresh water have been adopted. For cadmium, the EQS are dependent on the hardness of the receptor water body. The most stringent EQS value has been used for this assessment. For zinc the EQS is calculated from the ambient background concentration in the local river catchment (WFD, 2015). The River Tawe is not listed, therefore the value for all other freshwaters has been used.

Groundwater as a General Resource:

In order to assess the potential risk to groundwater as a general resource beneath the site, we have adopted the 'concentrations of hazardous substances within groundwater below which the danger of deterioration of the groundwater quality is avoided' published by UKTAG (2016) have been adopted as assessment criteria. These UKTAG concentrations have been calculated from thresholds designed to be protective of drinking water, so may be conservative in this instance. Therefore, an exceedance may not necessarily indicate an unacceptable risk.

Hazardous Substances:

Some contaminants which can impact on controlled waters have been classed as hazardous substances (JAGDAG, 2019) and include arsenic, lead, mercury, and some of the polyaromatic and petroleum hydrocarbon compounds. Natural Resources Wales (NRW) require that the entry of hazardous substances into controlled waters is phased out, or at least any further entry should be minimised. The remaining contaminants are classed as non-hazardous. The classification of each determinand analysed is presented in the assessment tables.

5.4.3 Assessment of Leachate Test Results

The samples selected for leachate testing comprised Made Ground. The results of the leachate testing and their comparison to the relevant assessment criteria are presented in the Table below.

Table 5- Level One Controlled Waters Risk Assessment – Leachate Results (River Tawe)

Compound	Range Recorded	EQS - AA	Exceedances
Metals and Semi-metals:			
Arsenic ¹	0.53 – 3.0µg/l	50µg/l	None of 8
Cadmium ^{2,4}	<0.03µg/l	0.08µg/l	None of 8
Chromium ^{2,5}	<0.25 – 0.83µg/l	3.4µg/l	None of 8
Copper ²	1.1 – 4.7µg/l	1.0µg/l	8 of 8
Iron ³	58 – 230µg/l	1,000µg/l	None of 8
Lead ¹	0.25 – 2.3µg/l	1.2µg/l	3 of 8
Nickel ²	<0.5 – 0.5µg/l	4.0µg/l	None of 8
Zinc ^{2,6}	2.3 – 5.4µg/l	12.3µg/l	None of 8
Polyaromatic Hydrocarbons			
Anthracene ¹	<0.01 – 0.02µg/l	0.1µg/l	None of 8
Benzo[a]pyrene ¹	<0.01 – 0.11µg/l	0.00017µg/l	8 of 8
Naphthalene ²	<0.05 – 0.07µg/l	2.0µg/l	None of 8
Fluoranthene ³	<0.01 – 0.11µg/l	0.0063µg/l	8 of 8
Other Contaminants			
Cyanide ⁴	<40µg/l	1.0µg/l	8 of 8
Phenol ⁴	<1.5µg/l	7.7µg/l	None of 8
Notes: 1. Hazardous substance (JAGDAG, 2019). 2. Non-hazardous substance (JAGDAG, 2019). 3. Iron not classified by JAGDAG 2019. 4. Cadmium EQS based on hardness of <40mg/l CaCO₃. 5. All chromium present assumed to be chromium VI (conservative approach). 6. Zinc EQS based on ambient background concentration in catchment. 7. Based on River Tawe as main receptor. 8. EQS-AA – Environmental Quality Standard (estuarine/saline waters) - Annual Average or Mean. 9. Exceedances indicated in bold and colour coded as shown.			

Table 6 - Level One Controlled Waters Risk Assessment – Leachate Results (General Groundwater)

Compound	Range Recorded	UKTAG ⁵	Exceedances
Metals			
Arsenic1	0.53 – 3.0µg/l	5.0µg/l	None of 8
Chromium VI1,3	<0.25 – 0.83µg/l	5.0µg/l	None of 8
Lead1	0.25 – 2.3µg/l	5.0µg/l	None of 8
Mercury1	<0.01µg/l	0.5µg/l	None of 8
Polyaromatic Hydrocarbons			
Anthracene1	<0.01 – 0.02µg/l	0.05µg/l	None of 8
Benzo[a]pyrene ¹	<0.01 – 0.11µg/l	0.05µg/l	2 of 8
BbF ¹	<0.01 – 0.13µg/l	0.05µg/l	1 of 8
BghiP ¹	<0.01 – 0.08µg/l	0.05µg/l	1 of 8
BkF1	<0.01 – 0.04µg/l	0.05µg/l	None of 8
IDP ¹	<0.01 – 0.11µg/l	0.05µg/l	1 of 8
Notes: - Hazardous substance (JAGDAG, 2019). - Non-hazardous substance (JAGDAG, 2019). - All chromium present assumed to be chromium VI (conservative approach). - Assessment based on non-potable groundwater beneath the site. - UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only. - Exceedances indicated in bold and colour coded as shown.			
Key to PAH compounds: BbF: benzo[b]fluoranthene BkF: benzo[k]fluoranthene BghiP: benzo[ghi]perylene IDP: indeno[123-cd]pyrene			

The leachable levels of PAHs generally recorded exceedances above groundwater and surface water assessment criteria however, the exceedances were fewer in number compared to the general groundwater guidelines. Elevated levels of copper and lead were recorded relative to surface water standards.

5.5 Hazardous Ground Gas

5.5.1 Degradation of Organic Materials

To date, the installed wells have been monitored for levels of groundwater and ground gas on two occasions with a total of 6no. visits programmed.

Given the limited data collected to date no formal assessment can be undertaken and this will be provided in an addendum report on completion of the monitoring, however, at present ground gas levels indicate no methane and low levels (<1%) of carbon dioxide. This will be updated as further information becomes available.

At present, it has only been possible to install ground gas wells at shallow depth within the Made Ground and not within the deeper alluvial deposits which may contain peat/organic bands. This will require further consideration (see Section 7.0.).

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

No groundwater was encountered in the exploratory holes to a depth of 2.0m (2022 and 2023). In accordance with the BRE guidelines, we recommend that groundwater be considered as 'mobile' in terms of foundation concrete assessment.

5.6.3 Sulphate Levels

Laboratory test results indicate the levels of water soluble sulphate (as SO_4) in the Made Ground soils to be between 58 and 200mg/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 0.13 and 0.35% and total sulphur between 0.1 and 0.14%.

From these results, the calculated levels of total potential sulphate are between 0.3 and 0.42%, and oxidisable sulphides are between 0.01 and 0.29%. As the levels of oxidisable sulphide are below 0.3%, pyrite is unlikely to be present.

pH values in the Made Ground varied between 8.1 and 11.3, indicating alkaline soil conditions to exist. As the pH levels all exceed 5.5, there is no need to further assess the soils for the types of acids present (e.g. hydrochloric and nitric acids). 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:	200mg/l;
Total potential sulphate:	0.42%;
pH value:	8.1

6 Phase Two Geo-Environmental Risk Assessment

6.1 Discussion on Occurrence of Contamination and Distribution

A review of the history has indicated the site has previously been occupied by railway lines/sidings, embankments and former buildings, with other evidence suggesting the site is located on an area of extensive Made Ground. Investigation works have confirmed this, with Made Ground proven to 2.5m, with no natural ground deposits encountered.

Laboratory testing has indicated levels of potential contaminants to be below the guideline value for the adopted end use (residential land use with no private gardens).

The levels of PAHs in the leachate were above the stringent groundwater and surface water assessment criteria. Elevated levels of copper and lead were also recorded relative to surface water standards.

Ground gas monitoring is ongoing, however, results to date indicate the presence of low levels of carbon dioxide.

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 have been updated and revised in the Table below following information learned from the exploratory works and results of monitoring and laboratory testing.

Table 7 - Revised Risk Evaluation & Relevant Pollutant Linkages (RPL)

Source	Pathway	Receptor	Classification of Consequence	Classification of Probability	Risk Category	Further Investigation or Remedial Action to be Taken
Potential contaminants in shallow soils particularly anticipated Made Ground	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Site Users (residents)	Medium – potential for chronic levels.	Low likelihood ²	Moderate/Low Risk	See Section 7.0. For further discussion.
	Direct contact/ inhalation/ ingestion of contaminated soil or dust	Construction/ Maintenance Workers	Minor – standard PPE likely to be sufficient	Low likelihood ²	Low Risk	
	Leaching of soil contaminants	Impact on Groundwater /Potable Water	Mild – site lies on Secondary Aquifer	Likely ²	Moderate Risk	See Section 7.0. For further discussion.
	Leaching of soil contaminants	Impact on River Tawe	Medium – site lies adjacent to river	Likely ²	Moderate Risk	
Asbestos in shallow soils	Inhalation of fibres	Construction/ Maintenance Workers	Medium – potential for chronic levels	Low Likelihood	Low Risk	No evidence of asbestos encountered.
Soil sulphate and pyrite	Aggressive groundwater	Buried Concrete	Mild – damage to structures	High likelihood	Moderate/Low Risk	Generally low levels of pH/sulphate identified, however, slightly advanced concrete class required.
Hazardous ground gas/vapours	Asphyxiation/poisoning. Injury due to explosion.	Site Users/Visitors.	Severe – acute risk.	Likely ³	High Risk	Monitoring of ground gas wells is ongoing. .
	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 (residents)	Medium – potential for chronic levels	Likely ⁴	Moderate/High Risk	Risk identified in environmental report – see Appendix C.
Notes: 1. This table, updates, Table 4 in Section 3.2.2. 2. Contamination risk assessed in line with proposed end use. 3. Ground gas monitoring is ongoing. 4. Environmental data report (Appendix C) identifies that full Radon protection is required.						

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 the Land contamination risk management (LCRM) guidelines (formerly 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 asbestos was detected during this phase of works. If any ACM are encountered during development, the advice of a suitably qualified specialist should be sought, and any identified ACM removed from site by a licensed specialist contractor.

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.

Prior to refurbishment, and if not already completed, an asbestos building survey should be undertaken.

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

7.1.2 Site End Users

The proposed development comprises, the construction of a new extension and associated external areas of hard standing and landscaping. We further understand that no areas of private gardens are proposed (see Insert 1).

Based on the levels of contaminants encountered and the proposed end use, no specific remedial measures are required in the areas of proposed development (see Insert 1), however, some caution is warranted.

As works to date have been limited to the proposed extension area, deep Made Ground has been encountered, it would be prudent to expand the assessment to the proposed landscaping areas. Once the design is finalised, this could take the form of supplementary, shallow, sampling to provide further information on the potential for contamination to exist in future landscaping/communal green space areas.

Should the proposed end use change to include any areas of private gardens, this assessment should be reviewed to ensure it remains valid and protective for site end users.

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

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

7.2 Risks to Controlled Waters

The site has had a potential contaminative history and Made Ground has been identified. Generally, soil contamination levels are low and no obvious visual or olfactory signs of extraordinary contamination have been identified.

Leachate testing in the Made Ground has recorded elevated levels of PAHs relative to the stringent surface water and groundwater standards and elevated levels of copper and lead were recorded relative to surface water standards.

Considering the historic and current industrialisation of the wider area, widespread Made Ground of a similar nature, we consider it unlikely that the levels encountered would be considered regionally significant in the context of the area. In addition, a building and hardstanding is proposed which would reduce future infiltration compared to the current surface.

Whilst a low to moderate risk is posed, we do not consider remediation is warranted. If any contamination is encountered during the construction works, we recommend these are suitably removed or assessed further by a specialist.

It should be noted that these are comments related to general site context only. If infiltration drainage is a necessity to the scheme, then the levels of potential leachable contaminant will require further consideration, as infiltration features may create point sources of exacerbated leaching.

7.3 Risks from Ground Gas

7.3.1 Risk to the Development – Degradation of Organic Material

To date, the installed wells have been monitored for levels of groundwater and ground gas on two occasions with a total of 6no. visits programmed. Given the limited data collected to date no formal assessment can be undertaken and this will be provided in an addendum report on completion of the monitoring, however, at present ground gas levels indicate no methane and low levels (<1%) of carbon dioxide. This will be updated as further information becomes available.

At present, it has only been possible to install ground gas wells at shallow depth within the Made Ground and not within the deeper alluvial deposits which may contain peat/organic bands which will require further consideration. As part of the recommended supplementary works (see Section 9.0) it may be necessary to install deeper ground gas wells within the alluvium, should peat or significant organic deposits be encountered.

7.3.2 Risk to the Development – Radon

As discussed in Section 2.11, radon protection is required.

7.3.3 Risk to Construction and Maintenance Workers

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.

This will also be addressed further in our ground gas addendum, upon completion of all monitoring.

7.4 Risks to Property

7.4.1 Spontaneous Combustion

No evidence of combustible materials has been identified in the shallow soils, however, only a small portion of the site has been investigated and identified ground conditions to be similar to adjacent developments where loss on ignition is identified as a concern. At present, we would consider the risk associated with this aspect to remain and require further consideration.

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:	200mg/l;
Total potential sulphate:	0.42%;
pH value:	8.1

Based on these characteristic values, we consider that the site would be classified as Design Sulphate Class DS-2 and Aggressive Chemical Environment for Concrete Class AC-2, allowing for mobile groundwater.

7.4.3 Volumetrically Unstable (Slag) Deposits

Some fragments of slag were identified in the Made Ground. Whilst visually identified in low proportion, they were encountered in the majority of exploratory holes. This is consistent with findings from adjacent sites where extensive slag deposits have been identified.

As investigation works at the site have been limited, this will require further consideration to determine the type, extent and volume change potential of slag deposits. This would require the excavation of full size trial pits to allow observation and collection of suitable sample quality.

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 2.10.6, a specialist preliminary assessment has concluded that ‘a detailed desk study, whilst always prudent, is not considered essential in this instance’.

Therefore, 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, as the works have been undertaken in winter months and their growth is seasonal, their presence cannot be discounted.

8.1.3 Existing Foundations and Services

The site has been previously been developed and old foundations and underground structures are anticipated beneath the site. These sub-structures and any others identified during development should be grubbed up within the zone of influence of the development as part of the site preparation works.

Live services have been identified on site as described in Section 2.1. Considering the presence of these services, an allowance for a suitable exclusion zone should be made when planning the development and site works. Further details and permissions should be obtained from the provider. A network of land drains is likely to be present and may provide a seepage path into excavations. The land drains should be diverted where they enter foundation excavations.

8.1.4 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 8.6. For risks associated with sulphate attack see Section 7.4.2.

8.2.2 Coal Mining Hazard

The available Desk Study information has not indicated the potential for shallow coal seams and/or workings to be present beneath the site and as such, the risk posed by coal mining is considered to remain low.

8.2.3 Compressible Ground

Deep, potentially compressible Made Ground has been encountered in the areas investigation. It will be necessary to further assess this risk as part of recommended, supplementary works (see Section 8.3).

8.2.4 Shrinkage and Swelling

The natural alluvial soils were not encountered during the investigation and are likely to be present below the deep Made Ground and as such, it has not been possible to undertake an assessment of the potential for shrink swell. This should be addressed as part of recommended, supplementary works (see Section 8.3). In general, the use of trench fill foundations in these circumstances should be used with great caution as lateral swelling pressures on such large foundation surfaces can lead to rotation or other movement which could lead to failure of the foundation, and they may be subject to uplift forces from the soil swelling.

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

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

8.2.5 Volumetrically Unstable (Slag) Deposits

Some fragments of slag were identified in the Made Ground. Whilst visually identified in low proportion, they were encountered in the majority of exploratory holes. This is consistent with findings from adjacent developments where extensive slag deposits have been located.

As investigation works at the site have been limited, this will require further consideration to determine the type, extent and volume change potential of slag deposits. This would require the excavation of full size trial pits to allow observation and collection of suitable sample quality.

8.3 Outline Foundation Discussion

The following foundation advice is presented as outline only and further ground investigation and assessment is required particularly with regard to the nature and extent of volumetrically unstable slag deposits, prior to further consideration of appropriate foundation types.

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

Based on available evidence the anticipated deep (unproven) Made Ground is unlikely to support the use of traditional trench fill foundations, particularly for a more sensitive development, which is to adjoin an existing building. It is likely that a more suitable foundation will be the use of a raft on excavated/replaced material, vibro-ground improvement or the use of piles.

In order to allow a suitable assessment of achievable foundation loads and potential settlement (for non-piled foundations) it will be necessary to prove the full thickness of Made Ground, potential for obstructions and unstable deposits to be present (such as slag), and the insitu strength characteristics via the undertaking of a deep borehole within the extension footprint. If piled foundations are a preferred option, this additional investigation would be required to inform pile design and depth.

Each foundation option will present challenges such as obstructions to piling or excavation and removal of unsuitable soils for shallow foundations.

8.4 Floor Slab Foundations

Due to the presence of over 600mm of Made Ground, potentially volumetrically unstable slag deposits and deeper soft compressible soils at the site, we consider that ground bearing floor slabs would not be suitable for the development, and floor slabs should be suspended or incorporated where raft foundations are used.

8.5 Pavement Design

We understand that vehicle access roads/hardstanding are proposed at the site.

California Bearing Ratio (CBR) tests have not been carried out at the site, but based on experience and published guidelines, a CBR value of 2% is considered appropriate for preliminary design purposes, for the near surface Made Ground soils. Actual design values should be determined for designated areas as required.

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.

8.5.1 Susceptibility to Frost Action

Given their plasticity, the near surface Made Ground is considered to be frost susceptible. A total thickness of 450mm non-frost susceptible pavement construction will be required to avoid frost heave.

8.6 Excavation and Dewatering

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

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

Based on our understanding of the proposed development, no significant groundwater ingress is anticipated above 2m depth. Where water ingress occurs it is likely that pumping from screened sumps within shallow excavations will be adequate.

8.7 Soakaway Drainage

8.7.1 Soakaway Design

The shallow soils encountered in the investigation (to a depth of 2.0m) are comprised of variable Made Ground and the use of infiltration drainage in such conditions requires careful consideration.

As part of our 2022 works, 3no. soakaway infiltration tests were undertaken, as summarised on the table below. Sufficient infiltration was achieved within the test period to allow an infiltration rate to be calculated on all three fills at soakaway test location SA3 only, as it was not possible to

achieve a head of water within the Made Ground encountered in SA1 and SA2. This indicates that the soils are of coarse nature (as was observed and logged during the construction of the pits) and void spaces are also likely present, especially where angular boulders are encountered.

Table 8: Results of Soakaway Testing

G. Results of Soakaway Testing				
Test ID	Test Depth	Fill Number	Measured Infiltration Rate ¹	Infiltration Strata
SA1	2.00m	No measurable head of water achievable – test incomplete.		Made Ground.
SA2	2.50m	No measurable head of water achievable – test incomplete.		
SA3	0.85m	1	5 x 10 ⁻⁵ m/sec	
			4 x 10 ⁻⁵ m/sec	
		2	4 x 10 ⁻⁶ m/sec	
Notes: 1. Testing undertaken in accordance with BRE 365. Water level fell to 25% of fill depth.				

SA3 indicated infiltration rates of between 4×10^{-5} m/sec and 4×10^{-6} m/sec. At this stage, given the limited soakaway assessment data, we do not consider that a characteristic infiltration rate can be given for the site, due to the likely variable rates that will occur within the Made Ground. Further assessment should be undertaken in the areas of proposed soakaway/attenuation locations once they have been finalised.

As discussed in Section 5.3, the use of infiltration drainage in Made Ground (if essential) will also require further consideration of the risk posed to the underlying groundwater and River Tawe, due to the presence of leachate contaminants identified. The potential for volumetrically unstable slag will also need to be considered, as if identified, the addition of water to the soil could exacerbate volume change.

8.7.2 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 5m 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.

8.7.3 Regulatory Considerations

8.7.3.1 Natural Resources Wales

Natural Resources Wales has a general policy that no direct discharge of surface run-off would be accepted in vulnerable groundwater aquifers. Given the shallow depth of the bedrock at the site, any soakaways would result in the direct discharge of surface water run-off into the aquifer. We recommend that enquiries are made to Natural Resources Wales to identify whether they would allow such discharge at the site. As a minimum, risk mitigation measures such as oil interceptors are likely to be required.

8.7.3.2 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 any development.

9 Recommendations

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

Required Further Actions:

- Completion of ground gas and groundwater level monitoring and provision of addendum report.
- Undertaking of supplementary, deep, investigation below the proposed extension to allow confirmation of type and likely performance of foundation options, and installation of deeper ground gas wells.
- Once the scheme is finalised, review of contamination assessment to ensure it remains valid and suitable for proposed end use.
- Further consideration of the potential impact of volumetrically unstable (slag) deposits via a detailed trial pitting exercise.
- Assessment of potential for spontaneous combustion, which could be combined with the undertaking of the trial pit exercise identified above.

Recommended Further Actions:

- If infiltration drainage is essential, supplementary testing at exact locations where drainage features are proposed.
- If infiltration drainage is essential, further consideration of leachate and volume change potential.
- Enquiries to NRW to confirm acceptance of soakaways and any risk mitigation measures required.
- Further assessment of the risk posed by flooding as/when required.
- Re-measure CBR values at sub-grade prior to pavement construction.
- Assessment of sensitivity of CBR value with changes in moisture content.
- 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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