



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

TE1750-TE-00-XX-RP-GE-001-V05

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FINAL

Prepared for:

Net World Sports

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**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : i of vii

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

CONTENTS

1.	INTRODUCTION.....	1
1.1.	Proposed Development	1
1.2.	Previous Reports	1
1.3.	Objectives	2
1.4.	Assumptions.....	2
2.	SITE DETAILS AND DESCRIPTION	3
3.	PREVIOUS INVESTIGATION FINDINGS	4
4.	PRELIMINARY CONCEPTUAL SITE MODEL.....	7
4.1.	Uncertainties.....	7
5.	FIELDWORK.....	11
5.1.	Scope of Ground Investigation.....	11
5.2.	Geoenvironmental Testing	13
5.3.	Geotechnical Testing.....	14
6.	GROUND CONDITIONS	15
6.1.	Strata Profile	15
6.2.	Strata Descriptions.....	17
6.3.	Obstructions.....	19
6.4.	Visual and Olfactory Evidence of Contamination	19
6.5.	Groundwater Observations During Fieldwork	19
6.6.	Groundwater Monitoring.....	19
7.	PRELIMINARY GEOTECHNICAL ASSESSMENT	21
7.1.	Determination of pH and Water-Soluble Sulphate.....	21
7.2.	Geotechnical Parameters.....	22
7.3.	Floors	27
7.4.	Earthworks.....	27
7.5.	Groundworks, Excavation Stability and Groundwater Dewatering	28
8.	HUMAN HEALTH RISK ASSESSMENT	29
8.1.	Data Interpretation Approach	29
8.2.	Selection of Generic Assessment Criteria (GAC)	29
8.3.	Human Health Risk Assessment.....	30
8.4.	Utilities	30
8.5.	Construction and Maintenance Workers.....	30
9.	CONTROLLED WATERS RISK ASSESSMENT	32



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : ii of vii

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

9.1.	Introduction	32
9.2.	Controlled Waters Environment Conceptual Site Model Summary	32
9.3.	Groundwater Testing	32
10.	GROUND GAS RISK ASSESSMENT	34
10.1.	Introduction	34
10.2.	Ground Gas Monitoring Results	34
10.3.	Ground Gas Risk Assessment	36
10.4.	Radon Gas	41
11.	REVISED CONCEPTUAL SITE MODEL AND GENERIC QUANTITATIVE RISK ASSESSMENT OF POLLUTANT LINKAGES	42
12.	PRELIMINARY WASTE MATERIALS CLASSIFICATION	46
12.1.	Introduction	46
12.2.	Preliminary Waste Materials Classification	47
12.3.	Materials Re-Use	49
13.	CONCLUSIONS AND RECOMMENDATIONS	50
13.1.	Conclusions	50
13.2.	Recommendations	51
14.	REGULATORY APPROVALS	52
15.	REFERENCES	53
16.	GLOSSARY OF TERMS	56

TABLES

Table 2.1 Current Site Overview.	3
Table 3.1 Report Review Summary	4
Table 3.2 Detailed UXO Report Summary	5
Table 4.1 Preliminary Assessment of Potential Pollutant Linkages (Continued on Next Page).	8
Table 5.1 Scope of Ground Investigation and Rationale	11
Table 5.2 Scope of Monitoring Installations	12
Table 5.3 Schedule of Chemical Testing for Human Health Risk Assessment and Preliminary Waste Soils Assessment.	13
Table 5.4 Schedule of Chemical Testing for Controlled Waters Risk Assessment.	13
Table 5.5 Geotechnical Laboratory Testing Schedule.	14
Table 6.1 Important Site Observations Summary	19
Table 6.2 Field Observations of Groundwater.	19
Table 6.3 Groundwater Monitoring Results Summary	20



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : iii of vii
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Table 7.1 Results of Soil pH Testing and Water-Soluble Sulphate Determination.....	21
Table 7.2 Soil Classification Test Results for cohesive soils	23
Table 7.3 Particle Size Classification	23
Table 7.4 Triaxial Testing Summary	25
Table 7.5 Possible Foundation Solutions	27
Table 7.6 Compaction Results Summary.....	27
Table 9.1 Summary of Measured Concentrations of Dissolved Phase Groundwater Potential Contaminants of Concern in Excess of WQS Values	33
Table 10.1 Ground Gas Monitoring Results Summary – Final Monitoring Programme of 4 No. Visits.....	35
Table 10.2 From Table 5.5a CIRIA C665 - Typical/idealised periods of monitoring (after Wilson et al, 2005)	36
Table 10.3 From Table 5.5b CIRIA C665 - Typical/idealised frequency of monitoring (after Wilson et al, 2005)	36
Table 10.4 Initial Worst-Case GSV Calculation – Unit 2 Zone	39
Table 10.5 Initial Worst-Case GSV Calculation – Detailed Planning Site excluding Unit 2 Zone	40
Table 11.1 Revised Assessment of Potential Pollutant Linkages (Continued on Next Page).	43
Table 12.1 Preliminary Materials Waste Classification	48

FIGURES

Figure 2-1 Recent Aerial Photograph from Groundsure	3
Figure 6-1 Schematic Drawing of Ground Conditions	16
Figure 7-1 Reported SPT-N Value with Depth	24
Figure 7-2 Shear strength from In-Situ Shear Vane Results	25



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : iv of vii
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

APPENDICES

Appendix A - Drawings

Appendix B - Exploratory Hole Logs

Appendix C - Geoenvironmental Soil Laboratory Results

Appendix D - Geoenvironmental Groundwater Laboratory Results

Appendix E - Geotechnical In Situ Fieldwork and Laboratory Results

Appendix F - Groundwater and Gas Monitoring Results

Appendix G - Photographs

Appendix H - Groundsure Report

Appendix I - Previous Site Investigation Report (Available as a Separate Document)

Appendix J - Definitions of Terms Used in Qualitative and Quantitative Risk Assessments

Appendix K - Human Health Assessment Criteria

Appendix L - Controlled Waters Risk Assessment

Appendix M - Assessment Criteria Applied for Ground Gas

Appendix N - Chemical and Geotechnical Test Sampling

Appendix O - Complying With Control of Asbestos Regulations 2012



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : v of vii

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

EXECUTIVE SUMMARY

Introduction	Tier Environmental was commissioned by Net World Sports to undertake a Ground Investigation for the areas in which full planning permission is sought for the site on Bryn Lane, Wrexham. The purpose of the investigation was to determine the nature and extent of soil and groundwater beneath the Site for the purposes of environmental and geotechnical assessment.
Proposed land use	The proposals comprise a commercial development, including industrial and storage & distribution uses, and ancillary retail/hotel floorspace with associated roadways, pavements and parking areas. As part of the proposals there are areas of soft landscaping across the site.
Site location and surrounding land uses	The site is located at Land North of Bryn Lane, Wrexham, LL13 9UT. The Site is currently in use as agricultural fields, with surrounding land uses comprising both residential to the north and industrial to the south of Bryn Lane. There are no nearby significant current land uses in the vicinity of the Site.
Previous investigations	Tier Environmental have previously conducted a Preliminary Risk Assessment for the Site: report reference: "TE1624-TE-00-XX-RP-GE-001-V03" dated June 2023. A full copy of this report is included within Appendix I. The PRA covers both the outline planning and detailed planning areas of the Site.
Fieldwork	Fieldwork was conducted between 5 th and 23 rd of June 2023, supervised by a suitably qualified Tier Environmental Engineer and comprised: • 21 No. machine excavated trial pits to depths between 3.00m bgl and 4.00m bgl. • 7 No. hand excavated trial pits to depths between 1.00m bgl and 1.20m bgl. • 11 No. cable percussive boreholes to depths between 10.00m bgl and 15.45m bgl. • 12 No. window sample boreholes to depths between 2.38m bgl and 5.45m bgl.
Laboratory testing	Samples of soil and groundwater were submitted for analysis of a range of metal, other inorganic and organic components including asbestos. Geotechnical testing was scheduled on selected samples. All testing was undertaken at accredited laboratories.
Ground conditions	The site is broadly underlain site wide by topsoil to depths of 0.18m to 0.46m bgl or Made Ground to depths of between 0.34m to 0.55m bgl, principally in the east of the site. These are underlain by natural soils comprised of Devensian Till, described as a firm becoming stiff and locally very stiff Clay. A more weathered horizon of brown clay was recorded in the order of 0.30m to 0.92m thick overlying the dark grey unweathered Till which was proven to the maximum drilled depth of 15.15m bgl. Sand lenses were also recorded near surface to 0.45m and 0.63m bgl. Localised areas of soft organic clays and peat are described within the east of the site within an infilled pond from depths of 0.33m to 1.90m bgl to depths of between 1.25m to 2.80m bgl. Groundwater was encountered between 0.20 to 7.30m bgl, with a shallow body of between circa 0.20-3.10m and a deeper body of between circa 4.50m to 7.30m bgl in the cable percussive boreholes. Trial pits recorded limited light seepage and some shallow inflow from Made Ground soils.
Ground stability	No geotechnical or stability issues were highlighted in the desk study review. Ground conditions were stable across the majority of Site. Locally softer cohesive materials associated with a former infilled pond were observed in the east of the Site but the trial pits both within this area and other areas across the Site were observed to be stable during the trial pitting works and no spalling was observed
Foundations and floor slabs	Given the encountered ground conditions and the nature of the proposed development, the most likely foundation solution would be a pads or similar traditional shallow foundations. Based on the range of shear strengths derived from <i>in-situ</i> shear testing, an allowable bearing capacity of circa 150-170kN/m² could be achieved at 1.20m bgl. Localised over excavation of organic rich Made Ground soils and Peat as recorded in TP117 and TP118 in the east of the site under proposed Unit 2 (which would not be considered suitable as a founding stratum and would arise to differential settlements beyond tolerable limits) may be required, with deepening of foundations or engineered replacement with suitable material. Piles could be considered where loadings cannot be transferred to shallow soils.
Sulphate class	The conclusion of the assessment is that a DS-4 and ACEC Class AC-4 may be required for buried concrete design purposes within Made Ground soils and for natural soils, based on results from groundwater testing. Further testing and detailed analysis may be considered to attempt to reduce this class. This class is being driven by elevated sulphate within 'deeper' groundwater sampled from the cable percussive boreholes. It should be noted that the level of 3200 mg/l is only just exceeding the threshold of 3000 mg/l for a DS-3 class.
Phosphorus	The Site is located within the River Dee and Bala Lake Designated Special Area of Conservation (SAC). The drainage strategy/design for the proposed development should therefore incorporate appropriate on-site and/or off-site mitigation measures which should be agreed with the regulatory authorities. The proposed development will involve the development of the majority of the site, with buildings and hardstanding proposed and demolishing the farm buildings at Little Acorns and Honey Suckle Cottage off Francis Lane. Not only



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : vi of vii

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

	will this act to inhibit infiltration into the ground, it will also largely remove the source of agricultural phosphate from the site. The site won topsoil will be reused within the development within screening bunds and soft landscaping, but agricultural fertilisers and manure will no longer be used on the site. Wastewater drainage from the proposed development will be either via the on-site combined sewer and the Five Fords WwTW or on-site wastewater treatment and discharge to the on-site surface water drainage system.
Contamination – Human Health	No measured soil concentrations of potential contaminants of concern have been reported in excess of Generic Assessment Criteria (GACs) protective of human health appropriate to the proposed land use. On this basis , it is not considered that the site represents a potential risk to end-users. Of the 23 No. of Made Ground samples submitted for asbestos screening, none were reported to contain asbestos.
Contamination – Controlled Waters	From a conceptual site model perspective, the Devensian Till is classified as a Secondary Undifferentiated Aquifer, and the bedrock geology is classified as a Principal Aquifer associated with Kinnerton Sandstone Formation in the western/northern parts of the Site and a Secondary A Aquifer associated with the Salop Formation comprising mudstone in the southern / southeastern part of the Site. There is an inferred fault located beneath the site orientated from southwest to northeast associated with these two bedrock formations. The site is within a Source Protection Zone Total Catchment 3 associated with the Principal Aquifer, and the nearest surface water receptor comprises an underground water course 110m west. There are no potable or non-potable water abstractions located within 1km of the Site. The low permeability cohesive Till deposits have been proven to depths of circa 15.00m bgl in this investigation and are recorded to depths of circa 26.0 to 38.0m bgl in nearby BGS records which is considered sufficient to provide protection of the underlying bedrock aquifers from any vertical migration of potential contaminants of concern. In addition, it is not considered that the proposed shallow foundation solution will form any preferential pathways to the underlying Principal Aquifer. On this basis the controlled waters sensitivity is considered to be low. Measured groundwater concentrations of copper, chromium, nickel, zinc, anthracene, Sum PAHs, fluoranthene, benzo(a)pyrene, total ammonia and electrical conductivity are not considered to present a risk to the controlled waters environment for the following reasons: • The potential for significant dilution between the Site and nearby significant water bodies; • The low sensitivity of the controlled waters environment; • The localised nature of those soil leachate concentrations in excess of the WQS and the absence of any reported widespread leachable concentrations; • The fact that the Site will incorporate buildings / hardstanding and a dedicated drainage system that shall reduce infiltration rates through the soils; • The absence of any nearby potable or non-potable groundwater abstractions; • The protection offered to the underlying Principal Aquifer by the presence of >10.0m of low permeability cohesive Till soils. • The absence of a nearby viable surface water body where a consumption of fish by humans exposure scenario would be realised for fluoranthene and benzo(a)pyrene.
Gas protection	Based on the WS105 being installed in a historically infilled pond, Tier have zoned the site into the proposed Unit 2 zone and the remainder of the site zone. For the Unit 2 Zone, a Gas Screening Value of 1.32 l/hr has been recorded based on a maximum peak methane concentration of 60.1%v/v and the maximum peak flow rate of 2.2 l/hr. Assessment of this gas screening value alone places <u>the Unit 2 Zone in a Characteristic Situation 3 – Moderate Risk Scenario in accordance with CIRIA C665 for which ground gas protection measures are required</u>. This is driven, however, by an instance of elevated peak methane from well WS105 only. This location targeted a historic infilled pond and logs described soils of organic clays and peat; this is considered the primary source for this elevated methane and carbon dioxide. It is anticipated that these materials will be removed as part of enabling works due to them being geotechnically unsuitable; this will remove the source of the elevated methane and carbon dioxide, effectively placing the Unit 2 Zone in the same Zone as the remainder of the site, i.e. a <u>Characteristic Situation 1 – Very Low Risk Scenario</u>. However, this would only be applicable if these soils are removed; if the soils remain then the whole of Unit 2 must remain classified as a CS3. For the remainder of the site Zone, a Gas Screening Value of 0.062 l/hr has been recorded based on a maximum carbon dioxide concentration of 15.4%v/v and a representative steady flow rate of 0.4l/hr. Assessment of this gas screening value alone places <u>the remainder of the Site Zone in a Characteristic Situation 1 – Very Low Risk Scenario for which no ground gas protection measures are required</u>.
Radon Requirements	The majority of the Site lies within an area where less than 1% of the properties are above the action level whereby no radon protection measures are required. The south of the site is within an area where 1-3% of properties are above the action levels and therefore confirmation that no basic radon protection measures are required should be confirmed with the Local Building Control Office. UK Radon indicates testing/protection may be required for high risk locations i.e. basements



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : vii of vii

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Other issues	A gas main runs through the Site in the East (oriented north to south) which meant excavations and boreholes could not be undertaken within this area; a recommended exclusion zone of 30m and compulsory 15m exclusion zone either side of the main was enforced by Wales and Western Utilities. Based on ecological sensitivity following an assessment on the Site; it was not possible to conduct intrusive investigations in the close proximity of existing trees, hedgerows and ponds. Tier Environmental did not undertake any machine operated intrusive investigation within 10m of these features.
Further works	Confirmation of the locations of the gas main that is to be diverted and the existing combined sewer.
Waste Soils Classification	Basic waste characterisation has determined that all Made Ground soils are non-hazardous. WAC testing has not been completed as part of these works and final waste disposal routes should be confirmed prior to removal from site. It is anticipated that natural soils will be suitable for disposal to an inert waste landfill.
Materials re-use	Subject to volumetric cut and fill requirements the majority of Made Ground materials and all of natural soil materials and may be considered chemically suitable for potential re-use subject to careful management and placement of materials and in line with an appropriate end-of-waste protocol such as WRAP Quality Protocol for Aggregates from Inert Waste, U1 Exemption or a Materials Management Plan in accordance with the CL:AIRE Definition of Waste Code of Practice (DoWCoP). Suitability for re-use would also be subject to confirmation of the geotechnical suitability depending on whether the materials are to be re-used in load bearing areas. This would need to be detailed in a supporting document. Please note that any previously landfilled or mining waste materials may not be appropriately subject to consideration under DoWCoP and may not be re-used under DoWCoP unless sufficient lines of evidence and agreement with the local Environment Agency Waste Team can be sought beforehand. In addition, Section 12.3 of this report includes statements with respect to re-use of excavated and stockpiled clean naturally occurring soils within the site and re-use on other sites. These statements are designed to provide a clear intention to reuse any clean, naturally occurring soils derived from future excavations at this Site (which may also include temporary future stockpiling these materials).



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 1 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

1. INTRODUCTION

Tier Environmental was commissioned by Net World Sports to undertake a Land Contamination Risk Management (LCRM) Ground Investigation for an area of land referred to as Bryn Lan – Detailed Planning, located on the land north of Bryn Lane, Wrexham, LL13 9UT (the “Site”).

The title of this report is in accordance with that described in the Land Contamination Risk Management guidance (available at <https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm>) which has superseded CLR 11:

Stage 1:

- LCRM Tier 1 Preliminary Risk Assessment Report
- LCRM Tier 2 Generic Quantitative Risk Assessment Report

1.1. Proposed Development

This report relates to the detailed/full planning application areas associated with hybrid planning application reference P/2023/0497. A separate report has been produced by Tier in relation to the outline planning application areas of the hybrid application

Under current proposals the development will comprise:

- Demolition of existing buildings, site clearance and preparation works, including removal of vegetation and reprofiling of topsoil, where necessary;
- Construction of a new warehouse unit, providing 33,595 sqm Gross External Area (GEA) for B1c (light industry appropriate in a residential area), B2 (general industrial) and B8 (storage & distribution) uses (Unit 2);
- Construction of 8 new smaller units (Units 3-7; 14-16), providing a total of 29,659 sqm GEA for B1c (light industry appropriate in a residential area), B2 (general industrial) and B8 (storage & distribution) uses;
- Access and parking provision, including new access junctions, internal roads, service yards and car and HGV parking. Two new junctions are proposed (in detail) providing vehicular access, as well as cycle and pedestrian access, from Bryn Lane/Industrial Estate Road with an additional access road for a substation. Car parking spaces, HGV trailer spaces and HGV lorry spaces are proposed across the application site;
- Retention and enhancement of some existing on-site green spaces and provision of landscaping around the application site; and
- Implementation of drainage/attenuation measures.

Areas of proposed soft landscaping are located across the Site as presented in Appendix A. As such, in accordance with the ‘*Updated technical background to the CLEA model*’ (Environment Agency, 2009) and ‘*Suitable 4 Use Levels*’ (LQM / CIEH 2015) the proposed generic land use for this development is Commercial / Industrial.

1.2. Previous Reports

Tier Environmental have previously conducted a Preliminary Risk Assessment for the Site: report reference: “TE1624-TE-00-XX-RP-GE-001-V03” dated June 2023. A full copy of this report is included within Appendix I. The PRA covers both the outline planning and detailed planning areas of the Site.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 2 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

1.3. Objectives

Taking into account the proposed development of the Site, the objectives of this appraisal were:

- To determine current ground and groundwater conditions.
- To determine the potential risks to human health and the wider environment.
- To provide a preliminary waste soils classification.
- To determine potential risks posed to the Site from hazardous ground gases and / or vapours.
- Provide preliminary outline remedial measures to manage any identified risks.
- To provide preliminary geotechnical parameters to inform floor slab and foundation recommendations.

1.4. Assumptions

The following assumptions are made in this report:

- It is assumed that ground levels will not change significantly from those described in this report or as shown on proposed development drawings. If this is not the case, then amendments to the recommendations made in this report may be required.
- The ground investigation has been designed with due consideration of known or suspected constraints (including underground services and access constraints).
- Any references to observations of suspected asbestos-containing materials are for information only and should be verified by a suitably qualified asbestos specialist and/or confirmed by laboratory analysis.
- The use of the term 'Topsoil' within this report is based on a visual identification only and that these materials have not been classified in accordance with BS3882:2015.
- The use of the terms 'shallow' and 'deep' within this report (from a geotechnical perspective) assume *typically* between ground level to circa 3.00m below ground level (bgl) for 'shallow' and greater than 3.00m bgl regarded as 'deep'.
- The comments and opinions presented in this report are based on the findings of the desk study and ground conditions encountered during intrusive investigation works performed by Tier Environmental and the results of tests carried out within one or more laboratories. There may be other conditions prevailing on the Site which have not been revealed by this investigation and which have not been taken into account by this report.
- Responsibility cannot be accepted for any conditions not revealed by this investigation. Any diagram or opinion on the possible configuration of the findings is conjectural and given for guidance only. Confirmation of intermediate ground conditions should be undertaken if deemed necessary.

This report has been prepared for the sole use of Net World Sports. No other third party may rely upon or reproduce the contents of this report without the written approval of Tier Environmental. If any unauthorised third party comes into possession of this report, they rely on it entirely at their own risk and the authors do not owe them any Duty of Care or Skill.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 3 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

2. SITE DETAILS AND DESCRIPTION

Table 2.1 Current Site Overview.

Site name	Bryn Lane – Full Planning
Site address	Land north of Bryn Lane, Wrexham, LL13 9UT. A site location plan is included as Drawing No. TE1750-TE00-XX-DR-GE-001-V01 within Appendix A.
National Grid Reference (NGR)	338807, 350938
Approximate Site area	20.06ha
Site shape	The Site is irregular in shape
Current land use on the Site	The Site is predominantly agricultural with both grassed and cropped fields, with a residential / farm property (Little Acorns) located in the southern extent of the Site, and a residential property, Honeysuckle Cottage, located in the northern extent of the Site. The agricultural fields are delineated by trees and hedgerows.
Surrounding land uses	The Site is surrounded by agricultural land, residential properties to the northwest and industrial buildings associated with the industrial estate to the south of Bryn Lane.
General topography and ground levels	The land slopes from approximately 40m AOD in the west to between 27 and 31m AOD in the east and northeast which follows the general topographical trend in the surrounding area.

An aerial photograph (from publicly available online maps) of the Site is shown below with the wider site boundary in blue and the detailed application site boundary shown in red.

Figure 2-1 Recent Aerial Photograph from Groundsure





GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 4 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

3. PREVIOUS INVESTIGATION FINDINGS

Tier Environmental have previously conducted a Preliminary Risk Assessment for the Site (report reference: TE1624-TE-00-XX-RP-GE-001-V03, dated June 2023). A full copy of this report is included within Appendix I. The PRA covers both the outline planning and detailed planning areas of the Site.

A Detailed Unexploded Ordnance Risk Assessment has also been completed by 1st Line Defence Ltd (Ref: DA18240-00, dated July 2023).

Table 3.1 Report Review Summary

Introduction	Tier Environmental was commissioned by Net World Sports to undertake a desk study and Phase I Preliminary Risk Assessment for the proposed commercial development at Bryn Lane, Wrexham. The purpose of this investigation was to establish land use history and review the available information to determine the geoenvironmental setting of the Site and develop a preliminary conceptual site model with due consideration of potential soil and groundwater contamination, hazardous ground gases and mining.
Proposed land use	The proposals comprise a commercial development, including industrial and distribution, and ancillary retail/hotel floorspace.
Site location and surrounding land uses	The site is located at Bryn Lane, Wrexham, nearest post code LL13 9XW. To the north and east of the site the area is agricultural with a few residential houses and Wrexham Industrial Estate to the west and south of the site and the Clays Golf Driving Range and golf Course is west of the site. There are no nearby significant current land uses in the vicinity of the Site.
Site history	The Site was historically agricultural. Approximately 3 No. wells were identified in the south of the site within an area which will remain undeveloped under the current scheme. Pond locations and sizes are shown to vary over time indicating the potential for some of them to have been potentially infilled. Ridley View (shown in the present day location of Little Acorns) was developed in the south by 1992 (residential / farm). Pertinent surrounding land uses include farms, the Royal Ordnance Factory (Wrexham) to the south of the Site (as close as 20m south) and associated buildings and tanks etc, a clothing factory to the south (60m south), Wrexham Industrial Estate (25m south at its closest point). Given that the Site itself did not form part of the ROF Wrexham site it is not considered that there are any risks from explosives at the Site.
Geology, Hydrogeology and Hydrology	No previous ground investigation reports have been provided to Tier Environmental; however, available BGS information does not indicate the presence of any artificial ground on the Site (although land immediately south is shown to comprise 'Landscaped Ground'). Localised Made Ground within the Little Acorns farm/residential property and Honeysuckle Cottage area and potentially within historically infilled ponds may be anticipated. Superficial deposits comprise a Secondary Undifferentiated Aquifer associated with Devensian Till – Diamicton which has been proven in BGS logs to comprise cohesive materials locally to depths of Circa 26 to 38m bgl which is considered sufficient to provide protection of the underlying bedrock aquifers from any vertical migration of potential contaminants of concern. Bedrock comprises a Principal Aquifer associated with Kinnerton Sandstone Formation in the western/northern parts of the Site and a Secondary A Aquifer associated with the Salop Formation comprising mudstone in the southern / southeastern part of the Site. There is an inferred fault located beneath the site orientated from southwest to northeast associated with these two bedrock formations. There is a Source Protection Zone Total Catchment 3 located beneath the Site associated with the Principal Aquifer; however, the thickness of cohesive Till above this is considered to provide sufficient protection from any shallow contaminants of concern. The nearest surface water receptor comprises an underground water course 110m west. There are no potable or non-potable water abstractions located within 1km of the Site. On this basis the controlled waters sensitivity is considered to be low. The Site is located within the phosphate sensitive freshwater catchment of the River Dee and Bala Lake Special Area of Conservation (SAC).
Ground Gases	There are no landfills located within 250m of the Site. The only viable potential source of ground gases is therefore on-site localised Made Ground / potentially infilled ponds and off-site Made Ground.
Radon Requirements	The Site is not located within a high risk radon area and therefore basic radon protection measures are not currently required for the proposed development. Testing existing buildings and fitting radon prevention in new buildings might still be considered, particularly if there is a high risk location such as a routinely occupied basement.
Ecological Sensitivity	The Site does not lie within an ecologically sensitive area.
Potential contaminative features	There are 4 No unspecified tanks south of the Site within 250m. A farm is located in the southern part of the Site and a residence in the north of the site. Numerous potentially infilled ponds have been identified within the site.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 5 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Mining and quarrying	The Site Is not located within a mining area or an area subject to historic quarrying.
Previous investigations	Tier Environmental is not aware of any previous intrusion ground investigations within the site.
Phosphates	The Site is located within the River Dee and Bala Lake Designated Special Area of Conservation (SAC). The drainage strategy/design for the proposed development should therefore incorporate appropriate on-site and/or off-site mitigation measures which should be agreed with the regulatory authorities.
Unexploded Ordnance	The UXO risk is considered to be low based on publicly available maps; however, given the proximity of the former Royal Ordnance Factory, Wrexham immediately south of the Site it is recommended that a detailed UXO desk study is carried out for the Site.
Preliminary Conceptual Site Model Summary	Moderate / low to moderate risks have been identified for human health receptors and low risks have been identified for the controlled waters environment from inorganic, organic and asbestos impacts within any localised Made Ground associated with the former agricultural land use and farm in the south of the Site, Honeysuckle Cottage, located in the northern extent of the Site, and any potentially infilled ponds. Moderate / low risks to human health have been identified from the off-site former ROF Wrexham located immediately south of the Site. Moderate to moderate / low risks have been identified associated with hazardous ground gases generated from on-site localised Made Ground / potentially infilled ponds and off-site Made Ground. Low risk has been identified with regard to phosphates within treated wastewater affecting the River Dee and Bala Lake SAC.
Waste Soils Classification	Based on the history of the Site and the anticipated potential contaminants of concern, it is unlikely that significant quantities of hazardous waste soil materials will be encountered; however, some may be locally present beneath some areas of the Site (potential infilled ponds and asbestos containing materials within demolition rubble at gate entrances). This will be subject to confirmatory investigation, sampling, laboratory analysis and waste classification in accordance with the Guidance on the Classification and Assessment of Waste (WM3).
Materials re-use	Subject to volumetric fill requirements and a future assessment of suitability of re-use (both chemically and geotechnically), some materials may be considered for potential re-use in line with an appropriate end-of-waste protocol such as WRAP Quality Protocol for Aggregates from Inert Waste, U1 Exemption or a Materials Management Plan in accordance with the CL:AIRE Definition of Waste Code of Practice (DoWCoP).
Further works	An intrusive ground investigation is currently underway that will further refine the preliminary conceptual site model and confirm the baseline phosphate concentrations across the site. It is recommended that a full UXO desk study is carried out for the Site.

Table 3.2 Detailed UXO Report Summary

German Ari Delivered UXO Risk	During WWII, the site was situated within Wrexham Rural District, which was subject to an overall very low density of bombing with an average of 3.8 items of recorded ordnance per 1,000 acres. Any bombing in the region that did occur appears to have been largely opportunistic and as a result of its position on the flight path to the important target of Liverpool. The only viable bombing target in the area was the nearby Royal Ordnance Factory (ROF) Wrexham. - Anecdotal sources attest that while the Luftwaffe may have been aware of the presence of ROF Wrexham, it was never struck by German bombing. This may have been due to its relatively isolated location. Despite the available source base being somewhat limited, no evidence of any bombing within the site footprint or the wider vicinity could be found. - Available high-resolution imagery of the site taken following the war indicates no evidence of ground disturbances or debris which could be indicative of on- site bomb damage. This is corroborated by pre- and post-war OS mapping which show no significant changes to the site and its immediate vicinity. - While the majority of the site did contain open agricultural ground, the area is considered likely to have been relatively frequently accessed and observed given both the presence of adjacent roadways and structures, as well as the nearby presence of ROF Wrexham. Ground conditions onsite are also anticipated to have been reasonably conducive to the detection of UXO, given the relatively good condition of the open land and the presence of a structure within the north of the site. - In summary, given the very low bombing density of Wrexham Rural District, and the lack of evidence to suggest that any bombing occurred within ROF Wrexham or its wider vicinity, the site is not considered to be at an elevated risk of contamination from German aerial delivered UXO. As such, the site has been assessed to be at a Low Risk of German UXO.
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**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 6 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

UXO Risk Assessment	1st Line Defence has assessed that there is an overall Low Risk from German and anti-aircraft unexploded ordnance at the site of proposed works. There is also an assessed Low Risk from Allied unexploded ordnance.
Recommended Risk Mitigation Measures	The following risk mitigation measures are recommended to support the proposed works at the Bryn Lane, Wrexham site: • UXO Risk Management Plan (a free template to fill in which includes a set of guidelines, a suspect UXO action flowchart, and an example risk management plan) • Site Specific UXO Awareness Briefings to all personnel conducting intrusive works.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 7 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

4. PRELIMINARY CONCEPTUAL SITE MODEL

Based on the information provided in the Preliminary Risk Assessment report a combined preliminary conceptual site model and conceptual exposure model was developed for the proposed future land use and has been reproduced below. This summarises the understanding of surface and sub-surface features, the potential contaminant sources, transport pathways and receptors. In assessing the likely contaminants of concern present at the Site, reference has also been made to Defra and Environment Agency supporting documentation. A preliminary qualitative risk assessment has also been made of the likelihood of the linkage operating and its potential significance in accordance with CIRIA C552.

The potential pollutant linkages identified and the qualitative risk assessment for these are presented in Table 4.1 below. The terms used in the preliminary qualitative risk assessment are defined in Appendix J.

4.1. Uncertainties

The following uncertainties exist in the preliminary conceptual model:

- The presence of any features unrecorded by the historic maps.
- Any unrecorded geological features.
- Any unrecorded pollution events during the Site's history.



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 8 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Table 4.1 Preliminary Assessment of Potential Pollutant Linkages (Continued on Next Page).

Justification / Comments
• Currently, the Site comprises predominantly agricultural use with a residential / farm property (Little Acorns) located in the southern extent of the Site, and Honeysuckle Cottage located in the northern extent of the Site. The agricultural fields are delineated by localised copses of trees and hedgerows. The majority of the Site is covered in grass with the exception of the area at the Little Acorns and Honeysuckle Cottage where some localised hardstanding is anticipated. Little Acorns appear to include barns and areas of equipment potentially associated with agricultural use (including a possibly horse walker). Ponds appear to be located in the western and southern parts of the Site. • The Site was historically agricultural with approximately 3 No. wells identified in the southern part of the Site. Pond locations and sizes are shown to vary over time indicating the potential for some of them to have been potentially infilled. Ridley View (shown in the present day location of Little Acorns) was developed in the south by 1992 (residential / farm). • Pertinent surrounding land uses include farms, the Royal Ordnance Factory (Wrexham) to the south of the Site (as close as 20m south) and associated buildings and tanks etc, a clothing factory to the south (60m south), Wrexham Industrial Estate (25m south at its closest point). Given that the Site itself did not form part of the ROF Wrexham site it is not considered that there are any risks from explosives at the Site. • No previous ground investigation reports have been provided to Tier Environmental; however, available BGS information does not indicate the presence of any artificial ground on the Site (although land immediately south is shown to comprise 'Landscaped Ground'). Localised Made Ground within the Little Acorns farm/residential property and Honeysuckle Cottage area and potentially within historically infilled ponds may be anticipated. • Superficial deposits comprise a Secondary Undifferentiated Aquifer associated with Devensian Till – Diamicton which has been proven in BGS logs to comprise cohesive materials locally to depths of Circa 26 to 38m bgl which is considered sufficient to provide protection of the underlying bedrock aquifers from any vertical migration of potential contaminants of concern. Bedrock comprises a Principal Aquifer associated with Kinnerton Sandstone Formation in the western/northern parts of the Site and a Secondary A Aquifer associated with the Salop Formation comprising mudstone in the southern / southeastern part of the Site. There is an inferred fault located beneath the site orientated from southwest to northeast associated with these two bedrock formations. • There is a Source Protection Zone Total Catchment 3 located beneath the Site associated with the Principal Aquifer; however, the thickness of cohesive Till above this is considered to provide sufficient protection from any shallow contaminants of concern. The nearest surface water receptor comprises an underground water course 110m west. There are no potable or non-potable water abstractions located within 1km of the Site. On this basis the controlled waters sensitivity is considered to be low. • There are no landfills located within 250m of the Site and the Site is not located within a high risk radon affected area. The only viable potential source of ground gases is therefore on-site localised Made Ground / potentially infilled ponds and off-site Made Ground. • The Site is located within the phosphate sensitive freshwater catchment of the River Dee and Bala Lake Special Area of Conservation (SAC). The proposed development will involve covering the site mostly in buildings and hardstanding and demolishing the farm buildings at Little Acorns. Not only will this act to inhibit infiltration into the ground, it will also largely remove the source of agricultural phosphate from the site. The site won topsoil will be reused within the development within screening bunds and soft landscaping, but agricultural fertilisers and manure will no longer be used on the site. Wastewater drainage from the proposed development will be either via the on-site combined sewer and the Five Fords WwTW or on-site wastewater treatment and discharge to the on-site surface water drainage system.



GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 9 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Source	Potential Contaminants of Concern	Pathway	Receptor	Consequence	Probability	Qualitative Risk Assessment
Localised Made Ground associated with the former agricultural land use and farm in the south of the Site and any potentially infilled ponds.	Metals PAHs pH Hexavalent chromium	Direct contact, dust inhalation and ingestion	Future site users (commercial)	Medium	Likely	Moderate Risk
			Adjacent site users residential/commercial	Medium	Low Likelihood	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Medium	Likely	Moderate Risk
		Migration of mobile contaminants from Made Ground soils to adjacent sites along services and conduits	Adjacent site users residential/commercial	Medium	Low Likelihood	Moderate / Low Risk
		Migration via water pipes	Future site users (commercial)	Medium	Likely	Moderate Risk
		Lateral and/or vertical migration of mobile contaminants.	Aquifer 1 - Secondary (Undifferentiated) Aquifer associated with Devensian Till	Mild	Low Likelihood	Low Risk
			Aquifer 2 - Principal Aquifer associated with Kinnerton Sandstone Formation	Medium	Unlikely	Low Risk
			Aquifer 3 - Secondary A Aquifer associated with Salop Sandstone Formation	Medium	Unlikely	Low Risk
			Culverted watercourse located approximately 110m west.	Mild	Low Likelihood	Low Risk
	Naphthalene (a semi-volatile PAH) TPH / BTEX / MTBE Phenols	Vapour inhalation, direct contact, dust inhalation and ingestion	Future site users (commercial)	Medium	Likely	Moderate Risk
			Adjacent site users residential/commercial	Medium	Low Likelihood	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Medium	Likely	Moderate Risk
		Migration of mobile contaminants from Made Ground soils to adjacent sites along services and conduits	Adjacent site users residential/commercial	Medium	Low Likelihood	Moderate / Low Risk
		Migration via water pipes	Future site users (commercial)	Medium	Likely	Moderate Risk
		Lateral and/or vertical migration of mobile contaminants.	Aquifer 1 - Secondary (Undifferentiated) Aquifer associated with Devensian Till	Mild	Low Likelihood	Low Risk
			Aquifer 2 - Principal Aquifer associated with Kinnerton Sandstone Formation	Medium	Unlikely	Low Risk
			Aquifer 3 - Secondary A Aquifer associated with Salop Sandstone Formation	Medium	Unlikely	Low Risk
			Culverted watercourse located approximately 110m west.	Mild	Low Likelihood	Low Risk
	Asbestos	(Dust migration and) dust inhalation	Future site users (commercial)	Medium	Likely	Moderate Risk
			Adjacent site users residential/commercial	Medium	Low Likelihood	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Medium	Likely	Moderate Risk
Former ROF Wrexham and associated tanks located off-site	TPH / BTEX / MTBE VOCs / SVOCs Free phase product	Vapour inhalation, direct contact, dust inhalation and ingestion	Future site users (commercial)	Medium	Low Likelihood	Moderate / Low Risk
			Adjacent site users residential/commercial	Medium	Low Likelihood	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Medium	Low Likelihood	Moderate / Low Risk
		Migration of mobile contaminants from Made Ground soils to adjacent sites along services and conduits	Adjacent site users residential/commercial	Medium	Low Likelihood	Moderate / Low Risk
		Migration via water pipes	Future site users (commercial)	Medium	Low Likelihood	Moderate / Low Risk
		Lateral and/or vertical migration of mobile contaminants.	Aquifer 1 - Secondary (Undifferentiated) Aquifer associated with Devensian Till	Mild	Low Likelihood	Low Risk
			Aquifer 2 - Principal Aquifer associated with Kinnerton Sandstone Formation	Medium	Unlikely	Low Risk
			Aquifer 3 - Secondary A Aquifer associated with Salop Sandstone Formation	Medium	Unlikely	Low Risk



GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 10 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Source	Potential Contaminants of Concern	Pathway	Receptor	Consequence	Probability	Qualitative Risk Assessment
			Culverted watercourse located approximately 110m west.	Mild	Low Likelihood	Low Risk
Phosphates from the proposed development from staff wastewater discharges containing human excreta and detergents.	Phosphates	Discharge of treated wastewater into the River Dee or tributaries	River Dee and Bala Lake SAC	Medium	Unlikely	Low Risk
On-site localised Made Ground / potentially infilled ponds and off-site Made Ground.	Hazardous ground gasses (methane, carbon dioxide, hydrogen sulphide, carbon monoxide and depleted oxygen)	Inhalation (indoor and outdoor)	Future site users (commercial)	Severe	Low Likelihood	Moderate Risk
			Adjacent site users residential/commercial	Severe	Unlikely	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Severe	Low Likelihood	Moderate Risk
		Migration of hazardous ground gases from beneath the Site to adjacent sites along services or other preferential conduits	Adjacent site users residential/commercial	Severe	Unlikely	Moderate / Low Risk
		Migration of ground gas / explosion	Buildings and services	Severe	Unlikely	Moderate / Low Risk

For definition of the terms used in the qualitative risk assessment, please see Appendix J.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 11 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

5. FIELDWORK

The information contained in this report is limited to areas of land accessible during the ground investigation within the Site boundary, as indicated on the Site plan, presented in Appendix A as Drawing No. TE1750-TE-00-XX-DR-GE-001-V01.

Tier Environmental scoped the intrusive ground investigation using guidance presented in:

- BS 10175:2011+A2:2017;
- Land Contamination Risk Management (LCRM) - <https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm>;
- BS 5930:2015+A1:2020;
- BS EN 1997:2004 and 2007.

Tier Environmental's standard strata description criteria are compliant with the above guidance.

5.1. Scope of Ground Investigation

The ground investigation was conducted between 5th and 23rd June 2023 and was supervised by a suitably qualified Tier Environmental engineer. Table 5.1 below provides a summary of the exploratory holes completed and rationale. Exploratory hole locations are presented on Drawing No. TE1750-TE-00-XX-DR-GE-002-V01.

Table 5.1 Scope of Ground Investigation and Rationale

Exploratory Hole Type	Exploratory Hole Reference	Exploratory Hole Depths (m bgl)	Rationale
Trial pits	TP101 to TP121	3.00m to 4.00m	To confirm the shallow ground conditions across the Site, relatively shallow groundwater presence and rate of inflow, stability of excavations, and to enable shallow soil sampling for geotechnical and geoenvironmental parameters.
	TP117, TP118, TP119, TP121	3.20m to 4.20m	Completed within the vicinity of a historic pond to determine the shallow ground conditions and presence of any infill material
Window sample boreholes	WS101 to W1S04 and W1S06 to WS112	2.38m to 5.45m	To confirm the shallow and deep ground conditions across the Site, conduct <i>in situ</i> geotechnical tests, facilitate soil sampling for geotechnical and geoenvironmental parameters and installation of combined ground gas and groundwater monitoring wells.
	WS105	5.45m	Completed within the vicinity of a historic pond to determine the shallow ground conditions and presence of any infill material, and installation of combined ground gas and groundwater monitoring well.
Cable percussion boreholes	CP101 to CP111	10.00m to 15.45m	To confirm the shallow and deep ground conditions across the Site, conduct <i>in situ</i> geotechnical tests, facilitate soil sampling for geotechnical and geoenvironmental parameters and installation of combined ground gas and groundwater monitoring wells.
Hand dug pits	HDP101 to HDP107	1.00m bgl to 1.20m bgl	To confirm the shallow ground conditions across the Site, relatively shallow groundwater presence and rate of inflow, and to enable shallow soil sampling for geoenvironmental parameters.

The following constraints were identified during the ground investigation works:



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 12 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

- An intermediate pressure gas main runs through the east of the Site (oriented north to south). Wales and Western utilities marked out the gas main and set up a recommended 30m exclusion zone and compulsory 15m exclusion zone either side of the gas main, meaning no intrusive investigation could be conducted within this area.
- Following a third party ecological investigation on Site, the existing trees, hedgerows and ponds were detailed to be ecologically sensitive; therefore Tier Environmental did not undertake any machine operated intrusive investigation within 10m of these areas.
- 2 No. existing occupied houses are located within the site boundary; however, it was not possible to complete works within these areas.
- A combined sewer is present in the west of the site (oriented north to south) an exclusion zone was also set up around this service

Table 5.2 Scope of Monitoring Installations

Exploratory Hole Location	Strata Targeted	Slotted Response Zone (m bgl)	Rationale
CP101	Till	1.00 to 15.00	Targeting shallow ground gas and groundwater body
CP102	Till	1.00 to 10.00	Targeting shallow ground gas and groundwater body
CP103	Till	1.00 to 15.00	Targeting shallow ground gas and groundwater body
CP104	Till	1.00 to 10.00	Targeting shallow ground gas and groundwater body
CP105	Till	1.00 to 10.00	Targeting shallow ground gas and groundwater body
CP106	Till	1.00 to 10.00	Targeting shallow ground gas and groundwater body
CP107	Till	1.00 to 15.00	Targeting shallow ground gas and groundwater body
CP108	Till	1.00 to 10.00	Targeting shallow ground gas and groundwater body
CP109	Till	1.00 to 10.00	Targeting shallow ground gas and groundwater body
CP110	Till	1.00 to 15.00	Targeting shallow ground gas and groundwater body
CP111	Till	1.00 to 10.00	Targeting shallow ground gas and groundwater body
WS101	Till	1.00 to 5.00	Targeting shallow ground gas and groundwater body
WS105	Made Ground, Peat and Till	1.00 to 5.00	Targeting shallow ground gas from historic infilled pond and groundwater body
WS107	Till	1.00 to 4.00	Targeting shallow ground gas and groundwater body
WS108	Till	1.00 to 5.00	Targeting shallow ground gas and groundwater body
WS111	Till	1.00 to 5.00	Targeting shallow ground gas and groundwater body
WS112	Till	1.00 to 5.00	Targeting shallow ground gas and groundwater body

Depths and accurate descriptions of strata and groundwater observations made during investigation works, together with details of the samples recovered, are presented on the Engineer's exploratory hole records in Appendix B.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 13 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

5.2. Geoenvironmental Testing

Sampling and QA/QC protocols are presented in Appendix N. Tier Environmental's schedule of chemical laboratory testing is presented in Table 5.3 and Table 5.4. The testing was carried out by Element Materials Technology, a UKAS and MCerts (where appropriate for soils analysis) accredited laboratory.

Human Health and Preliminary Waste Classification Laboratory Testing

Based upon the conclusions of the preliminary risk assessment, Tier Environmental scheduled chemical laboratory testing on selected soil samples. The purpose of the testing was to:

- Determine the concentration and spatial distribution of potential contaminants of concern in the Made Ground.
- Determine the chemical composition and properties of the shallow natural soils.
- Determine the concentration of phosphate on Site.
- Undertake a *preliminary* soils waste classification and waste disposal route determination.

Table 5.3 Schedule of Chemical Testing for Human Health Risk Assessment and Preliminary Waste Soils Assessment.

Laboratory analysis	Made Ground 1 (Topsoil)	Made Ground 2 (Clay)	Made Ground 3 (Sand)	Made Ground 4 (Pond Infill)	Natural Soils (Till)
Tier Environmental soil suite*	14	7	1	2	3
Asbestos screen	15	7	1	3	0
Speciated TPH / BTEX / MTBE	14	7	0	3	1
VOCs / SVOCs	0	2	0	0	0
Organophosphorus pesticides	11	4	1	1	2
Organophosphate at PO ₄	7	4	1	1	6
Organophosphate at PO ₄ (low)	7	4	1	1	6
BRE SD1	0	0	0	0	20
Standard Explosives Suite	0	0	0	1	0

*For definition of Tier Environmental analytical suites, please see Appendix N. NA - not applicable.

Controlled Waters Laboratory Testing

Based upon the conclusions of the preliminary risk assessment, Tier Environmental scheduled chemical laboratory testing on selected groundwater samples. The purpose of the testing was to:

- Determine the dissolved phase concentrations of potential contaminants of concern within groundwater beneath the Site;

Table 5.4 Schedule of Chemical Testing for Controlled Waters Risk Assessment.

Laboratory analysis	Groundwater
Tier Environmental groundwater suite*	8



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 14 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Laboratory analysis	Groundwater
Speciated TPH / BTEX / MTBE	8
Organophosphorus pesticides	8
Organophosphate at PO ₄	8
Organophosphate at PO ₄ (low)	8

*For definition of Tier Environmental analytical suites, please see Appendix N. NA - not applicable.

5.3. Geotechnical Testing

Geotechnical laboratory testing was scheduled by Tier Environmental on selected samples as presented in Table 5.5. The testing was performed by Murray Rix Northern Ltd, a UKAS and MCerts (where appropriate for soils analysis) accredited laboratory. Test certificates including details of appropriate testing standards are presented in Appendix E and discussed in Section 7, below.

Table 5.5 Geotechnical Laboratory Testing Schedule.

Test	Stratum type	Number of tests	Rationale
1. Classification			
Atterberg limit (including Moisture Content)	Till	14	a) Volume change potential. b) Plasticity assessment (comply with Eurocode 7 description) c) Consistency Index. d) Determine soil type (e.g., clay/silt). e) Use as an empirical guide to soil shear strength
Particle size distribution (wet/dry sieve)	Till	8	a) Classify soils for earthworks purposes. b) Establish type of soil (comply with Eurocode 7 description).
2. Compaction			
2.5 kg rammer dry density/moisture content relationship test	Till	12	Establish maximum dry density and optimum moisture content of materials to assess suitability for reuse within earthworks
3 .Compressibility			
One-dimensional consolidation	Till	8	Determine the long term consolidation behaviour of cohesive soils.
4. Shear strength (total stress)			
Unconsolidated undrained triaxial ("quick undrained triaxial")	Till	22	Quantitative means of determining undrained shear strength of soils for: a) use in bearing capacity calculations; b) modelling the short term behaviour of slopes and retaining structures; c) pile design; d) determining suitability of cohesive materials for vibro-replacement ground improvement techniques.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 15 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

6. GROUND CONDITIONS

The following section provides a summary of the ground conditions encountered during the ground investigation including strata profile, obstructions and visual / olfactory evidence of contamination. Exploratory hole logs are provided in Appendix B.

Photographs of ground investigation works are provided in Appendix G.

6.1. Strata Profile

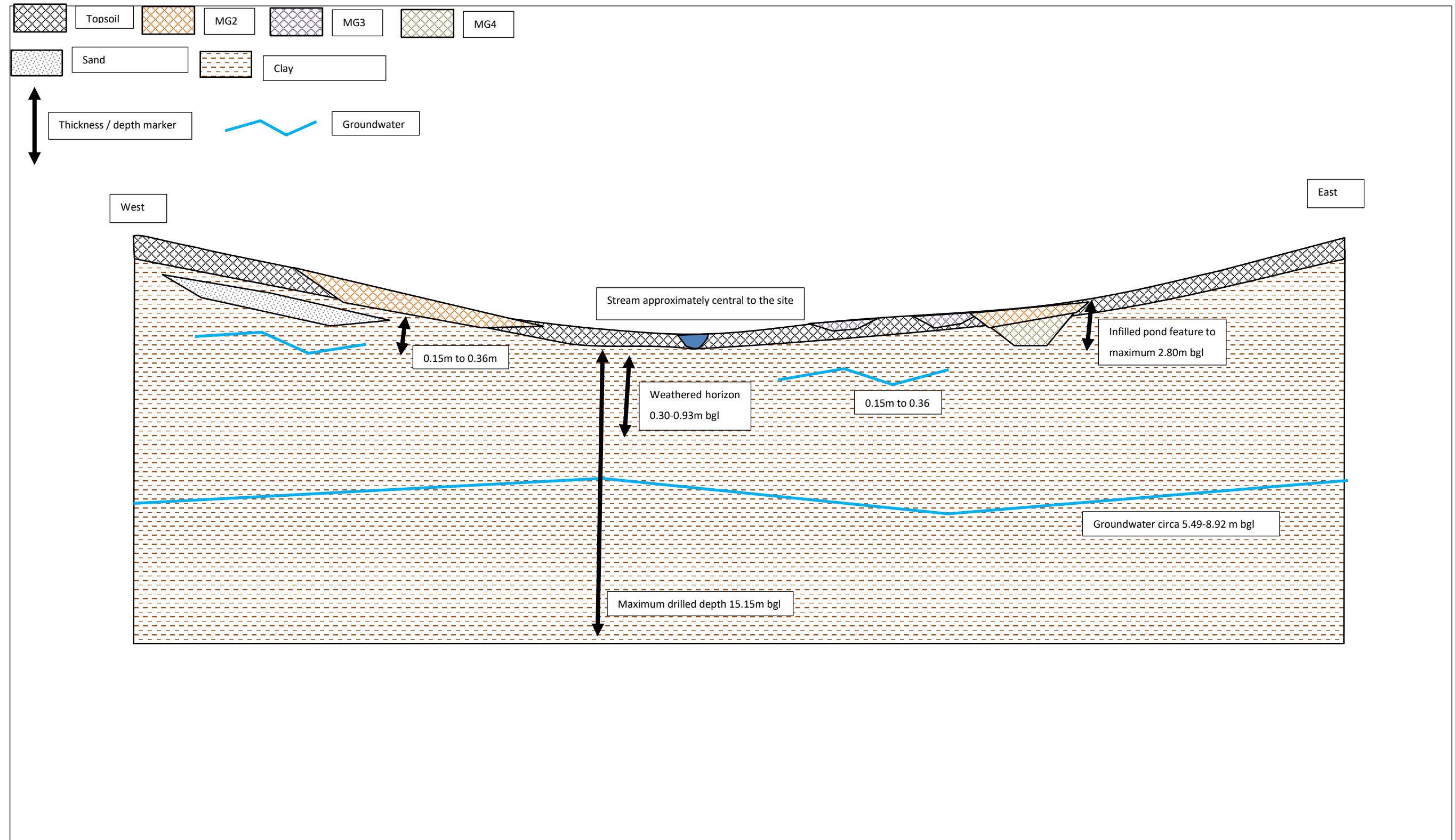
Figure 6-1 presented below provide a schematic summary of the ground conditions beneath the Site. The distinct populations of strata identified have been numbered and correspond with the more detailed descriptions below.



GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 16 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Figure 6-1 Schematic Drawing of Ground Conditions





GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 17 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

6.2. Strata Descriptions

Made Ground – MG1

Locations encountered	HDP104, HDP105, HDP107, TP101 to TP121, WS101 to WS104, WS106 to WS112, CP101 to CP111
Depths encountered from top of stratum (range)	Ground Level
Depths encountered to base of stratum (range)	0.18m to 0.46m bgl
Thickness (range)	0.18m to 0.46m
Spatial location on site	Widespread across site
General description	A Topsoil described as a dark brown, slightly gravelly, clayey, fine to coarse Sand or firm to stiff, orangish brown, sandy, gravelly CLAY. The gravel is fine to medium, angular to subrounded of mudstone and limestone. Frequent rootlets throughout

Made Ground – MG2

Locations encountered	HDP102, HDP103, HDP106, TP117, TP118, WS105, WS111
Depths encountered from top of stratum (range)	Ground Level to 1.25m bgl
Depths encountered to base of stratum (range)	0.20m to 1.90m bgl
Thickness (range)	0.20m to 1.50m
Spatial location on site	Predominantly in the east of the site and locally in the south. Thickest in the vicinity of the infilled pond.
General description	Soft, dark brown, slightly sandy, gravelly Clay. Gravel is fine to coarse, angular gravel of concrete, brick, limestone and mudstone.

Made Ground – MG3

Locations encountered	HDP101, WS105
Depths encountered from top of stratum (range)	Ground Level
Depths encountered to base of stratum (range)	0.40m to 0.50m bgl
Thickness (range)	0.40m to 0.50m
Spatial location on site	Record in the east of the site in the infilled pond and ditches between fields
General description	Light brown, sandy, fine to coarse, angular Gravel of concrete, brick, limestone, asphalt and sandstone. Sand is fine to medium

Made Ground – MG4

Locations encountered	HDP103, TP117, TP118, WS105
Depths encountered from top of stratum (range)	0.33m to 1.90m bgl
Depths encountered to base of stratum (range)	1.20m to 2.80m bgl



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 18 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Thickness (range)	0.50m to 0.92m
Spatial location on site	Located in the east of the site within the vicinity of a historic pond.
General description	Black clayey gravelly spongy pseudo-fibrous to fibrous Peat with gravel of concrete and brick

Drift Deposits – DD1

Firm brown Clay (Till)	
Locations encountered	HDP101, HDP102, HDP104 to HDP107, TP103 to TP107, TP109 to TP111, TP113 to TP115
Depths encountered from top of stratum (range)	0.18m to 0.50m bgl
Depths encountered to base of stratum (range)	0.50m to 1.27m bgl
Thickness (range)	0.30m to 0.93m
Spatial location on site	Widespread across the site
General description	Typically a firm, light orangish brown, slightly gravelly, sandy, silty Clay where the gravel is fine to medium, angular to rounded of mudstone and quartz. Considered a more weathered form of the Till.

Drift Deposits – DD2

Stiff to Very Stiff Grey Clay (Till)	
Locations encountered	TP101 to TP121, WS101 to WS112, CP101 to CP111
Depths encountered from top of stratum (range)	0.25m to 2.80m bgl
Depths encountered to base of stratum (range)	2.38m to 25.15m bgl
Thickness (range)	>1.40m to >14.80m bgl (thickness not proven)
Spatial location on site	Located site wide
General description	Generally a stiff to very stiff, dark brown to dark grey, slightly sandy, slightly gravelly CLAY. Sand is fine to medium, gravel is fine to coarse, angular to subrounded of mudstone, sandstone, coal and quartz.

Drift Deposits – DD3

Sand (Till)	
Locations encountered	TP112, TP116, WS107
Depths encountered from top of stratum (range)	0.25m to 0.30m bgl
Depths encountered to base of stratum (range)	0.45m to 0.63m bgl
Thickness (range)	0.15m to 0.36m
Spatial location on site	Localised lenses, no spatial correlation
General description	A light yellowish brown, clayey, silty, gravelly, fine to coarse Sand where the gravel is mudstone, sandstone, coal and occasional igneous lithologies.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 19 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

6.3. Obstructions

No buried obstruction or services were encountered during the ground investigation works.

6.4. Visual and Olfactory Evidence of Contamination

No visual or olfactory evidence of contamination was observed during the works; however, a summary of other important observations noted during Tier Environmental investigations is summarised in the Table 6.1 below:

Table 6.1 Important Site Observations Summary

Exploratory Hole Location	Depth Range (m bgl) Encountered From	Depth Range (m bgl) Encountered To	Location on Site	Description
TP117	0.22	1.35	East of the site within vicinity of a historic pond	Strong natural organic odour and Peat
TP118	0.33	1.80		Strong natural organic odour and Peat
WS105	1.90	2.80		Very soft grey clay, peat and brick
HDP103	0.70	1.20		Very soft grey clay, peat and brick

6.5. Groundwater Observations During Fieldwork

Table 6.2 below provides a summary of the groundwater observations during the fieldworks. Further information of groundwater observed is presented in the exploratory hole logs in Appendix B.

Table 6.2 Field Observations of Groundwater.

Exploratory hole	Strike (m bgl)	Rise in groundwater after 20 mins. (m bgl)	Formation	Observations
CP101	11.20	10.90	Till	None
CP103	13.50	13.30	Till	None
CP107	14.70	9.00	Till	None
CP110	13.20	12.00	Till	None
HDP103	0.70	No rise	Made Ground	Seepage
TP102	2.30	No rise	Till	Seepage
TP117	0.30	No rise	Made Ground	Moderate inflow
TP118	0.40	No rise	Made Ground	Moderate inflow
WS105	1.90	No rise	Made Ground	Seepage

6.6. Groundwater Monitoring

Table 6.3 below provides a summary of the groundwater monitoring results conducted to date. In total, 4 No. visits have been carried out between 17th July 2023 and 14th September 2023.



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 20 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Table 6.3 Groundwater Monitoring Results Summary

Exploratory hole	Response Zone	Depth range (m bgl)	Formation	Observations
CP101	1.00 to 15.00	0.20 – 1.90	Till	None
CP102	1.00 to 10.00	4.50 – 4.90	Till	None
CP103	1.00 to 15.00	3.10 – 6.69	Till	None
CP104	1.00 to 10.00	2.06 – 6.19	Till	None
CP105	1.00 to 10.00	0.77 – 0.86	Till	None
CP106	1.00 to 10.00	1.60 – 7.03	Till	None
CP107	1.00 to 15.00	0.53 – 1.30	Till	None
CP108	1.00 to 10.00	3.10 – 5.59	Till	None
CP109	1.00 to 10.00	4.10 – 7.28	Till	None
CP110	1.00 to 15.00	2.00 – 2.02	Till	None
CP111	1.00 to 10.00	3.74 – 7.30	Till	None
WS101	1.00 to 5.00	0.30 – 0.50	Till	None
WS105	1.00 to 5.00	0.23 – 0.61	MG	Slight natural organic odour
WS107	1.00 to 4.00	2.57 – 3.20	Till	Slow recharge recorded
WS108	1.00 to 5.00	0.90 – 1.40	Till	None
WS111	1.00 to 5.00	2.80 – 4.42	Till	None
WS112	1.00 to 5.00	1.14 – 1.69	Till	None

Groundwater was encountered between 0.20 to 7.30m bgl, with a shallow body of between circa 0.20-3.10m and a deeper body of between circa 4.50m to 7.30m bgl in the cable percussive boreholes. Trial pits recorded limited light seepage and some shallow inflow from Made Ground soils.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 21 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

7. PRELIMINARY GEOTECHNICAL ASSESSMENT

7.1. Determination of pH and Water-Soluble Sulphate

Representative samples of the soil and groundwater encountered during the Tier Environmental ground investigations, were tested to determine their pH and concentrations of water-soluble sulphate (SO_4^{2-}). The results are presented in Appendix C and summarised in the Table 7.1 below. It is assumed that the Site is a 'natural ground' site, and the groundwater is 'mobile' in accordance with BRE SD1.

The conclusion of the assessment is that a DS-4 and ACEC Class AC-4 may be required for buried concrete design purposes within Made Ground soils and for natural soils, based on results from groundwater testing. Further testing and detailed analysis may be considered to attempt to reduce this class. This class is being driven by elevated sulphate within 'deeper' groundwater sampled from the cable percussive boreholes. It should be noted that the level of 3200 mg/l is only just exceeding the threshold of 3000 mg/l for a DS-3 class.

Whilst no evidence of gross hydrocarbon contamination has been observed at the Site, a concrete specialist should review the TPH results and ground conditions summary within this report to ensure appropriate concrete design against retardation / degradation due to hydrocarbons.

Table 7.1 Results of Soil pH Testing and Water-Soluble Sulphate Determination.

Exploratory Hole Location	Depth (m bgl)	pH	Water-soluble sulphate (mg/l)	Design sulphate class	ACEC sulphate class
MADE GROUND					
TP117	0.40	6.34	370.5	<10 No. samples, the mean of the highest 2 No. results (rounded to 100 mg/l) is taken as the characteristic value: 500 mg/l DS-2	Mean of the lowest 20% of values is used as the characteristic value: 6.64 AC-2
TP118	1.70	7.19	605.3		
HDP101	0.30	7.7	7		
HDP102	0.10	8.01	49.9		
HDP103	0.30	8.13	32.1		
HDP103	1.20	6.94	217		
HDP106	0.15	7.69	31.9		
WS105	1.20	8.51	32.4		
TOPSOIL					
TP101	0.10	8	62.9	>10 No. samples, the mean of the highest 20% of results (rounded to 100 mg/l) is taken as the characteristic value: 50 mg/l DS-1	Mean of the lowest 20% of values is used as the characteristic value: 6.43 AC-1
TP102	0.20	6.71	29.6		
TP104	0.10	6.86	18.4		
TP105	0.30	6.67	22.8		
TP106	0.15	6.55	15.3		
TP107	0.10	6.71	15.6		
TP108	0.30	7.56	34.7		
TP109	0.15	7.38	3.1		
TP111	0.10	6.82	2.1		
TP114	0.05	6.55	23.3		
TP116	0.10	5.96	35.6		
TP117	0.20	8.08	29		
TP120	0.30	8.02	12.2		
TILL					
TP103	2.70	8.56	131.3		



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 22 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Exploratory Hole Location	Depth (m bgl)	pH	Water-soluble sulphate (mg/l)	Design sulphate class	ACEC sulphate class
TP110	0.50	8.39	359.8	>10 No. samples, the mean of the highest 20% of results (rounded to 100 mg/l) is taken as the characteristic value: 500 mg/l DS-2	Mean of the lowest 20% of values is used as the characteristic value: 8.36 AC-1
TP121	1.00	8.54	280.2		
CP101		8.51	175.4		
CP103		8.88	104.8		
CP104		8.54	94.3		
CP105		8.53	195.6		
CP107		8.54	150.3		
WS101	1.20	8.66	90.8		
WS102	1.20	8.86	105.8		
WS103	3.00	8.63	248.1		
WS104	2.00	8.57	85.5		
WS106	2.00	8.6	298.3		
WS107	4.00	8.52	380.9		
WS108	5.00 SPT	8.61	235.9		
WS109	2.00 SPT	8.68	146.2		
WS110	2.00 SPT	8.41	690.4		
WS111	2.00 SPT	8.45	380		
WS112	3.00 SPT	8.27	446.9		
CP103	8.00	8.41	293.6		
CP107	8.00	8.59	227.8		
CP108	4.70	8.32	434.5		
GROUNDWATER					
WS111	NA	7.68	1979.7	Highest determined concentration (rounded to 100 mg/l) is taken as the characteristic value: 3200mg/l DS-4	Mean of the lowest 20% of values is used as the characteristic value: 7.28 AC-4
CP101	NA	7.62	3165.1		
CP107	NA	7.89	720.7		
CP102	NA	7.83	2369.8		
CP104	NA	7.23	485.2		
WS105	NA	7.34	129.5		
WS108	NA	7.81	1240.4		
WS112	NA	7.79	901.2		

ACEC - Aggressive Chemical Environment for Concrete (see BRE, 2005).

7.2. Geotechnical Parameters

The data obtained during the Ground Investigation has been assessed for the recorded soil types in order to provide characteristic values in order to aid the final foundation design.

Cohesive Soils

Moisture content and Atterberg Limit testing was undertaken on samples from cohesive superficial material at the site. A summary of the results is shown in Table 7.2 below.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 23 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Table 7.2 Soil Classification Test Results for cohesive soils

Exploratory hole	Depth (m bgl)	Stratum	MC (%)	LL (%)	PL (%)	PI (%) (Modified)	Class	Volume Change Potential	Consistency Index
TP117	0.7	Peat	67	80	25	52.25	Very High	High	0.24
TP118	0.5	Peat	416	NA	NA	NA	NA	Non plastic	NA
TP121	1.8	Till	20.2	41	21	19.6	Medium	Low	1.04
CP103	0.60-0.90	Till	18.2	38	18	19	Medium	Low	0.99
TP103	3.00-3.30	Till	20.3	40	18	21.12	Medium	Medium	0.90
CP105	8.1	Till	44.2	60	24	36	High	Medium	0.44
CP109	0.50-0.80	Till	15.9	45	17	27.16	Medium	Medium	1.04
TP101	0.20-0.30	Topsoil (clay)	22.4	42	18	23.52	Medium	Medium	0.82
TP102	1.30-1.60	Till	18.2	41	16	24	Medium	Medium	0.91
TP104	0.40-0.60	Weathered Till	18.1	39	17	21.78	Medium	Medium	0.95
TP108	2.2	Till	17.6	42	18	23.52	Medium	Medium	1.02
TP114	1.5	Till	18.6	42	18	23.76	Medium	Medium	0.98
TP116	1.6	Till	18.3	42	17	23.75	Medium	Medium	0.95
TP120	1.3	Till	23.4	40	20	19.8	Medium	Low	0.83

ND - Not determined; MC - Moisture content, LL - Liquid limit, PL - Plastic limit, PI - Plasticity index.

Consistency index (CI) is obtained from Atterberg limits and is allowed by Eurocode 7 as a scientific means of determining consistency of clays over and above an engineer merely sticking a thumb in ($CI = (LL - mc) / PI$ using unmodified PI).

11 No. Atterberg Limit Tests were performed on samples of identified cohesive Till soils, 1 No. on cohesive topsoil and 2 No. on peat soils. Results indicate the material is of generally medium plasticity Clay. Of the peat soils, 1 No. recorded very high plasticity soil and 1 No. was recorded non-plastic likely attributed to the organic content of this soil.

Granular Soils

8 No. samples of cohesive natural soils were submitted for determination of their Particle Size Distribution. Table 7.3 below summarises the soil classification in accordance with Table 6/1 of the Specification for Highway Works Series 600.

Table 7.3 Particle Size Classification

Location	Depth (m bgl)	Description	Series 600 Class*	Series 600 Typical Use
TP112	0.50	Clayey silty SAND	2A, 2B, 7A	Cohesive General Fill, Fill to Structures
TP115	0.70	Firm slightly gravelly CLAY	2A, 2B, 7A	Cohesive General Fill, Fill to Structures
TP121	1.80	Stiff sandy gravelly CLAY	2A, 2B, 7A	Cohesive General Fill, Fill to Structures
CP101	11.7-12.00	Very stiff sandy gravelly CLAY	2A, 2B, 7A	Cohesive General Fill, Fill to Structures
TP105	1.00	Firm slightly gravelly CLAY	2A, 2B, 7A	Cohesive General Fill, Fill to Structures
CP107	5.50-5.80	Stiff sandy gravelly CLAY	2A, 2B, 7A	Cohesive General Fill, Fill to Structures



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 24 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Location	Depth (m bgl)	Description	Series 600 Class*	Series 600 Typical Use
TP107	0.90-1.10	Firm sandy CLAY	2A, 2B, 7A	Cohesive General Fill, Fill to Structures
TP111	0.30	Stiff slightly gravelly CLAY	2A, 2B, 7A	Cohesive General Fill, Fill to Structures

Shear Strength Parameters

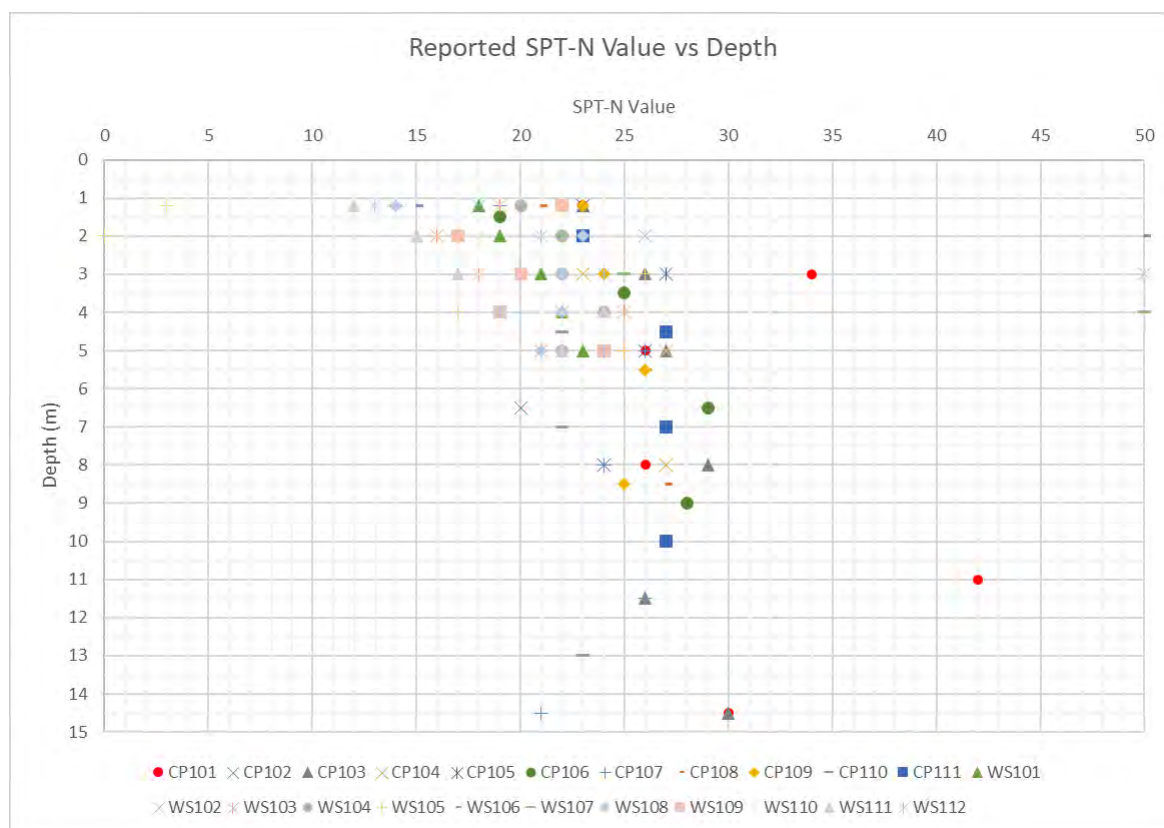
A total of 146 No. hand shear vane tests were completed within the cohesive soils on site. In addition, undisturbed samples recovered from cable percussive drilling have been submitted for laboratory testing.

Standard Penetration Tests (SPT) were carried out in all of the boreholes. The undrained shear strength of the natural clay strata tested can be estimated using the relationship developed by Stroud, where:

$$C_u = f_1 \times \text{SPT N60 value}$$

The value of f_1 is dependent on the Plasticity Index (Ip). A further review of derived shear strengths will be completed following receipt of the geotechnical testing results. In the meantime, Figure 7-1 below shows the recorded SPT-N value against depth.

Figure 7-1 Reported SPT-N Value with Depth



Results indicate a general range of between N=12-23 at 1.20m bgl suggesting firm to stiff soils, with the above visual representation showing a general increasing SPT-N value with depth. Where depth was achieved with the cable percussive rigs, results do not tend to exceed circa N= 30, which would



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

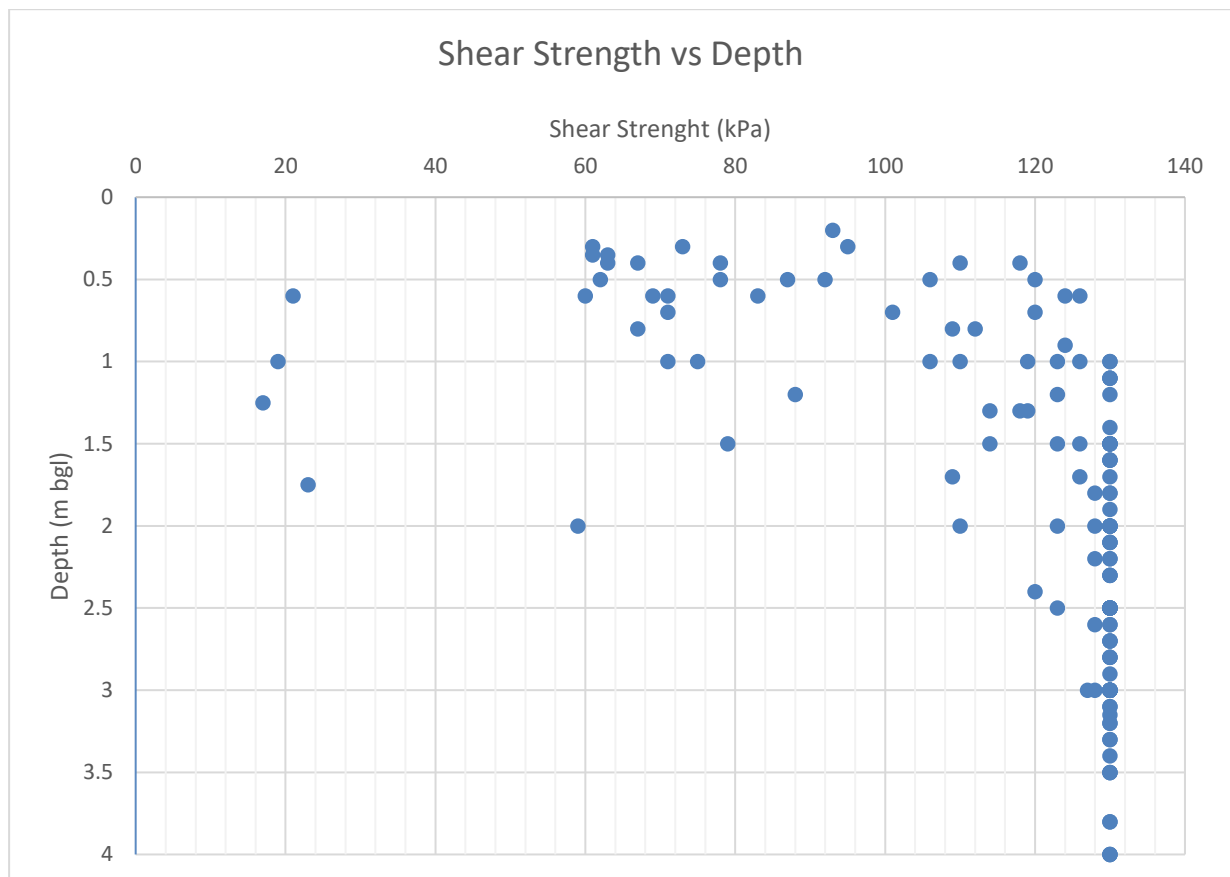
Page No : 25 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

be within the stiff to very stiff cohesive soil category. Shallow refusal was also met between 2.00-4.00m bgl within some window sample locations, reaching SPT-N values of $N \geq 50$. Laboratory data will be reviewed upon receipt; however shear strengths have been derived from in-situ hand shear vane tests taken within trial pits, and presented within Figure 7-2 below.

Figure 7-2 Shear strength from In-Situ Shear Vane Results



Results indicate generally high strength ($>75\text{kPa}$) cohesive soils which would equate to stiff soils. Generally soils improve with depth and reach the shear vane limit of 130kPa from 1.10m bgl. Localised low-end values of $17\text{-}23\text{ kPa}$ have been recorded within an area of a historic pond with soft organic rich soils. Removing these low results would give a range of between $75\text{-}130\text{kPa}$ for soils at circa 1.20m bgl.

Triaxial Testing

22 No. samples of undisturbed cohesive soils were also submitted for determination of undrained shear strength by means of multistage triaxial compression. Results for the first increment are tabulated below:

Table 7.4 Triaxial Testing Summary

Location	Depth (m bgl)	Cell Pressure (kPa)	Shear Strength (kPa)
CP101	2.20-2.65	20	187
	9.70-10.15	95	165
CP102	3.30-3.75	35	153



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 26 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Location	Depth (m bgl)	Cell Pressure (kPa)	Shear Strength (kPa)
	8.30-8.75	80	127
CP103	2.30-2.75	25	200
	13.10-13.55	130	51
CP104	4.40-4.85	45	139
	7.10-7.55	70	137
CP105	4.30-4.75	45	119
	9.60-10.05	95	144
CP106	1.20-1.65	15	33
	5.30-5.75	55	112
CP107	2.20-2.65	16	76
	6.50-6.95	65	105
CP108	4.50-4.95	45	101
	6.90-7.35	70	118
CP109	2.20-2.65	20	169
	9.60-10.05	95	86
CP110	1.20-1.65	10	173
	5.60-6.05	55	166
CP111	3.4	35	44
	8.5	85	87

Oedometer Testing

Results from 8 No. incremental loading oedometer tests suggest M_v values (coefficient of volume compressibility) of between circa 0.10-0.30m²/MN which would fall into low to medium compressibility categories. Values are dependent on final loadings and should be reviewed once confirmed.

Foundation Recommendations

The site is broadly underlain site wide by topsoil to depths of 0.18m to 0.46m bgl or Made Ground to typical depths of between 0.34m to 0.55m bgl, principally in the east of the site. These are underlain by natural soils comprised of Devensian Till, described as a firm becoming stiff and locally very stiff Clay. A more weathered horizon of brown clay was recorded in the order of 0.30m to 0.92m thick overlying the dark grey unweathered Till which was proven to the maximum drilled depth of 15.15m bgl. Sand lenses were also recorded near surface to 0.45m and 0.63m bgl. Localised areas of soft organic clays and Peat are described within the east of the site within an infilled pond from depths of 0.33m to 1.90m bgl and to depths of 1.25m to 2.80m bgl. These soft soils would not be considered suitable as a founding stratum and would arise to differential settlements beyond tolerable limits.

Given the encountered ground conditions and the nature of the proposed development, the most likely foundation solution would be a pads or similar traditional shallow foundations. Based on the range of shear strengths derived from in-situ shear testing, an allowable bearing capacity of circa 150kN/m² could be achieved at 1.20m bgl. Localised over excavation of organic rich Made Ground soils and Peat as recorded in WS05, TP117 and TP118 may be required, with deepening of foundations or engineered replacement with suitable material.

Piles could be considered where loadings cannot be transferred to shallow soils. These would be adopted for the entire structure, dependent upon the design requirements and economic feasibility. Piles are likely to be the most appropriate solution due to the absence of a suitable founding stratum at shallow depth and the overall increase in levels. It is considered that a bored, CFA or Rotary piled solution would be suitable for the site.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 27 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Table 7.5 Possible Foundation Solutions

Location	Unit	Foundation Solution	Considerations
East	2	Pad Foundations	- Soft organic clays and peat associated with Infilled Pond. - Gas main diversion - Localised shallow groundwater
Central	3-5	Pad Foundations	Ecological considerations/stream diversions
Central	6-10	Pad Foundations	- Combined sewer main diversion - Localised shallow groundwater
South	14-16	Pad Foundations	Possible softer soils along field boundaries/ditches

The following softer spots were encountered during investigation works which may require localised excavation and replacement:

- Infilled pond in the east of the site with organic clays and peat soils;
- Potentially infilled or diverted section of ditch in the north of the site in TP222;
- Deeper alluvial soils are anticipated in the vicinity of the existing streams/brooks which may require spanning.

It is generally considered that particularly geotechnically unsuitable materials, such as soft organic rich pond infill, would be excavated and perhaps re-used within landscaped bunds.

7.3. Floors

With regard to the design and construction of normal ground bearing floor slabs, these may be suitable for the majority of the developments however it must be noted at the outset, that due to the potential variability of strata across the footprint of the buildings, the proposed regrading works and low shear strengths in organic rich clays, a ground bearing slab may not be appropriate for all units without some form of ground improvement. Consideration is also required for any proposed watercourse diversions.

7.4. Earthworks

The compaction data has been assessed by comparing the results against criteria commonly used in earthworks to achieve an adequate density for engineered fills. The criteria indicate whether the samples could achieve in excess of 95% of Maximum Dry Density (MDD – a requirement often included in highways specifications) and whether they could be compacted to less than 5% air voids ratio (a requirement applied where raft foundations are to be adopted). Results of compaction testing are summaries in Table 7.6

Table 7.6 Compaction Results Summary

Sample	Depth (m bgl)	Soil	Natural Moisture Content (%)	Optimum Moisture Content (%)	Moisture Content at 95% Maximum Dry Density (%)	Conditioning Required?
TP112	0.50	Clayey silty SAND	13.9	19	22	Yes – too dry
TP115	0.70	Firm slightly gravelly CLAY	16.9	21	24	Yes – too dry
TP117	0.70	Made Ground: Very Soft CLAY	67	27	32	Yes – too wet
TP121	1.80	Stiff sandy gravelly CLAY	20.2	22	25	Yes – too dry
CP101	11.7-12.00	Very stiff sandy gravelly CLAY	16.9	17	21	Yes – too dry



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 28 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

TP105	1.00	Firm slightly gravelly CLAY	21.8	21	25.5	No
CP107	5.50-5.80	Stiff slightly gravelly CLAY	19.5	21	24.5	Yes – too dry
TP107	0.90-1.10	Stiff sandy gravelly CLAY	22.4	21	23.5	No
TP111	0.30	Firm sandy CLAY	13.8	17	20.5	Yes – too dry
CP109	0.50-0.80	Stiff slightly gravelly CLAY	15.9	16	19.2	Yes – too dry
TP104	0.40-0.60	Firm slightly gravelly CLAY	18.1	13	17	Yes – too wet
TP114	1.50	Firm slightly gravelly CLAY	18.6	19	23	Yes – too dry

The results of compaction testing undertaken on samples indicate that it could be recompacted to achieve >95% of MDD and <5% air voids. Based upon the results obtained, the natural could be used as an engineered fill, subject to other suitability considerations. It should be noted that suitability for compaction is highly dependent on the initial moisture content of the material to be compacted. Some processing of the material (including screening and crushing of unsuitable elements) may be required during the enabling works phase to remove over-sized or unsuitable material. Where Made Ground is to be reused as an engineered fill, it would be sensible to select granular fills only and subject them to a confirmatory testing regime where they were required to achieve a compaction specification as a structural fill.

Construction plant should be provided with an adequate working platform in line with the requirements of BRE report, “BR 470: Working Platforms for Tracked Plant”. Again, further advice should be sought from the temporary works designer. However, the following factors should be considered. It is understood that the existing Made Ground at the Site is to be excavated and re-engineered to remove buried obstructions. Excavated materials will be processed and re-engineered as an Engineered Fill. During construction, the in situ CBR value must be checked against the Design CBR value, to confirm design requirements are being met.

7.5. Groundworks, Excavation Stability and Groundwater Dewatering

In our opinion, there should be no particular difficulties in excavating the strata indicated in the boreholes utilising an appropriate and suitably sized mechanical excavator. Excavations into existing Made Ground and the underlying natural soils should be assumed to be unstable. No man entry into unsupported excavations should be allowed without an appropriate risk assessment. Reference to CIRIA report 097 (1983) should be made to establish suitable means of support or battering of excavation sides.

It is recommended that all excavations to greater than 1.20 metres depth, or for shallower excavations where groundwater is encountered above this level are closely supported, especially where man entry is required. Alternatively, where space permits, the excavations might be battered back to an appropriate angle. Standing groundwater levels of between 0.20 to 7.30m bgl, were encountered in the boreholes / trial pits. Should groundwater seepages occur, and water accumulate in shallow excavations it should be able to be removed by pumping from a filtered sump. However, groundwater control by more robust means, such as well pointing, may be required locally.

It should be noted that should deep basements be constructed as part of the development then we would recommend that the standpipes are monitored for groundwater levels for an extended period of time and take into consideration seasonal variations and periods of very wet weather to measure the fluctuation of the standing water levels. It should be noted that groundwater inflows and levels are likely to be subject to seasonal and climatic variations.



8. HUMAN HEALTH RISK ASSESSMENT

Results of chemical analysis are presented in full in Appendix C.

8.1. Data Interpretation Approach

The analytical data obtained were reviewed for completeness and consistency. The data for each sample type was then compiled, screened against the Generic Assessment Criteria (GACs) for a commercial/industrial land use and those potential contaminants of concern which were found to exceed the GACs were then subjected to detailed analysis as described below.

Previously, it was possible for results from soil (and leachate) samples to be subject to statistical assessment in accordance with a 2008 guidance document (CL:AIRE / CIEH Guidance on Comparing Soil Contamination Data with a Critical Concentration). This guidance has now been withdrawn and replaced with the following document:

- Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration (CL:AIRE 2020)

The purpose behind statistical assessment is ultimately to determine whether concentrations of contaminants are at levels that present potential risk to the future site users (and the wider environment if the statistical assessment is conducted on leachate test results).

The new guidance places even greater emphasis and reliance on the desk study being carried out first, appropriately detailed sampling strategies, collection and testing of samples for contamination and use of appropriate screening criteria.

The guidance requires an increased number of criteria to be met before a robust statistical assessment can be conducted and introduces the principle of the Central Limit Theorem (CLT); a key tool of statistics that is used in the comparison of confidence intervals with the critical concentration. A common 'rule of thumb' is that the CLT will apply provided your sample size is between 20 and 50.

On this basis, Tier Environmental considers that statistical assessment in accordance with the CL:AIRE 2020 guidance may not be applied in this instance given that the number of samples obtained is below 20 No. for any given identified soil population.

Due consideration of the ground conditions, distinct identifiable populations of soil and proposed development layout has been undertaken and, where appropriate, laboratory results associated with discrete populations or 'hotspots' have been assessed separately.

8.2. Selection of Generic Assessment Criteria (GAC)

In short, for the majority of the contaminants of concern, LQM/CIEH Suitable 4 Use Levels (S4ULs) published in 2015 have been adopted as GACs for a commercial/industrial land use; however, further details on the hierarchical approach for the selection of the GACs used as screening criteria for this assessment is provided in Appendix K.

These values are considered as appropriate screening criteria as they incorporate updated assumption exposures derived for the production of C4SLs but within the context of deriving screening criteria above which assessment of the risks or remedial action may be needed (i.e. within the context of the planning regime rather than Part 2A context for which C4SLs were derived).

For those potential contaminants of concern where the selected GAC is dependent on Soil Organic Matter content (SOM), an assumed SOM of 1% been selected based on the reported Total Organic Carbon (TOC) concentrations (which have been converted to SOM by dividing by a conversion



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 30 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

factor of 0.58). It should be noted; however, that for any soil samples where the TOC may be artificially driven by the presence of petroleum hydrocarbons, that these TOC results have been removed from the data set when determining an appropriate characteristic SOM. For this purpose, Tier Environmental have notionally considered that any TOC results from soil samples where the measured total TPH concentration exceeds 500mg/kg should be removed.

8.3. Human Health Risk Assessment

No measured concentrations of potential contaminants of concern have been reported in excess of the respective GACs protective of human health for a commercial/industrial land use.

Measured Potential Contaminant of Concern Concentrations without Publicly Available GACs

No measured concentrations of potential contaminants of concern for which there are no current publicly available GACs have been reported in excess of the laboratory method detection limit.

Explosives Suite

No measured concentrations of potential contaminants of concern within the explosives suite have been reported in excess of the laboratory method detection limit.

Asbestos

Asbestos can be present in soil as fragments of bulk Asbestos Containing Materials (ACMs) (e.g. asbestos cement sheeting) and also as discrete asbestos fibres within the soil matrix. This investigation has carried out assessments to determine whether both bulk fragments and / or fibres are present in the soil at the site. The asbestos assessment commenced on site with inspection of the Made Ground by our suitably qualified supervising engineer for the presence of bulk ACMs.

During the fieldwork no suspected ACMs were identified.

Of the 23 No. of Made Ground samples submitted for asbestos screening, none were reported to contain asbestos.

8.4. Utilities

It is recommended that the results of the chemical testing and details of the proposed remedial works are provided to the appropriate utility companies to determine the necessity for service protection.

8.5. Construction and Maintenance Workers

Contamination may pose a short-term (acute) or long-term (chronic) risk to workers during construction and maintenance. The potential risks must be specifically assessed as part of the health and safety evaluation for the works to be performed in accordance with prevailing legislation. Site practices must conform to the specific legislative requirements and follow appropriate guidance (e.g., HSE, 1991; CIRIA, 1996).

On the basis of the results obtained, no potential exposure risks to construction and maintenance workers have been highlighted:



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 31 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Asbestos has not been reported during the ground investigation works; however, in the event that previously unidentified asbestos is identified during future earthworks / construction works at concentrations above 0.001% w/w (i.e. above 'trace' levels), the Control of Asbestos Regulations 2012 should be adhered to. A summary of complying with CAR: risk assessments, licensing and training is provided in Appendix O is provided for reference.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 32 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

9. CONTROLLED WATERS RISK ASSESSMENT

9.1. Introduction

In order to assess whether there is a potentially unacceptable risk of pollution of controlled waters, samples of groundwater have been submitted for laboratory chemical analysis as per the summary presented in Table 5.4 within this report. Analytical data from groundwater sample testing undertaken by Tier Environmental have been evaluated against Water Quality Standard (WQS) values appropriate to the Conceptual Site Model.

In accordance with Part 2A of the Environmental Protection Act 1990, Tier Environmental has made regard to all of the WQS values that are relevant to the Site and a judgment has been made against the most stringent of those relevant standards. Further details are provided, along with the approach for selection of TPH / BTEX WQS values, in Appendix L.

In some instances, the laboratory method detection limit is greater than the appropriate WQS value. In these instances, only measured concentrations in excess of the laboratory method detection limit have been considered likely to potentially represent a possible significant risk to controlled waters.

For those potential contaminants of concern for which the WQS values are dependent on hardness (e.g. cadmium EQS values), an appropriate hardness in mg CaCO₃/l will be selected based on the reported values in the groundwater beneath the Site.

9.2. Controlled Waters Environment Conceptual Site Model Summary

From a conceptual site model perspective, the Devensian Till is classified as a Secondary Undifferentiated Aquifer, and the bedrock geology is classified as a Principal Aquifer associated with Kinnerton Sandstone Formation in the western/northern parts of the Site and a Secondary A Aquifer associated with the Salop Formation comprising mudstone in the southern / southeastern part of the Site. There is an inferred fault located beneath the site orientated from southwest to northeast associated with these two bedrock formations. The site is within a Source Protection Zone Total Catchment 3 associated with the Principal Aquifer, and the nearest surface water receptor comprises an underground water course 110m west. There are no potable or non-potable water abstractions located within 1km of the Site. The cohesive Till deposits have been proven to depths of circa 15.00m bgl in this investigation and are recorded to depths of circa 26.0 to 38.0m bgl in nearby BGS records which is considered sufficient to provide protection of the underlying bedrock aquifers from any vertical migration of potential contaminants of concern. On this basis the controlled waters sensitivity is considered to be low.

The proposed development will involve the development of the majority of the site, with buildings and hardstanding proposed and demolishing the farm buildings at Little Acorns and Honey Suckle Cottage off Francis Lane. Not only will this act to inhibit infiltration into the ground, it will also largely remove the source of agricultural phosphate from the site. The site won topsoil will be reused within the development within screening bunds and soft landscaping, but agricultural fertilisers and manure will no longer be used on the site. Wastewater drainage from the proposed development will be either via the on-site combined sewer and the Five Fords WwTW or on-site wastewater treatment and discharge to the on-site surface water drainage system.

9.3. Groundwater Testing

Table 9.1 below summarises the measured concentrations of contaminants of concern from groundwater samples at the Site that have been reported in excess of the respective WQS values.



GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 33 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Table 9.1 Summary of Measured Concentrations of Dissolved Phase Groundwater Potential Contaminants of Concern in Excess of WQS Values

Potential Contaminant of Concern	Units	LoD*	WQS	Maximum Concentration	No. samples >WQS	Monitoring Well Location
Copper	µg/l	3	1	8	3 of 8	WS111
Chromium (total)	µg/l	0.2	3.4	4.8	1 of 8	WS111
Nickel	µg/l	0.2	4	7.7	2 of 8	CP104
Zinc	µg/l	1.5	10.9	14.8	3 of 8	WS105
Anthracene	µg/l	0.005	0.1	0.209	1 of 8	WS105
Fluoranthene	µg/l	0.005	0.0063	1.86	3 of 8	WS105
Benzo(a)pyrene	µg/l	0.005	0.00017	1.19	2 of 8	WS105
Sum PAHs [†]	µg/l	0.02	0.1	3.59	2 of 8	WS105
Total Ammonia	mg/l	0.03	0.6	5.47	2 of 8	CP104
Electrical Conductivity	uS/cm	2	2500	6320	4 of 8	CP101

* LOD= Laboratory Method Limit of Detection

[†]Sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, indeno(1,2,3-cd)pyrene.

Measured groundwater concentrations of copper, chromium, nickel, zinc, anthracene, Sum PAHs, total ammonia and electrical conductivity have been reported in excess of the WQS protective of the controlled waters environment by either the same order of magnitude or one order of magnitude. Given the marginal nature of these exceedances, the potential for significant dilution between the Site and nearby significant water bodies, the low sensitivity of the controlled waters environment as described in Section 9.2 above, the localised nature of those soil leachate concentrations in excess of the WQS and the absence of any reported widespread leachable concentrations, the fact that the Site will incorporate buildings / hardstanding and a dedicated drainage system that shall reduce infiltration rates through the soils, the absence of any nearby potable or non-potable groundwater abstractions, the protection offered to the underlying principal aquifer by the presence of >10.0m of low permeability cohesive Till soils, it is not considered that these measured concentrations pose a risk to the controlled waters environment.

Measured concentrations of fluoranthene and benzo(a)pyrene have been reported in excess of the respective WQS protective of the controlled waters environment by between 2 No. orders of magnitude and 4 No. orders of magnitude. Further specific consideration of the reported soil leachate concentrations of fluoranthene and benzo(a)pyrene concentrations have been made. The EQS values for fluoranthene and benzo(a)pyrene are derived assuming bioaccumulation in fish and ultimately consumption of the fish by humans which is an exposure scenario that is not viable for this Site given the absence of a nearby viable surface water body where this will scenario be realised.

Subsequent sensitivity analysis has demonstrated that measured groundwater concentrations of fluoranthene and benzo(a)pyrene have been reported only *marginally* in excess of the respective Maximum Allowable Concentrations (MAC) EQS values for Inland Surface Waters by up to one order of magnitude. As such, and in the absence of viable 'bioaccumulation in fish and consumption of fish by humans' scenario given the other evidence listed above, it is therefore considered that the reported soil leachate concentrations of fluoranthene and / or benzo(a)pyrene are unlikely to present a potential risk to the controlled waters environment.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 34 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

10. GROUND GAS RISK ASSESSMENT

10.1. Introduction

The ground gas risk assessment has been undertaken in accordance with the following guidance:

- BS 8485:2015+A1:2019;
- CIRIA C665, 2007;
- Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide Are Present, NHBC, 2007;
- A Pragmatic Approach to Ground Gas Risk Assessment RB17. CL:AIRE, 2012; and,
- Ground Gas Monitoring and 'Worst-Case' Conditions TB17, CL:AIRE, 2018

The ground gas risk assessment has been conducted with full consideration of the viable sources, pathways and receptors included within the Preliminary Conceptual Site Model presented in Section 4.

Ground gas monitoring was conducted in conjunction with groundwater monitoring (and sampling); however, it should be noted the gas monitoring was conducted first, prior to any groundwater monitoring / sampling works. The monitoring well locations and construction were designed with due consideration of the proposed development layout and preliminary conceptual site model. Further information pertaining to monitoring wells is provided in Table 5.2.

10.2. Ground Gas Monitoring Results

The full ground gas monitoring results from the installations are presented in Appendix F and summarised below:



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 35 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Table 10.1 Ground Gas Monitoring Results Summary – Final Monitoring Programme of 4 No. Visits

Strata Targetted by Response Zone	Monitoring Well Reference	Maximum peak gas flow rate (l/h)	Maximum steady state gas flow (l/h)	Maximum peak CH4 (%v/v)	Maximum steady state CH4 (%v/v)	Maximum peak CO2 (%v/v)	Maximum steady state CO2 (%v/v)	Lowest O2 recorded (%v/v)
Till	CP101	0.2	0.2	2.2	2.2	15.4	15.4	17.2
Till	CP102	2.1	0.1	0.1	0.1	4.5	3.3	14.1
Till	CP103	2.1	0.4	0.1	0.1	6.1	4.9	12.6
Till	CP104	17.3	1.1	1.4	0.1	4.0	4.0	14.0
Till	CP105	0.3	0.3	0.6	0.1	7.0	4.0	13.7
Till	CP106	0.1	0.1	0.1	0.1	2.2	2.1	16.4
Till	CP107	0.2	0.2	0.1	0.1	0.8	0.5	20.1
Till	CP108	0.1	0.1	0.1	0.1	2.6	2.5	17.4
Till	CP109	0.3	0.3	6.0	0.1	2.8	2.5	17.4
Till	CP110	0.3	0.3	0.1	0.1	2.3	2.1	18.5
Till	CP111	2.2	0.3	0.1	0.1	2.2	2.0	12.4
Till	WS101	1.9	0.2	0.1	0.1	3.2	2.8	16.2
MG	WS105	0.3	0.3	60.1	5.9	38.5	13.7	0.2
Till	WS107	0.2	0.2	0.1	0.1	2.9	2.9	18.0
Till	WS108	0.3	0.3	0.1	0.1	2.5	2.5	17.4
Till	WS111	0.2	0.2	0.1	0.1	2.6	2.6	17.3
Till	WS112	0.3	0.3	0.1	0.1	1.6	1.5	13.0

Bold = maximum value reported across all visits.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 36 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

10.3. Ground Gas Risk Assessment

Table 10.2 and Table 10.3 demonstrate how, in accordance with CIRIA C665, the periods and frequency of monitoring have been selected for the Site.

Table 10.2 From Table 5.5a CIRIA C665 - Typical/idealised periods of monitoring (after Wilson et al, 2005)

		Generation Potential of the Source				
		Very Low	Low	Moderate	High	Very High
Sensitivity of development	Low (commercial)	1 month	2 months	3 months	6 months	12 months
	Moderate (flats)	2 months	3 months	6 months	12 months	24 months
	High (residential with gardens)	3 months ¹	6 months	6 months	12 months ¹	24 months

Notes:

1 NHBC guidance also recommends this period of monitoring (Boyle and Witherington, 2007).

2 There is no industry consent over "high", "medium" or "low" generation potential of source.

Table 10.3 From Table 5.5b CIRIA C665 - Typical/idealised frequency of monitoring (after Wilson et al, 2005)

		Generation Potential of the Source				
		Very Low	Low	Moderate	High	Very High
Sensitivity of development	Low (commercial)	4	6	6	12	12
	Moderate (flats)	6	6	9	12	24
	High (residential with gardens)	6 ¹	9	12	24 ¹	24

Notes:

1 NHBC guidance also recommends this period of monitoring (Boyle and Witherington, 2007).

2 There is no industry consent over "high", "medium" or "low" generation potential of source.

The total atmospheric pressure range of the ground gas monitoring data included in this report was between 1014 mbar and 1016 mbar. This range covers moderate (1000 mbar to 1015mbar) and high (>1015 mbar) atmospheric pressures. Monitoring events included periods of falling and rising pressure trends.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

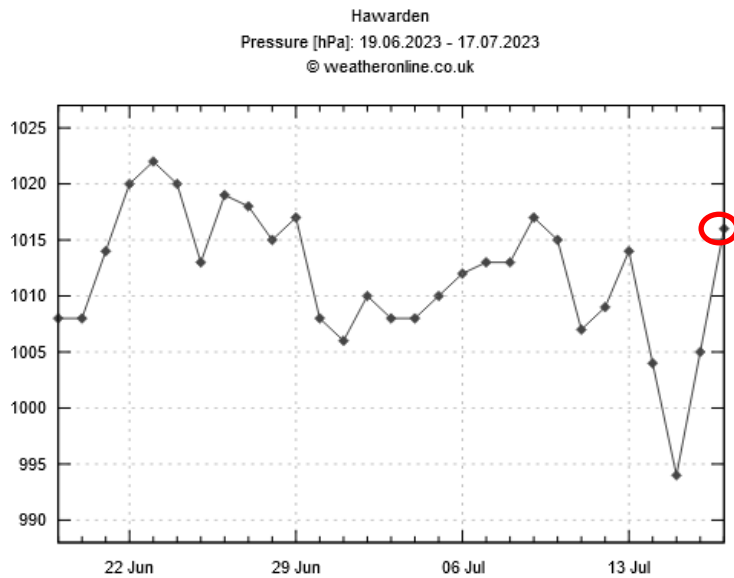
Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 37 of 57

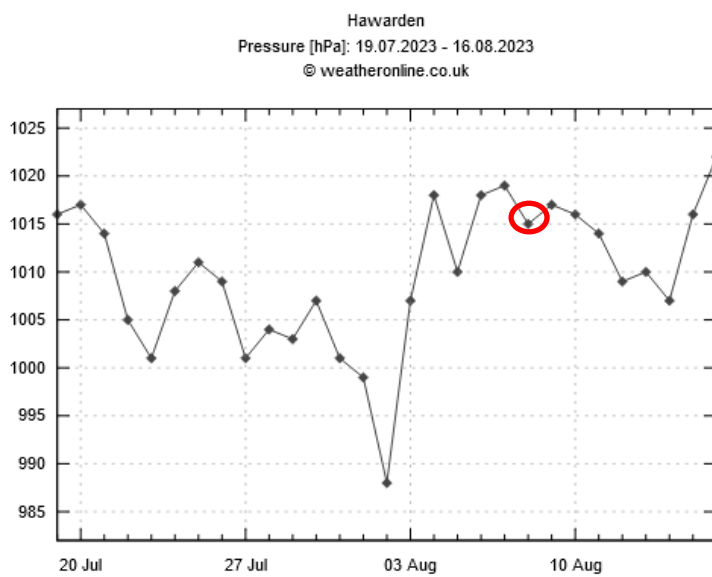
Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Visit 1 – 17/07/2023



Visit 2 – 08/08/2023





GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

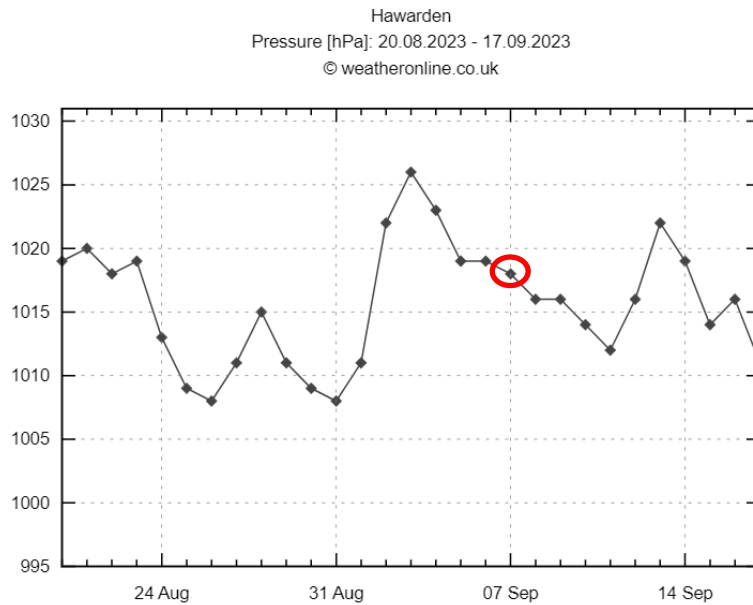
Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 38 of 57

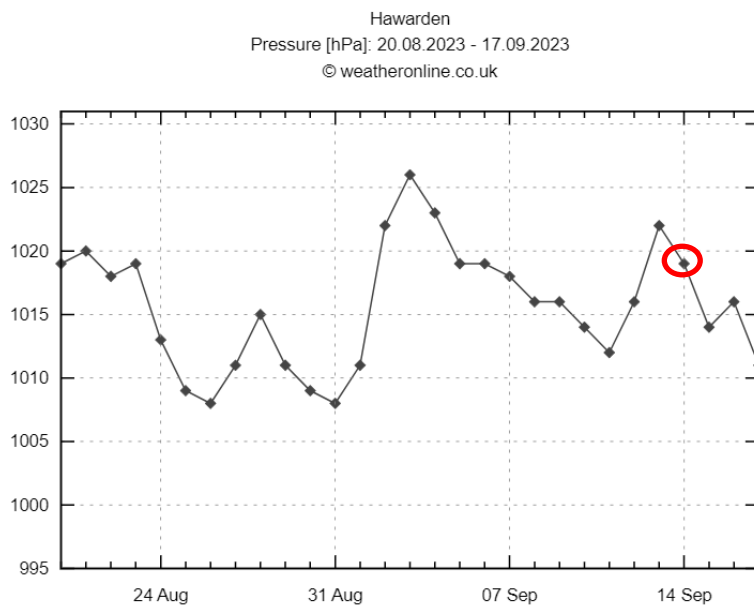
Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Visit 3 – 07/09/23



Visit 4 – 14/09/23



Consideration of Groundwater Effects

An assessment has been made to determine whether groundwater levels beneath the Site lie at a shallow depth at, or above, the plain section of the monitoring well or within cohesive strata. In those instances where shallow groundwater is located within the plain section of the monitoring well pipe or within cohesive strata this can result in 'groundwater pumping' or a 'piston effect' where the measured peak (and in some cases steady) flow



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 39 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

rates reported at these monitoring well locations are significantly (and artificially) influenced by the pressures formed in the void above the groundwater in the plain section of the pipe or within the pipework installed within cohesive strata, as opposed to being truly representative of the ground gas flow rates. In such instances, this scenario can create 'artificial' negative and/or relatively high peak positive readings depending on whether the groundwater levels have increased or decreased in between monitoring events or since installation of the monitoring wells.

The results of gas monitoring have indicated the following instances where groundwater pumping is likely to have influenced the measured ground gas flow rates such that they may be reasonably discounted from the Gas Screening Value (GSV) calculation:

- CP104 on visit 3 where a peak flow rate of 10.4l/hr was recorded and CP104 on visit 4 where a peak flow rate of 17.3l/hr was recorded.
- No significantly high concentrations of methane or carbon dioxide were recorded within CP104 on the visits which recorded high flow rates.
- Flow rates dropped off to steady levels of not detected on visit 3 and 0.4l/hr on visit 4.
- Groundwater levels have risen by between 1.55m bgl and 2.29m bgl compared to visit 2 which is the likely cause for the elevated flow rates from groundwater pumping/piston effect within the cohesive Till.

The results of the ground gas monitoring have been assessed in accordance with the criteria specified for this Site, which were derived as described in Appendix M.

Initial 'Worst-Case' GSV Calculation – Carbon Dioxide and Methane

An initial conservative assessment has been made by calculating a 'worst-case' Gas Screening Value (GSV) for the Site by using:

- the maximum reported methane or carbon dioxide concentration (whichever is highest) from any monitoring well and during any ground gas monitoring visit; and,
- the remaining maximum peak positive flow rate (after any negative flow rates or 'artificially' high flow rates have been discounted as described above) from any monitoring well and during any ground gas monitoring visit.

Based on the results of the gas monitoring, Tier has 'zoned' the site due to organic rich deposits associated with a potentially infilled pond in WS105 and therefore an initial Worst Case GSV has been derived for the proposed Unit 2 area and the rest of the Site separately:

Table 10.4 Initial Worst-Case GSV Calculation – Unit 2 Zone

Ground Gas	Maximum Reported Peak Concentration (% v/v)				
Methane (CH ₄)	60.1	}	→	Selected Concentration used in GSV Calculation (% v/v)	
Carbon dioxide (CO ₂)	38.5				
				60.1	
				X	
				2.2	
				=	
					1.32

A separate GSV has been calculated for the rest of the Site using a maximum selected gas concentration and a steady state flow rate. A steady flow rate of 1.1l/hr was recorded in CP104 on the first visit; however, this has been discounted from the calculation as no measured concentrations of methane, carbon monoxide or hydrogen sulphide were detected and carbon dioxide levels were recorded below 5% v/v. The peak steady flow rate



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 40 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

of 1.1l/hr in CP104 was recorded on the first monitoring visit, with the next highest steady flow rate being 0.4l/hr and therefore it is likely that this was due to the borehole settling and not representative of the flow rates on Site. As a result, a representative maximum steady flow rate of 0.4l/hr has been selected to calculate the GSV for the remaining Site excluding the Unit 2 Zone.

Table 10.5 Initial Worst-Case GSV Calculation – Detailed Planning Site excluding Unit 2 Zone

Ground Gas	Maximum Reported Peak Concentration (% v/v)		Selected Concentration used in GSV Calculation (% v/v)		Maximum Appropriately Selected Gas Flow Rate (l/hr)		'Worst case' GSV (l/hr)
Methane (CH ₄)	2.2	}	15.4	X	0.4	=	0.062
Carbon dioxide (CO ₂)	15.4						

Based on the results of the GSV calculations the proposed Unit 2 development should be classified as a Characteristic Situation 3 – Moderate Risk Scenario for which ground gas protection measures are required and the remainder of the Site should be classified as a Characteristic Situation 1 – Very Low Risk Scenario for which no ground gas protection measures are required.

CIRIA C665 provides two separate methods to 'characterise' a site that firstly requires the assessor to distinguish between two fundamental development 'situations':

- **Situation A** - Any development other than Situation B (e.g. factories, shops, commercial, warehouses, schools, cinemas, sports centres, stadiums, high rise housing, housing with basements, etc) for which the **Modified Wilson and Card 'Characteristic Situation' classification system** is applied; and,
- **Situation B** - Low rise building with minimum ventilated under floor void (min 150 mm) for which the **NHBC Traffic light classification system** is applied

In this instance, as the Site is due to be developed as commercial units, it shall be regarded as a 'Situation A' scenario for the purposes of the ground gas risk assessment.

Table 10.4 demonstrates that the Unit 2 Zone area of Site is placed in a Characteristic Situation 3 - Moderate Risk Scenario on the basis of the 'worst case' GSV alone. However, this is driven by an instance of elevated peak methane from well WS105 only. This location targeted a historic infilled pond and logs described soils of organic clays and peat. This is considered the primary source for this elevated methane and carbon dioxide. It is considered that these materials will be removed as part of enabling works due to its being geotechnically unsuitable, i.e. it will remove the source of the elevated methane and carbon dioxide, effectively placing the Unit 2 Zone in the same Zone as the remainder of the Site within a Characteristic Situation 1 – Very Low Risk Scenario. **However, this would only be applicable if these soils are removed; if the soils remain then the whole of Unit 2 MUST remain classified as a CS3.**

Although 3 No. instances have been recorded of carbon dioxide levels above 5% v/v (excluding WS105) in the remainder of the Site Zone, Tier considers that a CS1 classification remains applicable due to the absence of significant source in the wells which recorded these concentrations, and that groundwater levels were higher when these concentrations were recorded possible creating an artificial 'piston' effect of the gas.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 41 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Carbon Monoxide and Hydrogen Sulphide

There is no current UK risk assessment guidance available for carbon monoxide and hydrogen sulphide derived from ground gases.

A maximum peak carbon monoxide concentration of 5 ppm has been reported which is below the workplace long term exposure limit (30ppm) and the workplace short term exposure limit (200ppm) published by the Health and Safety Executive (EH40/2005 Workplace Exposure Limits) and below the WHO long term (24 hours) indoor exposure guideline value (5.68 ppm).

A maximum peak hydrogen sulphide concentration of 1 ppm has been reported which is below the workplace long term exposure limit (5ppm) and the workplace short term exposure limit (10ppm) published by the Health and Safety Executive (EH40/2005 Workplace Exposure Limits).

Considerations for Construction and Maintenance Workers

During engineering and construction activities, the ground gas data indicate that the following aspects are to be considered during the preparation of relevant site H&S plans, method statements and related documents, and appropriate working methods adopted:

- **Carbon dioxide concentrations in ground gas:** The measured CO₂ concentrations in ground gas reported are elevated relative to background levels and could present an asphyxiation risk in excavations and other confined spaces. The Health & Safety Executive has published information defining safe occupational exposure levels for CO₂ and the latest guidance must be consulted to determine whether the ground gas regime necessitates specific precautions during site works.
- **Methane concentrations in ground gas:** The measured methane concentrations in ground gas reported are elevated relative to background levels and could give rise to explosive mixtures in confined spaces. Safe working methods should be adopted to mitigate this risk.

10.4. Radon Gas

The majority of the Site lies within an area where less than 1% of the properties are above the action level whereby no radon protection measures are required. The south of the site is within an area where 1-3% of properties are above the action levels and therefore confirmation that no basic radon protection measures are required should be confirmed with the Local Building Control Office. UK Radon indicates testing/protection may be required for high-risk locations i.e. basement.



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 42 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

11. REVISED CONCEPTUAL SITE MODEL AND GENERIC QUANTITATIVE RISK ASSESSMENT OF POLLUTANT LINKAGES

The preliminary combined conceptual site model and conceptual exposure model, developed from the desk study information and presented in Section 4, has been revised in light of the ground investigation and the chemical analysis results presented above in Table 11.1, below.

A revised qualitative risk assessment has also been made of the likelihood of the linkage operating and its potential significance in accordance with CIRIA C552.



GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 43 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Table 11.1 Revised Assessment of Potential Pollutant Linkages (Continued on Next Page).

Justification / Comments
- The site is broadly underlain site wide by topsoil to depths of 0.18m to 0.46m bgl or Made Ground to depths of between 0.34m to 0.55m bgl, principally in the east of the site. These are underlain by natural soils comprised of Devensian Till, described as a firm becoming stiff and locally very stiff Clay. A more weathered horizon of brown clay was recorded in the order of 0.30m to 0.92m thick overlying the dark grey unweathered Till which was proven to the maximum drilled depth of 15.15m bgl. Sand lenses were also recorded near surface to 0.45m and 0.63m bgl. Localised areas of soft organic clays and peat are described within the east of the site within an infilled pond from depths of 0.33m to 1.90m bgl to depths of between 1.25m to 2.80m bgl. - No measured soil concentrations of potential contaminants of concern have been reported in excess of Generic Assessment Criteria (GACs) protective of human health appropriate to the proposed land use. On this basis, it is not considered that the site represents a potential risk to end-users. - Of the 23 No. of Made Ground samples submitted for asbestos screening, none were reported to contain asbestos. - From a conceptual site model perspective, the Devensian Till is classified as a Secondary Undifferentiated Aquifer, and the bedrock geology is classified as a Principal Aquifer associated with Kinnerton Sandstone Formation in the western/northern parts of the Site and a Secondary A Aquifer associated with the Salop Formation comprising mudstone in the southern / southeastern part of the Site. There is an inferred fault located beneath the site orientated from southwest to northeast associated with these two bedrock formations. The site is within a Source Protection Zone Total Catchment 3 associated with the Principal Aquifer, and the nearest surface water receptor comprises an underground water course 110m west. There are no potable or non-potable water abstractions located within 1km of the Site. The cohesive Till deposits have been proven to depths of circa 15.00m bgl in this investigation and are recorded to depths of circa 26.0 to 38.0m bgl in nearby BGS records which is considered sufficient to provide protection of the underlying bedrock aquifers from any vertical migration of potential contaminants of concern. On this basis the controlled waters sensitivity is considered to be low. - Measured groundwater concentrations of copper, chromium, nickel, zinc, anthracene, Sum PAHs, fluoranthene, benzo(a)pyrene, total ammonia and electrical conductivity are not considered to present a risk to the controlled waters environment for the following reasons: - The potential for significant dilution between the Site and nearby significant water bodies; - The low sensitivity of the controlled waters environment; - The localised nature of those soil leachate concentrations in excess of the WQS and the absence of any reported widespread leachable concentrations; - The fact that the Site will incorporate buildings / hardstanding and a dedicated drainage system that shall reduce infiltration rates through the soils; - The absence of any nearby potable or non-potable groundwater abstractions; - The protection offered to the underlying principal aquifer by the presence of >10.0m of low permeability cohesive Till soils. - The absence of a nearby viable surface water body where a consumption of fish by humans exposure scenario would be realised for fluoranthene and benzo(a)pyrene. - The Site is located within the phosphate sensitive freshwater catchment of the River Dee and Bala Lake Special Area of Conservation (SAC). The proposed development will involve the development of the majority of the site, with buildings and hardstanding proposed and demolishing the farm buildings at Little Acorns and Honey Suckle Cottage off Francis Lane. Not only will this act to inhibit infiltration into the ground, it will also largely remove the source of agricultural phosphate from the site. The site won topsoil will be reused within the development within screening bunds and soft landscaping, but agricultural fertilisers and manure will no longer be used on the site. Wastewater drainage from the proposed development will be either via the on-site combined sewer and the Five Fords WwTW or on-site wastewater treatment and discharge to the on-site surface water drainage system. <u>Based on the results of the GSV calculations the proposed Unit 2 development should be classified as a Characteristic Situation 3 – Moderate Risk Scenario for which ground gas protection measures are required and the remainder of the Site should be classified as a Characteristic Situation 1 – Very Low Risk Scenario for which no ground gas protection measures are required</u> - The Unit 2 Zone area of Site has been placed in a Characteristic Situation 3 - Moderate Risk Scenario on the basis of the 'worst case' GSV alone. However, this is driven by an instance of elevated peak methane from well WS105 only. This location targeted a historic infilled pond and logs described soils of organic clays and peat. This is considered then primary source for this elevated methane and carbon dioxide.



**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 44 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

Alternatively, if this material will be removed as part of enabling works due to its being geotechnically unsuitable, it will remove the source of the elevated methane and carbon dioxide, effectively placing the Unit 2 Zone in the same Zone as the remainder of the Site within a Characteristic Situation 1 – Very Low Risk Scenario. **However, this would only be applicable if these soils are removed; if the soils remain then the whole of Unit 2 MUST remain classified as a CS3.**



GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 45 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Source	Potential Contaminants of Concern	Pathway	Receptor	Consequence	Probability	Qualitative Risk Assessment
On-site localised Made Ground / potentially infilled ponds and off-site Made Ground.	Hazardous ground gasses (methane, carbon dioxide, hydrogen sulphide, carbon monoxide and depleted oxygen)	Inhalation (indoor and outdoor)	Future site users (commercial)	Severe	Low Likelihood	Moderate Risk
			Adjacent site users residential/commercial	Severe	Unlikely	Moderate / Low Risk
			Construction, site investigation, demolition and future maintenance workers	Severe	Low Likelihood	Moderate Risk
		Migration of hazardous ground gases from beneath the Site to adjacent sites along services or other preferential conduits	Adjacent site users residential/commercial	Severe	Unlikely	Moderate / Low Risk
		Migration of ground gas / explosion	Buildings and services	Severe	Unlikely	Moderate / Low Risk

For definition of the terms used in the qualitative risk assessment, please see Appendix J.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 46 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

12. PRELIMINARY WASTE MATERIALS CLASSIFICATION

12.1. Introduction

If the Site is to be redeveloped and materials are disposed off Site, the material exported from the Site to Landfill should be hauled by a registered waste carrier in accordance with Duty of Care Regulations 1991 and the Hazardous Waste Regulations 2005.

There will be requirement for the waste producer to provide appropriate Waste Acceptance Criteria (WAC) testing of the Soils for disposal to ensure that the soils are appropriately classified and that the landfill is licensed to receive such soils. Mixing of hazardous and non-hazardous waste is not permitted. For any hazardous wastes, a consignment note shall be completed, signed, and retained by all parties involved. The consignment note shall state the volume of waste, a physical description of the material and statement of its chemical composition. The waste consignment notes shall be kept by the contractor for a period of at least two years. For non-hazardous wastes, a Waste Transfer Note (WTN) shall be completed. The WTN should be signed and a copies should be kept by the contractor for a period of at least two years. Finally, consignment notes and WTNs shall be shown to an enforcement officer from the local council or Natural Resources Wales, if asked.

Approach to Assessing Hazard Properties

Flammability and Oxidisability

For any samples flagged as possessing hazardous properties flammability and oxidisability, for which there are no thresholds, Tier Environmental has used professional judgment and on-site observations to decide whether the waste soil, as a whole, is likely to be flammable or oxidising. It should be noted that flammability/oxidisability alone are unlikely to result in a hazardous classification for waste soil.

Worst Case Metal Compounds

The choice of an appropriate worst case metal compound in soil has been made on the basis of the available lines of evidence. For example, if laboratory chemical analysis has demonstrated that no measured concentrations of hexavalent chromium have been reported in excess of the laboratory method detection limit, there it would be regarded as evidence of an absence of a soil source of hexavalent chromium. In such an instance, the worst case metal chromates may be replaced in favour of the next worst case metal compound.

pH

For samples that have been determined as hazardous based on pH alone and cement/concrete has been identified in the sample, Tier Environmental may assume that the high pH was due to the crushing process in the laboratory and is not representative of the waste as a whole. If further detailed determination of this is required then Tier Environmental recommend that such assessment is carried out on these results in a manner described in the AGS Waste Classification for Soils – A Practitioners' Guide (dated 2019):

- Consideration of the acid/alkali reserve to be conducted (as described in WM3 Appendix C4 and C8).
- If large enough, the cement/concrete fraction may be separated manually before testing. Waste concrete from construction and demolition which doesn't contain hazardous substances is non-hazardous (LoW code 17-01-01).
- If cement/concrete has been identified in the sample, a second analysis may be conducted on an 'as received' sample, avoiding the need for crushing before testing. The high pH is typically associated with the finer fractions of cement. If the 'as received' sample has an acceptable pH, this provides additional confidence that the high pH was due to the crushing process and is not representative of the waste as a whole.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 47 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Asbestos

With respect to asbestos, If the waste contains fibres that are free and dispersed then the waste will be hazardous if the waste as a whole contains 0.1% w/w or more asbestos in accordance with WM3. If the waste contains any identifiable pieces of suspected asbestos containing material (i.e. any particle of a size that can be identified as potentially being asbestos by a competent person if examined by the naked eye), then these pieces must be assessed separately. The waste is hazardous if the concentration of asbestos in the piece of asbestos containing material is 0.1% w/w or more. The waste shall then be regarded as a mixed waste and classified accordingly.

The following codes will then be assigned to the asbestos waste as appropriate:

- 17 06 05* Construction material containing asbestos
- 17 06 01* Insulation material containing asbestos

17 06 05* would normally be used in preference to 17 06 01* for the asbestos in asbestos contaminated soil and stones in accordance with WM3.

Tier Environmental Geoenvironmental engineers hold up to date UKATA Asbestos Awareness training certificates in order to demonstrate 'competence' that is required as described in WM3.

Flammable Liquid Waste

Tier Environmental consider that such a hazard property would apply if free phase product has been reported in the sample. As such, in those instances where materials are classified as hazardous based on this alone and no free phase product is encountered, it is considered that the materials may be regarded as being non-hazardous. Please note that the table below includes a column to show whether free phase product has been encountered within the sample location.

12.2. Preliminary Waste Materials Classification

Tier Environmental have assessed the chemical results in terms of basic waste characterisation of materials on site. This provides a preliminary assessment of whether a material is potentially non-hazardous or hazardous waste.

The results of this preliminary assessment are summarised in the following table.

Natural Soils / Bedrock

Representative samples of natural soils have been obtained during the investigation.

The results of basic waste characterisation are summarised in the table below. It is likely that any natural soils (that are not impacted by any known contamination from shallow Made Ground, or unexpected contamination) would be suitable for disposal to an inert waste landfill. It is recommended that the landfill is approached to confirm this position prior to off-site disposal. Otherwise, additional testing will be required to confirm the waste disposal route for natural soils beneath the Site.



GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 48 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

Table 12.1 Preliminary Materials Waste Classification

Exploratory Hole Location	Sample Depth (m bgl)	Simplified Description of the Sample	Basic Waste Characterisation Result	If 'Potentially Hazardous': Is it Possible to Demonstrate the Material is Non-Hazardous?
TP101	0.10	Topsoil: Dark brown sandy gravelly Clay	Non-Hazardous	N/A
TP102	0.20	Topsoil: Dark brown sandy gravelly Clay	Non-Hazardous	N/A
TP103	2.70	Natural: Brown gravelly Clay (Till)	Non-Hazardous	N/A
TP104	0.10	Topsoil: Dark brown sandy gravelly Clay	Non-Hazardous	N/A
TP105	0.30	Topsoil: Dark brown sandy gravelly Clay	Non-Hazardous	N/A
TP106	0.15	Topsoil: Dark brown clayey Sand	'Potentially hazardous' but can be downgraded to non-hazardous (see next column for details).	Yes. Driven by 'HP 3(i): Flammable "flammable liquid waste"' (hazard statement: Flam. Liq. 3; H226 "Flammable liquid and vapour.").
TP107	0.10	Topsoil: Dark brown clayey Sand		However, Tier Environmental consider that such a hazard property would apply if free phase product has been reported in the sample. As no free phase product was encountered, it is considered that the materials above may be regarded as being non-hazardous .
TP108	0.30	Topsoil: Dark brown clayey sandy Silt		
TP109	0.15	Topsoil: Dark brown clayey Sand	Non-Hazardous	N/A
TP110	0.50	Natural: Brown gravelly Clay (Till)	Non-Hazardous	N/A
TP111	0.10	Topsoil: Dark brown sandy gravelly Clay	Non-Hazardous	N/A
TP112	0.20	Topsoil: Dark brown sandy gravelly Clay	'Potentially hazardous' but can be downgraded to non-hazardous (see next column for details).	Yes. Driven by 'HP 3(i): Flammable "flammable liquid waste"' (hazard statement: Flam. Liq. 3; H226 "Flammable liquid and vapour.").
				However, Tier Environmental consider that such a hazard property would apply if free phase product has been reported in the sample. As no free phase product was encountered, it is considered that the materials above may be regarded as being non-hazardous .
TP114	0.05	Topsoil: Dark brown clayey Sand	Non-Hazardous	N/A
TP116	0.10	Topsoil: Dark brown sandy gravelly Clay	'Potentially hazardous' but can be downgraded to non-hazardous (see next column for details).	Yes. Driven by 'HP 3(i): Flammable "flammable liquid waste"' (hazard statement: Flam. Liq. 3; H226 "Flammable liquid and vapour.").
TP117	0.20	Topsoil: Dark brown sandy gravelly Clay		However, Tier Environmental consider that such a hazard property would apply if free phase product has been reported in the sample. As no free phase product was encountered, it is considered that the materials above may be regarded as being non-hazardous .
TP117	0.40	Made Ground: Black clayey gravelly Peat		
TP118	1.00	Made Ground: Black clayey gravelly Peat		
TP118	1.70	Made Ground: Black clayey gravelly Peat		
TP120	0.30	Topsoil: Dark brown clayey Sand	Non-Hazardous	N/A
TP121	1.00	Natural: Brown gravelly Clay (Till)	Non-Hazardous	N/A
HDP101	0.30	Made Ground: Gravel of limestone, sandstone and brick	Non-Hazardous	N/A
HDP102	0.10	Made Ground: Gravelly Clay	'Potentially hazardous' but can be downgraded to non-hazardous (see next column for details).	Yes. Driven by 'HP 3(i): Flammable "flammable liquid waste"' (hazard statement: Flam. Liq. 3; H226 "Flammable liquid and vapour.").
				However, Tier Environmental consider that such a hazard property would apply if free phase product has been reported in the sample. As no free phase product was encountered, it is considered that the materials above may be regarded as being non-hazardous .
HDP103	0.30	Made Ground: Gravelly Clay	Non-Hazardous	N/A
HDP103	1.20	Made Ground: Black clayey gravelly Peat	'Potentially hazardous' but can be downgraded to non-hazardous (see next column for details).	Yes. Driven by 'HP 3(i): Flammable "flammable liquid waste"' (hazard statement: Flam. Liq. 3; H226 "Flammable liquid and vapour.").
HDP106	0.15	Made Ground: Gravelly Clay		However, Tier Environmental consider that such a hazard property would apply if free phase product has been reported in the sample. As no free phase product was encountered, it is considered that the materials above may be regarded as being non-hazardous .



12.3. Materials Re-Use

Subject to volumetric fill requirements and a future assessment of suitability of re-use (both chemically and geotechnically), some materials may be considered for potential re-use in line with an appropriate end-of-waste protocol such as WRAP Quality Protocol for Aggregates from Inert Waste, U1 Exemption or a Materials Management Plan in accordance with the CL:AIRE Definition of Waste Code of Practice (DoWCoP). Please note that any previously landfilled or mining waste materials may not be appropriately subject to consideration under DoWCoP and may not be re-used under DoWCoP unless sufficient lines of evidence and agreement with the local Natural Resources Wales Waste Team can be sought beforehand.

Re-Use of Excavated and Stockpiled Clean Naturally Occurring Soils on Other Sites

In addition, Tier Environmental are aware that CL:AIRE is classing stockpiled clean, naturally occurring soils as waste, unless their final destination is identified in a Materials Management Plan, before they are excavated. However, Tier Environmental consider that any clean naturally occurring soils arising from enabling works, earthworks or construction activities would be regarded as an asset and the default assumption for this Site (prior to excavation and stockpiling) is not the intention to discard these materials where they may be reasonably re-used on this, or another, development site. Stockpiling is a recognised, recommended means of safely storing soils. Whilst there may be advantages to leaving soils in-situ, stripping topsoil and subsoil prior to earthworks is a routine construction activity. Tier Environmental consider that it is not unreasonable to state that in the event that the developer owns another site where the construction phase is ongoing, soils can be transferred between their sites as an owned product and never become waste.

The above paragraph above is therefore considered a clear intention to reuse any clean, naturally occurring soils derived from excavations at this Site (which may also include temporary stockpiling these materials). It is considered; however, that in addition to this the following must be adhered to:

- Reuse does need to occur within a 'reasonable' timeframe (12 No. months); and,
- If soils are transferred to a third party (another developer), there needs to be some contractual agreement in place, as in this situation it is important to have something in place confirming that surplus soils are required by the third party.

Re-Use of Excavated and Stockpiled Clean Naturally Occurring Soils Within The Site They Are Excavated From

Further to the above, where soils are naturally occurring, uncontaminated and re-used on the site they are excavated from, they fall outside of the Waste Framework Directive (WFD) i.e. they will not be classified as a waste. Currently the CL:AIRE Definition of Waste Code of Practice states the following which appears to support this position: *"If the material is waste an Environmental Permit will be required to lawfully deposit or re-use it unless the material is "uncontaminated soil and other naturally occurring material excavated in the course of construction activities where it is certain that the material will be used for the purposes of construction in its natural state on the site from which it was excavated", which is excluded from waste regulation by the Waste Framework Directive (2008)."*



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 50 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

13.CONCLUSIONS AND RECOMMENDATIONS

13.1. Conclusions

- The site is broadly underlain site wide by topsoil to depths of 0.18m to 0.46m bgl or Made Ground to depths of between 0.34m to 0.55m bgl, principally in the east of the site. These are underlain by natural soils comprised of Devensian Till, described as a firm becoming stiff and locally very stiff Clay. A more weathered horizon of brown clay was recorded in the order of 0.30m to 0.92m thick overlying the dark grey unweathered Till which was proven to the maximum drilled depth of 15.15m bgl. Sand lenses were also recorded near surface to 0.45m and 0.63m bgl. Localised areas of soft organic clays and peat are described within the east of the site within an infilled pond from depths of 0.33m to 1.90m bgl to depths of between 1.25m to 2.80m bgl.
- Groundwater was encountered between 0.20 to 7.30m bgl, with a shallow body of between circa 0.20-3.10m and a deeper body of between circa 4.50m to 7.30m bgl in the cable percussive boreholes. Trial pits recorded limited light seepage and some shallow inflow from Made Ground soils.
- No measured soil concentrations of potential contaminants of concern have been reported in excess of Generic Assessment Criteria (GACs) protective of human health appropriate to the proposed land use. On this basis, it is not considered that the site represents a potential risk to end-users.
- Furthermore, of the 23 No. of Made Ground samples submitted for asbestos screening, none were reported to contain asbestos.
- In addition, no measured concentrations of potential contaminants of concern within the explosives suite have been reported in excess of the laboratory method detection limit.
- From a conceptual site model perspective, the Devensian Till is classified as a Secondary Undifferentiated Aquifer, and the bedrock geology is classified as a Principal Aquifer associated with Kinnerton Sandstone Formation in the western/northern parts of the Site and a Secondary A Aquifer associated with the Salop Formation comprising mudstone in the southern / southeastern part of the Site. There is an inferred fault located beneath the site orientated from southwest to northeast associated with these two bedrock formations. The site is within a Source Protection Zone Total Catchment 3 associated with the Principal Aquifer, and the nearest surface water receptor comprises an underground water course 110m west. There are no potable or non-potable water abstractions located within 1km of the Site. The low permeability cohesive Till deposits have been proven to depths of circa 15.00m bgl in this investigation and are recorded to depths of circa 26.0 to 38.0m bgl in nearby BGS records which is considered sufficient to provide protection of the underlying bedrock aquifers from any vertical migration of potential contaminants of concern. In addition, it is not considered that the proposed shallow foundation solution will form any preferential pathways to the underlying Principal Aquifer. On this basis the controlled waters sensitivity is considered to be low.
- Measured groundwater concentrations of copper, chromium, nickel, zinc, anthracene, Sum PAHs, fluoranthene, benzo(a)pyrene, total ammonia and electrical conductivity are not considered to present a risk to the controlled waters environment for the following reasons:
 - o The potential for significant dilution between the Site and nearby significant water bodies;
 - o The low sensitivity of the controlled waters environment;
 - o The localised nature of those soil leachate concentrations in excess of the WQS and the absence of any reported widespread leachable concentrations;
 - o The fact that the Site will incorporate buildings / hardstanding and a dedicated drainage system that shall reduce infiltration rates through the soils;
 - o The absence of any nearby potable or non-potable groundwater abstractions;
 - o The protection offered to the underlying principal aquifer by the presence of >10.0m of low permeability cohesive Till soils.
 - o The absence of a nearby viable surface water body where a consumption of fish by humans exposure scenario would be realised for fluoranthene and benzo(a)pyrene.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 51 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

- The proposed development will involve the development of the majority of the site, with buildings and hardstanding proposed and demolishing the farm buildings at Little Acorns and Honey Suckle Cottage off Francis Lane. Not only will this act to inhibit infiltration into the ground, it will also largely remove the source of agricultural phosphate from the site. The site won topsoil will be reused within the development within screening bunds and soft landscaping, but agricultural fertilisers and manure will no longer be used on the site. Wastewater drainage from the proposed development will be either via the on-site combined sewer and the Five Fords WwTW or on-site wastewater treatment and discharge to the on-site surface water drainage system.
- **Based on the results of the GSV calculations the proposed Unit 2 development should be classified as a Characteristic Situation 3 – Moderate Risk Scenario for which ground gas protection measures are required and the remainder of the Site should be classified as a Characteristic Situation 1 – Very Low Risk Scenario for which no ground gas protection measures are required**
- The Unit 2 Zone area of Site has been placed in a Characteristic Situation 3 - Moderate Risk Scenario on the basis of the 'worst case' GSV alone. However, this is driven by an instance of elevated peak methane from well WS105 only. This location targeted a historic infilled pond and logs described soils of organic clays and peat. This is considered the primary source for this elevated methane and carbon dioxide. Alternatively, if this material will be removed as part of enabling works due to its being geotechnically unsuitable, it will remove the source of the elevated methane and carbon dioxide, effectively placing the Unit 2 Zone in the same Zone as the remainder of the Site within a Characteristic Situation 1 – Very Low Risk Scenario. **However, this would only be applicable if these soils are removed; if the soils remain then the whole of Unit 2 MUST remain classified as a CS3.**
- Basic waste characterisation has determined that all Made Ground soils are non-hazardous. WAC testing has not been completed as part of these works and final waste disposal routes should be confirmed prior to removal from site. It is anticipated that natural soils will be suitable for disposal to an inert waste landfill.

13.2. Recommendations

- Confirmation of the locations of the gas main that is to be diverted and the existing combined sewer.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 52 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

14.REGULATORY APPROVALS

The conclusions and recommendations presented above are considered reasonable based on the findings of the site investigation. However, these cannot be guaranteed to gain regulatory approval and, therefore, the report should be passed to the appropriate regulatory authorities and/or other organisations for their comment and approval prior to undertaking any works on site.

It is recommended that conditions placed on any planning permission are discharged prior to commencement of site works.



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 53 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

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**GROUND INVESTIGATION REPORT FOR BRYN
LANE – FULL PLANNING AREAS, WREXHAM**

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 54 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

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GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05
Page No : 55 of 57
Engineer: Eve Rowland & Stuart Milne
Date: 20/10/2023

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GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 56 of 57

Engineer: Eve Rowland & Stuart Milne

Date: 20/10/2023

16.GLOSSARY OF TERMS

ACEC	Aggressive Chemical Environment for Concrete (classification)
aOD	Above Ordnance Datum
bgl	Below ground level
BGS	British Geological Survey
BRE	Building Research Establishment
CBR	California Bearing Ratio (test)
COMAH	Control of Major Accident Hazards (regulations)
Designated location	Site (and the ecosystem on that site) protected under national or international legislation. A potential ecological receptor to be considered as part of the assessment of land contamination. Example designated locations include SSSIs (q.v.), SACs (q.v.), national nature reserves, Ramsar sites and bird special protection areas.
DQA	Data Quality Assessment
DQO	Data Quality Objective
DQRA	Detailed Quantitative Risk Assessment
DWS	Drinking Water Standard
EQS	Environmental Quality Standard
GAC	Generic Assessment Criterion
GQA	General Quality Assessment (Environment Agency)
GSV	Gas Screening Value
HCV	Health Criteria Value
IPPC	Integrated Pollution Prevention and Control (regulations)
K _{ow}	Octanol-water partition coefficient
LEL	Lower Explosive Limit
LL	Liquid Limit
LoD	Limit of Detection (analytical)
LoQ	Limit of Quantification (analytical)
Mean Value Test	Statistical test (described in the CIEH Guidance) to estimate the mean value of a normally distributed population of data at a given level of confidence. Normally for contaminated land assessment, the 95th percentile (referred to as the 95%UCL or US95) is applied as a reasonable but conservative estimate of the mean concentration for comparison with the relevant assessment criteria.
Maximum Value Test	Statistical test (described in the CIEH Guidance) to identify whether an elevated concentration within a normally distributed data set forms part of the underlying population from which it has been sampled or whether it is an outlier (such as a localised area of contamination) that merits further consideration.
MC	Moisture Content
NGR	National Grid Reference
NIHHS	Notification of Installations Handling Hazardous Substances (regulations)
OS	Ordnance Survey
PI	Plasticity Index
PID	Photoionisation Detector
PL	Plastic Limit
ppm	Parts per million
ppmv	Parts per million by volume
QA	Quality Assurance
QC	Quality Control
SAC	Special Area of Conservation
SOM	Soil Organic Matter



GROUND INVESTIGATION REPORT FOR BRYN LANE – FULL PLANNING AREAS, WREXHAM

Report No : TE1750-TE-00-XX-RP-GE-001-V05

Page No : 57 of 57

Engineer: Eve Rowland & Stuart Milne

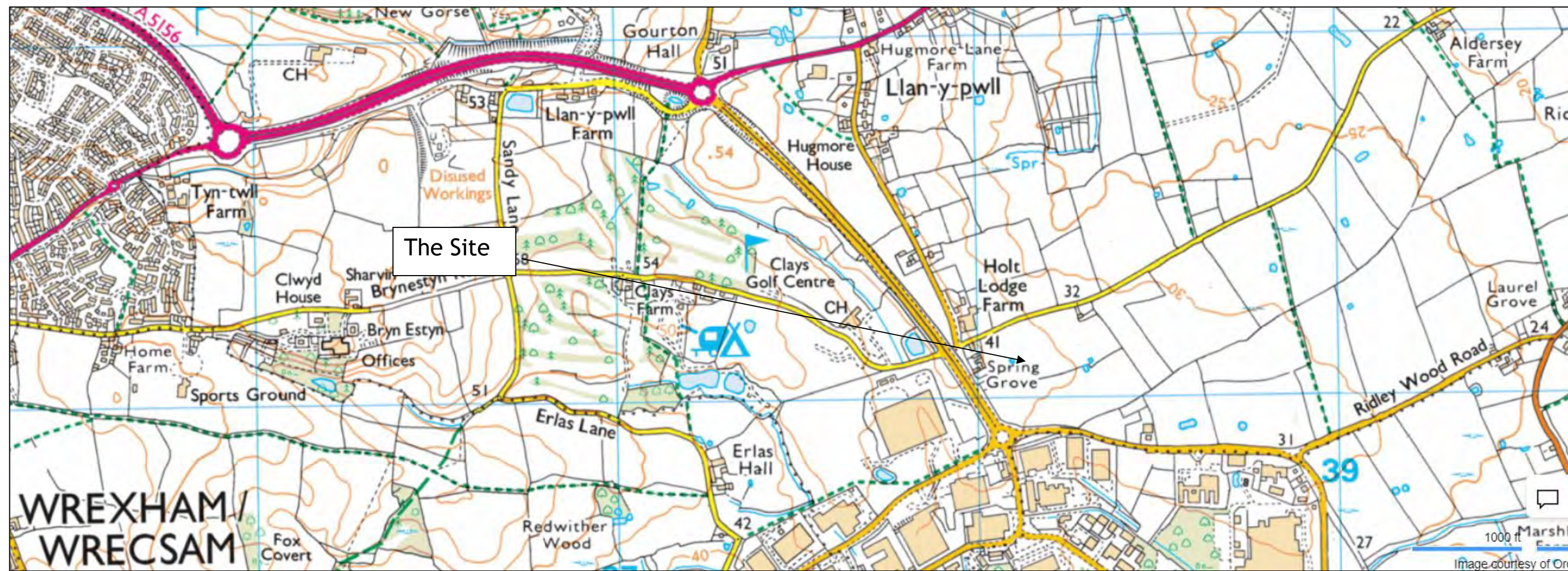
Date: 20/10/2023

SPT	Standard Penetration Test
SPZ	Source Protection Zone (see Appendix L)
SSAC	Site-Specific Assessment Criterion
SSSI	Site of Special Scientific Interest
SVOC	Semi-Volatile Organic Compound
TEF	Toxicity Equivalent Factor
TPH	Total Petroleum Hydrocarbons
TWA	Time Weighted Average
US95	95 th percentile estimate of the true mean value of a data population (also known as 95%UCL).
VOC	Volatile Organic Compound

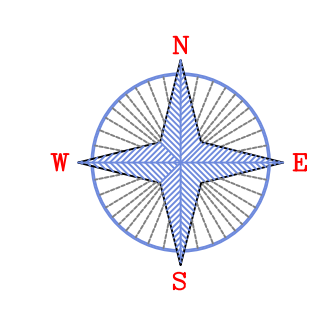
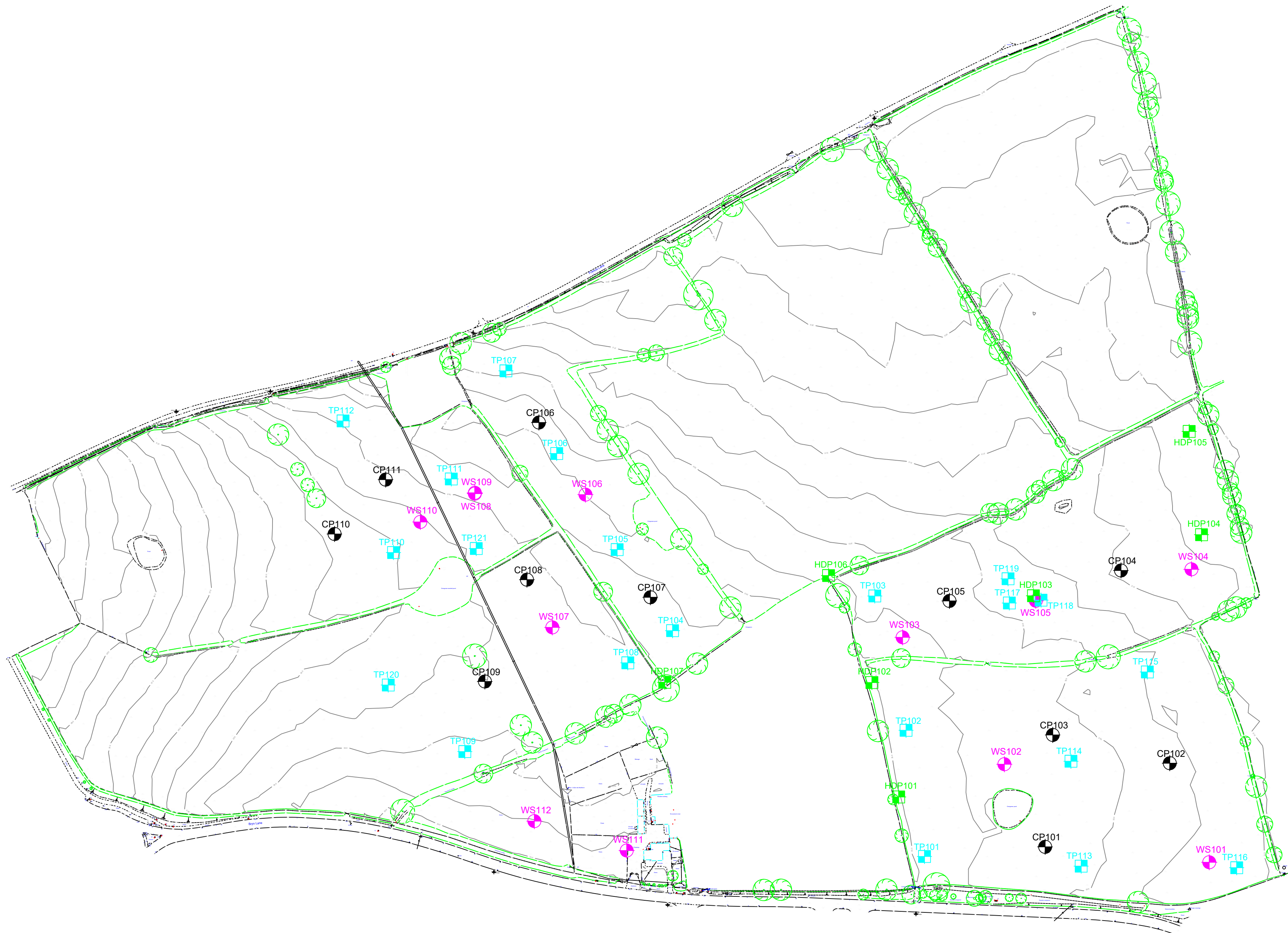
APPENDIX A - DRAWINGS



Site Location Plan



Contract Number:	TE1750
Contract Name:	Bryn Lane – Detailed Planning
Date:	29/06/2023
Scale:	NTS
Drawn by:	ER
Approved by:	SL
Drawing Number:	TE1750-TE-00-XX-DR-GE-001-V01



DO NOT SCALE



NOTES

-  Detailed Planning Trial Pit Location
-  Detailed Planning Hand Dug pit Location
-  Detailed Planning Cable Percussive Location
-  Detailed Planning Window Sample Location

P1	26/06/2023	CS	ISSUED FOR INFORMATION	ER	ER
REV	DATE	BY	DESCRIPTION	CHK	APD

DRAWING STATUS: PRELIMINARY



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CLIENT: NET WORLD SPORTS

PROJECT: BRYN LANE WREXHAM
DETAILED PLANNING

TITLE: EXPLORATORY HOLE LOCATION PLAN

SCALE: 1:200 @ A1	CHECKED: ER	APPROVED: ER
CAD FILE: -	DESIGN/DRAWN: CS	DATE: 26/06/2023
PROJECT No: TE1750	DRAWING No: TE1750-TE-00-XX-DR-GE-002-V01	REV: P1