



## **PHASE 2 GROUND INVESTIGATION:**

**GSL2949**

**VERSION 2**

**20 SEPTEMBER 2023**

**FINAL**

Prepared for:

Wales and West Housing

Prepared by: Ross Page

GroundSolve Ltd

## DOCUMENT CONTROL

|                          |            |
|--------------------------|------------|
| <b>Report No. :</b>      | GSL2949    |
| <b>Report Status:</b>    | FINAL      |
| <b>Version No.:</b>      | 2          |
| <b>Project Engineer:</b> | Ross Page  |
| <b>Date of Issue:</b>    | 20/09/2023 |

This report has been prepared by GroundSolve Ltd with all reasonable care and diligence, within the best practice and guidance current at the time of issue within the proposed redline boundary and proposed Site end use as presented by the Client.

This report is confidential to the Client and GroundSolve Ltd accepts no responsibility whatsoever to third parties to whom this report is presented.

| Version No. | Description of Issue / Revision | Date of Issue | Author             | Reviewed By         | Approved By                 |
|-------------|---------------------------------|---------------|--------------------|---------------------|-----------------------------|
| 01          | Draft                           | 24.08.23      | R J Page           |                     |                             |
|             |                                 |               | BSc (Hons) MSc FGS |                     |                             |
| 02          | FINAL                           | 20.09.23      | R J Page           | P Welsby            | S Fishburne                 |
|             |                                 |               | BSc (Hons) MSc FGS | Msci, MSc(eng), FGS | BEng(hons) MSc<br>CGeol FGS |

## CONTENTS

|          |                                                          |           |
|----------|----------------------------------------------------------|-----------|
| <b>1</b> | <b>INTRODUCTION.....</b>                                 | <b>9</b>  |
| 1.1      | Proposed Development .....                               | 9         |
| 1.2      | Objectives .....                                         | 10        |
| 1.3      | Previous Investigations .....                            | 11        |
| 1.4      | Limitations .....                                        | 11        |
| <b>2</b> | <b>SITE DETAILS AND DESCRIPTION .....</b>                | <b>12</b> |
| <b>3</b> | <b>PREVIOUS INVESTIGATIONS .....</b>                     | <b>13</b> |
| 3.1      | Review.....                                              | 13        |
| 3.2      | Previous Fieldwork.....                                  | 14        |
| 3.3      | Previous Chemical Testing .....                          | 16        |
| <b>4</b> | <b>FIELDWORK.....</b>                                    | <b>20</b> |
| 4.1      | Introduction .....                                       | 20        |
| 4.2      | Dynamic (Window) Sample Boreholes.....                   | 20        |
| 4.3      | Trial Pits .....                                         | 20        |
| 4.4      | Soakaway Tests.....                                      | 20        |
| 4.5      | Samples and Sample Containers.....                       | 21        |
| 4.6      | Gas and Groundwater Monitoring.....                      | 21        |
| <b>5</b> | <b>LABORATORY TESTING .....</b>                          | <b>22</b> |
| 5.1      | Chemical Laboratory Testing .....                        | 22        |
| 5.2      | Physical Laboratory Testing .....                        | 23        |
| <b>6</b> | <b>GROUND CONDITIONS .....</b>                           | <b>24</b> |
| 6.1      | General.....                                             | 24        |
| 6.2      | Ground Surface / Topsoil .....                           | 24        |
| 6.3      | Anthropogenic Materials .....                            | 24        |
| 6.4      | Natural Deposits .....                                   | 25        |
| 6.5      | Bedrock .....                                            | 25        |
| <b>7</b> | <b>GENERIC QUANTITATIVE RISK ASSESSMENT .....</b>        | <b>26</b> |
| 7.1      | Assessment for the Protection of Human Health .....      | 26        |
| 7.2      | Restrictions .....                                       | 26        |
| 7.3      | Results.....                                             | 27        |
| 7.4      | Assessment for the Protection of Controlled Waters ..... | 29        |
| 7.5      | Permanent Ground Gases.....                              | 30        |
| 7.6      | Risks to Human Health (Construction Phase) .....         | 31        |

|           |                                                         |           |
|-----------|---------------------------------------------------------|-----------|
| 7.7       | Conceptual Site Model.....                              | 32        |
| <b>8</b>  | <b>WASTE ASSESSMENT.....</b>                            | <b>35</b> |
| 8.1       | Waste Hierarchy .....                                   | 35        |
| 8.2       | Waste Characterisation and Classification.....          | 35        |
| <b>9</b>  | <b>GEOTECHNICAL ASSESSMENT AND RECOMMENDATIONS.....</b> | <b>37</b> |
| 9.1       | Laboratory Data Review.....                             | 37        |
| 9.2       | Insitu Testing.....                                     | 40        |
| 9.3       | Trees .....                                             | 42        |
| 9.4       | Mining Legacy .....                                     | 43        |
| 9.5       | Existing Culvert .....                                  | 43        |
| 9.6       | Foundation Recommendations.....                         | 44        |
| 9.7       | Reuse of Materials .....                                | 45        |
| 9.8       | Groundwater Conditions .....                            | 45        |
| 9.9       | Groundwater & Excavations .....                         | 46        |
| 9.10      | Buried Concrete and Pipework .....                      | 47        |
| 9.11      | Soakaways & Drainage.....                               | 48        |
| <b>10</b> | <b>REFERENCES.....</b>                                  | <b>49</b> |
| <b>11</b> | <b>DEFINITIONS .....</b>                                | <b>51</b> |

## TABLES

|                                                                      |    |
|----------------------------------------------------------------------|----|
| Table 2.1 Current Site Overview. ....                                | 12 |
| Table 3.1: Summary of Previous Investigations. ....                  | 13 |
| Table 3.2 - Summary of previous investigation exploratory holes..... | 14 |
| Table 3.3 - Summary of SPT N Values .....                            | 15 |
| Table 3.4 - Metals Suite.....                                        | 17 |
| Table 3.5 - Polyaromatic Hydrocarbons.....                           | 18 |
| Table 3.6 - Petroleum Hydrocarbons .....                             | 18 |
| Table 5.1: Suites of Analysis for Environmental Soil Samples.....    | 22 |
| Table 5.2: Summary of Physical Testing.....                          | 23 |
| Table 6.1 Summary of Strata Encountered .....                        | 24 |
| Table 7.1: Metals Suite.....                                         | 27 |
| Table 7.2: Polyaromatic Hydrocarbons .....                           | 28 |
| Table 7.3: Petroleum Hydrocarbons .....                              | 28 |
| Table 7.4: Summary of Ground Gas Monitoring .....                    | 30 |

|                                                          |    |
|----------------------------------------------------------|----|
| Table 8.1: Laboratory Sampling Testing Frequencies ..... | 36 |
| Table 9.1: Particle Size Distribution Testing.....       | 37 |
| Table 9.2: Compaction Testing Results .....              | 38 |
| Table 9.3: Summary of Classification Testing.....        | 39 |
| Table 9.4: Summary of SPT N Values .....                 | 40 |
| Table 9.5: Sulphate Testing Results .....                | 47 |

## **FIGURES**

|                                                        |    |
|--------------------------------------------------------|----|
| Figure 1 - Extract from Proposed Development Plan..... | 10 |
|--------------------------------------------------------|----|

## **APPENDICES**

Appendix A – Site Photographs

Appendix B – Previous Reports

Appendix C – Exploratory Hole Logs

Appendix D – Infiltration Test Results

Appendix E – Monitoring Results

Appendix F – Chemical Testing Results

Appendix G – Geotechnical Test Results

Appendix H – Summary Of Chemical Testing Results

Appendix I – Current Guidance For Ground Gas Risk Assessment

APPENDIX J – Guidance For Classification Of Soil For Off Site Disposal At A Landfill Site

APPENDIX K – Unforeseen Ground Contamination

## EXECUTIVE SUMMARY

|                                                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Introduction</b>                            | GroundSolve Ltd (GSL) was commissioned by Wales and West Housing ("the Client") to undertake a desk study of the proposed housing development at Ruabon Business Park, and to undertake a site investigation at the Site. This report presents the findings of the site investigation and makes recommendations based upon those findings.                                                                                                                                                                                                                                                                                 |
| <b>Proposed land use</b>                       | It is proposed that the Site will be developed into six industrial buildings with associated parking at the southern end of the site with the rest of the site being occupied by 43 residential properties along with associated parking and gardens with two areas of communal open space.                                                                                                                                                                                                                                                                                                                                |
| <b>Site location and surrounding land uses</b> | The site is located in Ruabon on Wynnstay Technology Park, Ruabon, Wrexham, LL14 6EN.<br>To the north of the site is open arable land, to the east and south there is industrial buildings and to the west there are residential properties.                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Site history</b>                            | The earliest available mapping (1873) indicates a shaft located within the southern half of the site most likely associated with the adjacent Wynnstay Colliery with the remainder agricultural fields. By 1899 the shaft is marked as disused and a secondary air shaft has been constructed immediately to the northeast. From 1899 onwards the site is used for the tipping of mining spoil from the colliery until its closure in 1962. By 1989 the site has been cleared and redeveloped into Wynnstay Technology Park with levels reduced and the shaft capped. The site remains broadly undeveloped to the present. |
| <b>Geology, Hydrogeology and Hydrology</b>     | The superficial deposits present on site are expected to be Devensian Glacial Till with the solid geology being the Pennine Lower Coal Measures Formation And Pennine Middle Coal Measures Formation (Undifferentiated) - Mudstone, Siltstone And Sandstone.<br><br>The superficial aquifer on site is classed as Secondary Undifferentiated.<br><br>The bedrock aquifer on site is classed as Secondary A.<br><br>There are no potable water extractions within 500m.                                                                                                                                                     |
| <b>Ground Gases</b>                            | There is a potential for ground gasses from backfill and made ground and possibly the mine shaft on site, however no major gas concentrations have been recorded to date.                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Radon Requirements</b>                      | Basic protection measures are required as 5 to 10 % of properties are affected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Potential contaminative features</b>        | Made ground is present at the site which could be a source of contamination as well as the surrounding industrial buildings.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Mining and quarrying</b>                    | The site is heavily impacted by historical coal mining with a significant thickness of mining spoil along with a disused shaft (now capped) and an air drift.                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Previous investigations</b>                 | GSL have previously conducted an investigation at the site in October 2020.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Unexploded Ordnance</b>                     | There is a low UXO risk at the site.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

|                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|--------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Preliminary Geotechnical Assessment</b> | <p><u>Option 1</u></p> <p>Limited ground improvement. This would involve excavating and recompacting the colliery spoil to a depth of 1.00m and then utilising a raft foundation, with an allowable bearing capacity of around 100kN/m<sup>2</sup>.</p> <p><u>Option 2</u></p> <p>Piled foundations taken through the Made Ground and weathered Glacial Till into the underlying firm to stiff clay.</p>                                                                                                                                                                                                                                                                                                                         |
| <b>Waste Soils Classification</b>          | <p>In order to determine whether soils can be sent to a licensed landfill for disposal further testing is required comprising landfill Waste Acceptance Criteria (WAC) analysis for both total concentrations for certain chemicals and for leachate analysis. No WAC testing was carried out as part of this investigation. WAC testing will have to be carried out to confirm the landfill waste classification and if any pre-treatment is required. This is best carried out once all material to be disposed of is stockpiled, and volumes can be accurately assessed. It should be noted that natural clay can be classified as Inert Waste 17 05 04: Soil and stones only (excluding topsoil, peat, soil and stones).</p> |
| <b>Materials re-use</b>                    | <p>Subject to volumetric fill requirements and a future assessment of suitability of re-use (both chemically and geotechnically), some materials <i>may</i> 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).</p>                                                                                                                                                                                                                                                                                    |

## 1 INTRODUCTION

GroundSolve Ltd (GSL) was commissioned by Wales and West Housing (“the Client”) to undertake a second phase site investigation and contaminated land risk assessment for an area of land off Wynnstay Lane in Ruabon, Wrexham referred to as Ruabon Business Park (the “Site”).

This report has been devised to generally comply with the relevant principles and requirements of a range of guidance including:

- Part IIA of the Environment Protection Act, 1990;
- BS5930:2015 +A1:2020: “Code of practice for site investigations”;
- BS10175: 2011 +A2:2017 “Investigation of Potentially Contaminated Sites - Code of Practice”;
- The Building Regulations 2010. Part C (HM Government 2013);
- Environment Agency: Land Contamination Risk Management (LCRM), Version 3, October 2020;
- Environment Agency (2017) “The Environment Agency’s Approach to Groundwater Protection” November 2018 Version 1.2.

### 1.1 Proposed Development

The proposed development is comprised of 43 residential properties with associated parking and garden areas as well as access roads and two areas of open recreational space. Also proposed are 6 industrial properties to the south of the site with associated parking and access road. See **Figure 1** below.



**Figure 1 - Extract from Proposed Development Plan**

## 1.2 Objectives

The purpose of the report is to provide an assessment of the site using published information and conditions at the site in relation to the proposed residential and industrial end use.

The findings and conclusions of the risk assessment have been set out and recommendations given for the proposed end use. If there is a subsequent change in the proposed land, the risk assessments and conclusions should be reviewed to determine whether they are still applicable for the revised end use.

This document is a working document and may need to be updated, in agreement with the relevant regulatory bodies, at any stage during development dependent on the conditions encountered. This version of this document is to be issued to regulators for approval (i.e., Wrexham County Council).

### **1.3 Previous Investigations**

A previous site investigation has been conducted by GSL during October 2020.

A phase one desk study report was undertaken prior to GroundSolve Ltd (GSL) undertaking a phase 2 site investigation and geotechnical report.

### **1.4 Limitations**

This report has been prepared for the sole use of Wales and West Housing. No other third party may rely upon or reproduce the contents of this report without the written approval of GroundSolve Ltd. If any unauthorised third party comes into possession of this report, they rely on it entirely at their own risk.

Access into each area/phase of the proposed development was slightly restricted due to the presence of an old storage container and a large amount of fly tipping present in the south of the site. There are also large stockpiles of soil and dense vegetation which will need to be cleared in order to easily access the site.

## 2 SITE DETAILS AND DESCRIPTION

Table 2.1 Current Site Overview.

|                                      |                                                                                                             |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Site name                            | Wynnstay Technology Park                                                                                    |
| Site address                         | Wynnstay Technology Park, Ruabon, Wrexham LL14 6EN                                                          |
| National Grid Reference (NGR)        | SJ 29204 43578                                                                                              |
| Approximate Site area                | 2 Hectares                                                                                                  |
|                                      |                          |
| Site shape                           | Roughly rectangular                                                                                         |
| Current land use on the Site         | Open wasteland                                                                                              |
| Surrounding land uses                | Open arable fields to the north and industrial buildings to the south with residential housing to the west. |
| General topography and ground levels | The site is relatively flat sloping from 131mAOD in the north of the site to 127mAOD in the south           |

### 3 PREVIOUS INVESTIGATIONS

The following works have previously been undertaken by GroundSolve:

- Phase II Geo-environmental Report (Ref:2387, issued October 2020).
- Phase I Preliminary Risk Assessment (Ref: 2949, issued August 2023).

The findings of these reports shall be summarised in the following sections and can be found in **Appendix B**.

#### 3.1 Review

A summary of the findings from previous reports is given in **Table 3.1** below:

**Table 3.1: Summary of Previous Investigations.**

|                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Site History</b>          | The earliest available mapping (1873) indicates a shaft located within the southern half of the site most likely associated with the adjacent Wynnstay Colliery with the remainder agricultural fields. By 1899 the shaft is marked as disused and a secondary air shaft has been constructed immediately to the northeast. From 1899 onwards the site is used for the tipping of mining spoil from the colliery until its closure in 1962. By 1989 the site has been cleared and redeveloped into Wynnstay Technology Park with levels reduced and the shaft capped. The site remains broadly undeveloped to the present. |
| <b>Geological Setting</b>    | <p>The superficial deposits present on site are expected to be Devensian Glacial Till with the solid geology being the Pennine Lower Coal Measures Formation and Pennine Middle Coal Measures Formation (Undifferentiated) - Mudstone, Siltstone and Sandstone.</p> <p>The superficial aquifer on site is classed as Secondary Undifferentiated of low groundwater vulnerability.</p> <p>The bedrock aquifer on site is classed as Secondary A of low groundwater vulnerability.</p>                                                                                                                                       |
| <b>Mining</b>                | The proposed development is in a surface area that could be affected by underground mining in 6 seams of coal at 140m to 320m depth, and last worked in 1927 however any movement in the ground due to coal mining activity associated with these workings should have stopped by now.                                                                                                                                                                                                                                                                                                                                     |
| <b>Waste</b>                 | <p>Waste material from the past mining activities it likely to be on site in the form of made ground.</p> <p>Evidence of fly tipping is present on the site.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Contamination Sources</b> | Potential contamination features comprise substations, made ground, historic tramway, historic colliery, and mine shaft.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

### 3.2 Previous Fieldwork

An investigation was undertaken on the 8<sup>th</sup> and 9<sup>th</sup> September 2020 and comprised the following.

- 10no. Windowless Sample boreholes (WS1 to WS10).
- 10no. Trial Pits (TP1 to TP10).
- 18no. Dynamic Cone Penetrometer tests to provide CBR values.

Below is a summary of the exploratory holes and the strata encountered from the previous investigation.

**Table 3.2 - Summary of previous investigation exploratory holes**

| Exploratory Hole | Depth to base of strata (mbgl) |                          |              | Groundwater | Comments                                                           |
|------------------|--------------------------------|--------------------------|--------------|-------------|--------------------------------------------------------------------|
|                  | Made Ground                    | Glacial Till (Weathered) | Glacial Till |             |                                                                    |
| TP1              | 1.10                           | -                        | -            |             | Terminated within the Made Ground                                  |
| TP1A             | 2.00                           | -                        | -            |             | Terminated within the Made Ground                                  |
| TP2              | 2.30                           | -                        | -            |             | Terminated within the Made Ground                                  |
| TP3              | 2.00                           | -                        | -            |             | Terminated within the Made Ground                                  |
| TP4              | 1.90                           | -                        | -            |             | Terminated within the Made Ground                                  |
| WS1              | 2.00                           | 5.00                     | 5.45         | 1.00        | Groundwater encountered perched on surface of cohesive Made Ground |
| WS2              | 2.50                           | 3.20                     | 5.45         | 2.00        | Groundwater encountered perched on surface of cohesive Made Ground |
| WS3              | 1.50                           | -                        | 5.45         | 1.50        | Groundwater encountered perched on surface of Glacial Till         |
| WS4              | 2.10                           | 4.00                     | 4.37         | 1.50        | Groundwater encountered perched on surface of cohesive Made Ground |
| WS5              | 2.00                           | 4.00                     | 5.35         | 1.00        | Groundwater encountered perched on surface of cohesive Made Ground |
| WS6              | 1.90                           | 3.00                     | 4.41         | 1.80        | Groundwater encountered perched on surface of Glacial Till         |
| WS7              | 1.50                           | 3.00                     | 5.36         | 1.50        | Groundwater encountered perched on surface of Glacial Till         |
| WS8              | 2.00                           | -                        | 5.45         | -           | No groundwater encountered. Glacial Till unweathered.              |

|      |      |   |      |      |                                                            |
|------|------|---|------|------|------------------------------------------------------------|
| WS9  | 2.18 | - | -    | -    | Terminated on obstruction within the Made Ground           |
| WS10 | 1.70 | - | 3.72 | 1.70 | Groundwater encountered perched on surface of Glacial Till |

All exploratory holes encountered made ground with only the deeper windowless sample holes encountering the natural deposits. All natural deposits were logged as glacial till. The majority of exploratory holes encountered an upper weathered surface of lower strength which extended to a maximum depth of 5.00m. The underlying unweathered Till was generally described as stiff to very stiff and was proven to a maximum depth of 5.45m. Standard Penetration Tests (SPTs) were conducted in all exploratory holes the results of which can be found in **Table 3.3** below.

**Table 3.3 - Summary of SPT N Values**

| Location | Depth (m bgl) | SPT N Values | Stratum                  | Estimated Undrained Shear strength (kPa) * |
|----------|---------------|--------------|--------------------------|--------------------------------------------|
| WS1      | 1             | 14           | Made Ground              | 70                                         |
|          | 2             | 3            | Glacial Till - Weathered | 15                                         |
|          | 3             | 5            | Glacial Till - Weathered | 25                                         |
|          | 4             | 12           | Glacial Till - Weathered | 60                                         |
|          | 5             | 50           | Glacial Till             | 250                                        |
| WS2      | 1             | 10           | Made Ground              | Granular Strata                            |
|          | 2             | 10           | Made Ground              | 50                                         |
|          | 3             | 12           | Glacial Till - Weathered | 60                                         |
|          | 4             | 27           | Glacial Till             | 135                                        |
|          | 5             | 23           | Glacial Till             | 115                                        |
| WS3      | 1             | 13           | Made Ground              | Granular Strata                            |
|          | 2             | 14           | Glacial Till             | 70                                         |
|          | 3             | 25           | Glacial Till             | 125                                        |
|          | 4             | 39           | Glacial Till             | 195                                        |
|          | 5             | 31           | Glacial Till             | 155                                        |
| WS4      | 1             | 8            | Made Ground              | Granular Strata                            |
|          | 2             | 8            | Glacial Till - Weathered | 40                                         |
|          | 3             | 6            | Glacial Till - Weathered | 30                                         |
|          | 4             | 50           | Glacial Till             | 250                                        |
| WS5      | 1             | 31           | Made Ground              | 155                                        |
|          | 2             | 3            | Glacial Till - Weathered | 15                                         |
|          | 3             | 14           | Glacial Till - Weathered | 70                                         |
|          | 4             | 40           | Glacial Till             | 200                                        |
|          | 5             | 50           | Glacial Till             | 250                                        |

| Location | Depth (m bgl) | SPT N Values | Stratum                  | Estimated Undrained Shear strength (kPa) * |
|----------|---------------|--------------|--------------------------|--------------------------------------------|
| WS6      | 1             | 14           | Made Ground              | Granular Strata                            |
|          | 2             | 7            | Glacial Till – Weathered | 35                                         |
|          | 3             | 30           | Glacial Till             | 150                                        |
|          | 4             | 50           | Glacial Till             | 250                                        |
| WS7      | 1             | 33           | Made Ground              | Granular Strata                            |
|          | 2             | 3            | Glacial Till – Weathered | 15                                         |
|          | 3             | 24           | Glacial Till             | 120                                        |
|          | 4             | 26           | Glacial Till             | 130                                        |
|          | 5             | 50           | Glacial Till             | 250                                        |
| WS8      | 1             | 34           | Made Ground              | Granular Strata                            |
|          | 2             | 10           | Glacial Till             | 50                                         |
|          | 3             | 30           | Glacial Till             | 150                                        |
|          | 4             | 24           | Glacial Till             | 120                                        |
|          | 5             | 34           | Glacial Till             | 170                                        |
| WS9      | 1             | 26           | Made Ground              | Granular Strata                            |
|          | 2             | 50           | Made Ground              | Asphalt Obstruction                        |
| WS10     | 1             | 37           | Made Ground              | Granular Strata                            |
|          | 2             | 42           | Glacial Till             | 210                                        |
|          | 3             | 39           | Glacial Till             | 195                                        |
|          | 3.6           | 50           | Glacial Till             | 250                                        |

\* Conversion factor=5 (Stroud & Butler)

### 3.3 Previous Chemical Testing

The Category 4 Screening Levels (C4SLs) published by DEFRA (2014) have been adopted in the first instance, which have been published for six substances to date. Where a C4SL is unavailable, the “Suitable 4 Use Levels” (S4ULs) published by LQM/CIEH (2015) have been adopted.

The GQRA is based on a soil with a Soil Organic Matter of 1%, for a residential with gardens end use.

## Metals

The results from the metal analysis have recorded very low concentrations with one exceedance of the applicable GACs which was Arsenic.

**Table 3.4 - Metals Suite**

| Metals               | Min<br>(mg/kg) | Max<br>(mg/kg) | Average<br>(mg/kg) | Count | Adopted Guideline<br>(mg/kg) | Source | Exceedances |
|----------------------|----------------|----------------|--------------------|-------|------------------------------|--------|-------------|
| Arsenic              | 2.8            | 57             | 17.98              | 8     | 37                           | C4SL   | 1           |
| Cadmium              | 0.3            | 0.8            | 0.53               | 8     | 290                          | S4UL   | 0           |
| Chromium             | < 0.1          | 0.7            | 0.34               | 8     | 22                           | C4SL   | 0           |
| Chromium III         | 10             | 29             | 16                 | 8     | 910                          | S4UL   | 0           |
| Chromium, Hexavalent | < 1.0          | <1             | 1                  | 8     | 21                           | C4SL   | 0           |
| Copper               | 24             | 60             | 41.5               | 8     | 2400                         | S4UL   | 0           |
| Lead                 | 15             | 72             | 45.38              | 8     | 200                          | C4SL   | 0           |
| Mercury              | < 0.05         | 0.18           | 0.08               | 8     | 1.2                          | S4UL   | 0           |
| Nickel               | 27             | 62             | 38.5               | 8     | 130                          | S4UL   | 0           |
| Phenol - Monohydric  | < 0.3          | 1.7            | 0.49               | 8     | 120                          | S4UL   | 0           |
| Selenium             | < 0.5          | 3.3            | 1.4                | 8     | 250                          | S4UL   | 0           |
| Zinc                 | 59             | 220            | 98.25              | 8     | 3700                         | S4UL   | 0           |

## PAHs

All samples selected for analysis have generally recorded low PAHs.

**Table 3.5 - Polyaromatic Hydrocarbons**

| Polyaromatic Hydrocarbons (PAH) | Min (mg/kg) | Max (mg/kg) | Average (mg/kg) | Count | Adopted Guideline (mg/kg) | Source | Exceedances |
|---------------------------------|-------------|-------------|-----------------|-------|---------------------------|--------|-------------|
| Acenaphthene                    | < 0.03      | <0.03       | 0.03            | 8     | 210                       | S4UL   | 0           |
| Acenaphthylene                  | < 0.03      | <0.03       | 0.03            | 8     | 170                       | S4UL   | 0           |
| Anthracene                      | < 0.03      | 0.09        | 0.04            | 8     | 2400                      | S4UL   | 0           |
| Benzo(a)anthracene              | < 0.03      | 0.34        | 0.07            | 8     | 7.2                       | S4UL   | 0           |
| Benzo(a)pyrene                  | < 0.03      | 0.27        | 0.06            | 8     | 5                         | C4SL   | 0           |
| Benzo(b)fluoranthene            | < 0.03      | 0.35        | 0.07            | 8     | 2.6                       | S4UL   | 0           |
| Benzo(g,h,i)perylene            | < 0.03      | 0.13        | 0.04            | 8     | 320                       | S4UL   | 0           |
| Benzo(k)fluoranthene            | < 0.03      | 0.14        | 0.04            | 8     | 77                        | S4UL   | 0           |
| Chrysene                        | < 0.03      | 0.39        | 0.08            | 8     | 15                        | S4UL   | 0           |
| Dibenzo(a,h)anthracene          | < 0.03      | <0.03       | 0.03            | 8     | 0.24                      | S4UL   | 0           |
| Fluoranthene                    | < 0.03      | 1.1         | 0.16            | 8     | 280                       | S4UL   | 0           |
| Fluorene                        | < 0.03      | <0.03       | 0.03            | 8     | 170                       | S4UL   | 0           |
| Indeno(1,2,3-c,d)pyrene         | < 0.03      | 0.12        | 0.04            | 8     | 27                        | S4UL   | 0           |
| Naphthalene                     | < 0.03      | 0.05        | 0.03            | 8     | 2.3                       | S4UL   | 0           |
| Phenanthrene                    | < 0.03      | 0.44        | 0.08            | 8     | 95                        | S4UL   | 0           |
| Pyrene                          | < 0.03      | 0.96        | 0.15            | 8     | 620                       | S4UL   | 0           |

## Petroleum Hydrocarbons (PHC)

No hydrocarbon impacted material was encountered during the fieldwork.

**Table 3.6 - Petroleum Hydrocarbons**

| Petroleum Hydrocarbons | Min (mg/kg) | Max (mg/kg) | Average (mg/kg) | Count | Adopted Guideline (mg/kg) | Source | Exceedances |
|------------------------|-------------|-------------|-----------------|-------|---------------------------|--------|-------------|
| Aliphatic C5-C6        | < 0.01      | <0.01       | 0.01            | 8     | 42                        | S4UL   | 0           |
| Aliphatic C6-C8        | < 0.01      | <0.01       | 0.01            | 8     | 100                       | S4UL   | 0           |
| Aliphatic C8-C10       | < 0.01      | <0.01       | 0.01            | 8     | 27                        | S4UL   | 0           |
| Aliphatic C10-C12      | < 1.5       | <1.5        | 1.5             | 8     | 130                       | S4UL   | 0           |
| Aliphatic C12-C16      | < 1.2       | <1.2        | 1.2             | 8     | 1100                      | S4UL   | 0           |
| Aliphatic C16-EC35     | < 1.5       | <1.5        | 1.5             | 8     | 65000                     | S4UL   | 0           |
| Aliphatic C35-C40      | < 3.4       | <3.4        | 3.4             | 8     | 65000                     | S4UL   | 0           |

| Petroleum Hydrocarbons | Min (mg/kg) | Max (mg/kg) | Average (mg/kg) | Count | Adopted Guideline (mg/kg) | Source | Exceedances |
|------------------------|-------------|-------------|-----------------|-------|---------------------------|--------|-------------|
| Aromatic C5-C7         | < 3.4       | <3.4        | 3.4             | 8     | 70                        | S4UL   | 0           |
| Aromatic C7-C8         | < 0.01      | <0.01       | 0.01            | 8     | 130                       | S4UL   | 0           |
| Aromatic C8-C10        | < 0.01      | <0.01       | 0.01            | 8     | 34                        | S4UL   | 0           |
| Aromatic C10-C12       | < 0.01      | <0.01       | 0.01            | 8     | 74                        | S4UL   | 0           |
| Aromatic C12-C16       | < 0.9       | <0.9        | 0.9             | 8     | 140                       | S4UL   | 0           |
| Aromatic >C16-C21      | < 0.5       | <0.5        | 0.5             | 8     | 260                       | S4UL   | 0           |
| Aromatic >C21-C35      | < 0.6       | <0.6        | 0.6             | 8     | 1100                      | S4UL   | 0           |
| Aromatic >C35-EC40     | < 1.4       | <1.4        | 1.4             | 8     | 1100                      | S4UL   | 0           |

The speciated Total Petroleum Hydrocarbons (TPH) results showed very low concentrations, with the majority below the relevant detection limits. The TPH concentrations are below the GAC's and do not represent a significant increased risk to long term human health and give no cause for concern.

## Asbestos

Laboratory assessments were carried out in order to confirm the site assessment that ACMs were absent, and no asbestos was detected in any of the samples retrieved from site.

## **4 FIELDWORK**

### **4.1 Introduction**

Additional fieldwork was carried out between 20<sup>th</sup> to 23<sup>rd</sup> June 2023. GroundSolve personnel were present to supervise all work, describe the ground encountered, and take samples. Fieldwork procedures were undertaken in accordance with the relevant sections of:

- BS5930:2015 + A1:2020 "Code of Practice for Site Investigations;"
- BS10175:2011 + A2:2017 "Investigation of Potentially Contaminated Sites – Code of Practice."

The investigation included:

- 5 No. windowless sample boreholes to a maximum depth of 5.00mBGL,
- 10 No. machine excavated trial pits to maximum depth of 4.00mBGL,
- 3 No. soakaway tests conducted across three of the trial pits,
- Sampling for chemical and geotechnical testing of soils,
- Description of the ground encountered in accordance with BS5930:2015 + A1:2020, Code of Practice for Site Investigations.

The locations of all exploratory holes can be found in **Figure 2** along with the locations of the previous investigations.

### **4.2 Dynamic (Window) Sample Boreholes**

5 No. windowless sampling boreholes (WS01 to WS05) were completed using a tracked windowless sample rig. The exploratory hole logs are presented in **Appendix C**.

### **4.3 Trial Pits**

10 No. trial pits (SA01 – SA03 and TT01 – TT07) were dug using a tracked excavator. The exploratory hole logs are presented in **Appendix C**.

### **4.4 Soakaway Tests**

Soakaway tests were conducted within three of the ten trial pits, using a tractor with towable water bowser. Two of the soakaways (SA01 and SA02) failed to drain due to the presence of low permeability clay, however SA03 drained rapidly as it was undertaken in an area of deep gravelly made ground of high permeability. The results are presented in **Appendix D**.

## **4.5 Samples and Sample Containers**

Soil samples for chemical analysis each comprised a pair of samples: a plastic tub for metals and inorganics and an amber glass jar for organics.

Soil samples were stored in cool boxes with ice packs and dispatched directly to the testing laboratory, for all phases of the investigation.

Samples for physical testing comprised of a plastic tub or bag and were dispatched to the testing laboratory.

## **4.6 Gas and Groundwater Monitoring**

Ground gas and water monitoring standpipes were installed in all five of the window samples. The results of which can be found in **Appendix E**.

## 5 LABORATORY TESTING

### 5.1 Chemical Laboratory Testing

Chemical samples were submitted to a UKAS accredited laboratory in accordance with ISO17025 and are also MCERTS accredited for soil analysis in accordance with the Environment Agency's scheme. The laboratory carries out Quality Assurance and Quality Control in accordance with BS ISO 17025 and participate in external laboratory comparison and quality control schemes. Details of the accreditation and the methods of analysis are provided on the relevant test reports.

The selection of samples for laboratory testing and analytes to be determined were made based on the preliminary CSM and relevant observations during the investigations. The sample selection rationale is as follows:

- To gain a good coverage across the Site of the various material types and strata encountered;
- To investigate the specific locations of previous potentially contaminative land uses as identified within the Phase 1 desk study and subsequent CSM;
- To fully characterise the potential made ground materials within the identified higher-risk areas.

The selected soil samples were tested for a range of typical contamination indicators including specific tests for contaminants suspected as being present from the desk study, CSM, and observations made on-site. Tests were also performed which were used to support the modelling of contaminant transport and impacts (e.g. TOC) and for waste classification purposes.

Each of the soil samples were analysed for the 'total' concentration of a suite of potential contaminants.

The results of the laboratory analysis are presented in **Appendix F**. The various suites of analysis for the soil are presented in **Table 5.1** below:

**Table 5.1: Suites of Analysis for Environmental Soil Samples**

| Determinant                                     | Soil Suite 1 |
|-------------------------------------------------|--------------|
| Number of Samples                               | 3            |
| <b>Index Tests</b>                              |              |
| Asbestos Screen / Quantification                | ✓            |
| pH                                              | ✓            |
| <b>Metals</b>                                   |              |
| As, Cd, Cr, Cu, Pb, Hg, Ni, Se, Zn (all totals) | ✓            |
| <b>Inorganics</b>                               |              |
| Acid Soluble Sulphate                           | ✓            |
| Cyanide - Total                                 | ✓            |
| Sulphate (2:1 extract on soil samples)          | ✓            |
| <b>Organics</b>                                 |              |

| Determinant                                      | Soil Suite 1 |
|--------------------------------------------------|--------------|
| Phenols - Total (monohydric)                     | ✓            |
| Total Organic Carbon (TOC)                       | ✓            |
| PAH (Speciated USEPA 16)                         | ✓            |
| Speciated TPH (C5-C35)                           | ✓            |
| Benzene, Toluene, Ethyl Benzene, Xylenes (BTEX); | ✓            |

## 5.2 Physical Laboratory Testing

Samples were submitted to Professional Soils Laboratory (PSL) who are UKAS accredited in accordance with ISO17025. The following geotechnical testing was undertaken with the results of this testing are presented in **Appendix G**. The various suites of analysis for the soil are presented in **Table 5.2**:

**Table 5.2: Summary of Physical Testing**

| Determinant                            | Samples Used in Testing |
|----------------------------------------|-------------------------|
| Number of Samples                      | 6                       |
| <b>Index Tests</b>                     |                         |
| pH                                     | ✓                       |
| Sulphate (2:1 extract on soil samples) | ✓                       |
| Atterberg                              | ✓                       |
| Moisture Content                       | ✓                       |
| PSD (Particle Size Distribution)       | ✓                       |
| BRE SD-1 Suite B                       | ✓                       |
| Compaction Test                        | ✓                       |

## 6 GROUND CONDITIONS

### 6.1 General

The site investigations have allowed the site-specific ground conditions to be described and this information was used to provide an improved conceptual ground model. The geology encountered during the site investigations was generally consistent with existing publicly available information online on the British Geological Survey (BGS) GeoIndex (onshore) viewer. A summary of the general strata encountered across the site is provided in **Table 6.1** below, with more detailed description given in the following sub sections.

**Table 6.1 Summary of Strata Encountered**

| Exploratory Hole | Depth to base of strata (mbgl) |                          |              | Groundwater | Comments                                                         |
|------------------|--------------------------------|--------------------------|--------------|-------------|------------------------------------------------------------------|
|                  | Made Ground                    | Glacial Till (Weathered) | Glacial Till |             |                                                                  |
| WS01             | 1.75                           | 2.50                     | 4.00         | -           |                                                                  |
| WS02             | 0.90                           | -                        | 2.00         | -           | Possible granular lens within Glacial Till                       |
| WS03             | 1.80                           | 3.20                     | 5.00         | 2.00        | Groundwater encountered perched on upper surface of Glacial Till |
| WS04             | 1.10                           | -                        | 4.00         | -           |                                                                  |
| WS05             | 3.00                           | -                        | -            | -           | Terminated within the Made Ground                                |

### 6.2 Ground Surface / Topsoil

The site surface is heavily vegetated in areas with little topsoil present across the site. The topsoil is generally described as a dark brown sandy gravelly clay.

### 6.3 Anthropogenic Materials

Made ground was present across the whole site to a maximum depth of 3.00m. The made ground was generally comprised a loosed to medium dense clayey very sandy gravel or or a dark brown sandy gravelly clay. The gravel present in the made ground was a mixture of sandstone concrete, clinker, coal, and brick. No visual or olfactory evidence of contamination was noted during the fieldwork.

## **6.4 Natural Deposits**

Underlying the Made Ground, Devensian (Glacial) Till was recorded throughout the site and proven to a depth of 5.45m bgl.

The Till appears to be in two layers; an upper softened/weathered layer – generally logged as a dark brown sandy gravelly clay and a lower unweathered layer logged as a greyish brown sandy gravelly clay.

Soil classification tests were carried out on the Till samples which revealed all such samples to be a clay of low plasticity, with liquid limits ranging from 27% to 36%, plastic limits ranging from 13% to 19%, a plasticity index between 13% and 20%, and a moisture content ranging from 14% to 31%. All results are presented in **Appendix G**.

## **6.5 Bedrock**

Bedrock was not encountered during this investigation; however shallow refusals were noted in a number of boreholes onsite.

## **7 GENERIC QUANTITATIVE RISK ASSESSMENT**

### **7.1 Assessment for the Protection of Human Health**

The results of the soil analyses are presented below, where they have been compared to suitable generic assessment criteria (GACs), in order to allow a generic quantitative risk assessment (GQRA) to be carried out for the site and the proposed development.

The Category 4 Screening Levels (C4SLs) published by DEFRA (2014) have been adopted in the first instance, which have been published for six substances to date. Where a C4SL is unavailable, the “Suitable 4 Use Levels” (S4ULs) published by LQM/CIEH (2015) have been adopted.

These criteria have been derived using the CLEA model for a range of standard end-use scenarios and a range of soil organic matter (SOM) contents. It should be noted that the C4SL values are derived on the basis of a “low level of toxicological concern”, while the S4UL values are based on a “tolerable” or “minimal” level of risk. As such, the S4ULs describe a lower level of risk than the C4SLs and are equivalent to the former Soil Guideline Values (SGVs, published by the Environment Agency) and the previous editions of the LQM/CIEH GAC values.

The GQRA is based on a soil with a Soil Organic Matter of 1%, for a residential with gardens end use.

A full summary of the chemical test results is presented in **Appendix H**.

### **7.2 Restrictions**

The main restriction at the site is the presence of the culvert running through the site, the mine shaft towards the south of the site and an associated ventilation shaft. The issues surrounding this have been mitigated against by proposing an open recreational area be above the shaft as to reduce the load on the surrounding ground.

Trial pits TT01 and TT02 followed the potential path of the ventilation shaft that may still be on site. A large metal column support is present in TT01, and horizontal metal beams were present in TT02 which appeared to follow the approximate direction of the possible air shaft. No large voids were found.

TT03 was located above the location of the mine shaft that is/was present on site. At a depth of 2.85m bgl metal sheets and a concrete slab were present. The concrete slab appeared to be in good condition.

Four trial pits were formed in a line running north south in order to locate the potential culvert that runs below the site. Water was encountered in TT04 which may have a connection to the possible culvert but no evidence of it was found in any of the trial pits.

## 7.3 Results

### Metals

The results from the metal analysis have recorded very low concentrations with no exceedances of the applicable GACs.

Table 7.1: Metals Suite

| Metals               | Min<br>(mg/kg) | Max<br>(mg/kg) | Average<br>(mg/kg) | Count | Adopted Guideline<br>(mg/kg) | Source | Exceedances |
|----------------------|----------------|----------------|--------------------|-------|------------------------------|--------|-------------|
| Arsenic              | 8              | 25             | 16                 | 3     | 37                           | C4SL   | 0           |
| Cadmium              | 0.2            | 0.2            | 0.13               | 3     | 22                           | C4SL   | 0           |
| Chromium             | 5.4            | 12             | 8.2                | 3     | 910                          | S4UL   | 0           |
| Chromium, Hexavalent | 0              | 0              | 0                  | 3     | 21                           | C4SL   | 0           |
| Copper               | 13             | 36             | 26.33              | 3     | 2400                         | S4UL   | 0           |
| Lead                 | 0.9            | 22             | 14.63              | 3     | 200                          | C4SL   | 0           |
| Mercury              | 0.05           | 0.05           | 0.05               | 3     | 1.2                          | S4UL   | 0           |
| Nickel               | 6.8            | 34             | 21.27              | 3     | 130                          | S4UL   | 0           |
| Phenol - Monohydric  | 0.8            | 6.7            | 2.6                | 3     | 120                          | S4UL   | 0           |
| Selenium             | 0.6            | 1.5            | 0.87               | 3     | 250                          | S4UL   | 0           |
| Zinc                 | 6              | 72             | 37                 | 3     | 3700                         | S4UL   | 0           |

Groundsolve conclude that the risk from metal concentrations to the proposed development is considered low.

## PAHs

All samples selected for analysis have generally recorded low PAHs.

**Table 7.2: Polyaromatic Hydrocarbons**

| Polyaromatic Hydrocarbons (PAH) | Min (mg/kg) | Max (mg/kg) | Average (mg/kg) | Count | Adopted Guideline (mg/kg) | Source | Exceedances |
|---------------------------------|-------------|-------------|-----------------|-------|---------------------------|--------|-------------|
| Acenaphthene                    | < 0.03      | < 0.03      | < 0.03          | 3     | 210                       | S4UL   | 0           |
| Acenaphthylene                  | < 0.03      | < 0.03      | < 0.03          | 3     | 170                       | S4UL   | 0           |
| Anthracene                      | < 0.03      | < 0.03      | < 0.03          | 3     | 2400                      | S4UL   | 0           |
| Benzo(a)anthracene              | < 0.03      | < 0.03      | < 0.03          | 3     | 7.2                       | S4UL   | 0           |
| Benzo(a)pyrene                  | < 0.03      | < 0.03      | < 0.03          | 3     | 5                         | C4SL   | 0           |
| Benzo(b)fluoranthene            | < 0.03      | < 0.03      | < 0.03          | 3     | 2.6                       | S4UL   | 0           |
| Benzo(g,h,i)perylene            | < 0.03      | < 0.03      | < 0.03          | 3     | 320                       | S4UL   | 0           |
| Benzo(k)fluoranthene            | < 0.03      | < 0.03      | < 0.03          | 3     | 77                        | S4UL   | 0           |
| Chrysene                        | < 0.03      | < 0.03      | < 0.03          | 3     | 15                        | S4UL   | 0           |
| Dibenzo(a,h)anthracene          | < 0.03      | < 0.03      | < 0.03          | 3     | 0.24                      | S4UL   | 0           |
| Fluoranthene                    | < 0.03      | < 0.03      | < 0.03          | 3     | 280                       | S4UL   | 0           |
| Fluorene                        | < 0.03      | < 0.03      | < 0.03          | 3     | 170                       | S4UL   | 0           |
| Indeno(1,2,3-c,d)pyrene         | < 0.03      | < 0.03      | < 0.03          | 3     | 27                        | S4UL   | 0           |
| Naphthalene                     | < 0.03      | 0.29        | 0.12            | 3     | 2.3                       | S4UL   | 0           |
| Phenanthrene                    | < 0.03      | 0.13        | 0.06            | 3     | 95                        | S4UL   | 0           |
| Pyrene                          | < 0.03      | < 0.03      | < 0.03          | 3     | 620                       | S4UL   | 0           |

## Petroleum Hydrocarbons (PHC)

No hydrocarbon impacted material was encountered during the fieldwork.

**Table 7.3: Petroleum Hydrocarbons**

| Petroleum Hydrocarbons | Min (mg/kg) | Max (mg/kg) | Average (mg/kg) | Count | Adopted Guideline (mg/kg) | Source | Exceedances |
|------------------------|-------------|-------------|-----------------|-------|---------------------------|--------|-------------|
| Aliphatic C5-C6        | < 0.01      | < 0.01      | < 0.01          | 3     | 42                        | S4UL   | 0           |
| Aliphatic C6-C8        | < 0.01      | < 0.01      | < 0.01          | 3     | 100                       | S4UL   | 0           |
| Aliphatic C8-C10       | < 0.01      | < 0.01      | < 0.01          | 3     | 27                        | S4UL   | 0           |
| Aliphatic C10-C12      | < 1.5       | < 1.5       | < 1.5           | 3     | 130                       | S4UL   | 0           |
| Aliphatic C12-C16      | < 1.2       | < 1.2       | < 1.2           | 3     | 1100                      | S4UL   | 0           |
| Aliphatic C16-EC35     | < 3.4       | < 3.4       | < 3.4           | 3     | 65000                     | S4UL   | 0           |
| Aliphatic C35-C40      | < 3.4       | < 3.4       | < 3.4           | 3     | 65000                     | S4UL   | 0           |

| Petroleum Hydrocarbons | Min (mg/kg) | Max (mg/kg) | Average (mg/kg) | Count | Adopted Guideline (mg/kg) | Source | Exceedances |
|------------------------|-------------|-------------|-----------------|-------|---------------------------|--------|-------------|
| Aromatic C5-C7         | < 0.01      | < 0.01      | < 0.01          | 3     | 70                        | S4UL   | 0           |
| Aromatic C7-C8         | < 0.01      | < 0.01      | < 0.01          | 3     | 130                       | S4UL   | 0           |
| Aromatic C8-C10        | < 0.01      | < 0.01      | < 0.01          | 3     | 34                        | S4UL   | 0           |
| Aromatic C10-C12       | < 0.9       | < 0.9       | < 0.9           | 3     | 74                        | S4UL   | 0           |
| Aromatic C12-C16       | < 0.5       | < 0.5       | < 0.5           | 3     | 140                       | S4UL   | 0           |
| Aromatic >C16-C21      | < 0.6       | < 0.6       | < 0.6           | 3     | 260                       | S4UL   | 0           |
| Aromatic >C21-C35      | < 1.4       | < 1.4       | < 1.4           | 3     | 1100                      | S4UL   | 0           |
| Aromatic >C35-EC40     | < 1.4       | < 1.4       | < 1.4           | 3     | 1100                      | S4UL   | 0           |

The speciated Total Petroleum Hydrocarbons (TPH) results have shown very low concentrations, with the majority below the relevant detection limits. The TPH concentrations are below the GAC's and do not represent a significant increased risk to long term human health and give no cause for concern.

## 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 of asbestos and discrete fibres are present in the soil at the site. The asbestos assessment commenced on site with inspection of the Made Ground by our site staff for the presence of bulk ACMs. During the fieldwork no suspected ACMs were identified.

Laboratory assessments were carried out in order to confirm the site assessment that ACMs were absent, and no asbestos was detected in any of the samples retrieved from site.

## 7.4 Assessment for the Protection of Controlled Waters

The total concentrations detected within soil samples are predominantly relatively marginal in human health terms and do not indicate particularly high concentrations which would be indicative of a significant source of groundwater contamination. There is a significant layer of low permeability Glacial Till below the Made Ground. Overall, it is assessed that there is a low possibility of a contaminant linkage between and the underlying groundwater in the Secondary Undifferentiated Aquifer.

Groundsolve believes that the site does not pose a significant risk to Controlled Water because:

- There are low to negligible levels of contaminants present;
- The site is underlain by low permeability glacial till;

## 7.5 Permanent Ground Gases

The risk of permanent ground gases is potentially quite high due to the past mining history of the site as well as the large amount of made ground present across the site.

### Measured Gas Concentrations

To date, four out of six rounds of gas monitoring have been carried out by GroundSolve in the five gas monitoring wells. The highest flow rates, methane, and carbon dioxide concentrations to date, together with the lowest oxygen levels (i.e., a combination of the worst-case temporal conditions recorded) from the monitoring visits are summarised in the

**Table 7.4** below:

**Table 7.4: Summary of Ground Gas Monitoring**

| Borehole | Response Zone mbgl | No. of monitoring occasions | Steady State Flow (l/hr) | Methane (%v/v) | Carbon Dioxide (%v/v) | Oxygen (% v/v) | Water Level mbgl | Atmospheric pressure readings mb |
|----------|--------------------|-----------------------------|--------------------------|----------------|-----------------------|----------------|------------------|----------------------------------|
| WS01     | 1.50               | 4                           | 0.1                      | 0.3            | 3.1                   | 19.5           | Dry              | 1005                             |
| WS02     | 1.00               | 4                           | 0.1                      | 0.1            | 2.5                   | 17.6           | Dry              | 1005                             |
| WS03     | 2.00               | 4                           | 0.1                      | 0.1            | 1.9                   | 17.5           | 1.80             | 1005                             |
| WS04     | 1.00               | 4                           | 0.1                      | 0.2            | 2.3                   | 16.9           | Dry              | 1005                             |
| WS05     | 3.00               | 4                           | 0.1                      | 0.2            | 2.1                   | 18.4           | 2.75             | 1005                             |

\* limit of detection on gas monitor

### Ground Gas Assessment

Background information relating to the origin and production of landfill and ground gases are presented in **Appendix I**, together with current guidance on the assessment of ground gases. In accordance with this approach and the above measured ground gas levels, it is considered that the worst-case temporal conditions may not have been measured during the monitoring period. However, it is anticipated that the worst-case temporal conditions will not be significantly worse than those presented in **Table 7.4** above. The gas flow rates measured across the whole of the site at all of the monitoring visits was less than the instrument detection limit of 0.1 l/hr. From Table 8.5 of CIRIA C665 the worst-case Characteristic Situation for the site are as follows:

**Table 7.5 Characteristic Gas Situations**

| Borehole Number | Steady State Flow | CH <sub>4</sub> |            |                          | CO <sub>2</sub> |            |                          |
|-----------------|-------------------|-----------------|------------|--------------------------|-----------------|------------|--------------------------|
|                 | l/h               | % v/v           | GSV (l/hr) | Characteristic Situation | % v/v           | GSV (l/hr) | Characteristic Situation |
| WS01            | 0.1               | 0.3             | 0.0003     | 1                        | 3.1             | 0.0031     | 1                        |
| WS02            | 0.1               | 0.1             | 0.0001     | 1                        | 2.5             | 0.0025     | 1                        |
| WS03            | 0.1               | 0.1             | 0.0001     | 1                        | 1.9             | 0.0019     | 1                        |
| WS04            | 0.1               | 0.2             | 0.0001     | 1                        | 2.3             | 0.0023     | 1                        |
| WS05            | 0.1               | 0.2             | 0.0002     | 1                        | 2.1             | 0.0021     | 1                        |

No major methane concentrations have been recorded. Based on the Ground Gas Assessment it can be seen that the carbon dioxide conditions at the site are the main risk driver regarding the gas conditions. To date, the fieldwork and ground gas concentrations are indicating low gas risk and CS1 conditions, which would require no remedial measures. However further gas monitoring is required to fully assess the ground gas risk.

The Site is located within an area where the radon risk is high, with estimated 5% to 10% of properties affected by radon; therefore, basic radon protective measures are required.

## 7.6 Risks to Human Health (Construction Phase)

During the construction works there will be a risk from dust to on-site workers and people occupying adjacent properties. Appropriate risk assessments should be carried out by the contractor to allow appropriate controls for the mitigation of risk to health of construction workers to be put in place. This risk can be controlled to within acceptable limits by:

- Method statement for site activities including control of dust generation;
- Having adequate site hygiene facilities allowing staff to keep a good level of personal hygiene;
- The method statement shall have a contingency plan which should be implemented if the presence of significantly elevated levels of lead is suspected in groundworks; and
- Only permitting smoking or eating on site in appropriate pre-designated areas.

As a minimum it is anticipated the works will be undertaken in accordance with BRE best practise guidance, and that the following measures will be introduced to assist with control of dust generation during the groundworks phase of the works:

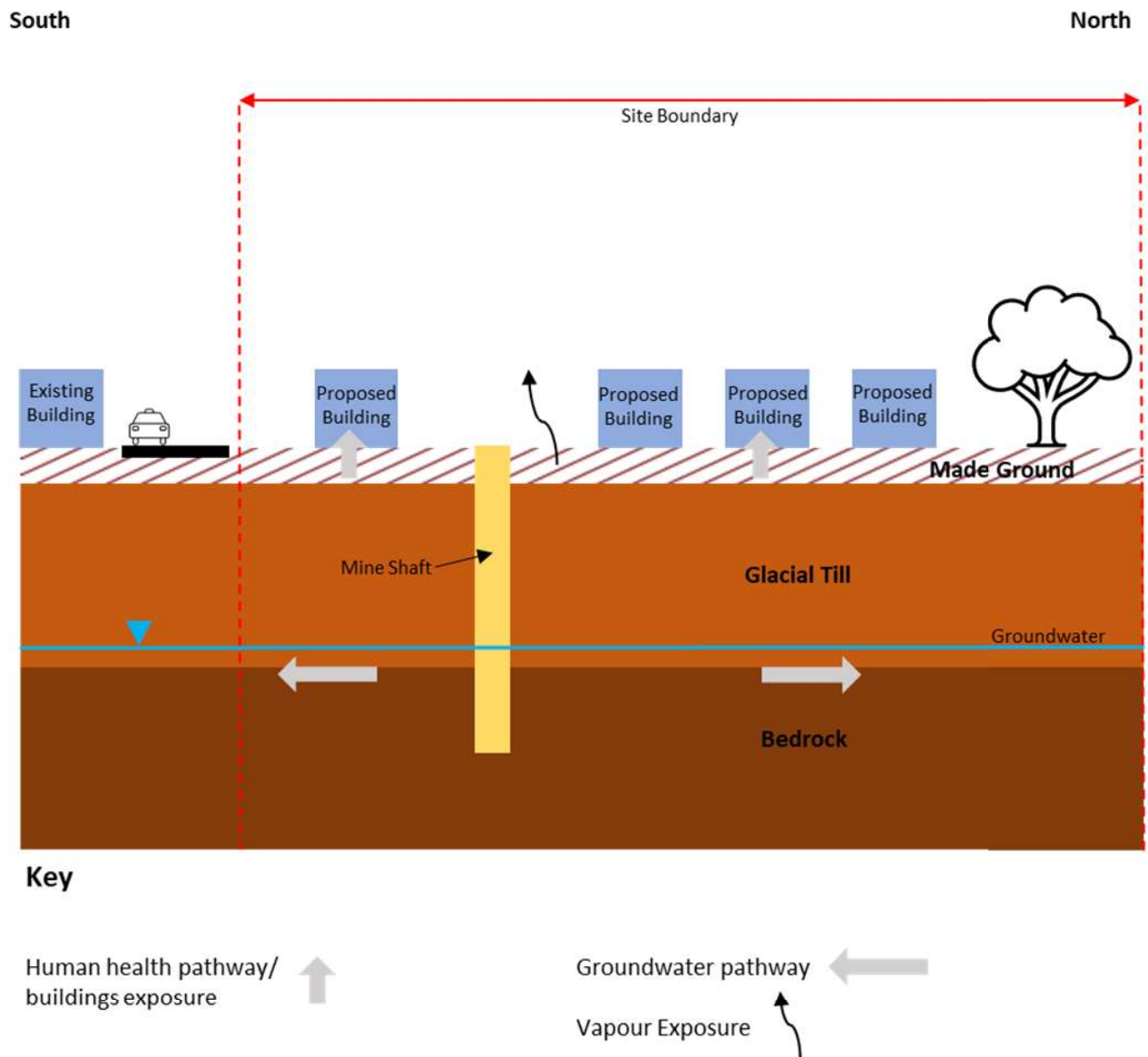
- Access roads and any stockpiles created during groundworks should be regularly damped down with water;
- Vehicles used to transport materials/wastes and aggregates should be enclosed or tarpaulined;
- Vehicle movements and speed should be kept to a minimum within the site ;
- Dust generating equipment (e.g., mobile crushing and screening equipment) should be located to minimise potential nuisance impacts to receptors as far as practicable; and
- Minimising drop heights of all loading and unloading activities that involve the transfer of soils and demolition materials.

## **7.7 Conceptual Site Model**

The proposed development comprises 43 residential properties along with associated parking and gardens with two areas of communal open space and six industrial buildings with associated parking.

The conceptual site model has been updated since the Phase 1 Preliminary Risk Assessment, as the findings of the Phase 2 site investigation revealed the following general downward succession:

- Site surface: topsoil in localised areas;
- Made Ground;
- Devensian Till: Encountered in all areas apart from SA03, TT03 and WS05. It is generally logged as a dark brown sandy gravelly clay and a greyish brown sandy gravelly clay.



**Figure 3 - Conceptual Site Model**

The potential contamination at the site has been assessed using the contaminant-pathway-receptor linkage approach. Following the site investigation, the plausible contaminant sources have been updated or confirmed as past mining activities as well as the made ground due to the back filling of the past mining activities.

The results of site investigation and laboratory analysis generally record negligible to zero concentrations of potential contaminants.

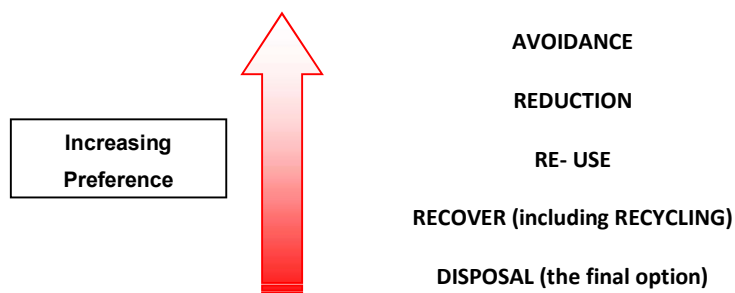
Due to the location of the mine shaft an open grassed area is proposed in the area of the shaft in order to reduce the load on the shaft as well as create an exclusion zone.

Whilst unexpected contamination is not anticipated, the proposed development could encounter previously unrecorded hotspots of contaminants. These will be assessed and mitigated in accordance with current good practice.

## 8 WASTE ASSESSMENT

### 8.1 Waste Hierarchy

In accordance with government guidance, it is required that the production and disposal of waste is managed in accordance with the following hierarchy of preference:



### 8.2 Waste Characterisation and Classification

If there is a portion of excess soil this will then have to be sent to a suitable landfill site. A two-phase approach is required comprising:

- Waste Characterisation; and
- Waste Classification (Waste Acceptance Criteria).

#### Waste Classification

In order to determine whether soils can be sent to a licensed landfill for disposal further testing is required comprising landfill Waste Acceptance Criteria (WAC) analysis for both total concentrations for certain chemicals and for leachate analysis. No WAC testing was carried out as part of this investigation. WAC testing will have to be carried out to confirm the landfill waste classification and if any pre-treatment is required. This is best carried out once all material to be disposed of is stockpiled, and volumes can be accurately assessed. It should be noted that natural clay can be classified as Inert Waste 17 05 04: Soil and stones only (excluding topsoil, peat, soil and stones).

#### Testing Frequency

There are also set requirements for the required sampling and testing frequencies for materials being sent for disposal at landfills. The required testing frequencies for each different waste type are summarised in **Table 8.1** below.

**Table 8.1: Laboratory Sampling Testing Frequencies**

| Testing Level                                                                                            | Quantity of Waste      | Number of Samples                           |                                             |
|----------------------------------------------------------------------------------------------------------|------------------------|---------------------------------------------|---------------------------------------------|
|                                                                                                          |                        | Homogeneous                                 | Heterogeneous & New Wastes                  |
| <b>Level 1 Characterisation</b><br>(Description, Total Concentrations & Leaching)                        | <100T                  | 2                                           | 5                                           |
|                                                                                                          | <500T                  | 3                                           | 8                                           |
|                                                                                                          | <1000T                 | 5                                           | 14                                          |
|                                                                                                          | 10,000 T               | 11                                          | 22                                          |
|                                                                                                          | Per additional 10,000T | +5 pro rata                                 | +10 pro rata                                |
| <b>Level 2 Compliance</b><br>For Regularly Generated Wastes<br>(Total Concentrations & Leaching)         |                        | 1 per defined waste sub-population per year | 3 per defined waste sub-population per year |
| <b>Level 3 Verification</b><br>Delivery document & visual check<br>Chemical testing as per Level 2 suite |                        | Visual – Each Load                          | Visual – Each Load                          |
|                                                                                                          |                        | 1 per year per waste stream                 | 3 per year per waste stream                 |

## 9 GEOTECHNICAL ASSESSMENT AND RECOMMENDATIONS

### 9.1 Laboratory Data Review

The proposed development includes the construction of 43 residential properties along with associated parking and gardens with two areas of communal open space and six industrial buildings with associated parking.

The topography of the site slopes from south to north ranging from approximately 130mAOD in the north of site to approximately 127mAOD in the south.

No loading information has been provided for this report.

#### Made Ground

Made ground is present across the entire site proven to a maximum depth of 3.00m the material generally comprises colliery spoil, which has been excavated from underground during mining operations. It was variable, with the following general descriptions:

- Loose, reddish brown to black, sandy, angular to subangular, fine to coarse gravel of mudstone, slag, brick and burnt shale.
- Firm, dark grey, silty, slightly gravelly clay.
- Very stiff, orangish brown, slightly sandy, gravelly clay, gravel is fine to coarse sub angular to angular mudstone and coal.
- Very dense, dark grey, slightly sandy, clayey, fine to coarse, sub angular to angular gravel, with a high cobble content.

PSD Testing generally confirmed the made ground to be well graded, with the constituents summarised in **Table 9.1** below. Fines content was generally below 15%.

**Table 9.1: Particle Size Distribution Testing**

| TP No | Depth | Silt/clay % | Sand % | Gravel % | Cobbles % | Uniformity co-efficient | Remarks                           |
|-------|-------|-------------|--------|----------|-----------|-------------------------|-----------------------------------|
| TP 01 | 0.50  | 7           | 30     | 63       | 0         | 44.71                   | Very sandy GRAVEL (MG)            |
| TP 02 | 1.00  | 4           | 14     | 78       | 4         | 29.77                   | Slightly clayey sandy GRAVEL (MG) |
| TP 03 | 1.00  | 11          | 31     | 58       | 0         | N/a                     | Sandy GRAVEL (MG)                 |

|       |      |    |    |    |    |       |                                             |
|-------|------|----|----|----|----|-------|---------------------------------------------|
| TP 04 | 0.50 | 11 | 26 | 56 | 7  | N/a   | Sandy GRAVEL (MG)                           |
| TP 05 | 0.50 | 9  | 27 | 64 | 0  | 61.07 | Clayey sandy GRAVEL (MG)                    |
| TP 06 | 1.00 | 9  | 24 | 67 | 0  | 102   | Clayey GRAVEL (MG)                          |
| TP 07 | 1.00 | 7  | 41 | 52 | 0  | 38    | Clayey very sandy GRAVEL (MG)               |
| TP 08 | 1.00 | 15 | 31 | 52 | 0  | N/a   | Very sandy GRAVEL (MG)                      |
| TP 09 | 0.50 | 7  | 21 | 72 | 0  | 59.8  | Clayey Sandy GRAVEL (MG)                    |
| TP 10 | 1.00 | 5  | 20 | 75 | 0  | 36.7  | Slightly clayey sandy GRAVEL (MG)           |
| SA01  | 2.50 | 53 | 36 | 11 | 0  | N/a   | Slightly gravelly sandy CLAY (GT)           |
| TT01  | 0.95 | 13 | 20 | 51 | 16 | N/a   | Clayey sandy GRAVEL (MG)                    |
| TT03  | 1.00 | 18 | 10 | 49 | 23 | N/a   | Clayey slightly sandy GRAVEL (MG)           |
| TT05  | 1.50 | 13 | 17 | 36 | 34 | N/a   | Clayey slightly sandy GRAVEL & COBBLES (MG) |

(MG) = Made Ground (GT) Glacial Till

Compaction testing undertaken on bulk samples of the Made Ground and is summarized in **Table 9.2** below.

**Table 9.2: Compaction Testing Results**

| TP No | Depth (m) | OMC % | MDD Mg/m <sup>3</sup> | NMC % | Difference ± | Remarks                                                                                                           |
|-------|-----------|-------|-----------------------|-------|--------------|-------------------------------------------------------------------------------------------------------------------|
| TP 03 | 1.0       | 9.0   | 2.02                  | 17.9  | +8.9         | Material significantly above OMC would require screening or drying prior to placement                             |
| TP 06 | 1.0       | 13.5  | 1.89                  | 14.1  | +0.6         | Suitable for reuse as dug                                                                                         |
| TP 09 | 0.5       | 15.5  | 1.76                  | 18.5  | +3.0         | Suitable for reuse as dug                                                                                         |
| TT01  | 0.95      | 11    | 1.85                  | 9     | -2.0         | Suitable for reuse as dug                                                                                         |
| TT03  | 1.00      | 9     | 2.11                  | 5     | -3.0         | Suitable for reuse as dug                                                                                         |
| TT05  | 1.50      | 11    | 1.89                  | 17    | +6.0         | Material significantly above OMC with elevated fines content would require screening or drying prior to placement |

## Glacial Till

The Till appears to be in two layers; an upper softened/weathered layer – generally logged as a dark brown sandy gravelly clay and a lower unweathered layer logged as a greyish brown sandy gravelly clay proven to 5.45m.

The classification testing results on the clay strata are summarised below:

**Table 9.3: Summary of Classification Testing**

| Hole           | Depth (m) | Moisture Content (%) | % passing 425µm sieve | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index | Modified Plasticity Index | Plasticity   | Volume Change Potential | Remarks                                 |
|----------------|-----------|----------------------|-----------------------|------------------|-------------------|------------------|---------------------------|--------------|-------------------------|-----------------------------------------|
| SA01           | 3.00      | 16                   | 87                    | 31               | 15                | 16               | 14                        | Low          | Low                     | Sandy gravelly CLAY (GT)                |
| TP01           | 1.50      | 24                   | 20                    | 35               | 15                | 20               | 4                         | Intermediate | Low                     | Slightly sandy clayey GRAVEL (MG)       |
| TP04           | 2.00      | 23                   | 8                     | 33               | 17                | 16               | 1                         | Low          | Low                     | Sandy gravelly CLAY (MG)                |
| WS3            | 3.00      | 14                   | 37                    | 26               | 13                | 13               | 5                         | Low          | Low                     | Stiff sandy CLAY (GT)                   |
| WS5            | 2.00      | 31                   | 17                    | 36               | 19                | 19               | 3                         | Intermediate | Low                     | Soft sandy CLAY (GTW)                   |
| WS8            | 1.50      | 20                   | 17                    | 32               | 15                | 15               | 2                         | Low          | Low                     | Stiff Sandy CLAY (GT)                   |
| WS01           | 3.50      | 14                   | 96                    | 27               | 14                | 13               | 13                        | Low          | Low                     | Stiff sandy slightly gravelly CLAY (GT) |
| <b>Minimum</b> |           | <b>14</b>            | <b>8</b>              | <b>27</b>        | <b>13</b>         | <b>13</b>        | <b>1</b>                  |              |                         |                                         |
| <b>Maximum</b> |           | <b>31</b>            | <b>96</b>             | <b>36</b>        | <b>19</b>         | <b>20</b>        | <b>14</b>                 |              |                         |                                         |

MG Made Ground, GT Glacial Till, GTW Glacial Till - Weathered

Testing indicates that the clays show limited evidence of desiccation with moisture contents lower than the plastic limits, and low volume change potential.

## 9.2 Insitu Testing

SPT N-values were recorded throughout each borehole and are summarised in **Table 9.4** below for the material encountered.

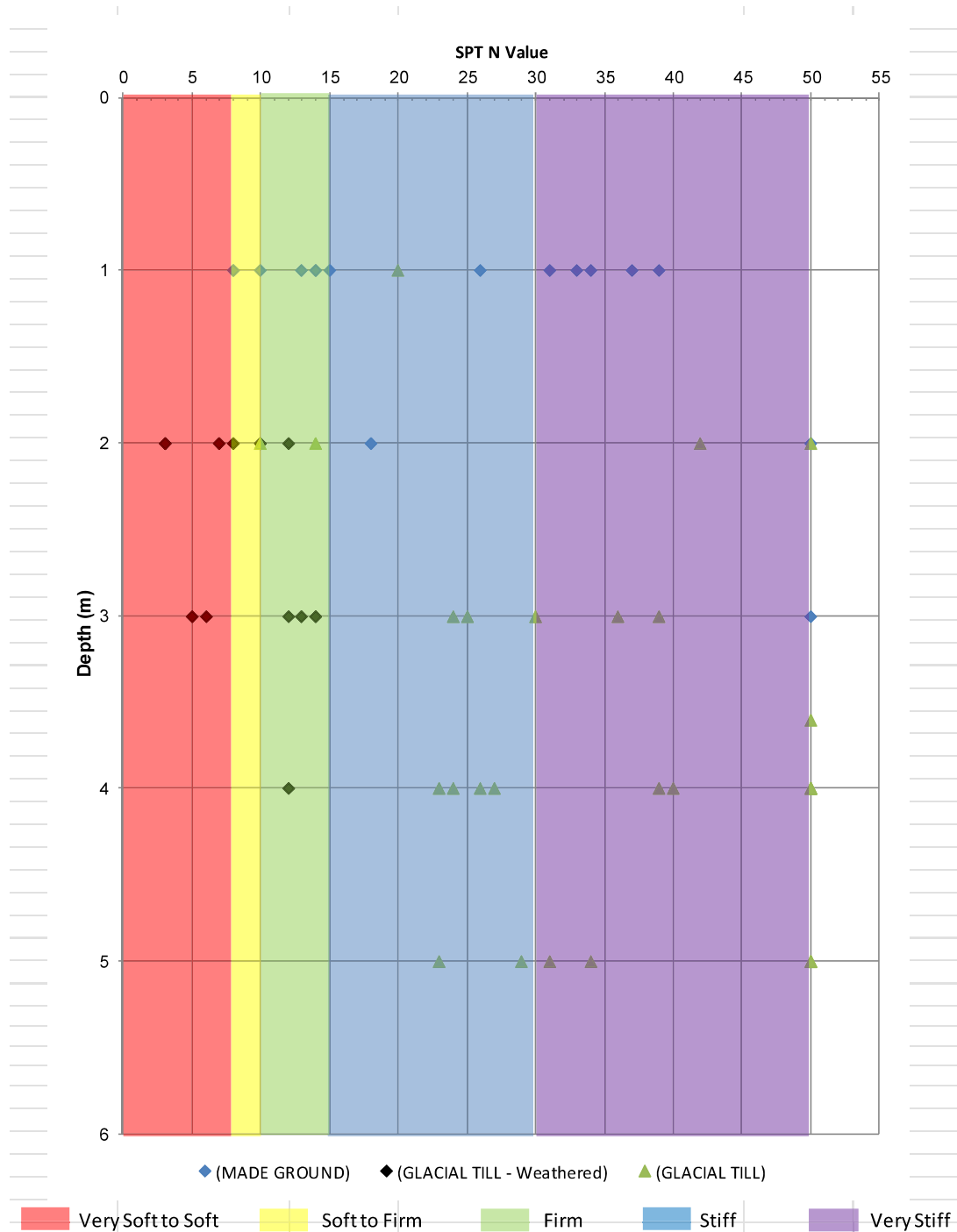
**Table 9.4: Summary of SPT N Values**

| Location | Depth (m bgl) | SPT N Values | Stratum                  | Estimated Undrained Shear strength (kPa) * |
|----------|---------------|--------------|--------------------------|--------------------------------------------|
| WS01     | 1             | 31           | Made Ground              | Granular Strata                            |
|          | 2             | 12           | Glacial Till - Weathered | 60                                         |
|          | 3             | 36           | Glacial Till             | 180                                        |
|          | 4             | 50           | Glacial Till             | 250                                        |
| WS02     | 1             | 20           | Glacial Till             | Granular Strata                            |
|          | 2             | 50           | Glacial Till             | Granular Strata                            |
| WS03     | 1             | 15           | Made Ground              | Granular Strata                            |
|          | 2             | 10           | Glacial Till – Weathered | 50                                         |
|          | 3             | 13           | Glacial Till - Weathered | 65                                         |
|          | 4             | 23           | Clay                     | 115                                        |
|          | 5             | 29           | Clay                     | 145                                        |
| WS04     | 1             | 8            | Made Ground              | Granular Strata                            |
|          | 2             | 10           | Glacial Till             | 50                                         |
|          | 3             | 14           | Glacial Till             | 70                                         |
|          | 4             | 50           | Glacial Till             | 250                                        |
| WS05     | 1             | 39           | Made Ground              | Granular Strata                            |
|          | 2             | 18           | Made Ground              | Granular Strata                            |
|          | 3             | 50           | Made Ground              | 250                                        |

\* Conversion factor=5 (Stroud & Butler)

The SPT N values are consistent with the presence of an upper water softened/weathered layer within the Glacial Till extending to a maximum depth of 5.00m with values ranging between 3 – 14 (soft to firm) with an average of 9. The underlying unweathered Till shows a general trend increasing in strength with depth (**Plate 1**) with an estimated undrained shear strength typically in the range of 100 - 175kN/m<sup>2</sup> (high strength).

Plate: 1 SPT N-Values Vs Depth



### **9.3 Trees**

A number of mature trees and bushes are located on or adjacent to the site boundary. A comprehensive tree survey of those trees within the site boundary, and up to 20m beyond the site boundary (assuming mature high water demand trees are not present along the boundary) will be required to determine the effect of existing trees to proposed properties and also to assess the condition of trees which are to remain.

Any proposed felling or removal of trees or hedgerows should be agreed with the Local Authority as part of the pre-planning discussions for development and should be carried out outside the bird nesting season (it may be possible that tree felling can be carried out during the bird nesting season under the direction of an ecologist).

Care must be taken to ensure that any existing trees scheduled for retention are not adversely affected by construction operations. Further guidance on this aspect of site works is given in the British Standards "Guidance for Trees in Relation to Constructions", BS5837.

## **9.4 Mining Legacy**

The site has a former mine shaft on site, which given the cap diameter of 9.60m, may have been up to 4.80m in diameter, which ties in with the historical plans. The shaft has been drilled and grouted, and also capped. The top of the cap is recorded at an elevation of 121.15mAOD, which given the current contours is around 3m depth.

In addition, on the 1899 historical plan an air shaft is shown some 20m to the north of the main shaft, which on later editions is indicated to be a chimney some 5m in diameter. It is considered that this does not represent a conventional air shaft sunk to the workings. Instead, it is likely that as the air shaft had a building next to it then the No 2 shaft was being used as a ventilation shaft at this time, with the building being a fan house sucking air up the shaft.

A total of 3 trial trenches were completed to locate the air drift and fan house (TT01 – TT03). Pits TT01 & 02 recorded Made Ground to between 1.70 and 2.00m overlying the natural Glacial Till. Both excavations encountered steel and timber shoring along with variations in depth to the underlying Till. It is anticipated these are indicative of the location and depth of the former drift. TT03 encountered the existing shaft cap at 3.00m which is consistent with the recorded details.

In view of the above it is considered that the drift was located at shallow depth and was backfilled as part of the demolition and remediation of the site. Backfill is unlikely to have been undertaken in a controlled manner and is likely to comprise the mining spoil loosely tipped into the drift, consequently it is recommended that the drift is excavated down to the underlying competent strata and the subsequent excavation backfilled with a suitably compacted granular fill.

## **9.5 Existing Culvert**

A drainage strategy report was produced for the site in May 2017 by Tier Consult (TC) for N/S Holdings. This highlighted the presence of a culverted watercourse along the western site boundary, an existing surface water sewer in the existing estate access road, which discharges into the culvert via a manhole located at the estate entrance junction.

TC also produced a letter report regarding the route of a culvert, which passes beneath the site, which was issued in August 2016. This culvert is considered to be the same one as seen exiting from beneath the spoil mound on the 1873 historical plans.

The route of the culvert was based on a GroundSure report, which drew a straight line between the “Sink” and “Issue” either side of the site. Therefore, TC undertook a Sonde survey in July 2016 to confirm the route of the culvert. It recommended that the development be designed so that no buildings are proposed over the confirmed route of the sewer.

However, the survey by TC shows the culvert must have been diverted to run down the side of the estate road probably at the time Llangollen road was widened and the new access road constructed in the early 1990's.

This therefore means that the old culvert was either diverted at the time of the site's reclamation, or it is still present beneath the site in its abandoned state. The subsequent GSL report completed in 2020 suggested that further investigation was required to determine whether the culvert remains in situ.

As part of the recent investigation a Ground Penetrating Radar (GPR) Survey was completed along the suspected line of the culvert along with completion of 4 trial trenches (TT04 – TT07). Neither survey or trial trenches found any evidence of the culvert with ground conditions consistent with those encountered within the remaining exploratory holes. In view of this it is considered that the risk posed by the potential for the culvert to remain is reduced to as low as reasonably possible.

## **9.6 Foundation Recommendations**

Several options have been considered for the foundations, with the following issues relevant when choosing the most appropriate foundation type:

- Depth to founding strata,
- Stability of excavations,
- Volume of materials that needs to be taken off site,
- Can excavated arisings be left on site,
- Final development levels.

The thickness of made ground means that and conventional spread foundations would need to be in excess of 2m deep throughout the site. The trial pits revealed that the pits were unstable in places, which would increase the volumes of concrete used due to overbreak in the foundation's sides. Whilst this could be limited by leaving excavations until concrete is on its way to site this may not always fit in with the availability of Building Control inspectors. In addition, the underlying glacial till was found to vary considerable in strength across the site ranging from very soft in places to stiff in others. Finally, there is a perched water table at the base of the made ground. For this reason, conventional spread foundation has been discounted as an option.

In view of the above there are two options available.

### **Option 1**

Raft foundations to be designed assuming an allowable bearing pressure of 50kN/m<sup>2</sup> in the existing colliery spoil. The low bearing pressure being chosen to account for any differences in the density of the colliery spoil beneath individual building plots. To increase the bearing pressure, it would be possible to carry out limited ground improvement. This would involve excavating and recompacting the colliery spoil to a depth of 1m beneath the underside of the raft, with the bearing pressure increased to 100kN/m<sup>2</sup>. Rafts should be designed with edge beams extending a minimum of 0.75m below final external ground levels.

### **Option 2**

As an alternative to raft foundations it should be possible to adopt a piled foundation solution. Final pile type, diameter and depth will be the responsibility of the detailed designer however as a guide it is suggested a conventional CFA pile taken through the made ground and weathered Till into the underlying firm to stiff clay would be suitable. Exact capacities will be subject to confirmatory design but a 7.5m 300mm diameter pile should give ultimate capacities in the region of 200kN.

The use of a piled foundation will necessitate the adoption of suspended floor slabs.

When footings have been initially sized then full design of these should be carried out in accordance with BS EN 1997-1: 2004 +A1 2013: Eurocode 7 – Geotechnical Design – Part 1: General rules (including UK National Annex of November 2007) and BS8004: 2015 : Code of practice for foundations.

## **9.7 Reuse of Materials**

The site investigation has confirmed that there is a lack of topsoil on site, which will need to be imported. Prior to import it should be validated by appropriate testing.

The investigation has confirmed that both the Made Ground and Glacial Till on site is suitable for re-use on site as a structural fill subject to placement and compaction with an approved earthworks specification.

## **9.8 Groundwater Conditions**

Four rounds of groundwater monitoring have been carried out to date by Groundsolve in the groundwater monitoring well installations. Groundwater level varies between 1.80m and 2.93m bgl.

## **9.9 Groundwater & Excavations**

Firstly, it will be necessary to strip all surface vegetation and organic matter which should be taken off site to a suitably licensed landfill facility. It will also be necessary to remove several of the trees on site and grub out any root systems, which can be backfilled with well compacted site won material.

Excavations will then be in made ground comprising colliery spoil and possibly glacial till, which should be possible using conventional earthmoving equipment although larger plant will have higher excavation rates.

The trial pits confirmed that excavations in the colliery spoil could be unstable, therefore, excavations deeper than 1.20m that are to be entered should be shored or battered back for safety reasons.

Shallow excavations for foundations and services are unlikely to encounter water seepages. If encountered they should be easily catered for by pumping from sumps cut within the excavation.

Deeper excavations into the glacial till will encounter slight seepages which can be catered for as described above. The underlying glacial till is of very low permeability and the investigation confirms the surface to be generally following the existing topography. Therefore, it would be prudent to excavate any drainage runs up gradient to ensure excavations are self-draining.

All excavations should be carried out in accordance with CIRIA Report 97 "Trenching Practice" and BS6031: 2009: Code of Practice for Earthworks. Further guidance on this aspect of site works is given in the British Standards for "Workmanship on Building Sites", BS 8000, Parts 1 and 14, and in the Construction Industry Training Board's Site Safety Note 10.

## 9.10 Buried Concrete and Pipework

The results of laboratory pH and sulphate content are summarised in **Table 9.5** below and indicate that ACEC Class AC-1 conditions prevail in accordance with BRE Special Digest 1, 2005 (the Design Concrete Class). Therefore, special precautions are not required at the site for the design of concrete in terms of the durability and structural performance.

**Table 9.5: Sulphate Testing Results**

| Hole                 | Depth (m) | pH  | Sulphate (Aq Extract) mg/l | Sulphate Acid extract (%) | Total Sulphur(TS) % | Total Potential Sulphate (TPS) % | Oxidisable Sulphides (OS) % | Pyrite Present? (Y/N) | Design Sulphate Class (DS) | ACEC Class | Design Concrete Class (DC) |
|----------------------|-----------|-----|----------------------------|---------------------------|---------------------|----------------------------------|-----------------------------|-----------------------|----------------------------|------------|----------------------------|
| SA01                 | 0.9       | 4.8 | 70                         | 0.74                      | 0.32                | 0.96                             | 0.22                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| TP02                 | 2.1       | 7.8 | 1700                       |                           |                     |                                  |                             |                       | DS-3                       | AC-2s      | DC-2                       |
| TP04                 | 0.50      | 6.7 | 89                         | 0.11                      | 0.08                | 0.24                             | 0.13                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| TP06                 | 1.00      | 7.6 | 110                        | 0.05                      | 0.04                | 0.12                             | 0.07                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| TP10                 | 0.50      | 7.6 | 110                        | 0.25                      | 0.12                | 0.36                             | 0.11                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| WS02                 | 3.50      | 7.7 | 94                         |                           |                     |                                  |                             |                       | DS-1                       | AC-1s      | DC-1                       |
| WS04                 | 2.00      | 7.6 | 100                        |                           |                     |                                  |                             |                       | DS-1                       | AC-1s      | DC-1                       |
| TP01                 | 2.00      | 5.4 | 110                        |                           |                     |                                  |                             |                       | DS-1                       | AC-1s      | DC-1                       |
| TP01                 | 0.50      | 8   | 55                         | 0.04                      | 0.05                | 0.15                             | 0.11                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| TP02                 | 0.50      | 6.6 | 17                         | 0.12                      | 0.06                | 0.18                             | 0.06                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| TP05                 | 0.50      | 6.3 | 15                         | 0.06                      | 0.06                | 0.18                             | 0.12                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| TP07                 | 0.50      | 7   | 30                         | 0.09                      | 0.07                | 0.21                             | 0.12                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| TP08                 | 0.50      | 7.1 | 18                         | 0.28                      | 0.19                | 0.57                             | 0.29                        | N                     | DS-1                       | AC-1s      | DC-1                       |
| Minimum              |           | 4.8 | 15                         | 0.04                      | 0.04                | 0.12                             | 0.06                        |                       | DS-1                       | AC-1s      | DC-1                       |
| Maximum              |           | 8   | 1700                       | 0.74                      | 0.32                | 0.96                             | 0.29                        |                       | DS-3                       | AC-2s      | DC-1                       |
| Characteristic Value |           | 6.9 | 200.0                      | 0.2                       | 0.1                 | 0.3                              | 0.1                         |                       | DS-1                       | AC-1s      | DC-1                       |

### **9.11 Soakaways & Drainage**

A drainage strategy report was produced for the site in May 2017 by Tier Consult for N/S Holdings. As part of this It is understood that four soakaway test were carried out on site. We have not seen the results of these tests. However, the subsequent report concluded that the site was unsuitable for soakaway due to the presence of made ground overlying impermeable clay.

Additional soakaway tests were carried out during the recent fieldwork at three locations. Two tests failed to drain during the soakaway tests due to the low permeability Glacial clay and one drained away due to a localised area of gravel.

Based on the ground conditions encountered in the site investigation, and in situ testing results we would not consider the site to be suitable for the use of soakaway drainage.

Therefore, attenuation of water was recommended using Greenfield run off rates for all storm events up to and including a 100-year event and +30% climate change allowance.

At present, it is proposed to provide an attenuation pond in the area of Public Open Space adjacent to the shaft.

There are risks involved with the placement of this pond next to the treated shaft. Water would be able to flow into the shaft despite it being grouted and could potentially lead to shaft instability. Therefore, it is recommended that any such pond be lined to prevent infiltration into the shaft.

The soakaway testing result are presented in **Appendix D**.

## 10 REFERENCES

- BRE BR211 (2015). Radon: Guidance on Protective Measures for New Dwellings. IHS BRE Press, Bracknell.
- BRE SD1 (2005). Concrete in Aggressive Ground. Special Digest 1 (revised edition). IHS BRE Press, Bracknell.
- BRE 414 (2001) Protective measures for housing on gas-contaminated land. BRE.
- BS 10175:2011+A2:2017 Investigation of Potentially Contaminated Sites - Code of Practice. British Standards Institution, London.
- BS5930:2015+A12020 Code of practice for ground investigations BSI
- BS8485 2015 Code of Practice for the design of protective measures for methane and carbon dioxide ground gases in new buildings. British Standards
- BS8576-2013 Guidance on investigations for ground gas – permanent gases and volatile organic compounds (VOCs). BSI,
- CIRIA Rep R 132 (1996) A Guide for Safe Working on Contaminated Sites. Report 132, CIRIA, London.
- CIRIA C552 (2001) Contaminated land risk assessment. A guide to good practice (report no. C552).
- CIRIA C665 (2007) Assessing the risks posed by hazardous gases to buildings CIRIA, London
- CIRIA C681 (2009) Unexploded ordnance (UXO) A guide for the construction industry (C681)
- CIRIA C785 (2019) Unexploded ordnance (UXO) risk management guide for land-based projects (C785)
- CIRIA C758D (2019) Abandoned mine workings manual (C758D)
- Contaminated Land: Applications in Real Environments (CL:AIRE) (2011) Definition of Waste Code of Practice (version 2).
- Department of Environment Food and Rural Affairs (DEFRA) (2012) Environmental Protection Act 1990:Part 2A Contaminated Land Statutory Guidance (report no. PB13735).
- Environment Agency (2000) Technical Aspects of Site Investigation. Report P5-065/TR, Environment Agency, Bristol.
- Environment Agency (2002) Guidance on Monitoring Landfill Leachate, Groundwater and Surface Water. Report LFTGN02, Environment Agency, Bristol.
- Environment Agency (2007) Evaluation of Models for Predicting Plant Uptake of Chemicals from Soil. Report SC050021/SR, Environment Agency, Bristol.
- Environment Agency (2015) Guidance on the Classification and Assessment of Waste Technical Guidance WM3 (1st edition).European Union (1998) Drinking Water Directive (Council Directive 98/83/EC).
- Land Contamination Risk Management (LCRM) Environment Agency October 2020  
<https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm> .
- LQM/CIEH Ltd (2015) S4ULs for Human Health Risk Assessment. Land Quality Press, Nottingham.
- SoBRA (2017) Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health from Volatile Contaminants in Groundwater – Version 1.0.
- The Water Framework Directive, (Standards and Classification) Directions (England and Wales).
- World Health Organisation (2017) Guidelines for Drinking Water Quality (4th edition).
- Britain From Above - <https://britainfromabove.org.uk/en/image/WPW060399>
- <http://www.warstateandsociety.com/Bombing-Britain>

<https://www.epa.gov/pfas/basic-information-pfas>

UK Maps of Radon, <http://www.ukradon.org/information/ukmaps>

Health and Safety Executive (2015) Construction (Design and Management) Regulations.

Coal Authority Interactive Map Viewer, <http://mapapps2.bgs.ac.uk/coalauthority/home.html>

BGS Geology of Britain Viewer <http://mapapps.bgs.ac.uk/geologyofbritain/home.html>

## 11 DEFINITIONS

|       |                                                                           |
|-------|---------------------------------------------------------------------------|
| 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)                           |
| DQRA  | Detailed Quantitative Risk Assessment                                     |
| DWS   | Drinking Water Standard                                                   |
| EQS   | Environmental Quality Standard                                            |
| GAC   | Generic Assessment Criterion                                              |
| GQA   | General Quality Assessment (Environment Agency)                           |
| GQRA  | Generic Quantitative Risk Assessment                                      |
| GSV   | Gas Screening Value                                                       |
| HCV   | Health Criteria Value                                                     |
| IPPC  | Integrated Pollution Prevention and Control (regulations)                 |
| NGR   | National Grid Reference                                                   |
| NIHHS | Notification of Installations Handling Hazardous Substances (regulations) |
| OS    | Ordnance Survey                                                           |
| ppm   | Parts per million                                                         |
| ppmv  | Parts per million by volume                                               |
| SAC   | Special Area of Conservation                                              |
| SPZ   | Source Protection Zone (see <b>Error! Reference source not found.</b> )   |
| SSAC  | Site-Specific Assessment Criterion                                        |
| SSSI  | Site of Special Scientific Interest                                       |

## **FIGURES**

