

Our ref: 7962si

Site Investigation Report
for land at
Cwrt Pentwmpath,
Llay

For: Castlemead Group Limited
Abenbury House
17 Wilkinson Business Park
Clywedog Road South
Wrexham
LL13 9AE

21st December 2022

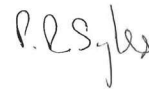
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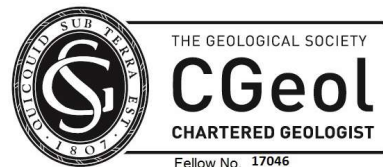
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**Document Revision**

Report Reference	Date	Description	Prepared	Checked and Approved
7962si	21 st December 2022	Site Investigation Report	J A Lewis	P R Sykes

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1.0 Introduction

- 1.1 This report details the findings of the site investigation for a proposed residential development on land at Cwrt Pentwmpath, Llay. This report was prepared on instructions received from our client Castlemead Group Limited, Abenbury House, 17 Wilkinson Business Park, Clywedog Road South, Wrexham, LL13 9AE .
- 1.2 The copyright of this report and the associated plans/documents prepared by Coopers (Chester) Ltd, trading as Coopers, is solely owned by Coopers. Consequently, neither this report nor the associated plans/documents may be reproduced, published or adapted without the express written approval of Coopers. Complete copies of this report may, however, be made and distributed by our client as an expedient in dealing with matters directly related to its commission.
- 1.3 The accuracy of map extracts cannot be guaranteed and it should be recognised that different conditions on /adjacent the site may have existed between and subsequent to the various map surveys. Historical map extracts are produced as an appendix report by Groundsure under licence from Ordnance Survey. Coopers can reproduce and use these extracts in this report under their Ordnance Survey Licence No. AL100005579.
- 1.4 Where data supplied by others, including that from previous investigations, has been used it has been assumed that the information is correct. No responsibility can be accepted by Coopers for inaccuracies within the data supplied by others. We would advise that our client makes their own detailed enquiries to the Local Authorities to determine any additional planning constraints which may be applied to this site and which have not been identified within this report.
- 1.5 The results of the exploratory holes are based upon the facts established from observations and field tests. It should be recognised that strata may vary considerably from point to point and the groundwater regime may be influenced by seasonal or other factors. While every attempt is made to assess the likelihood and extent of such variations, conditions may nevertheless exist which are undisclosed by this investigation.
- 1.6 This report has been prepared in accordance with the Building Regulations “Site preparation and resistance to contaminants and moisture: Approved Document C”, 2013 and complies with the requirements associated with the planning guidance. This report should address the conditions placed within the planning conditions regarding the ground conditions and contamination. This report has been prepared in accordance with the requirements of the NHBC Standards, Chapter 4.1. The scope of this report complies with the criteria for certification under the Initial Assessment including the Desk Study (D1), the Walkover Survey (D2), and the Basic Investigation (D4). This report constitutes a Tier 1: Preliminary Risk Assessment and Tier 2: Generic Quantitative Risk Assessment in accordance the Environment Agency online guidance Land Contamination: Risk Management (LCRM). The report is also prepared in accordance with BS10175: 2011+A2:2017, and complies with Phase 1 (Preliminary Investigation), and Phase 2 (Exploratory Investigation) investigation.
- 1.7 The further actions deemed necessary to be completed prior to development of the proposed site for residential development have been listed in Section 23.0 of this report. The full extent of further actions may not be limited to those issues stated and, during the course of the development, additional further actions may be required.

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- 1.8 **The report should be read in its entirety, including all associated drawings and appendices. Coopers cannot be held responsible for any misinterpretations arising from the use of extracts that are taken out of context.**
- 1.9 Arboricultural survey and advice on arboricultural issues are considered to be outside the scope of this report except for their effect on the foundations to the proposed buildings. Where identification of any species is made, especially invasive plants such as Japanese knotweed, Himalayan balsam or giant hogweed, this should only be considered as a preliminary assessment and subject to confirmation by a professional ecologist. Coopers takes no responsibility for failing to identify, or the incorrect identification of, any tree or plant species on site.
- 1.10 This report is prepared and written in the context of the purposes stated above and should not be used in a different context. Furthermore, new information, improved practices and legislation may necessitate an alteration to this report in whole or in part after its submission. Therefore, with any change in circumstances or after the expiry of one year from the date of this report, the report should be referred to Coopers for reappraisal.

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2.0 Executive Summary

Grid Reference	SJ 335 557 (Refer to Drawing No. 7962/L1)
Approximate Area	1.17 acre (0.474 ha)
Site Investigation Data (Appendices 7 to 10)	The excavation of a 5 No. machine dug trial pits, 3 No. infiltration test pits, 1 hand dug trial pit and hand held dynamic cone penetrometer test location on 23 rd November 2022 by Coopers.
Basis of Assessment (Section 3.0)	The proposed development will consist of residential properties potentially including 1 No. two storey apartment block, 1No. semi detached and one mews of bungalows with associated private gardens, landscaping and car parking with a current electricity sub-station to remain in situ.
Site Location, Description and Boundaries (Section 4.0)	The site was located to the south of Eighth Avenue, Llay. The site comprised of a 2No. two storey apartment blocks with car parking, gardens and soft landscaping and an electricity sub-station.
Site History (Section 5.0)	The site was shown to be greenfield land since the earliest historical mapping, until it was developed with the apartment blocks by 1980.
Hazardous Installations (Section 6.0)	No hazardous installations or permitted sites recorded on site or within 250m of the site boundary.
Utility Locations (Sections 4.0 and 6.0)	- Overhead and underground British Telecom (BT) lines crossing the site. - High voltage power lines are present in the north of the site connected to an on site electricity sub-station. Low voltage power lines cross the centre of the site approximately north to south from the electricity sub-station, then along the southern end of the western site boundary and also follow just parallel to the outside of the eastern site boundary. - Foul sewers cross the site, draining off to the south east. - Surface water drainage flows to on site soakaway pits. - A potable water supply pipe enters the site along the western boundary. - A gas supply is present along Eighth Avenue to the west of the site boundary and to the south of the site. - Overhead service lines were surveyed on site but the service was undefined.
Protected sites etc (Section 7.0)	A Local Nature Reserve was recorded 709m to the south of the site and numerous Ancient Woodlands within the vicinity of the site, the nearest being 44m to the north east. There are no archaeologically protected sites within 250m of the site.
Geology, Hydrology & Hydrogeology (Section 8.0)	The information below is based upon the desk study information only: <u>Drift</u> – Glaciofluvial deposits of sand and gravel below the majority of the site with Glacial Till comprised of clay, sand and/or sand and gravel deposits across the north western boundary. <u>Bedrock</u> – Salop Formation comprised of mudstone, sandstone and conglomerates. <u>Geological Faults</u> – an inferred fault is present approximately 400m to the west of the site of the site, trending north west to south east. <u>Groundwater</u> - the Glaciofluvial deposits were designated as a Secondary (A) Aquifer, the Glacial Till a Secondary (Undifferentiated) Aquifer, and the bedrock as a Secondary (A) Aquifer. The site does not lie within a Groundwater Source Protection Zone. There were no permitted groundwater abstraction points within 2km of the site. <u>Hydrology</u> – Nant y Gaer was the nearest surface water course 82m to the north east of the site. <u>Flood Risk</u> – the site lies in an area with a 0.1% chance of flooding from rivers, surface water and small watercourses and the sea. The highest risk due to surface water flooding was recorded to be 0.1m to 0.3m depth as a 1 in 100 year occurrence in the far south east of the site only. The remainder of the site was reported as not being at risk due to surface water flooding. <u>Mineral Safeguarding</u> No historical mineral planning permissions are applicable to the site and the site lies outside a mineral safeguarding area. A Category 1 Aggregates Safeguarding Area for sand and gravel lies adjacent to the site with a very low likelihood that this resource would be accessed adjacent to the proposed development. <u>Oil and Gas Production</u> The UK government has placed a moratorium on hydraulic fracturing (or fracking) of shales but the geological potential exists for this to occur in the future.

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Coal Mining and Brine Extraction (Section 9.0)	The area is not affected brine extraction. However, the site is underlain by 5 No. coal seams at depths 680m and greater, in which extraction ceased by 1966. There are no recorded mine entries within 750m of the site and no opencast mining in the area. There is no known proposal for mine working at depth or opencast in the area. There are no records of subsidence due to coal mine working in the locality of the site. No special precautions are considered necessary due to the past mine extraction.
Ground Conditions (Section 11.0)	<u>Topsoil/madeground (similar to topsoil):</u> No topsoil recorded only madeground (similar to topsoil) on site, including brick, rare glass, ceramics and plastics. <u>Madeground:</u> Shallow madeground including generally brick, glass, ceramics, natural stone and plastic, with limestone gravel below tarmacadam hardstanding and in service trenches. <u>Drift strata:</u> Interbedded sand and clay strata, generally with a clayey sand band overlying clay then a gravelly sand stratum below. Sand and gravel was found locally. <u>Bedrock:</u> Not encountered. <u>In situ testing:</u> The clay strata were proven to be between firm and very stiff with undrained shear strengths of between 78kPa and 182kPa recorded, giving an approximate equivalent safe bearing capacity of between 133kPa and 312kPa. Equivalent Standard Penetration Test values in the sand and gravel stratum recorded N values of 15 and above confirming the sand and gravel to be at least medium dense. The sand strata were assumed to be at least loose to medium dense. <u>Underground structures:</u> No structures such as floor slabs recorded but services were encountered within exploratory holes. <u>Groundwater:</u> Only minor groundwater seepages were noted in two locations perched at the head of the clay strata.
Ground Gas Risk Assessment (Section 12.0)	No recorded historical or active landfill sites are present within 250m of the site. The conceptual model has demonstrated that there is a negligible risk posed to the proposed development. The site is therefore classified as Green in accordance with the NHBC Report No. 10627-R01(04)/CS1 in accordance with BS8485:2015+A1:2019.
Radon (Section 12.0)	Basic precautions are required for radon in the new buildings on this site.
Contamination (Section 13.0)	No contamination encountered in any of the strata. No mobile contamination identified on site to date. Standard polyethylene piping may be used.
Sub-Soil Classification (Section 14.0)	<u>Soil Properties</u> Natural sand – assumed to be frost susceptibility. Clay – medium shrinkage. <u>Concrete Classification (Based on BRE Special Digest 1 (2005))</u> The worst case sulphate conditions for the site would be: natural clay - DS-1, AC-1s, DC-1; natural sand - DS-1, AC-1, DC-1.
Trees (Section 15.0)	Mature and semi mature trees line the site boundary and have been present on site until recent felling.
Ground Floor Slabs (Section 16.0)	Precast (block and beam) suspended floor slabs are likely to be used on site.
Anticipated Foundations (Section 17.0)	The foundation types are subject to finalised planning layout, ground conditions and external works levels and investigation following demolition. Foundations have been proposed based on the current ground levels. Foundations are likely to be on mixed bearing strata of firm, firm to stiff and stiff clay, loose to medium dense sand and medium dense sand and gravel. Maximum safe bearing capacity 100kPa recommended. Bearing strata at less than 1.2m depth across part of the building footprints but extending deeper in areas of tree influence in the clay up to 2.5m below current ground level, with heave precautions required in some sections. Therefore, mass concrete trenchfill foundations with localised heave precautions are recommended.
Dewatering, Trench Side Stability (Sections 18 and 19.0)	Significant dewatering would not be required in deep excavations and service/drainage trenches. However, seasonal factors may affect changes in groundwater levels at the site, resulting in the requirement for dewatering for shallow foundations or drainage trenches. Generally, clays, sands and sand and gravel encountered across the site will remain stable in the short term but may become unstable after being left open over longer periods of time.

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Potential Infiltration (Section 20.0)	The three infiltration test locations each failed on the first test, showing the shallow ground conditions would be unsuitable for permeable paving in the proposed car parking area. Infiltration rates at depth in the east of the site were very slow, currently indicating that a deep crate infiltration system would not be practicable.
Road and Parking Sub-Grade (Section 21.0)	The clay materials can achieve in situ CBRs between 3% and 5%. The sands beyond the clay should be able to achieve an estimated in situ CBR of up to 5%. The loose to medium dense sand can be engineered to achieve an estimated in situ CBR of up to 5% and the medium dense sand and gravel to achieve between 5% and 10%.
Build phase remediation and validation (Section 22.0)	Remediation – - No known remediation required across the site with regards to contamination. - Madeground (similar to topsoil) and madeground are chemically suitable for use but due to glass fragments and other anthropogenic inclusions cannot be used in the growing medium. - It is recommended that the madeground (similar to topsoil) is removed from site. The madeground may be re-used below hardstanding and building footprints. - Additional soil sampling required in the vicinity of electricity sub-station once the services have been disconnected and the tarmacadam forming the car park has been removed to assess for potential presence of PCBs. If present, soils containing PCBs will require delineation and segregation and assessment for their potential re-use. Should PCBs be encountered in the soils, these soils will require delineation and segregation should they require excavation, to prevent the re-use of these soils within the growing medium and assess the potential for their re-use on site if required. - A low density polyethylene (LDPE) membrane 400µm (1600 gauge) recommended for installation in conjunction with the pre-cast suspended concrete floor slab as protection against radon ingress. Validation – - An addendum letter report with regards to the PCB sampling and risk assessment would need to be provided by a qualified geo-environmental consultant for submission to Wrexham CBC, in support of the planning application and the NHBC. - If topsoil and/or sub-soil are imported to site, sampling for chemical testing required. - Validation of removal of madeground and madeground (similar to topsoil) from growing medium. - Validation report to be provided to the regulators with regards to data collated relating to the imported soils. - Validation of radon protection measures recommended together with validation reporting.
Further Actions (Section 23.0)	- Submit this site investigation report to Wrexham CBC in support of the planning application and approval from the CLO and to the NHBC for approval. - Due to the presence of services within and adjacent to the site, consultations should be held with service providers regarding plans to adopt, divert, or abandon the services. - Soil sampling, risk assessment and reporting with regards to potential PCBs in the vicinity of the electricity sub-station following the disconnection of the services and lifting of the car park surface. Report to be submitted to Wrexham CBC in support of the planning application. - Additional investigation of ground conditions following demolition of the current buildings and in the vicinity of the proposed mews bungalows to aid foundation design. - In situ CBR tests undertaken within road corridors and parking areas. - Refinement of plot specific foundations, following production of finalised external works drawings and drainage plans. - Delineation/segregation of madeground (similar to topsoil) and madeground, with removal of madeground (similar to topsoil) from site. - Removal of waste stockpile from site to a permitted waste management site. - Validation of the radon protection installation is recommended with the production of a validation report, for submission to the regulators for approval (if the latter is required). - The direct transfer of topsoil/subsoil to the site would require the application of either a U1 exemption or an MMP, depending on the volumes to be imported. - Validation of imported topsoil and subsoils if required, with validation report prepared for submission to Wrexham CBC in support of the planning application. - If surplus strata require offsite removal they are likely to require testing to confirm suitability for the intended end use at the receiving site. Where strata are intended for landfill they may require testing for Waste Acceptance Criteria (WAC).

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3.0 Basis of Assessments

3.1 Development proposals

The proposed development will consist of 25 No. residential properties potentially including semi-detached and mews bungalows and one two storey apartment block, with associated car parking, private gardens and public open space. The proposed planning layout is presented in Munro Associates Preliminary Site Layout (Option B) Drawing No. 20.211 P-105 RevB, presented in Appendix 16.

It is assumed that all materials and workmanship will comply with the Building Regulations and the NHBC Standards.

3.2 Previous site investigation

Coopers are unaware of any previous site investigation being undertaken at the site.

4.0 Site Location, Description and Boundaries

4.1 General

The 1.17 acre (0.474 ha) site was located to the east of Eighth Avenue, Llay, approximately 5.5km to the north of Wrexham town centre, at National Grid Reference SJ 335 557. The location of the site is shown on Drawing No. 7926/L1 in Appendix 16.

The site was irregular in shape. The site was recorded to lie at approximately 80m above Ordnance Datum (aOD) at the northern corner of the site and 75.5m aOD at the southern corner of the site.

4.2 Site description

At the time of the investigation, the site was occupied by 2 No. two storey apartment blocks interlinked with a walkway, one building present in the north west of the site the other in the centre. The buildings were surrounded by lawned areas, 2 No. private gardens, parking bays, access paths and an access road. A single garage was present in the far east of the site and 4 No. outbuildings were present in the southern half of the site. Photographs 1 to show the general site status. The layout of the site can be seen in Drawing No. 7962/AP, presented in Appendix 16.

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Photograph 1: View to the north showing site access road and east end of current apartment block



Photograph 2: View to the south west along the front of the apartment blocks, with slope up to Eighth Avenue and telegraph pole/overhead BT lines in west corner of site



Photograph 3: View to the north west



Photograph 4: View to the south east across the current car park

The site was surrounded by board fencing along the western boundary, which followed part of the access road. The private gardens were fenced off with mesh and board fences. Rail fencing followed the access paths and access road. A waste heap, covering an area approximately 1m x 1m, including soil, wire mesh, wooden planks and concrete was located to the west of the site (see Photograph 5).

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Photograph 5: Waste heap in west of site

The site sloped down from the north at approximately 80m above Ordnance Datum (aOD) to 77m aOD in the south. It also sloped down from approximately 78.5m aOD in the far west of the site to 76.5m aOD in the east of the site. The main decrease in site levels was noted to be in the northern half of the site, with a bank falling by approximately 1m over approximately 3m distance to the west and north of the building in the west of the site.

The majority of the trees originally present across the site, had recently been felled. Mature trees and a hedge were present along the northern half of the eastern site boundary.

An electrical sub-station was located immediately next to the garage (see Photograph 6) and backing onto the central part of eastern boundary. A coarse limestone gravel, clear of vegetation, was present around the sub-station with turf beyond the gravel surround to the northern side. No evidence of possible contamination was observed around the outside of the sub-station.



Photograph 6: View to the north west



Photograph 7: View to the south east across the current car park

A BT telegraph pole was located on the western site boundary with overhead wires extended across the western part of the site to the buildings (see Photograph 2). A street light was present in the far west corner and far north corner of the site and a further light was located adjacent to the car park. Manholes for soakaways were observed in the east of the site.

As shown in Drawing No. 7962/AP, presented in Appendix 16, the site was bounded by Eighth Avenue to the north west and a public footpath to the south west, with residential properties beyond to the north, west and south of the site. A field was located adjacent to the north east of the site. An above ground domestic kerosene fuel tank was noted adjacent to the far south east corner of the site boundary, as shown in Photograph 7.

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5.0 Site History

Information regarding the history of the site and its immediate adjacent area (<250m radius) is shown on the available historical OS mapping at scales of 1:10,560, 1:10,000, 1:1,250 and 1:2,500 supplied by Groundsure Insights, presented in Appendix 1. All relevant former features indicated on the maps on site have been reproduced on the Site Plan, Drawing No. 7962/01 contained in Appendix 16.

On Site: The first available historical OS map of 1872 indicated the site to have been agricultural land, subdivided by field boundaries. The early maps show the site was originally formed by parts of 8 No. fields, segregated with tree lined hedges/fencing. The current buildings were constructed by circa 1980 together with the electricity sub-station adjacent to the north eastern site boundary.

Adjacent: The historical maps record the surrounding land use from 1872 as agricultural land with:

- 1 No. pond 50m to the south west, 1 No. approximately 200m to the north east and 1 No. 200m to the north west;
- scattered residential buildings, one being immediately adjacent to the south eastern site boundary;
- a minor road approximately 100m to the east of the site;
- 3 No. wells, the nearest being approximately 100m to the east of the site; and
- a water course flowing north west to south east, approximately 100m to the north east of the site boundary, with a woodland following the course.

By, 1899 1 No. small gravel pit approximately 10m in diameter, was present approximately 170m to the north east, which was no longer present by 1960.

By 1938, a housing estate with public open spaces had been developed in the vicinity of the site, including Eighth Avenue, adjacent to the western site boundary, the 2 No. ponds to the north west and south have been developed upon. A depression was recorded in a public open space approximately 210m to the south west of the site from circa 1960 until 1973. By 1970 a depot was noted to be present approximately 100m to the south of the site.

The pond and area of the former gravel pit to the north east of the site were constructed upon by a residential development built by 1980.

6.0 Hazardous Installations and Development Constraints

6.1 The Groundsure Enviro+Geo Insight report, dated 11th November 2022 (presented in Appendix 2) indicates that none of the following were present within 250m of the site, at the time of issue.

- Records of active or historic Part A(1) permits and Integrated Pollution Prevention and Control processes.
- Records of active or historic Part A(2) and Part B activities.
- Records of enforcement or prohibition notices.
- Records of Environment Agency Recorded Pollution Incidents for Lists 1 and 2 substances.
- Records of storage and release of Radioactive Substances.
- Records of sites determined as Contaminated Land under Part 2A EPA 1990.
- Records of Environment Agency underground high pressure oil and gas pipelines.
- No fuel stations.

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- Records of operational and non-operational permitted landfill sites, waste treatment and disposal sites and non-operational waste transfer stations.

2 No. pollution incidents were reported to have occurred within the last 10 years, one 14m to the north east and one 189m to the east of the site in 2013 and 2014 respectively. Both incidents related to the impact caused by sewage effluent with a minor impact recorded to land and no impact to air.

6.2 The Groundsure Enviro+Geo Insight report did not record any of the following hazardous sites within 500m of the proposed development:

- Records of current COMAH and NIHHS sites.
- Records of planning hazardous substance consents and enforcements.
- Notification of installations handling hazardous substances.

6.3 The consultation response from Wrexham County Borough Council (CBC), presented in Appendix 3, confirmed that they hold no record of closed, operational or proposed landfill sites within 250m of the proposed development.

6.4 The Wrexham CBC response identified that, according to their records, the only potentially contaminative use on site may be due to the presence of the electricity sub-station on site. This resulted in the planning condition being recommended for a contamination assessment to be undertaken with regards to the Planning Application Reference P/2022/0914).

6.5 The site is referenced on generic risk maps of being at low risk of unexploded ordnance, with no recorded military, target or UXO finds recorded in the local area.

6.6 Service plans were provided by the client, which recorded the following, as depicted on Drawing No. 7962/01, presented in Appendix 16:

- Overhead and underground British Telecom (BT) lines crossing the site.
- High voltage power lines are present in the north of the site connected to an on site electricity sub-station. Low voltage power lines cross the centre of the site approximately north to south from the electricity sub-station, then along the southern end of the western site boundary and also follow just parallel to the outside of the eastern site boundary.
- Foul sewers cross the site, draining off to the south east.
- Surface water drainage flows to on site soakaway pits.
- A potable water supply pipe enters the site along the western boundary.
- A gas supply is present along Eighth Avenue to the west of the site boundary and to the south of the site.
- Overhead service lines were surveyed on site but the service was undefined.

7.0 Animal Burial Sites and other Environmental, Archaeological, Ecological and Conservation Issues

7.1 The Animal and Plant Health Agency does not provide information concerning records relating to animal burial sites. However, the agency recommends that it should be contacted immediately if animal burials are encountered during development works.

7.2 According to the Groundsure Enviro+Geo Insight report (presented in Appendix 2) there were no Sites of Special Scientific Interest (SSSI), Special Protection Areas, Special Areas of Conservation, Ramsar Sites, National Nature Reserves, Environmentally Sensitive Areas, Areas of Outstanding Beauty or National Parks within 1km of the site.

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- 7.3 The Groundsure Enviro+Geo Insight report referenced a Local Nature Reserve, located 709m to the south of the site and numerous Ancient Woodlands within the vicinity of the site, the nearest being 44m to the north east.
- 7.4 The Groundsure Enviro+Geo Insight report did not report any archaeological protected sites within 250m of the site.
- 7.5 A tree survey had been undertaken by Tree Solutions, dated 17th September 2021, as presented in Appendix 4. This provides details relating to the presence of the hedges and trees/former trees present on site.
- 7.6 No ecological surveys concerning invasive species or protected species were provided to Coopers. If these have not been undertaken, it is recommended that specialists are consulted.

8.0 Geology, Hydrology & Hydrogeology

8.1 Drift

The geological maps referenced in the Groundsure Enviro+Geo Insight report (presented in Appendix 2) and the Geology of Britain Viewer presented on the BGS website () record drift comprising Glaciofluvial deposits (sand and gravel) below the majority of the site with Glacial Till (clay potentially interbedded with sands/sands and gravels) immediately adjacent to the north western site boundary and overlapping this boundary. The Glacial Till was shown to extend off site to the south west and north east, as well as to the west.

The nearest BGS borehole log SJ35NW6 (see Appendix 5) for a location approximately 400m to the west of the site, indicates drift deposits comprising gravel to 37.49m below ground level (bgl).

8.2 Bedrock

The geological maps referred to in Section 8.1 show the drift deposits are underlain across the site by the Salop Formation comprised of mudstone, sandstone and conglomerates at depths considered likely to be greater than at least 20m bgl, according to the nearest BGS borehole log.

8.3 Geological Faults

The BGS mapping indicates an inferred fault is present approximately 400m to the west of the site of the site, trending north west to south east.

8.4 Groundwater Vulnerability, Hydrogeology and Hydrology

According to the Groundsure Enviro+Geo Insight report (presented in Appendix 2) and Magic Map (<https://magic.defra.gov.uk/MagicMap.aspx>), the Glaciofluvial deposits underlying the site were designated as a Secondary (A) Aquifer and the Glacial Till overlapping the site boundary was designated as a Secondary (Undifferentiated) Aquifer. The bedrock was designated as a Secondary (A) Aquifer.

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The site was recorded as not lying within a Groundwater Source Protection Zone. According to the Groundsure Enviro+Geo Insight report, there were no current groundwater abstractions within 2km of the site. The nearest historical groundwater abstraction permit was recorded for general farming and domestic purposes at 1.88km to the north east of the site. Wrexham CBC advised that they hold no record of any private water supplies within 2km of the site (see Appendix 3).

The nearest surface water course recorded on the OS mapping, is Nant y Gaer, 82m to the north east of the site. This flows north west to north east and is a tributary of the River Alyn, approximately 800m to the south east of the site. The River Alyn is a surface water body considered under the Water Framework Directive. The last status of this water body was recorded by the Groundsure Enviro+Geo Insight report to have a good chemical rating, a moderate ecological rating and an overall moderate rating in 2016.

No current surface water abstraction permits were noted within 1km of the site.

The general topography of the site was recorded to slope slightly down gradient from north to south and from west to east. This trend is generally towards the surface water courses the Nant y Gaer to the east and the River Alyn to the south east. It was considered that, should there be any shallow groundwater flow within the drift deposits, that this would follow this trend towards the water courses, particularly the Nant y Gaer.

8.5 Flood Risk

According to the Natural Resources Wales website (<https://naturalresources.wales/flooding/managing-flood-risk/understanding-your-flood-risk-results?>), there was a 0.1% chance of flooding from rivers, surface water and small watercourses and the sea at the site. The Groundsure Enviro+Geo Insight report recorded the highest risk due to surface water flooding of 0.1m to 0.3m depth to be a 1 in 100 year occurrence in the far south east of the site only. The remainder of the site was reported as not being at risk due to surface water flooding.

Site specific assessments of flood risks are not part of the remit of this report. Reference should be to relevant specialist assessments of flood risk and drainage for further details on limitations and requirements to mitigate against risks of flooding for the proposed end use.

8.6 Subsidence Hazards

According to the Groundsure Enviro+Geo Insight report, the site was assessed to have a negligible to very low risk hazard of being affected by natural ground subsidence, shrink swell clay, landslides, collapsible deposits, running sand, dissolution of soluble rocks and compressible ground stability.

8.7 Mineral Safeguarding

Where mineral resources are present the mineral planning authority may designate areas as Mineral Safeguarding Areas (MSA) and Mineral Consultation Areas (MCA). These are aimed to safeguard areas from unnecessary sterilisation by non-mineral development.

The Groundsure Enviro-Geo Insight report stated that there are no historical mineral planning permissions applicable to the site. The site was indicated by the BGS and Welsh Government “North East Wales: Aggregates Safeguarding Map for Wales” as lying outside a mineral safeguarding area but with a Category 1 Aggregates Safeguarding Area for sand and gravel adjacent to the north east.

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Given the location of this area was indicated as following the Nant y Gaer surface water course with a designated Ancient Semi-Natural Woodland along its banks, there is a very low likelihood that this resource would be accessed adjacent to the proposed development.

8.8 Oil and Gas Production

The UK government has placed a moratorium on unconventional extraction of onshore natural gas via hydraulic fracturing (or fracking) of shales (primarily Bowland Shale Formation – within Carboniferous bedrock). As with many parts of north east Wales the geological conditions exist which are locally favourable for small scale onshore gas production via fracking. Subject to political and socio-economic considerations there is potential that the fracking of shale gases may occur locally in the future, which would be subject to regulatory and planning obligations.

9.0 Coal Mining, Brine Extraction and Other Mine Extraction

- 9.1 The Coal Authority Interactive Map Viewer reports that the site lies within a Coal Mine Reporting Area. A CON29M Coal Mining report was obtained for the site (see Appendix 6), which indicates that the site is underlain by past underground mining within 5 No. coal seams at depths between 680m and 910m bgl. These were last worked in 1966. The site does not lie within an area of current underground coal mining.

There are no recorded mine entries within 20m of the site, or within the site boundary, according to the Coal Authority report and there were none recorded on the Coal Authority Interactive Map Viewer within 750m of the site.

While the site overlies future potential reserves of coal, the Coal Authority is not aware of any proposed coal mining in the area, due to applications received or licences granted.

No known opencast mining has occurred within the site boundary and the site does not lie within 200m of an opencast coal mine. There are no proposals to undertake opencast coal mining within 800m of the site boundary.

The Coal Authority is not aware of any subsidence due to coal mining on site or in the area, which may have posed structural damage to properties. The Authority has no record of mine gas emissions posing a risk to properties in the area.

- 9.2 It is considered that the effects of coal mining within the area will not have an adverse impact on the proposed development as the coal measures are located at depth greater than 680m bgl with no shallow coal measures present, and mining activities ceased in 1966. The Coal Authority consider that over the time period since then, subsidence will have ceased. The most likely method used to extract the coal at such depths would have been long wall mining. This method involved the advancement of the face supports once coal had been extracted, leaving the rock unsupported leading to collapse where coal had been removed. Subsidence tended to correlate with the advancement of the working face, with influence at the surface occurring after a time lag. Studies have shown that subsidence activities generally may occur between 2 years and 7 years with a few instances taking up to 11 years. Therefore, no special precautions are required for the proposed development in respect of coal extraction.
- 9.3 The Groundsure Enviro+Geo Insight report (see Appendix 2) stated that the site does not lie within an area affected by any other form of mine extraction, including brine extraction activities. No special precautions are required for the proposed development in respect of such mining activities.

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10.0 Ground Investigation Methodology

- 10.1 Coopers were commissioned by Castlemead Group Limited to undertake a site investigation, in order to determine potential geotechnical and geo-environmental risks and constraints associated with the proposed residential development and to assess the infiltration potential of the ground to assist with the proposed drainage design.
- 10.2 The ground investigation was undertaken while residents still occupied the buildings to be replaced by the new development. Exploratory hole locations were limited by the presence of the current buildings, fencing, live services across the whole site and the need to maintain safe access for the residents. A survey of on site services was provided to Coopers, the locations of which can be seen on Drawing No. 7962/01 presented in Appendix 16.
- 10.3 The ground investigation was completed on 23rd November 2022. Coopers supervised the excavation of 5 No. machine dug trial pits (TP101 to TP05) and 3 No. machine dug infiltration test pits using a JCB 3CX machine and undertook 1 No. hand dug trial pit (HDTP01). The locations of the exploratory holes are also depicted on Drawing No. 7962/01.

The trial pits were excavated to between depths of 2.6m and 2.8m bgl, with the exception of TP05, which was terminated at 1.3m bgl, due to the potential presence of underlying services identified during the excavation.

The hand dug trial pit was excavated at a location where services were present in the near vicinity and the ground levels prevented safe access to the excavator.

Infiltration test pits ITP01 and ITP03 were excavated to shallow potentially permeable strata to assess the potential for the installation of permeable paving below the proposed car park, these being excavated to 1.8m bgl and 1.0m bgl respectively. ITP02 was taken to 2.5m, to assess the potential for a deep infiltration system.

- 10.4 The exploratory hole locations were positioned in part to gain a spread which would enable assessment of the general ground conditions across the site. The proposed location of infiltration test pit ITP02 was to be nearer to the electricity sub-station but due to the detection of site services at the proposed location, ITP02 needed to be moved further south to the location presented on Drawing No. 7962/01. Due to the electricity sub-station being live, with services feeding and exiting the substation on the three accessible sides, it was not feasible to undertake any excavation immediately adjacent to the substation.
- 10.5 In situ testing was undertaken to enable assessment of the bearing capacities of the strata encountered. Hand shear vane tests were completed on cohesive strata within the trial pits, where feasible. One hand held dynamic cone penetrometer test location was completed adjacent to trial pit TP02, in order to establish the equivalent standard penetration test (SPT) N values of the sand and gravel.
- 10.6 The presence of all the exploratory holes permitted Coopers to select soil samples for chemical analysis in order to characterise the made ground and natural ground conditions. The samples were submitted to Derwentside Environmental Testing Services Limited (DETS), an MCERTS accredited laboratory, for chemical analysis. All samples analysed were stored in appropriate containers supplied by the laboratory. Where samples were not collected immediately by the laboratory, these were refrigerated to ensure they were kept at a temperature below 8°C.

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The chemical analysis appropriate to the environmental risk assessment was scheduled as discussed in Section 13.7. Samples were also scheduled for analysis applicable to the assessment of sulphate attack on concrete, as discussed in Section 14.

- 10.7 Cohesive soil samples were also taken for submission to Murray Rix for geotechnical testing, this including moisture content and plasticity index.

11.0 Ground Conditions

11.1 General

The data collated from the exploratory holes undertaken by Coopers was used to define the ground conditions across the site. The locations of the exploratory holes are illustrated on Drawing No. 7962/01, in Appendix 16. Exploratory hole logs are presented in Appendices 7 to 10.

11.2 Topsoil/madeground (similar to topsoil)

No topsoil was identified in the exploratory holes. Madeground (similar to topsoil) was present in each exploratory hole, these having been excavated within areas of soft landscaping, with the exception of infiltration test pit ITP02, excavated within the current car park. The madeground (similar to topsoil) had the same characteristics across the site, this being a slightly gravelly, sandy silt. The gravel comprised various lithologies and anthropogenic inclusions, predominantly brick but also rare glass, ceramics and plastic. This stratum varied between 0.2m and 0.5m thick.

11.3 Madeground

Madeground was encountered in trial pits TP01, TP02, TP05 and infiltration test pits ITP01 to ITP03. This ranged between 0.01m and 1.1m thickness, the base of the madeground ranging between 0.3m and 0.7m bgl except in TP05 where the depth of madeground was recorded to 1.3m bgl but the overall depth could not be proven. It is considered that this was likely to be within a service trench.

Madeground in ITP02, located in the car park, comprised 0.1m thick tarmacadam over a 0.2m thick gravel base of limestone. This was found to overlie a relic topsoil.

Madeground gravel, 0.1m thick, was also encountered in TP01, the gravel being comprised of limestone and mudstone, possibly associated with an adjacent service trench fill.

Madeground in the remaining exploratory holes was recorded to be generally a slightly silty, slightly clayey, gravelly sand, the gravel being comprised of brick, glass, natural stone and plastic fragments. A low cobble content of brick was also reported in some locations.

11.4 Natural strata

Drift strata

The ground investigation identified that generally there were interbedded sand and clay strata across the site. The bedding tended to follow a similar pattern across the centre of the site from east to west.

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A slightly silty gravelly sand with variable proportions of clay, usually clayey to very clayey, tended to be present immediately below the made ground (similar to topsoil) and made ground strata. This sand stratum was present to depths ranging between 0.9m and 1.3m bgl and was between 0.5m to 0.9m thick. Below this was a slightly sandy, slightly gravelly, silty clay. The base of this stratum ranged between 1.3m and greater than 2.6m bgl (depth not proven in TP03) and was between 0.4m and at least 1.3m thick. A second sand stratum was present below the clay, this being slightly silty and gravelly to very gravelly. The lower sand stratum was not encountered in trial pit TP03, but it is considered that it may be present below the clay stratum. The lower sand stratum was present to at least 1.8m and 2.8m bgl at the base of the trial pits and the thickness was up to at least 1.1m.

In trial pit TP02, a clay stratum was encountered immediately below the made ground, this having a high sand content. This overlay a slightly clayey sand and gravel below with a second slightly silty, sandy clay stratum below. The clay stratum was present to 1.3m bgl and 0.6m thick. The sand and gravel stratum was recorded to 2.7m bgl and was 1.4m thick.

A very clayey sand stratum was recorded below the made ground (similar to topsoil) in trial pit TP04 to 1.8m bgl (1.3m thick). However, this lay immediately over the second slightly silty sand stratum, with no clay encountered within the trial pit, the second sand stratum noted to the base of the trial pit at 2.8m bgl, being at least 1m thick.

Bedrock

No bedrock was encountered within the exploratory hole locations.

11.5 In-situ test results

The field observations of the clay identified this to be usually firm, becoming firm to stiff with depth in places. However, the clay in trial pit TP03 was described as being very stiff and appeared to be desiccated in comparison with the clay elsewhere on site. Hand shear vane tests undertaken within the upper clay sample arisings from the trial pits indicated that the clays were generally firm to stiff, with undrained shear strengths being between 78kPa and 98kPa. These when converted would provide an approximate equivalent safe bearing capacity of between 133kPa and 168kPa. An undrained shear strength of 120kPa was recorded confirming the field description of the clay being stiff, where the sample was taken in TP01, converted to an approximate equivalent safe bearing capacity of 205kPa. The very stiff clay in TP03 was confirmed by undrained shear strengths of 150kPa and 182kPa being recorded. This clay would provide an approximate equivalent safe bearing capacity of between 257kPa and 312kPa.

It was considered, based on field observations, that the sands across the site are generally loose to medium dense. The hand held DCP test, DCP01, recorded equivalent standard penetration test (SPT) N values in the sand and gravel stratum of at least 15 and greater (see results in Appendix 10). This confirmed the sand and gravel stratum at this location was at least medium dense, providing an equivalent safe bearing capacity of at least 100kPa.

11.6 Subterranean structures

No structures such as floor slabs were encountered during the site investigation.

A shallow service cable was encountered in the east face of the trial pit TP01, potentially a BT cable, offset from the mapped location.

An obstruction was encountered in trial pit TP05 at 1.3m, which may have been associated with an electricity cable.

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11.7 Groundwater

No significant groundwater was encountered during the ground investigation. Minor seepages were noted in only two locations, at the head of the clay stratum, in TP01 (at 0.9m bgl) and ITP02 (at 1.0m bgl).

11.8 Visual and olfactory observations

No visual or olfactory evidence of mobile/volatile contamination was recorded in any of the exploratory holes. No evidence spillages was seen around the electricity sub-station.

12.0 Landfill Sites and Ground Gases

12.1 General

Coopers have appraised the potential risk of ground gases to provide a conceptual model in terms of source-pathway-receptor in accordance with:

- BS8576:2013 “Guidance in investigations for ground gas. Permanent gases and volatile organic compounds”.
- BS 8485:2015+A1:2019 “Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings”.
- CIEH - “The local authority guide to ground gas”. S Wilson, G Card and S. Haines. September 2008.
- CL:AIRE - RB17 “A pragmatic approach to ground gas risk assessment”. November 2012.
- “Technical paper: Risk and reliability in gas protection design – 20 years on: Part 1”. G. Card, J Lucas and S Wilson. August 2019.
- NHBC (2007) “Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present. 10627-R01(04)”.
- NHBC (2016) Technical Extra 20. “Ground gas update – site assessment, characterisation and design of gas protection measures”

It should be noted that the characteristic design models within the NHBC reports assume standard residential houses have a pre-cast suspended slab, this being the required floor slab type in zones of tree influence with heave (discussed in Section 15). It is also likely to be commercially preferential to use suspended pre-cast (block and beam) floor slabs where ground gas protection measures are required. For other types of buildings or slab construction reference should be made to the design and assessment criteria within alternative guidance documents referenced above.

All information and advice regarding requirements for gas precaution measures are considered to be provisional until approval from statutory bodies has been granted.

The gas generation potential of the ground conditions on site has been appraised in accordance with the CL:AIRE Research Bulletin RB17 and BS8576:2013, which outline an approach for pragmatic assessments of hazardous ground gas on low risk sites without in situ monitoring. The approach for this site has been used based upon the conceptual site model discussed below, which demonstrates the potential sources of ground gases, the pathways available to the proposed development and the receptors.

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12.2 Potential Sources

Landfills (on and off site)

The Groundsure Enviro+Geo Insight report, presented in Appendix 2 and the Wrexham CBC consultation response, presented in Appendix 3, did not identify any registered operational or non-operational landfill sites located within 250m of the site boundary or on site.

Coal Mining

A preliminary risk assessment has made reference to the CL:AIRE “Good Practice for Risk Assessment for Coal Mine Gas Emissions”, October 2021, as the site lies within an area of coal mining activities.

The site was recorded by the Coal Authority as being underlain by deep coal measures between 680m and 910m bgl, which have been worked up until 1966. Based on the age and depth of the coal seams, these are likely to have become flooded which will significantly reduce the potential for ground gas to be generated, such that there is a negligible to very low likelihood of ground gas generation potential.

The Coal Authority did not refer to any shallow mine workings within the vicinity of the site.

The Coal Authority report stated that there is no record of mine gas emissions requiring action by the Coal Authority within the boundary of the site.

Deep madeground (on site)

Only shallow madeground was identified on site, which did not contain any organic matter. Therefore, for this reason and the fact that no deep madeground was encountered on site, which may be considered as a potential source for ground gas generation, the madeground present would not be considered as a significant source of ground gas on site.

Organic Rich Strata (on site)

No organic strata were encountered on site and the likelihood of this being present is considered to be negligible based on the BGS recorded drift geology for the site and there being no former ponds recorded on the historical mapping, in which organic rich strata may typically be found.

Other off site features

Three ponds were recorded as being present within the vicinity of the site, the nearest having been 50m to the south west, then one 200m to the north east and one 200m to the north west. A small gravel pit approximately 10m in diameter, was present approximately 170m to the north east, which was no longer present by 1960. The ponds to the south west and north west are likely to have been infilled by 1938 and the pond to the north east and the gravel pit were infilled by 1980, when housing was developed over these voids.

It is considered that the materials used to fill the ponds and gravel pit would have been suitable for construction purposes and therefore would likely have included limited proportions of organic matter. The voids did not cover a significant area, therefore the volume of fill and depth was limited. If organic matter was present within the fill materials this would likely have degraded over the time since they were placed within the voids, such that the ground gas generation potential would now be very low and any ground gas generated would comprise only carbon dioxide. Consequently, the flow rate potential of the ground gas if generated would be very low.

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A depression was recorded in a public open space (POS) approximately 210m to the south west of the site from circa 1960 until 1973. This appears to still be a public open space with a sports pitch on recent Google Earth photographs, the ground being level, indicating the void was filled. It is unknown if any organic inclusions were within the fill, but given the age of the fill, as discussed above, organic matter present would likely have significantly degraded by now. Remaining organic matter would have a low potential to generate significant concentrations of ground gas. Any ground gas generated would likely comprise slightly elevated carbon dioxide concentrations with a very low flow rate potential, but negligible methane concentrations.

Radon

The Groundsure Enviro+Geo Insight report provides an assessment of the percentage likelihood of residential properties within a 75m grid which are affected by radon levels above the action level. The data having been sourced from the BGS and Public Health England. This stated that the proposed development lies within an area where between 5% and 10% of residential properties are affected by radon concentrations above the action level. As such, basic radon protection measures are required for the proposed properties.

12.3 Potential Pathways

The coal measures are known from the BGS mapping to be at significant depth of at least 680m bgl. These are overlain by the Salop Formation comprised of mudstone and sandstone with conglomerates, further overlain by drift deposits likely to be greater than 20m deep, which include clay strata. It is considered that if any mine gases were generated within the coal seams, there would be a negligible likelihood that this would be able to migrate to the surface due to the significant depth. The overlying bedrock which includes mudstone, which tends to have a low permeability and drift strata including low permeability cohesive strata, would also attenuate this migration. No significant pathways are present within the proximity of the site, which may provide preferential pathways, with the nearest inferred fault line being reported approximately 400m from the site and no coal mine openings being recorded within 750m of the site. Three historical wells were recorded approximately 100m beyond the site boundary, but it is considered that these would have been sunk into the overlying sandstone within the Salop Formation, if they were sunk into the bedrock, in order to obtain a potable water supply. These wells being isolated offsite, would not form a pathway for potential mine gas between the coal seams and the site.

If carbon dioxide was generated by the fill in the POS to the south of the site, the majority of this would more likely dissipate vertically to the surface of the POS. Some lateral migration of the ground gas may take place via the intervening relatively permeable Glaciofluvial strata, identified by the BGS mapping. A proportion of this may also subsequently migrate vertically to the surface dissipating to the air where soft cover is present. Intervening service trenches, being filled with granular materials may also provide preferential pathways if the natural ground is more cohesive, diverting ground gases. Given the distance of 210m between the POS and the site, and the potential for only slightly elevated carbon dioxide concentrations to be present with very low flow rate potential, it is considered unlikely that significant concentrations of ground gases would be able to migrate to the site boundary.

The former offsite ponds would likely be located within depressions in the cohesive Glacial Till identified by the BGS mapping as being present beyond the site boundary. The relatively low permeability of these strata would limit the migration of potential very low concentrations of carbon dioxide with low flow rate potential from the former ponds. The distance would provide attenuation and in the case of the pond location to the north east, there is an intervening valley, which would reduce the potential gas migration between the pond to the north east and the site. This would also have the same effect on any ground gas which may migrate from the former gravel pit.

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It is considered unlikely that significant concentrations of carbon dioxide will reach the foundations, where they may find pathways into the properties via cracks within the floor slabs and surrounding service entrances, causing elevated concentrations within the buildings. It is unlikely that carbon dioxide concentrations may build up in confined spaces such as service trenches. However, contractors would need to undertake their own risk assessment should it be necessary to enter confined spaces.

12.4 Receptors

Future Occupants: The primary receptors are anticipated to be the future occupants of the residential plots if there was a build up due to the ingress of potential hazardous gases through the ground floor slabs of the properties. These are considered highly sensitive receptors for the purposes of the conceptual model.

Adjacent residents and workers: These can be exposed to hazardous gas if sources of gas are generated on site and migrate beyond the site boundary or preferential pathways exist for the horizontal migration of gases beyond the site boundary.

Construction/Maintenance Workers: Other receptors include construction workers, primarily through work within trenches or excavations where preferential pathways for the migration and collection of gases could occur. HSE guidance on safe working in confined space details potential dangers from gases within trenches, assessments required and precautions to take prior to entering a confined space. The appointment of a supervisor to ensure the necessary procedures and precautions are in place where construction workers intend to enter a confined space is advisable in accordance with HSE guidance.

12.5 Ground Gas Conceptual Site Model Summary

The conceptual model has demonstrated that there were no sources of ground gas on site and no significant sources within 250m of the site boundary, with only a very low potential for ground gas generation and very low flow rate potential within former ponds, a small gravel pit and a depression within the POS. Deep coal seams are present below the site but with a negligible to very low likelihood of ground gas generation potential.

The intervening ground conditions, distance and topography between the potential ground gas sources will attenuate any ground gases generated. It is therefore considered that there is a negligible risk posed by ground gases to the proposed development.

12.6 Ground gas remediation/verification requirements

The conceptual model has demonstrated that there is a negligible risk posed to the proposed development from potential ground gases arising from sources on site and beyond the site boundary. As such, the site would be classified as CS1 in accordance with BS8485:2015+A1:2019, and Green in accordance with the NHBC Report No. 10627-R01(04). No ground gas protection measures will be required within the development. However, basic radon protection measures will be required in the new build plots, in accordance with BRE Report 211, "Radon: Guidance on Protective Measures for New Dwellings", 2015.

Remediation requirements

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The design of Basic Radon protection measures follow BRE 211 (2015) “Radon: Guidance on protective measures for new buildings”. The radon protection measures are required for all occupied buildings. Should there be internal garages, radon protection is required for internal garages and adjoining garages which include an internal door to the habitation. No radon protection measures are required for detached garages.

The BRE 211 guidance references the provision of a virgin polymer, low density polyethylene (LDPE) membrane of a minimum thickness of 300µm (1200 gauge) within the floor slab construction with subfloor ventilation to satisfy basic protection measures. BRE 211 details that the radon membrane may be liable to damage during installation and construction and that where there is risk of this a thicker and/or reinforced membrane should be installed. Due to the tendency for 300µm thick membranes to be damaged during installation, some manufacturers are withdrawing this specification and now producing radon membranes with a minimum thickness of 400µm (1600 gauge), which Coopers recommend for use with a pre-cast suspended floor slab, likely to be used on site.

The membrane should be sealed (taped or welded) and provide a continuous barrier to the external wall of the building, other than service entry pipes which are to be sealed to the membrane. The position of the membrane within the floor slab construction is included within the enclosed typical details by floor slab construction.

Typical construction details with radon mitigation measures for a pre-cast slab, the client’s preferred floor slab type, are illustrated in Drawing No. 7962/LRH&HRH/BR/PC/RA/G/01 presented in Appendix 16. These provide general guidance. These drawings can be applied to apartment block but being potentially the more complex than the house plots, it is recommended that a specific design is provided to match the architectural layout once floor slab is determined.

Public Health Wales recommend, in reference to the UK Health Security Agency (formerly Public Health England), that future residents undertake radon monitoring within the first year of occupation. Should radon be identified above target levels then remedial measures such as extraction of the subfloor ventilation layer (if installed) will be required. Whilst these can be undertaken via the air bricks to the subfloor void, these can be difficult to install and some developers prefer the addition of a further access plug connecting the subfloor to the surface. While is acceptable to construct the property with a cast in situ floor slab with no sub-floor void, this factor may need to be taken into consideration when designing the floor slab construction.

BRE 211 details that there is no specific statutory requirement for inspection of radon protection measures, however if not installed correctly then there is a high risk this will be identified following occupation and require costly remedial measures. BRE 211 therefore strongly recommends inspection of the membrane installation is carried out. Once the floor slab design is known then procedures for verification of the radon membranes can be provided.

This assessment should be provided to the regulatory bodies for approval prior to commencing development.

12.7 Conclusions

The site is characterised as Green in accordance with the NHBC Report No. 10627-R01(04)/CS1 in accordance with BS8485:2015+A1:2019. However, the site is located within an area where between 5% and 10% of residential properties are affected by radon concentrations above the action level. Consequently, basic radon protection measures are required for the proposed properties.

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This assessment should be provided to Wrexham CBC for approval prior to commencing development.

13.0 Contamination

13.1 Conceptual Model

In accordance with current guidance and best practice, this risk assessment has been assessed in the form of potential sources of contamination and the pathways with which they may affect potential targets/receptors. The targets/receptors have been assessed to determine how they are likely to use the land and hence consider what actual risk is likely to be present associated with identified contamination on site. Recommendation for site investigation has been assessed in light of the land use and the form of possible contamination which may be encountered.

13.2 Potential Point Sources of Contamination

The source types listed below detail the potential contamination that could affect the receptors if present. A brief description of the potential pathways and receptors is included (where applicable) with each source type as these are intrinsically linked within the conceptual model. A more detailed assessment of the receptors and the method of pathway migration is listed in Sections 13.3 and 13.4 respectively.

Sources on site

The site had been a greenfield site since the first available mapping, until the current buildings were developed by 1980, together with an electricity sub-station in the east of the site. Shallow madeground and reworked natural ground was expected to be present on site, used in the development of the buildings and associated hardstanding, as was encountered within the exploratory holes discussed in Section 11.0. A small waste heap approximately 1m x 1m was present included what appeared to be inert materials these being soil, wooden planks, mesh and concrete, which will need to be removed from site once the development commences.

No visual or olfactory evidence of contamination was recorded within the exploratory holes.

Based on the inclusions within the madeground (similar to topsoil)/madeground, elevated concentrations of metals, semi-metal elements and compounds, speciated polycyclic aromatic hydrocarbon (PAH) (16) compounds and low frequency asbestos fibres may typically be found in association with such materials. However, as the madeground (similar to topsoil)/madeground was recorded to contain limited anthropogenic materials, contaminant concentrations would likely be low across the main body of the site.

Prior to the ban on the production of polychlorinated biphenyl compounds (PCBs) in the UK, these were typically used within electricity sub-stations. The manufacture of PCBs was banned in the UK in 1981, and the retention of PCBs within equipment has gradually been phased out since then, this now being limited to restricted volumes in certain apparatus. Where reasonably practicable PCBs must be removed from equipment completely but by 2025, this will be mandatory.

The on-site electricity sub-station would therefore have contained PCBs when it was first brought into operation, but it is not known if the system has been partially or totally drained of the PCBs to date. No evidence of spillages was noted on the gravel surrounding the electricity sub-station. Had there been leaks within the sub-station these would most likely have been contained within the structure of the building.

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With total soil concentrations in the general madeground (similar to topsoil) and madeground potentially being low, these would have a very low potential to leach in elevated concentrations. As the madeground is only in thin strata and present only in parts of the site, it is considered, that should there be any leachate generated from the madeground (similar to topsoil)/madeground, concentrations would be very low and would not provide a significant loading.

Ground Gas

The sources of hazardous ground gas and the risk posed to the development have been addressed within Section 12.0 of this report.

Adjacent land uses

No land uses were identified immediately adjacent to the site boundary which may give rise to leachable contaminants and those which may be windblown in the form of dust to pose a risk to the future receptors. One modern plastic above ground domestic kerosene fuel tank was identified adjacent to the south east corner of the site boundary. This appeared to be in good condition, with a low likelihood of leaks expected. Spillages could have occurred during the filling of the tank, but given the cut-out system on delivery tankers there is a low likelihood this could have occurred. If leaks or spillages have taken place, this would have resulted in elevated total petroleum hydrocarbon (TPH) compounds in the soils, which can mobilise through the soil.

Former ponds, 50m and more beyond the site boundary have been built upon. Therefore, it is considered that any madeground used in the development or permitted to remain would have contained limited mobile contaminants. Any leachate potentially generated from the madeground would likely be limited due to overlying housing or hardstanding reducing rain infiltration through the madeground or where open to water infiltration, the leachability potential would have been reduced over time.

Shallow fill placed within the POS 210m to the south west of the site in the 1970s, may give rise to leachable/mobile contaminants. However, given the age of the materials it is likely that the leachability potential has reduced.

13.3 Targets/Receptors

Proposed land use and future site users

The proposed development is to comprise residential properties with associated private gardens and shared landscaped areas and car parking. The future site users will include the occupants, visitors and maintenance contractors to the residential properties.

As can be seen on the Munro Associates Preliminary Site Layout (Option B) Drawing No. 20.211 P-105 RevB, presented in Appendix 16, the electricity sub-station is to remain in-situ as part of the redevelopment of the site. The access road immediately adjacent to the electricity sub-station will also remain. Car parking will still be present adjacent to the south of the substation with soft landscaping surrounding this. It is considered that residents may only walk adjacent to the electricity sub-station but would not be undertaking any activities such as gardening in this area. Contractors may undertake maintenance of the landscaping adjacent such as mowing the lawn. Given the services in this area, it would not be feasible to undertake any planting at depth.

Adjacent Landowners

Should contamination be encountered, during dry periods on site when soils are exposed, contaminated dusts may be created by the development and be carried with the prevailing wind. We would advise that during dry periods, the site is dampened down to suppress the dust.

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Following the completion of the development, wind blown dusts may migrate from the gardens and landscaped areas.

Controlled waters

The site is underlain by Glaciofluvial deposits designated as a Secondary (A) Aquifer. It is considered unlikely that this would provide a sufficient local water supply but may support a base flow for the nearby surface water course. The Glacial Till overlapping the site boundary was designated as a Secondary (Undifferentiated) Aquifer. The bedrock was designated as a Secondary (A) Aquifer, the bedrock being at greater than 20m bgl. Although the aquifer within the bedrock was defined as being a potential water supply, being a Secondary (A) Aquifer, the site was recorded as not lying within a Groundwater Source Protection Zone and no current groundwater abstractions were recorded within 2km of the site.

The nearest surface water course the Nant y Gaer, lies 82m to the north east of the site, this being a tributary of the River Alyn, approximately 800m to the south east of the site. No current surface water abstraction permits were noted within 1km of the site.

13.4 Pathways

Where ground is bare of vegetation or only lightly vegetated, if contaminated soils or asbestos fibres are present, these could become windborne during dry periods of weather, thereby potentially transporting contaminants. Site users and adjacent site users may become exposed to potential contaminants arising from the made ground.

Exposure pathways for contact to soils are dependent upon the types of contaminants. The greatest exposure for future residents to the potential contaminants on site is through dermal contact, ingestion via hand to mouth contact, or direct ingestion of soil or soil adhered to home grown vegetation. Airborne contaminants in dust may be inhaled. Soils may also be tracked back into the house permitting the inhalation of indoor dust.

PCBs have a low mobility and leachability in soils, due to adsorption to the soils. If a leak or spillage of PCBs had occurred historically, the contaminant is not expected to have migrated a significant distance from the electricity sub-station. There was no visual or olfactory evidence of contaminants within the exploratory holes in the vicinity of the electricity sub-station. If PCB contamination had mobilised a short distance, given the topography of the site trending north to south and west to east, this may be present below the current and proposed car park. PCBs have a low volatility, therefore they would not pose a risk due to vapour inhalation within the proposed residential properties. Future residents of the site are unlikely to come into contact with the PCBs, as these would be below mainly hardstanding and a limited area of newly placed landscaping. Grounds maintenance contractors would not be expected to be digging in this area due to underlying services.

Should there have been spillages or leaks of kerosene from the above ground domestic fuel tank, any fuel is likely to have migrated away from the site boundary due to the topography sloping away to the south and east.

Contractors may come into contact with contaminants elsewhere on site within the made ground (similar to topsoil) and made ground, if present, when undertaking maintenance work on the properties or in the road corridors. However, exposure is deemed as short term and controlled under health and safety applications.

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The drift strata generally comprised interbedded clay and sand strata. This drift strata may extend beyond the site boundary towards the south east but Glacial Clays would be expected towards the north west. Lateral groundwater migration would be impeded by the cohesive clay strata and upper clayey sand strata, but where it finds a pathway into the deeper gravelly sand strata, this may migrate towards the south and east following the general topography of the site and the surrounding area. If any leachates were generated, these would be attenuated by the upper clay and clayey sand strata.

The general topography beyond the site was recorded to slope slightly down gradient from north to south and from west to east, generally towards the surface water courses the Nant y Gaer to the east and the River Alyn to the south east. It was considered that, should there be any shallow groundwater flow within the drift deposits, that this would follow this trend towards the water courses, particularly the Nant y Gaer.

The ground conditions and distance would attenuate any potential leachates generated, from reaching the underlying Secondary (A) Aquifer within the bedrock at least 20m bgl and the nearest surface water course lying 82m to the north east of the site.

13.5 Summary of preliminary risk assessment for human health

The preliminary conceptual site model has shown that the site has been greenfield land, which subsequently was developed with the residential properties currently on site. Shallow madeground (similar to topsoil) and madeground identified on site may contain elevated concentrations of inorganic contaminants, speciated PAH (16) compounds and asbestos fibres, although the likelihood is deemed to be very low due to the nature of the madeground (similar to topsoil)/madeground. The madeground (similar to topsoil)/madeground was recorded to contain anthropogenic inclusions of brick, ceramics, glass and plastic, which tend to be relatively inert. The small waste heap was considered to pose a negligible risk of contamination.

An electricity sub-station on site will have contained PCBs during the course of its use, which if spillages had occurred, would have migrated a limited distance due to adsorption to soils. The sub-station is to remain on site and proposed adjacent hardstanding and underlying services will prevent future site users coming into contact with PCBs in the ground if present, assuming the soils remain in situ, making this a negligible risk to future residents, as it would be unlikely for them to come into contact with PCB contaminated soils. There would be a very low potential for ground maintenance contractors to come into contact with such soils. However, consideration should be given to the potential for the soils to be relocated to the garden growing medium during the construction process. Any soils containing PCB contamination may then pose a moderate to high risk to the health of future residents, being exposed due to dermal contact, ingestion of contaminated soils and vegetables and inhalation of contaminated dust indoors and outdoors.

Should elevated concentrations of contaminants be present within the madeground (similar to topsoil)/madeground, the site users may become exposed to these materials in the growing medium, with predominant exposure pathways being ingestion of contaminated soils via hand to mouth or plant uptake and inhalation of dust indoors and outdoors. Madeground (similar to topsoil)/madeground would pose a negligible to very low risk to adjacent site users should any of these materials become airborne as dust.

Generally, off site sources of contaminants were deemed to pose a negligible risk to the proposed development. The adjacent above ground fuel tank poses a negligible to very low risk, with the likelihood of TPH contamination if present in the ground, migrating away from the site boundary.

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13.6 Summary of preliminary groundwater/hydrology risk assessment

A negligible risk is posed to the controlled waters receptors, the Secondary (A) Aquifer within the underlying bedrock and the surface water course 82m from the site due to the potential for only very low leachate concentrations to be generated, the attenuation of leachates migrating vertically through the clay and clayey sand bands and attenuation due to the distance between the source and the receptor.

13.7 Sampling Strategy

Coopers took soil samples from the exploratory holes on the site, with 3 No. madeground (similar to topsoil), 5 No. madeground, 2 No. sand and 1 No. clay samples scheduled for chemical analysis, as summarised in Table 1. The samples were submitted to DETS, an MCERTS accredited laboratory, the results of which are presented in Appendix 12.

There was no visual or olfactory evidence of mobile contamination in the exploratory holes to suggest presence of such contamination and as discussed in Section 13.2, the likelihood of TPH contamination having migrated onto site from the adjacent above ground kerosene fuel tank posing a negligible to very low risk. Due to there being no evidence of mobile contaminants in the exploratory holes in the vicinity of the electricity sub-station, PCBs were not scheduled for analysis. However, it is recommended that once the services are disconnected and the current hardstanding in the car park is removed, that soil samples are taken from adjacent to the electricity sub-station, in order to confirm that there have been no historical spillages of PCBs which may then be relocated across the site or may pose a risk to development contractors.

The testing schedule included the Coopers standard human health suite (CLR metals, cyanide, phenols and speciated (16) polycyclic aromatic hydrocarbon (PAH) compounds). Asbestos fibre identification was also scheduled on the madeground (similar to topsoil) and madeground samples.

Table 1 – Chemical analysis scheduled

Strata	Coopers suite	Asbestos Fibre ID
Madeground (similar to topsoil)	4	4
Madeground	4	5
Sand	2	-
Clay	1	-

13.8 Contamination Results

13.8.1 Human Health Risk Assessment

Assessment of soil results

The justification for human health risk assessment concerning chemical contaminants is included in Appendix 11.

The chemical analysis results relating to the soil samples taken were assessed by Coopers against the Soil Tier 1 Threshold values applied for residential properties with plant uptake for all samples taken, given that part of the site will have private gardens. The Soil Tier 1 Threshold Values applied, include the C4SLs where available. For other criteria, the S4ULs were applied except for copper, nickel and zinc, for which the phytotoxic threshold values are more conservative than those applicable to human health. These are relevant in assessing whether the materials on site may be detrimental to plant growth. The Soil Tier 1 Threshold Values are presented in Appendix 11. The chemical analysis results are presented in Appendix 12.

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None of the made ground (similar to topsoil), made ground, sand and clay samples were reported to contain concentrations of determinands in excess of the available Tier 1 Threshold values. None of the samples tested for potential presence of asbestos fibres were reported to contain asbestos fibres.

13.8.2 Controlled Waters Risk Assessment

No significant sources of contamination were identified in the exploratory holes. Therefore, the potential for leachates to be generated in significant concentrations by the materials on site is considered to be negligible.

13.8.3 Water Supply Pipes

The site is within the Hafren Dyfrdwy 'Severn Dee' water supply area. Subject to whether the development entirely fronts onto a road or footpath with an existing connection or comprises a new access road and requires the installation of a new water main, applications to connect an existing water main or construct a main must be made via Hafren Dyfrdwy's website

Guidance by the UK Water Industry Research organisation (UKWIR) (referenced in the "Contaminated Land Assessment Guidance", published by Water UK) requires the assessment of potable water supply pipelines to be made on a risk based approach. The procedures include a phased approach to risk assessment including preliminary risk assessment, and specifications for types of contaminants being tested.

Where sources of potential contaminants that could impact on a potable water supply are identified within the desk study or intrusive investigation, these are to be assessed to determine the impact on selection of pipe materials.

All strata within the site have been appraised and characterised. The site had no evidence of mobile contamination which may include TPH compounds, volatile organic compounds, semi-volatile compounds, phenols, chlorinated phenols and cresols which may impact on the water supply pipe materials. Concentrations would be considered to be below thresholds for standard PE pipes for mobile contaminants.

13.8.4 Revised conceptual site model following site investigation

The preliminary conceptual site model considered that there was a low likelihood that the made ground (similar to topsoil)/made ground would provide a source of contaminants, which may pose a risk to human health. The site investigation has shown that as there were no elevated concentrations of determinands, the made ground (similar to topsoil)/made ground poses a negligible risk to human health of the future site users, if these materials remained within the growing medium in the gardens. To date there is no evidence of PCB contamination in the ground in the vicinity of the electricity sub-station. Should any be present beyond the footprint of the sub-station this will pose a very low risk to the future occupants of the new residential properties, if this should be in soils present below hardstanding and topsoil, where no digging will take place. Due to the low mobility of the PCBs these are not expected to have migrated into the area of proposed gardens. However, consideration will need to be given to the potential for the soils in the vicinity of the sub-station to be relocated to the growing medium, during the development process, where the PCBs may then pose a moderate to high risk. The PCBs pose a negligible risk to controlled waters, due to their low mobility.

It is considered that with limited total soils concentrations, that there is no source to generate significant concentrations of leachates. Given the intervening low permeability clays and clayey sands, the distance to the underlying Secondary (A) Aquifer and the nearest surface water course, the site investigation confirms there is a negligible risk posed to controlled waters by the materials which have been encountered on site.

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14.0 Sub Soil Classification

14.1 General

Selected soil samples were scheduled for chemical and geotechnical analysis as discussed in Sections 10.6 and 10.7. Copies of the chemical and geotechnical results received are provided within Appendices 12 and 13, respectively.

14.2 Results of Laboratory Analysis

Table 2 - Summary of chemical analysis

Strata	No. of samples for analysis	SO ₄ (2:1) (water soluble)	pH	Mobile/ Static
		mg/l	-	
Madeground gravel	1	14	7.9	Mobile
Madeground sand	2	Highest concentration - 22	Lowest value - 6.0	Mobile
Natural clay	1	11	6.8	Static
Natural sand	1	Highest concentration - 14	Lowest value - 6.9	Mobile

Table 3 - Summary of geotechnical analysis

Strata	No. of samples for analysis	Plasticity Index (corrected)	Passing <425 micron
		%	%
Clay	3	15.84-21.25	72-85

14.3 Interpretation

Groundwater Mobility

Madeground sand - Mobile
Natural clay – Static
Natural sand – Mobile

Frost Susceptibility

Natural sand – assumed potential for more than 10% of silt within granular samples – frost susceptible

Shrinkage Potential

Clay – Medium

Soil/Groundwater Classification

Based upon Table C1 and D1 of BRE Special Digest 1 (2005), the Design Sulphate (DS) class, Aggressive Chemical Environment for Concrete (AC) class, and Design Concrete (DC) class for each of the strata types, except pyritic mudstone is given below: -

Madeground sand - DS-1, AC-1, DC-1
Natural clay – DS-1, AC-1s, DC-1
Natural sand – DS-1, AC-1, DC-1

Medium shrinkage clay has been recommended based on the highest corrected plasticity index (PI) results recorded on site.

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Any fill material to be imported onto the site should be tested and should not exceed the classifications given above.

Based upon the above classification, the ready-mixed concrete (designated mix) appropriate for Design Class DC-1, for the natural ground would be as detailed in Table 4.

Table 4 - Sub-structure ready mix concrete designations by end use over the site

<u>Use as substructure and ground floors</u>	<u>Ready-mixed concrete (designated mix)</u>
General Use:	
• Rough blinding (non-structural)	- GEN1
• Infill	- GEN1
• Unreinforced oversite concrete below timber floors	- GEN1
• Structural blinding and overbreak	- GEN1
• In situ external concrete for drives and paths	- PAV1
• In situ external concrete foundations for precast concrete paving slabs	- GEN1
• Fill to wall cavity	- GEN1
• Solid filling under steps	- GEN1
Floor Slabs:	
• House or garage with reinforced concrete floor slab, either suspended or precast.	- RC35
• House with non-reinforced slab (ground bearing) with either:	
a) Permanent finish to be added, e.g. screed or floating floor.	- GEN1
b) No permanent finish to be added, e.g. carpet.	- GEN2
• Garage with non-reinforced slab (ground bearing)	- GEN3
Foundations:	
• Strip foundations	- GEN1
• Trench fill	- GEN1
• Other mass concrete foundations	- GEN1
• Reinforced concrete footing	- RC35

Notes:

- 1) Worst case sulphate conditions over the entire site are ACEC Class AC-1/AC-1s, and Design Chemical Class DC-1.
- 2) Classification and designation in accordance with NHBC guidance, Section 2.1 – Table 1, and BS8500-1, 2006.
- 3) The above conditions represent the worst case conditions identified within the testing of soils on the site.
- 4) Any fill material to be imported onto the site should be tested and should not exceed the classifications given above.

15.0 Trees

- 15.1 Hedges and mature/semi mature trees were noted along part of the site boundaries, and to have been present sporadically across the site until recently within the site boundary, these having now been felled. Prior to the trees being felled they were surveyed by Tree Solutions, as presented in the report dated 17th September 2021 (see Appendix 4). The assessment was completed in accordance with the British Standard BS5837:2012.
- 15.2 Clay strata interbedded generally with sand strata and occasionally sand and gravel were encountered across the majority of the site. Based on the general nature of the clays, they may be subject to influence by changing moisture content associated with tree roots. The soils may be affected where existing tree roots are removed or their roots severed by construction foundations, which would cause rehydration of clay subsoils and subsequent swelling of the clay or 'heave' in clays with plasticity. Likewise, they may be impacted by the growth of immature or semi-mature trees, where the root ball expands and can cause the clay beneath foundations to shrink causing subsidence.

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- 15.3 The geotechnical results demonstrated the clay sampled in exploratory holes located away from trees to have a medium shrinkage potential. It was observed during the ground investigation that the clay sample taken from TP03 at 1.4m was desiccated, likely due to the close proximity of trees to this location and their moisture demand. The desiccation was confirmed by the geotechnical test results for this sample (see Appendix 13) which indicated the natural moisture content (13.5 %) to be less than the plastic limit (14%). This sample was not considered as being representative of the general clay characteristics of the site, due to its proximity to the trees. The sand bands present below the clay strata were noted at variable depths. There is a potential that the sand/sand and gravel strata may remove the impact of tree influence on the clay locally within the building footprints.

16.0 Ground Floor Slabs

16.1 General Requirements

Based upon the developer's general commercial preferences for floor slab construction, plots are more likely to be constructed with precast (block and beam) suspended concrete floor slabs.

16.2 Gas Precaution Measures

Based on the gas risk assessment undertaken, ground gas precaution measures will not be required, the site being characterised as CS1 in accordance with BS8485:2015+A1:2019/Green in accordance with the NHBC Traffic Light System. However, the site lies within an area where basic radon protection measures are required, with typical construction details for radon mitigation measures for a pre-cast slab, being illustrated in Drawing No. 7962/LRH&HRH/BR/PC/RA/G/01 presented in Appendix 16.

16.3 Heave Precautions

Based upon the ground conditions and assuming the clay has a medium shrinkage potential, properties may be liable to heave. Should these be constructed with a precast suspended concrete floor slab, these will require a sub floor void of 250mm.

17.0 Foundations

17.1 General

The locations of the exploratory holes are shown on Coopers Drawing No. 7962/01 in Appendix 16. Copies of the exploratory hole logs are presented in Appendices 7 to 10.

17.2 Development Proposals

The proposed development will consist of 25 No. residential properties potentially including 1 No. semi-detached building and 1 No. mews building comprised of bungalows and 1 No. two storey apartment block, with associated car parking, private gardens and landscaped areas. The proposed planning layout is presented in Munro Associates Preliminary Site Layout (Option B) Drawing No. 20.211 P-105 RevB, presented in Appendix 16.

It is assumed that all materials and workmanship will comply with the Building Regulations and the NHBC Standards. It is understood that there will be limited regrading of the site. Therefore, for the purposes of this report, it has been assumed that foundations will be constructed from the current ground levels.

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Where private drainage is proposed to be laid, careful consideration must be given to the relative levels of the foundations and the drainage pipework. This information needs to be reviewed to ensure that no foundations are being undermined by drainage pipework and that no foundation loads are being applied to the drainage pipework.

17.3 Tree Influence

As outlined in Sections 15.0 and 16.0, the clay strata, where present, are subject to volumetric change associated with trees with special precautions required for heave, where plots are located within the zone of tree influence.

17.4 Bearing Strata and Safe Bearing Capacities

Based upon the findings of the intrusive investigation and subject to finalised layout proposals we would anticipate that bearing strata would consist of the following:

- Loose to medium dense sand – 100kPa
- Medium dense sand and gravel – 150kPa
- Firm clay – 100 kPa
- Firm to stiff clay – 125 kPa
- Stiff clay - 150 kPa
- Very stiff clay - >150 kPa

17.5 Minimum Formation Depths

The assumed minimum foundation depths relative to proposed ground level should be assumed for the following strata types:

- Foundations on natural clay strata – 900mm
- Foundations on natural sand or sand and gravel – 600mm

17.6 Foundation Recommendations

All foundations and floor slabs for the plots should be specifically designed by a Structural Engineer once the planning layout, external works and slab level requirements have been finalised. The following options are conjectured for the proposed development area based upon depth to bearing strata from preliminary proposed slab levels. It should be noted that the proposals have not accounted for possible deeper remnant substructures, including for example drains or basements.

As discussed in Section 11, the site is underlain by interbedded firm, firm to stiff and stiff clay with loose to medium dense sand strata and localised medium dense sand and gravel. The three proposed buildings will span across variable bearing strata, assumed to include clay subject to tree influence below each proposed building footprint, as indicated on Drawing No. 7962/FDZ, presented in Appendix 16. However, further trial pits are recommended in the vicinity of the mews bungalows to determine whether sand is present below the whole footprint.

Sections of the each building are likely to be founding on firm, firm to stiff, or stiff clay which is partially located in the zone of tree influence, with foundations required to be greater than 1.2m depth but less than 2.5m from current ground level, but other sections are underlain by clay beyond the zone of tree influence and potentially sand and sand and gravel, where foundations would be 1.2m or less than the current ground level. Therefore, we would recommend that a **Mass Concrete Trench Fill Foundation** should be employed across the whole of each building footprint. The Drawing 7962/FDZ indicates that sections of the foundations will also require **heave precautions**.

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- Based on medium shrinkage clay, minimum foundation depth 0.9m below proposed ground level.
- Minimum concrete thickness is assumed to be 0.5m thick unless specifically designed.
- Formation is to step in areas of tree influence, in accordance with NHBC guidance.
- Maximum safe bearing capacity limited to 100kPa in firm, firm to stiff, stiff and very stiff clay, loose to medium dense, medium dense sand and sand and gravel taking account of the general structural design, although the strata may provide a greater safe bearing capacity in places.
- Foundation widths subject to engineering designs for house types by structural engineers.
- The viability for deeper mass concrete trench fill is largely determined by trench stability.
- If difficulty experienced constructing deeper trenches due to side wall instability then contact Coopers to advise on alternative options.
- Where influenced by trees the formation depths should be considered the minimum depth in cohesive strata.
- Where tree heave influence is recorded there is a requirement for compressible materials on the mass concrete trench fill foundation (as medium shrinkage potential clay), and the inclusion of a subfloor mitigation (250mm minimum void beneath block and beam floor slab).
- All former footings, service runs and pipes to be removed prior to construction of new foundations.

For further details refer to Drawing Nos. 7962/Tf/01 and 7962/TfH/01 in Appendix 16. The zones of foundation design have been illustrated on Drawing No. 7962/FDZ, presented in Appendix 16.

Foundation designs are preliminary and may alter with change in proposed slab levels and planning layout. Unexpected basements found following the demolition would also impact on the foundation design. It is recommended that additional investigation is undertaken within the building footprints following demolition to confirm ground conditions and in the vicinity of the proposed mews bungalows. Deeper foundations may then be required in the proposed apartment block. If sand was encountered below the whole footprint of the mews bungalows this would remove the tree influence on foundation design, with the potential for nominally reinforced strip foundations being possible.

18.0 Trench Side Stability

- 18.1 Generally, clays, sands and sand and gravel encountered across the site will remain stable in the short term but may become unstable after being left open over longer periods of time. This will also be highly dependent on the weather conditions at the time of excavation as well as the period of time the trench is left open.
- 18.2 Should trenches need to remain open for longer periods or require manned entry then they should be supported at all times or, where suitable, battered to the angle of repose of the soil. Battering of excavations should be avoided in the proximity of trees proposed for retention and existing structures without assessment from experienced engineering personnel.
- 18.3 Trench excavations for foundations/services must be adequately supported at all times and should be in accordance with the recommendations of CIRIA Report 97: Trenching Practice.
- 18.4 Further guidance on this aspect of site works is given in the British Standards for “Workmanship on Building Sites”, BS 8000, Parts 1 and 14, and in the Construction Industry Training Board’s Site Safety Note 10.
- 18.5 Shallow excavations are likely to be within the capacity of conventional hydraulic plant.

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19.0 Dewatering

- 19.1 Minor groundwater seepages were recorded perched at the head of the clay stratum, in TP01 (at 0.9m bgl) and ITP02 (at 1.0m bgl). Based on the site investigation significant dewatering would not be required in deep excavations and service/drainage trenches. However, it should be noted that seasonal factors may affect changes in groundwater levels at the site. Consequently, dewatering may be necessary in the winter or at times of prolonged rainfall for shallow foundations or drainage trenches.
- 19.2 If former/existing drainage runs are encountered during the excavation of either foundations or service/drainage trenches these will need to be immediately diverted around the excavation and proposed plot footprints, and the excavations may require localised dewatering where breached.
- 19.3 It is anticipated that surface runoff from the site itself may accumulate in open excavations and trenches, and may require dewatering.
- 19.4 Groundwater should not be discharged into the existing sewer system or ditches without prior agreement from Natural Resources Wales and the Local Authority.
- 19.5 Further guidance can be obtained from the CIRIA Report 113 entitled “Control of Groundwater for Temporary Works”.

20.0 Potential Infiltration

20.1 Infiltration test methodology

Coopers undertook BRE Digest 365 compliant infiltration testing, 23rd November 2022 at 3 No. locations, referenced ITP01 to ITP03, as illustrated on Drawing No. 7962/01, presented in Appendix 16. The infiltration test pit logs are presented in Appendix 8.

Depths of infiltration test pits were selected in order to assess the ground conditions appropriate to the preferred method of infiltration design. A permeable paving system was proposed below the car park in the centre of the site, with two shallow infiltration test pits excavated (ITP01 and ITP03). These were to be taken to 0.5m below the made ground, but a clayey sand 0.4m thick was encountered over clay at 0.5m below the made ground in ITP01 at this depth. The test pit was therefore excavated through the clay stratum to the sand stratum below at 1.7m bgl, this being excavated into by 0.1m. ITP03 was excavated to 1.0m bgl, within a 0.5m thickness of sand stratum below the made ground. A deep infiltration system was to be preferred in the east of the site, ITP02 being excavated to 2.5m bgl, the test pit including a clayey sand stratum over clay over a gravelly sand stratum. Minor spalling prevented the test pit being taken to a greater depth, so as to maintain the stability of the test pit. No groundwater was recorded in ITP01 and ITP03. A slight groundwater ingress was recorded in ITP02, perched at the head of the clay, but this did not accumulate at the base of the test pit.

A slotted pipe was placed in test pits ITP01 and ITP02 and backfilled with 20mm single sized limestone gravel. ITP03, being shallow and stable was left open. The pits were subsequently filled with water from a 3,000 gallon bowser to the base of the made ground stratum and monitored to determine the time of outflow between 25% to 75% of the effective depth to calculate infiltration rates (detailed below). If successful tests were to be completed in particular locations, these were to be retested two more times to simulate worst case conditions following heavy and prolonged rainfall events. The infiltration test data is presented in Appendix 14.

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20.2 Infiltration test results

The infiltration rates are summarised in Table 5 and the infiltration test results are presented in Appendix 14.

Table 5 – Summarised infiltration test pit results

Infiltration test pit location	Infiltration test	Time taken for water level to reach 25% effective depth	Time taken for water level to reach 75% effective depth	Infiltration rate (m/sec)	Pass/fail
ITP01	1	14.7 minutes	8 hours 15 minutes (projected time)	1.82E-06	FAILED
ITP02	1	36.14 minutes	3 hours 16 minutes	5.81E-06	FAILED
ITP03	1	54 minutes	4 hours (projected time)	9.8E-06	FAILED

ITP01

The test in infiltration test pit location ITP01 below the north side of the proposed car park, failed on the first test. The water level fell steadily to the 25% effective depth (0.705m bgl) after 14 minutes. The infiltration of the water then reduced significantly, with the 75% effective depth not having been reached after the last monitored depth at 2 hours 59 minutes. The time for the water level to reach the 75% effective depth was extrapolated to be in excess of 8 hours. A poor infiltration rate of 1.82E-06 m/sec was obtained. The first infiltration test was considered to have failed. This would not provide a sufficient infiltration rate for a permeable paving system.

ITP02

The water level in the deep infiltration test pit ITP02 in the east of the site fell at a slow steady rate throughout reaching the 25% effective depth after 36 minutes and the 75% effective depth only after 3 hours 16 minutes. A poor infiltration rate was achieved of 5.81E-06 m/sec, which would not be satisfactory to permit a deep crate infiltration system.

ITP03

The infiltration test undertaken in ITP03 in the south western area of the proposed car park failed, due to very poor infiltration rate. The water level only reached the 25% effective depth after 54 minutes. The rate continued to be very slow, with the 75 % effective depth not having been reached after almost 1.5 hours when the light was fading on site. If the infiltration rate was projected to the 75% effective depth, it is estimated it would have taken at least 4 hours to drain to this depth, but potentially more. The infiltration rate calculated, based on this projected rate was 9.8E-06 m/sec.

20.3 Conclusion

All three infiltration test pit locations failed. In ITP01 and ITP03, it is likely that this was due to the shallow clayey sand present immediately below the made ground, with clay known to be present below this stratum in ITP01. Based on the exploratory holes across the site, it is likely that clay is present below the sand stratum ITP03, slowing the infiltration rate down significantly. Although the infiltration rate in ITP02 failed, it was quicker than the shallow infiltration test pits potentially due to this being partially undertaken within a greater thickness of the deeper gravelly sand stratum.

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21.0 Road and Parking Bay Sub-Grade

- 21.1 Following the demolition and removal of current surfaces, the anticipated car parking and access paths sub-grade materials are likely to generally comprise loose to medium dense clayey sand but potentially also firm clay, as encountered in the west of the site to date (refer to exploratory hole logs presented in Appendices 7 to 10).
- 21.2 In accordance with Volume 7, Section 2 of the Department of Transport, Departmental Standard Interim Advice Note 73/06 Revision 1 – Design Manual for Roads and Bridges, and Plasticity Index values of firm, firm to stiff and stiff clay on this site, the clay subgrade is estimated to have a CBR of between 3% to 5%. It is estimated the loose to medium dense sand strata would provide a CBR of up to 5%.
- 21.3 Proposals are subject to the review by Wrexham CBC – Highways Department. However, we would recommend that all sub-grade materials are in situ CBR tested at proposed road formation level prior to final pavement design.
- 21.4 It is recommended that if initial roads and sewer construction is proposed to commence during the winter months then a longer period should be allowed for construction due to the potential for weather disruptions to the site.

22.0 Build Phase Remediation and Verification Requirements

22.1 Ground gas/radon

Based on the ground gas risk assessment, no ground gas mitigation measures will be required, as discussed in Section 12. the installation of basic radon protection measures will be required within the floor slab design, as discussed in Section 12.

22.2 Remediation to protect human health/controlled waters

Known ground conditions

Based on the current human health and controlled waters risk assessment relating to ground conditions encountered, no remediation measures will be required across the general site, due to the chemical characteristics of the materials encountered. However, additional soil sampling to assess for potential PCB contamination, is recommended adjacent to the electricity sub-station once the services have been disconnected and the tarmac forming the car park has been removed. Should PCBs be encountered in the soils, these soils will require delineation and segregation should they require excavation, to prevent the re-use of these soils within the growing medium and assess the potential for their re-use on site if required. An addendum letter report would need to be provided by a qualified geo-environmental consultant for submission to Wrexham CBC, in support of the planning application and the NHBC.

Unforeseen contamination

During the ground preparatory works, the groundworks contractor would need to maintain a watching brief to ensure that should areas of potentially undisclosed contaminant be found then a qualified geo-environmental consultant, such as Coopers, is contacted to visit the site to sample and assess the materials in order to determine whether remedial measures are required. Should this be the case then the findings, assessments, and remediation proposal may require regulatory approval prior to undertaking any remediation works. Should materials be identified that are geotechnically unsuitable to be re-used (such as buried trees) in the proposed development then these must be segregated and removed from site.

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22.3 Remediation with regards to acceptable physical characteristics of madeground (similar to topsoil) and madeground for re-use

While the madeground (similar to topsoil) and madeground have been shown to be chemically suitable for use, these soils have been identified as containing rare inclusions of brick and glass. The British Standards BS 3882:2015 for topsoil and BS8601:2013, state that topsoil and subsoil should be free of sharps such as glass. Therefore, it is recommended that the madeground (similar to topsoil) and madeground are not used within the private gardens or soft landscaping areas. However, it is considered that the subsoil, being granular, would be geotechnically suitable for use below hardstanding and below the proposed plots, if this can be segregated from the overlying madeground (similar to topsoil).

It is envisaged that there will be sufficient site won subsoil available for the development, but there may be a shortfall of topsoil. Materials to be imported to site would require validation as discussed in Section 22.4.

In accordance with Definition of Waste Code of Practice (discussed in Section 22.5), it would not be possible to transfer these materials for use in another development, so would need to be kept segregated from subsoil arisings to be designated for use on site or disposal.

22.4 Validation processes

Validation of growing medium

It is recommended that the gardens and soft landscaped areas are validated to confirm the removal of madeground (similar to topsoil) and madeground and therefore potential glass, prior to placement of the inert subsoils and topsoil. This may be undertaken by confirmation that the natural strata are exposed with photographic evidence.

Verification of imported materials if required

It is envisaged that there will be sufficient site won subsoil available for the development, but there may be a shortfall of topsoil, due to the physical nature of the madeground (similar to topsoil) present on site. Should soils need to be imported to site, for example to provide a growing medium in the gardens and soft landscaping areas, it is recommended that prior to accepting imported sources, samples should be analysed by the material provider, proving the soil inert, preferably with provenance to aid the certification of the site. Soils must not be accepted from areas where Japanese Knotweed or other invasive or injurious plants, as specified by the Natural Resources Wales, are suspected to have been growing.

We would advise that the suitable imported material should be sampled by an independent, suitably qualified geo-environmental consultant, to confirm the initial assessment that the material is inert. Currently, the NHBC are requesting certification from developers that all imported topsoil to sites is suitable for use. Clause 10.2.8 states “Topsoil should not contain contamination which may present a hazard to the occupants” and “Topsoil should be provided to a minimum thickness of 100mm”. BS3882 (2015) and the Contaminated Land Exposure Assessment (CLEA) guidelines provide advice on determining the “suitability of topsoil”.

The developer should maintain the integrity and quality of any topsoil/subsoil brought onto site, ensuring that it does not become cross contaminated through poor site practice.

Any imported inert fill/subsoil required for backfilling or regrading should comprise a good quality fill, free of demolition detritus (such as bricks, brick ties, etc) as well as deleterious materials (such as timber, glass and asbestos). These should have provenance and chemical analysis to prove the strata to be imported as inert prior to acceptance on site. The analysis from the provider of the inert fill must be current and relevant for the material being imported.

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Additional independent analysis of topsoil/subsoil should be completed to confirm the source documents. Reference has been made to the Welsh Contaminated Land Working Group guidance document relating to garden validations “Requirements for the chemical testing of imported materials for various end uses and validation of cover systems” The following chemical testing quota is recommended once the soils have been imported to the site. The type of testing and sample frequency is dependent upon the provenance of the materials.

- Topsoil Testing (greenfield source): 4 samples to be taken from deliveries up to 250m³ with an additional 1 sample per 250m³, for volumes greater than 250m³.
- Topsoil Testing (unverified source): 1 sample per 50m³.
- Subsoil Testing (greenfield): 4 samples to be taken from deliveries up to 250m³ with an additional 1 sample per 250m³, for volumes greater than 250m³.
- Subsoil Testing (quarried source): no requirement for testing.
- Subsoil Testing (unverified source): 1 sample per 50m³.

Confirmation of the volume of material imported to site must be provided to ensure that representative sampling has been undertaken in accordance with the required testing frequency.

Samples should be analysed for CLEA inorganics/metals, speciated (16) PAH compounds, phenols, banded aliphatic and aromatic TPH compounds, pH and asbestos fibre screen.

The copper, nickel and zinc threshold values in British Standard BS3882:2015 ‘Specification for Topsoil and Requirements for Use’ are significantly lower than the human thresholds and it is advised that these should be adopted for imported materials placed in gardens and areas of landscaping.

Should elevated concentrations be identified within the imported soils additional testing or assessments may be appropriate.

The testing of soils for validation must be taken from the construction site to ensure these are representative of the soils actually used within the gardens. The samples can be taken from stockpiles on site or in situ following placement within gardens and landscaping. Where soils are being kept within tested stockpiles on site it is imperative that good stockpile management practices are adopted. This can include segregation of stockpiles from different origin, fencing or warning signs to prevent inadvertent cross-mixing, and not placing stockpiles on tarmac roads, contaminated madeground or adjacent to areas of heavy plant traffic.

Results of the chemical analysis would be screened against the Tier 1 Threshold Values presented in the table in Appendix 11.

Validation report

A qualified geo-environmental consultant would be required to prepare a validation report with regards to the soils contaminated with PCBs if encountered and imported materials, if required. The report would need to include, for example, laboratory analysis, photographic records and delivery notes, where applicable.

This verification report would need to be submitted for approval in support of the planning application and NHBC conditions.

Proposed Temporary above Ground Fuel Storage Tank

It is anticipated that a bunded diesel fuel storage tank may be present within the compound area of the site during the construction phase and will be decommissioned once development is complete.

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Mobile filling of plant may also occur. Plant should be checked and maintained regularly to ensure fuel/oil leakages do not occur. All staff on the development site must be warned of the potential consequences that a fuel spillage will have for both the development and the surrounding environment.

Any contamination resulting from spillages during construction works may be considered under the Environmental Damage (Prevention and Remediation) (England) Regulations (2015). Any contaminants released during the development process must be immediately reported to statutory bodies and appropriate remediation agreed. These are likely to require consideration of the contamination in terms of the significant possibility of adverse effects (rather than significant harm) to land, water, habitats, and protected species.

It is recommended that the position of the fuel tanks are recorded and the ground underlying the tanks is sampled and analysed to confirm that spillages have not impacted these areas of the site.

22.5 Disposal and Control of Excavated Materials

It should be noted that where possible, all soils should remain on site, as part of a sustainable building policy, or where suitable to be transferred for re-use rather than sent to landfill. Should unforeseen contaminated soils be encountered which require re-use or additional soils are needed to raise site levels, depending on the volume, a Materials Management Plan (MMP) may be required. If the volume is below 1000 tonnes then it may be feasible to apply for a U1 waste exemption instead.

The intended use of soils excavated from the site would be detailed within the contractors MMP for implementation within the construction phase. The Material Management Plan would require the identification and classification of materials intended for re-use or disposal off-site (including classification as inert, non-hazardous, stable non-reactive hazardous, or hazardous waste) and volume targets for disposal of each type, prior to excavation.

Each soil type which is intended for removal will be classified with one of the following EC waste designation codes, as detailed within Environment Agency “*Technical Guidance WM3 - Hazardous Waste*”. Generally, the soils would be classified as:

- **17 05 04 soil and stones other than mentioned in 17 05 03 – not containing hazardous substances.**

Should soils be found to contain PCBs these may be classified as:

- **17 05 03 soil and stones containing hazardous substances**

Based upon the chemical analysis of the samples taken to date, Coopers can advise the waste characteristics of the natural strata, made ground (similar to topsoil) and made ground would likely be:

Non hazardous waste, likely to be inert following testing for Waste Acceptance Criteria (WAC) if intended for landfill.

Should soils be found to include PCBs, these may be categorised as:

Non hazardous waste, possible hazardous following testing for WAC if intended for landfill.

Materials are however a commodity and re-use, or transfer would be preferred.

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It is recommended that the chemical analysis results obtained to date plus future WAC analysis are provided to a waste disposal site for confirmation of the disposal route, to enable the detailed assessment and full characterisation of the waste.

Where materials are excavated for construction purposes these should be retained on site for engineering purposes where considered suitable for use, if possible, to ensure sustainability of the development. The developer may complete the works under the CL:aire Development Industry Code of Practice for the Definition of Waste, Version 2 (or superseding versions if relevant). Within the Code of Practice, there are two paths which may guide the documentation required for the form of soil management systems. The initial path expects a Remediation Strategy to be produced for the site (assuming it to be potentially contaminated) to determine which strata or areas of the site are considered to be contaminated with regard to the proposed land use (Route A). The second path expects a Design Statement to be utilised for those sites where there is no contamination per se (Route B). Based on the characteristics identified at this site to date, a Design Statement would be applicable.

Direct transfer of naturally occurring soils may be undertaken, however a robust assessment of the materials has to be undertaken to confirm this material is suitable for use and uncontaminated. It should be noted that the degree of threshold for contamination will be judged on the receiving sites requirements (based on the proposed end use).

The Code of Practice requires 4 No. factors to be addressed within the Material Management Plan:

- (1) Protection of human health and protection of the environment;
- (2) Suitability of use, without further treatment;
- (3) Certainty of use; and
- (4) Quantity of material.

With regard to Box A within the Code of Practice (c.3.7, p.13), the material types encountered have been classified to determine the 'Categorisation of materials within the ground'. Areas and volumes of strata noted below, will require assessment by a qualified quantity surveyor. These volumes would not represent the volumes of soils likely to be excavated through any part of the construction phase of the site redevelopment, rather the anticipated total volume of that stratum.

Table 6 - Categorisation of materials within the ground in accordance with CL:aire Code of Practice

(1) Material that is capable of being used in another place on the same site without treatment*; (2) Material that is capable of being used in another place on the same site following ex-situ treatment on site*; (3) Material that is capable of being used in another development site without treatment (Direct Transfer); (4) Material that is capable of being used in another development site following ex-situ treatment on another site e.g. Hub site*; (5) Material that is not capable of being used on the site or elsewhere and requires recovery or disposal off site as waste; or (6) Material that will be surplus to requirements and requires recovery or disposal off site as waste. * Having regard to the conceptual model (receptors and pathways) and appropriate risk assessment of the location where materials are to be used. We do not consider damping down to be treatment.

Madeground (similar to topsoil)(6)

The madeground (similar to topsoil) has been shown to be physically unsuitable for re-use within the growing medium in the gardens and soft landscaping. This will require disposal to a permitted waste disposal site.

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Madeground (1) and (6)

The madeground would not require treatment. It would not be suitable for re-use within the growing medium in the gardens and soft landscaped areas due to the physical nature of the material. However, it would be considered to be geotechnically suitable for use beneath buildings, roads and hardstanding (subject to suitable compaction designed for the end use).

Natural materials – subsoil (1), (3) and (6) proven to be suitable for use

Natural strata would not require treatment and would be suitable for re-use in gardens and soft landscaped areas as a growing medium, and where geotechnically suitable for use beneath buildings, roads, or as up fill (subject to suitable compaction for the designated end use). These materials if proven geotechnically and chemically suitable for use on other sites may be transferred under an MMP for the receiving site.

22.6 Risks to Groundworks Contractors

We do not anticipate that groundworks contractors will be detrimentally affected by the materials present on site assuming basic site hygiene is followed; comprising wearing gloves, overalls, steel toe capped boots and hard hat on site, and basic welfare facilities are present within the site.

23.0 Further Actions

- Submit this site investigation report to Wrexham CBC in support of the planning application and approval from the CLO and to the NHBC for approval.
- Due to the presence of services within and adjacent to the site, consultations should be held with service providers regarding plans to adopt, divert, or abandon the services.
- Soil sampling, risk assessment and reporting with regards to potential PCBs in the vicinity of the electricity sub-station following the disconnection of the services and lifting of the car park surface. Report to be submitted to Wrexham CBC in support of the planning application.
- Additional investigation of ground conditions following demolition of the current buildings and in the vicinity of the proposed mews bungalows to aid foundation design.
- In situ CBR tests undertaken within road corridors and parking areas.
- Refinement of plot specific foundations, following production of finalised external works drawings and drainage plans.
- Delineation/segregation of madeground (similar to topsoil) and madeground, with removal of madeground (similar to topsoil) from site.
- Removal of waste stockpile from site to a permitted waste management site.
- Validation of the radon protection installation is recommended with the production of a validation report, for submission to the regulators for approval (if the latter is required).
- The direct transfer of topsoil/subsoil to the site would require the application of either a U1 exemption or an MMP, depending on the volumes to be imported.
- Validation of imported topsoil and subsoils if required, with validation report prepared for submission to Wrexham CBC in support of the planning application.
- If surplus strata require offsite removal they are likely to require testing to confirm suitability for the intended end use at the receiving site. Where strata are intended for landfill they may require testing for Waste Acceptance Criteria (WAC).

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24.0 References

- A study of the published geological maps.
- A review of data held in the Coopers archives.
- Inspection of historical OS Maps provided by Groundsure.
- Review of Groundsure Enviro+Geo Insight report.
- Review of the GOV.UK website.
- Review of the BGS website.
- Review of the tree survey completed by Tree Solutions, dated 17th September 2021.
- The findings of exploratory holes undertaken by Coopers on 23rd November 2022.
- The results of contamination testing carried out by DETS.
- The results of geotechnical testing undertaken by Murray Rix.
- BS 3882:2015 - Specification for topsoil and requirement for use.
- BS 5837:2012 Trees in relation to design, demolition and construction. Recommendations.
- BS 5930:2015+A1:2020 - Code of Practice for Ground Investigations.
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- BS EN 1997-1:2004 - Eurocode 7. Geotechnical design. General rules.
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- Environment Agency Report: SC050021/SR3 - Updated technical background to the CLEA model, 2009.
- Environment Agency Report: SC050021/SR4 - CLEA Software (Version 1.04 beta) Handbook, 2009.
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