Report No. 30156/1B
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# SUPPLEMENTARY GEOENVIRONMENTAL APPRAISAL of land at BURLOW ROAD, HARPUR HILL, BUXTON (SOUTHERN SITE – 'SITE B')

**Prepared for**

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## SUMMARY OF GEOENVIRONMENTAL ISSUES

The site is located off Burlow Road/Hillhead Lane, Harpur Hill, approximately 3km south of Buxton (NGR SK 070 704) The site occupies an area of 4.72 hectares.

The site is 'Greenfield' in nature and has been in agricultural use since at least the mid 19$^{th}$ Century. Only modest development has taken place within the site. This has comprised the development of a small building and trackway in the centre of the site and a small sewage filter tank in the northeast of the site. These features were developed in the early 20$^{th}$ Century but were not present on site in the 1950s/70s. A small infilled quarry feature is shown to have been present in the late 19$^{th}$ Century immediately to the south of the proposed development area which was infilled in the past.

ALM has been commissioned by Barratt Homes Manchester to undertake a Supplementary Geoenvironmental Appraisal of the site. It is understood that the site is to be redeveloped with residential housing with private gardens, public open space and adoptable roads and sewers; an indicative proposed layout is available. ALM's investigation included a review of a previous desk study and ground investigation undertaken by GRM Development Solutions in 2006 and a ground investigation comprising 24 No. Trial Pits, 2 No. soakaway tests and associated chemical and geotechnical analysis of near surface soils.

A summary of salient geoenvironmental issues is provided in the Table below.

| **Issue** | **Remarks** |
|---|---|
| Made Ground | 'Reworked/disturbed' shallow and localised topsoil present beneath footprints to former buildings/structures and in the extreme northwest of the site.<br>Shallow demolition and filter gravels also present in these areas. |
| Natural Ground | Clayey natural topsoil present across the whole site to average depth of 0.3m.<br>Drift strata absent.<br>Completely Weathered Bee Low Limestone (sandy very silty clay) present across the whole site to 0.6-1.6m depth (average depth of ca. 1m).<br>Moderately Weathered Bee Low Limestone (rock) at 0.6-1.6m depth (average depth of ca. 1m). |
| Contamination | Localised 'reworked/disturbed' topsoil contaminated by lead, zinc, copper and cadmium.<br>Localised Demolition and filter gravel materials contaminated by lead, zinc, copper.<br>Natural topsoil materials locally contaminated by lead and copper and widespread naturally zinc but is considered suitable for reuse.<br>Completely Weathered Bee Low Limestone contaminated by naturally occurring concentrations of zinc but is considered suitable for reuse. |
| Hazardous Gas | Elevated 'background' concentrations of carbon dioxide probably derived from natural dissolution of limestone.<br>Site located in an area that will require full radon gas protection.<br>NHBC ' Amber 1' gas protection required (well-constructed gas proof membrane and ventilated sub-floor void) |
| Mining & Quarrying | Area historically and currently used for limestone extraction. Although the presence of small and shallow quarry features within the development area cannot be completely discounted, the likelihood of the presence of such features is considered to be very low. |
| Preparatory Works | Extensive site regrading anticipated involving re-distribution/re-engineering of Completely Weathered Limestone (clay) materials and preparation of shallow rock to create development platforms. |
| Foundations | Reinforced strip/trench foundations founding on Moderately Weathered Bee Low Limestone rock. |
| Groundwater & Excavations | No groundwater encountered during investigations and not anticipated to be encountered during site development.<br>In situ rock determined to be strong to very strong and thinly to medium bedded. Excavations within rock will be expected to be difficult and will require hydraulic breakers in trenches and hard ripping in more open excavations. |
| Flooding & Drainage | The site is not located in an area that is prone to 1:100 and 1:1000 year flood events.<br>In situ soakaway tests indicate that the use of soakaways as part of a sustainable surface water management scheme will be feasible. |
| Highways | A CBR of 1.5% should be assumed at this stage for proof rolled Completely Weathered Bee Low Limestone (clay) subgrade strata beneath proposed roadways. |

*This brief summary should not be assumed to represent a complete account of all the potential geo-environmental issues that may exist at the site. As such it is strongly recommended that the report be read in its entirety.*

Significant developer abnormals relating to geoenvironmental issues at the site are:

- Demolition of small existing building/shelter within the centre of the site grubbing up of foundations.
- Off site disposal of very localised and shallow 'reworked/disturbed' topsoil materials.
- Use of 600mm soil cover layer if/where localised demolition and filter gravel materials are exposed at surface in proposed garden areas. Alternatively, off site disposal of these materials.
- Site regrading works – the Completely Weathered Bee Low Limestone (clay) possesses a natural moisture content that is considerably in excess of optimum moisture content and may prove difficult to compact to 95% of maximum dry density unless it is dried and regrading works may be problematic in wet weather. Potential requirement to use lime stabilisation techniques.
- Shallow hard rock – will require the use of breakers in foundation/service trench excavations and overbreak will be anticipated. Ripping will also be required in more open excavations.
- Retaining walls – Based on indicative house plot finished floor levels, retaining walls are anticipated to be required at plot boundaries across the majority of the site that may be required to be significantly high in the western and southern margins of the site. Shallow hard rock will preclude the use of cantilever retaining structures.
- Existing sewers – Will impact on proposed development layout. May require diversion or, more likely, the incorporation of appropriate development easements.

Some further work is required, most notably:

- Consultations should be held at an early stage with Severn Trent Water Limited with respect to ascertaining the potential to re-align existing sewers that are present within the northern part of the site. Alternatively, consultations should seek to ascertain restrictions with respect to development in the vicinity of the sewers and the easements required.
- It is recommended that an 'Enabling Works Strategy' be prepared to include a volumetric assessment of the anticipated earthworks and types of materials to be used to create a sustainable development scheme, and a suitable development platform to required finished development levels.
- The finalised earthworks strategy would be required to be documented within a detailed 'Materials Management Plan' prepared and approved in accordance with CL:AIRE *'Definition of Waste: Development Industry Code of Practice Version 2'* (March 2011).

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## FOREWORD

This report has been prepared for the sole internal use and reliance of the Client named on page 1. This report shall not be relied upon or transferred to any other parties without the express written authorisation of ALM Consult Ltd (ALM); such authorisation not to be unreasonably withheld. If any unauthorised third party comes into possession of this report, they rely on it at their peril and the authors owe them no duty of care and skill.

The report presents observations and factual data obtained during our site investigation, and provides an assessment of geoenvironmental issues with respect to information provided by the Client regarding the proposed development. Further advice should be sought from ALM prior to significant revision of the development proposals.

The report should be read in its entirety, including all associated drawings and appendices. ALM cannot be held responsible for any misinterpretations arising from the use of extracts that are taken out of context.

The findings and opinions conveyed in this report (including review of any third party reports) are based on information obtained from a variety of sources as detailed within this report, and which ALM believes are reliable. All reasonable care and skill has been applied in examining the information obtained. Nevertheless, ALM cannot and does not guarantee the authenticity or reliability of the information it has relied upon.

The report represents the findings and opinions of experienced geo-environmental consultants. ALM does not provide legal advice and the advice of lawyers may also be required.

Intrusive investigation can only investigate shallow ground beneath a small proportion of the total site area. It is possible therefore that the intrusive investigation undertaken by ALM, whilst fully appropriate, may not have encountered all significant subsurface conditions. Consequently, no liability can be accepted for conditions not revealed by the exploratory holes. Any opinion expressed as to the possible configuration of strata between or below exploratory holes is for guidance only and no responsibility is accepted as to its accuracy

It should be borne in mind that the timescale over which the investigation was undertaken may not allow the establishment of equilibrium groundwater levels. Particularly relevant in this context is that groundwater levels are susceptible to seasonal and other variations and may be higher during wetter periods than those encountered during this commission.

Where the report refers to the potential presence of invasive weeds such as Japanese Knotweed, or the presence of asbestos containing materials, it should be noted that the observations are for information only and should be verified by a suitably qualified expert.

This report assumes that ground levels will not change significantly from those existing at present and that houses will be of two storey construction. If this is not to be the case, then some modification to this report may be required.

ALM cannot be responsible for the consequences of changing practices, revisions to waste management legislation etc that may affect the viability of proposed Remediation options.

ALM reserves the right to amend their conclusions and recommendations in the light of further information that may become available.

# SUPPLEMENTARY GEOENVIRONMENTAL APPRAISAL of land at BURLOW ROAD, HARPUR HILL, BUXTON (SOUTHERN SITE – 'SITE B')

## 1 INTRODUCTION

### 1.1 The Commission and Brief

1.1.1 ALM Consult Ltd (ALM), were commissioned by Barratt Homes Manchester to carry out a Supplementary Geoenvironmental Appraisal of land at Burlow Road, Harpur Hill, Buxton in the context of the proposed development of the site for low rise residential housing.

1.1.2 Another proposed development site, which is located off Burlow Road to the north of the study site, has also been the subject of a Supplementary Geoenvironmental Appraisal undertaken on behalf of Barratt Homes Manchester by ALM. This present report contains the findings of previous and supplementary geoenvironmental appraisal works relating exclusively to the 'Southern' Site (also referred to as 'Site B'). The findings of previous and supplementary geoenvironmental appraisal works relating to the 'Northern' Site (also referred to as 'Site A') are contained in ALM Report No. 30156/1A.

1.1.3 Correspondence regarding ALM's appointment, including the brief for this investigation, is included in Appendix C. The agreed scope of works included:

- A review of third party reports and other information.
- A site walkover and inspection.
- Confirm the site's land use history and environmental setting.
- An intrusive ground investigation comprising 24 No. Trial Pits and in situ soakaway tests.
- An assessment of the geotechnical properties of the near surface deposits to enable provision of foundation and highway recommendations.
- A qualitative assessment of contamination risks, with respect to potential receptors
- The provision of recommendations with respect to site preparatory and Remediation works.

1.1.4 The 'Southern' site has been the subject of a 'Preliminary Geoenvironmental Assessment/'Phase 1' Desk Study' and ground investigation that was undertaken by GRM Development Solutions (GRM) in 2006. The findings of the previous desk study and ground investigation works are presented in the following report:

- GRM Development Solutions. *"Land off Burlow Road, Harpur Hill, Buxton. Site Appraisal for Harpur Homes"*. Report No. GRM/P6222/COMB.1A, dated August 2014.

1.1.5 The findings of the GRM Desk Study have been reviewed and updated as part of this present study and are presented within Sections 3 and 4 of this present report.

1.1.6 The ground investigation works undertaken by GRM comprised the excavation of 20 No. trial pits and the performing of 5 No. in situ soakaway tests within additional trial pits, with associated preliminary chemical and geotechnical laboratory testing and an initial programme of ground gas monitoring. A summary of the findings of the previous ground investigation works is presented in Section 5 of this present report.

1.1.7 The primary aims of this 'supplementary' phase of investigation were to review the findings of the previous Desk Study and Ground Investigation works and to carry out further investigation works, principally in order to:

- Confirm ground conditions beneath the site to provide further recommendations with respect to foundations for proposed structures.
- Undertake further assessment and analysis of made ground materials previously noted to be on site.
- Undertake additional sampling and chemical and geotechnical analysis of topsoil materials and natural strata to further assess their potential for re-use within the proposed development.
- Undertake an assessment of the depth of rock strata to assist in the formulation of a site regrading scheme and to further assess the 'excavatability' of the rock strata with respect to the site regrade works and proposed foundation/service trenches.
- Undertake additional in situ soakaway tests.

1.1.8 The above 'supplementary' investigation works have therefore been designed to supplement, and be consolidated with, the findings of the previous GRM investigation to confirm and identify salient geoenvironmental issues affecting the site to enable the Client to obtain budget costs for the necessary site preparatory and remediation works.

## 1.2 The Proposed Development

1.2.1 Consideration is being given to the development of the site with 132 No. 2-3 storey domestic dwellings, associated gardens, public open space and adoptable roads and sewers.

1.2.2 Barratt Homes Manchester Drawing No. 1483/SK01 presented in Appendix B presents a 'Sketch Feasibility' layout of the proposed development.

## 1.3 Report Format and Limitations

1.3.1 All standard definitions, procedures and guidance are contained within Appendix A, which includes background, generic information on:

- Assessment of the site's environmental setting
- Ground investigation fieldwork (including techniques, in-situ testing and sampling)
- Geotechnical Testing
- Contamination Testing (including current guidance, notes about organics analyses, and WAC)
- Hazardous Gas (including potential sources and notes about current guidance)
- Soakaways

1.3.2 General notes and limitations relevant to all ALM geoenvironmental investigations are described in the Foreword and should be read in conjunction with this report. The text of the report draws specific attention to any modification to these procedures and to any other special techniques employed.

# 2 SITE DESCRIPTION

## 2.1 General

2.1.1 The site location is shown on Drawing No. 30156/B/1 presented in Appendix B to this report. Site details are summarised in Table 1 below.

**Table 1**
**General Site Details**

| Detail | Remarks |
|---|---|
| Location | 3 km south of Buxton town centre |
| NGR | SK 070 704 (407028E, 370481N) |
| Approximate Area | 4.72ha |
| Known services | Two 225mm diameter foul sewers are present in the north of the site leading to a Severn Trent Water pumping station that is present to the northeast of the site. An additional 100mm pressurised foul sewer leads from the pumping station and crosses the northern margins of the site – see **Drawing No. 30156/B/2** in Appendix B.<br>Water, gas and electricity mains are present along the verge of Burlow Road and in other nearby roads. |

## 2.2 Site Features ad Surrounding Land

2.2.1 An ALM Engineer completed a walkover survey of the site on the 11$^{th}$ August 2017.

2.2.2 Existing salient site features are depicted on Drawing No. 30156/B/2 in Appendix B. A topographical survey of the site has previously been prepared by Survey Systems Limited in July 2013, the results of which are also presented on Drawing No. 20156/B/2.

2.2.3 A selection of photographs taken during the course of the site walkover survey is presented in Appendix D. The location/orientation of the photographs are presented on Drawing No. 30156/B/3 in Appendix B.

2.2.4 The site exists as an irregular-shaped parcel of land covering an area of approximately 4.72ha and is located to the southwest of Burlow Road and to the west of Hillhead Lane in the area of Harpur Hill, Buxton. Access into the site is afforded by an existing gateway off Hillhead Lane in the east of the site as well as from a gateway via an adjacent farm yard to the north of the site.

2.2.5 The whole of the study site exists as an area of managed pasture that is currently used for the grazing of cattle containing few features of note (Photographs 1, 2 and 3 – Appendix D).

2.2.6 No structures are present on site with the exception of a small brick-constructed structure located within the centre of the site (Photograph 4). This small building may be the remnants of a former agricultural building, but the existing landowner has verbally indicated that there is anecdotal evidence that the building may have been used as a shelter in connection with rock blasting associated with nearby quarrying operations.

2.2.7 A series of mature trees are also present within the central portion of the site which would appear to denote the alignment of a former field boundary/hedgerow (Photograph 5).

2.2.8 Within the extreme northwest of the site, agricultural equipment (trailers etc) are locally stored and small stockpiles of soils, crushed rock and macadam are present in the vicinity (Photographs 6 and 7).

2.2.9 The eastern boundary and parts of the southern boundary of the site are denoted by dry stone walls. However, the western boundary and other parts of the southern boundary are not defined, although dry stone walls are present beyond the proposed development boundary. The northern boundary of the site comprises miscellaneous fences and stone walls denoting the rear gardens to adjacent residential properties located off Burlow Road and Dolby Road (Photograph 8).

2.2.10 Ground levels vary significantly across the site. In the northeast of the site, ground levels are at ca. 338mAOD from where ground levels steadily rise to the south and west to ca. 347 and 349mAOD respectively. Beyond the development site boundary ground levels continue to rise sharply to the south and west up to >370mAOD.

2.2.11 The study site is located on the southern margins of the village of Harpur Hill. To the north and northeast of the site are located predominantly semi-detached residential properties situated off Burlow Road and Dolby Road. A collection of portal framed agricultural buildings and farmyard areas are also present to the north/northwest of the site. An abattoir is located ca. 150m to the north of the site off Burlow Road.

2.2.12 Situated along the north-eastern boundary of the site, at the junction with Burlow Road and Hillhead Lane, is located a sewage pumping station that is operated by Severn Trent Water (Photograph 9). The pumping station is located within a small compound surrounded by chain link fencing.

2.2.13 Land to the east exists as open agricultural land (pasture) possessing dry stone wall field boundaries and areas of woodland. An active mineral railway is present ca. 150m to the east which serves the nearby Hillhead and Buxton Limestone Quarries that are present ca. 700m and 2.5km to the south and southeast of the site respectively.

2.2.14 Land immediately to the south and west of the study site exists as rough open grassland within which numerous outcrops of limestone bedrock are exposed (e.g. Photographs 1 and 2). A disused mineral railway is present ca. 150 to the west and south of the site boundary situated on a high embankment/rock terrace.

**Table 2**
**Summary Site Details**

| Feature | Remarks |
|---|---|
| Current Access | Off Burlow Road and Hillhead Lane |
| Topography | Sloping site. Ground levels at ca. 338mAOD in the northeast of the site rising to 347-349mAOD to the south and west with ground level rising significantly beyond. |
| Approximate areas | 11.5m$^2$ buildings<br>47,200m$^2$ grassland |
| Nature of boundaries | East and south (part) – dry stone walls.<br>West and south (part) – no physical boundary<br>North – rear garden fences/walls to residential properties |
| Surrounding land uses | North – Residential housing, farm buildings/yards and abattoir beyond<br>South – Open grassland and karst topography, limestone quarry (Hillhead Quarry)<br>West – Open grassland and karst topography, disused mineral railway<br>East – Open grassland and active mineral railway |

## 2.3 Site Operations

2.3.1 The study site is currently used for the grazing of livestock. The north-western part of the site is used for the storage of agricultural machinery and plant and for the ad hoc storage of small quantities of soils, rock and crushed macadam. Some tanks are stored within this part of the site, but these are empty and are only used periodically for carrying water.

## 2.4 Japanese Knotweed

2.4.1 During the site walkover, we did not notice the presence of any Japanese Knotweed. However, it should be noted that we are not qualified ecologists and as such cannot guarantee the absence of Knotweed or other invasive vegetation.

# 3 SITE HISTORY

3.1.1 In order to investigate the development history and previous land uses at the site and immediate surrounding land, site centred extracts from Ordnance Survey (OS) maps dating back to 1879 have been examined. The historical OS map extracts are presented in Appendix E to this report.

3.1.2 Table 3 below provides a summary of the salient points relating to the history of the site with respect to the proposed end use. It is not the intention of this report to describe in detail all the changes that have occurred on or adjacent to the site. Significant former uses/operations are highlighted in bold text for ease of reference.

**Table 3**
**Site History**

| Date(s) | Site | Surrounding Land |
|---|---|---|
| 1879/1883 | The site is shown to be in agricultural use.<br>A hedgerow is shown to have been present aligned NW-SE through the central-western part of the site. A further field boundary is shown in the northwest of the site. | Burlow Road and Hillhead Lane are both shown to have been present at this time.<br>A **small quarry** feature is shown immediately to the south of the south-eastern site boundary. Two further small quarry features are shown ca. 50m to the northeast of the site<br>A complex of **farm buildings** ('Haslin House') and an associated **small pond** are shown to the north of the site, beyond which were a row of terraced houses (possibly quarrymen's cottages)<br>A **mineral railway** is shown to have been present ca. 150m to the west and southwest of the site and **a limestone quarry** is shown 200m to the west of the site.<br>The **Harpur Hill (Lime) Works** and quarry complex are present 800m to the northwest. |
| 1899 | No significant changes | A **mineral railway** is shown to have been constructed ca. 150m to the east and northeast of the site and the L&NWR Buxton & High Peak Junction **Railway Line** is now shown ca. 100m to the west, southwest and south of the site |
| 1922/1924 | Little change is shown within the site which is still shown to be in agricultural use.<br>A small **rectangular building** is now shown to be present within the centre of the site with a **trackway** running towards it from Burlow Road | The small quarries to the south and the northwest of the site are no longer shown (possibly backfilled).<br>A collection of **rectangular buildings** are shown to have been constructed immediately to the north of the site (possibly agricultural storage buildings), with an additional row of terraced houses beyond.<br>**Allotment gardens** are shown 100m to the north.<br>Development of a **quarry** ca. 250m to the north (**Burlow Quarry and Lime Works**) |
| 1938-1955 | Little change is shown within the site which is still shown to be in agricultural use.<br>A small **filter tank** is shown in the east of the site near to the location of the present day sewage pumping station. | Development of **residential houses** immediately to the north of the site off Burlow Road and Dolby Lane.<br>Development of the **Hillhead Quarry (and tarmacadam works)** is shown 800m to the south of the site |

Continued…

…Table 3 Continued

| Date(s) | Site | Surrounding Land |
|---|---|---|
| 1967 | No significant changes | Development of an **abattoir** 200m to the north.<br>Development of a college 400m to the north. |
| 1973-77 | The rectangular building and filter bed are no longer shown within the site. | A **pumping station** is now shown immediately to the east of the site.<br>The Burlow Quarry 250m to the north is now shown as disused |
| 2000-Present | No significant changes | The Mineral and L&NWR Railway lines to the west, southwest and south of the site are now shown as disused/dismantled |

3.1.3 In summary, it would appear that the site has remained in agricultural use since the 19$^{th}$ Century. The only significant developments within the site have comprised a small agricultural building and associated trackway and a small sewage filter tank/bed. A small quarry feature was also present immediately to the south of the site. Drawing No. 30156/B/4 in Appendix B presents a summary of historical features within and in close proximity to the site.

# 4 ENVIRONMENTAL SETTING

## 4.1 General

4.1.1 Notes describing how the site's environmental setting has been assessed are included in Appendix A to this report. Information from High Peak Borough Council, Derbyshire County Council, the Environment Agency and the British Geological Survey (in the form of a *'Envirocheck'* report from Landmark Information Group Ltd) are presented in Appendix F. This information is summarised below.

## 4.2 Geology

4.2.1 The British Geological Survey (BGS) map (Sheet 111, 1:50,000 scale) shows that Drift strata are absent within the area of the site.

4.2.2 The BGS Geological Sheet for the area shows that the solid geology underlying the site comprises the Carboniferous Bee Low Limestone Formation. The Bee Low Limestone Formation generally comprises thickly bedded pale grey, pale brownish grey to grey, fine to medium-grained biosparitic limestone. A weathered profile of clay with limestone gravel/cobbles is anticipated to overlie the less weathered limestone strata. Outcrops of the Lower Miller's Dale Lava (a basalt) are shown immediately to south of the site.

4.2.3 Aitkenhead *et. al.* [1] indicate that the stratigraphic thickness of the Bee Low Limestones are generally in excess of 200m in the Buxton area and are underlain by the Woo Dale Limestone series comprising dark grey limestone and dolomite horizons.

4.2.4 The presence of limestone strata beneath the site may suggest a potential risk from karstic features such as sinkholes and caves. However, neither the geological information nor the historic mapping indicate the presence of such features on, or in the vicinity of, the site. The BGS consider there to be only a low risk of ground dissolution related stability hazards being present in this area.

***BGS Borehole Records***

4.2.5 No borehole records held by the BGS are available within the vicinity of the site. However, a log of the nearby Hillhead Quarry (ca. 700m to the south) is available which shows that the Bee Low Limestone extends to a depth of in excess of 133m and which locally possesses clay partings.

## 4.3 Hydrogeology

4.3.1 The Environment Agency classifies the Bee Low Limestone as a Principal Aquifer. The Lower Miller's Dale Lava strata are classified as a Secondary B Aquifer. The Environment Agency's 1:100,000 Groundwater Vulnerability Map (Sheet 17) indicates that the Bee Low Limestone is overlain by soils of intermediate leaching potential.

4.3.2 The natural aquifer properties of the area are dominated by the following:

- Structure – Flow below the water table is generally along bedding planes particularly in areas of shallow dip.
- Vertical Discontinuities – Groundwater flow along joints, faults and mineral veins. These are likely to be important for the vertical movement of groundwater, but less so for horizontal flows, unless they form a low angle with the hydraulic gradient.
- Lateral Discontinuities – Bedding planes form the main route for lateral flow within the aquifer.

[1] Aitkenhead, N, Chisholm, J I and Stevenson, I P (1985) *"Geology of the Country Around Buxton, Leek and Bakewell"*. Memoir of the BGS, Sheet 111.

- Lithology – Whilst the above factors are considered important for groundwater movement within the aquifer, intergranular flow also plays a significant part.

4.3.3 Little research has been carried out on the Carboniferous Limestone Aquifer in the Peak District Region due to the unpredictable presence or absence of local fractures. However, in general, transmissivities are generally less than 60 $m^2$/day (mean approximately 10 $m^2$/day) [2].

4.3.4 The limestone aquifer is known to contribute significantly to flow within local rivers as both identifiable discrete springs and direct discharge to river channels are common, with the direction of groundwater flow typically orientated towards river valleys. Due to the lack of superficial deposits overlying the limestone, direct recharge of the aquifer is considered to be significant.

4.3.5 The western half of the site is indicated to be located within a Groundwater Source Protection Zone (Inner Protection Zone I). The eastern half of the site is not located within any Groundwater Source Protection Zone.

4.3.6 The Groundwater Source Protection Zone Inner Zone I is understood to relate to the potable (bottled) water abstraction held by Buxton Water (Nestle Waters UK Limited) which permits the abstraction of 750$m^3$/day of groundwater from multiple points approximately 3km to the north of the site. Thermal spring groundwater is also used for supplying baths, hydrotherapy pools and a public fountain. This catchment area is derived from theoretical groundwater flow paths and recharge rates to support the mineral water abstractions and springs. It is understood that the source of the mineral water abstractions and mineral springs is from deep 'old' water mixing with 'younger' shallow water within shallower limestone aquifers which both outcrop and subcrop the study site.

4.3.7 High Peak Borough Council/Hockenhull Enterprises (Antigua) Ltd additionally hold a permit for the abstraction of 125$m^3$/day of groundwater for 'General Industrial, Commercial and Public Services Uses' ca. 1.3km to the north of the site.

4.3.8 The nearest permitted groundwater borehole abstraction to the site is located ca. 180 to the northwest of the site which is held by F Redfern & Sons for general washing and process waters in connection with their slaughtering activities at the Haslin Abattoir (40$m^3$/day).

4.3.9 Tarmac Cement and Lime Limited also hold a groundwater abstraction permit for process water (23$m^3$/day) ca. 1km to the southeast of the site within the Hillhead Quarry.

4.3.10 According to the '*Envirocheck*' Report (Appendix F) the site is located in an area where there is only limited potential for groundwater flooding to occur.

4.3.11 A review of topographic maps and aerial imagery suggests the absence of any water bodies within nearby quarry areas, which would suggest that groundwater is located at considerable depth beneath the site.

### 4.4 Hydrology

4.4.1 There are no surface water courses within 1km of the study site. The nearest surface water course is an unnamed tributary of the River Wye which flows in a northerly direction ca. 1.2km to the northwest of the site and which has a confluence with the easterly flowing River Wye 2.5km to the north of the site. The nearest surface water feature is a small water storage pond located ca. 25m to the northwest of the site which

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[2] British Geological Survey/Environment Agency (1997) *"The Physical Properties of Major Aquifers in England and Wales"*. BGS Technical Report WD-97-34 / EA R&D Publication No. 8

is understood to be used for livestock watering.

4.4.2 The Environment Agency website indicates that the site is not located within a river floodplain that would be prone to 1:100 and 1:1000 year flood events. However, the eastern/north-eastern margins of the site are indicatively shown in Appendix F to be prone to high (30 year recurrence interval), medium (100 year recurrence interval) and low (1000 year recurrence interval) risk of flooding by surface waters.

4.4.3 An unknown operator (assumed to be Severn Trent Water Limited) possesses a permit to discharge storm water sewage overflow ('sewage emergency discharge') to underground strata within the site at the Harpur Hill pumping station located immediately adjacent to the site on Hillhead Lane.

4.4.4 According to the *Envirocheck* report in Appendix F there have been no recorded pollution incidents to controlled waters with respect to the site.

### 4.5 Radon

4.5.1 According to Building Research Establishment Report BR 211 (2015), the site is located in an area that would require **Full** Radon gas protection measures for new buildings.

### 4.6 Mining / Quarrying

4.6.1 The site is not located in an area that has historically been mined for coal.

4.6.2 Historical Ordnance Survey maps (Appendix E) and the *Envirocheck* Report presented in Appendix F indicate the presence of a number of quarries within the vicinity of the site that have been worked for limestone. No historical operations would appear to have taken place within the site.

4.6.3 The nearest quarry is a small quarry feature located immediately to the south of the proposed development boundary that is shown to have been present in the late 19th Century and which would appear to have been infilled in the past (see Drawing No. 30146/B/4 in Appendix B). Similar small quarry features were also present at that time on land to the northeast and north of the site.

4.6.4 Large scale quarrying activity has historically taken place at Harpur Hill ca. 800m to the northwest of the site and historical and current quarrying activity takes place at Hillhead Quarry ca. 700m to the south. The Hillhead Quarry (accessed by Hillhead Lane which runs along the eastern boundary of the site) is currently operated by Tarmac and also recently by Forticrete. Limestone extraction is by opencast methods and the likelihood of limestone workings being present beneath the site is considered to be low.

4.6.5 Another limestone quarry and lime works (Burlow Works) were present ca. 150-400m to the north of the site off Heathfield Nook Road. This quarry has since been restored by inert waste materials (see Section 4.7 below).

### 4.7 Landfills

4.7.1 The *Envirocheck* report presented in Appendix F indicates the presence of a former landfill ca. 160m to the north of the site. This historical landfill site (known as the 'Burlow Works') located off Heathfield Nook Road first received wastes in 1970 that were used to restore a former limestone quarry and associated lime works. The site was operated by Mr W H Wright of Haslin House Farm, Harpur Hill.

4.7.2 No details of the types of wastes deposited within the former landfill are presented on the Environment Agency website or contained within the *Envirocheck* report. However, the present owner of the study site, Mr William Wright (the son of the former landfill operator), has verbally indicated that only inert wastes were deposited into a quarry void which was in the order of 10-12m deep. These materials have largely comprised clay soils and, in more recent years, comprised ca. 100,000 tonnes of crushed basalt derived from the construction of a nearby Morrison's supermarket. The former landfill has since substantially been restored to agricultural (pasture) land. However, Mr Wright has received approvals to grant extension to the original planning permission to complete the restoration of the Burlow Works site by means of imported soils and these works are currently ongoing (Derbyshire County Council Planning Permission No. CW1/0105/176).

4.7.3 Other areas of 'potentially infilled land' are indicatively shown in the *Envirocheck* report presented in Appendix F in connection with former areas of quarrying activity, although no details are known as to the nature (if any) of any fill materials.

## 4.8 Other Issues

4.8.1 The study site is not located within the Peak District National Park, the boundary of which is present ca. 700m to the east.

4.8.2 F Redfern and Sons Ltd operate an abattoir 160m to the north of the study site. The Haslin Abattoir is operated under an Integrated Pollution Prevention and Control Permit for 6.8 A(1) (B) activities involving the slaughter of animals >50t/day.

4.8.3 R Mycock and Sons Ltd located 70m to the north of the site hold a Local Authority Pollution Prevention and Control Permit for the 'blending, packing, loading and use of bulk cement'.

4.8.4 A Control of Major Accident Hazards (COMAH) site is located 870m to the west of the site. This site is operated by Christian Salveson Plc at the Buxton Industrial Park, Harpur Hill and is a 'Lower Tier' COMAH registration.

4.8.5 There are no reported fuel storage sites within 500m of the site.

# 5 PREVIOUS INVESTIGATION FINDINGS

## 5.1 General

5.1.1 As noted in Section 1.1.4, the site has been the subject of a previous geoenvironmental assessment/ground investigation that was undertaken by GRM Development Solutions (GRM) in 2006. The findings of the previous ground investigation are presented in the following report:

- GRM Development Solutions. *"Land off Burlow Road, Harpur Hill, Buxton. Site Appraisal for Harpur Homes"*. Report No. GRM/P6222/COMB.1A, dated August 2014.

5.1.2 The following sub-sections present a summary of the GRM's investigation findings.

## 5.2 Scope of Works

5.2.1 Fieldwork was supervised by GRM in May 2006 and comprised the exploratory holes listed below in Table 4.

**Table 4**
**Scope of Ground Investigation Works**
**Undertaken by GRM Development Solutions (2006)**

| Technique | Exploratory holes | Final depth(s) | Remarks |
|---|---|---|---|
| Trial pitting (machine dug) | TP01 – TP20 | 0.8 – 2.3m | Trial pit TP20 designed to target the 'footprint' of a former building. Additional (unnumbered) trial pits targeted the former filter tank feature.<br>Temporary gas monitoring standpipes installed into backfilled trial pit Nos. TP1, TP2, TP3, TP4 and TP5. |
| Trial pitting (machine dug) | STP01 – STP05 | 1.95 - 2.1m | In situ soakaway tests performed in accordance with BRE Digest 365 |

5.2.2 The exploratory hole logs relating to the GRM investigation are presented in Appendix G to this Report.

5.2.3 The locations of the exploratory holes established during the GRM 2006 investigation are shown on Drawing No. 30156/B/5 presented in Appendix B.

## 5.3 Ground Conditions

***Made Ground***

5.3.1 Made ground deposits were not observed during the GRM investigation to be widespread and were only encountered in the following exploratory holes.

5.3.2 GRM Trial Pit TP16 encountered re-worked very silty clay strata to a depth of 1.0m that were observed to overlie pea gravel. These materials represent a backfilled service trench associated with a pressurised foul sewer main.

5.3.3 GRM Trial Pit TP19 located in the extreme northwest of the site encountered shallow made ground materials to a depth of 0.2m comprising sandy clay (reworked topsoil) with some fine to coarse gravel of limestone, ash and metal fragments. It is considered that these materials may have been placed/stockpiled by the local farmer to form a small area of hardstand or a trackway upon which to store agricultural machinery in this location.

5.3.4 GRM Trial Pit TP20 was designed to target the footprint of a former building that is shown on historical OS maps to have been present within the centre of the site in the first half of the 20th Century (see Drawing No. 30156/B/4 in Appendix B). This trial pit encountered made ground deposits to 0.6m depth which comprised silty clay (reworked topsoil) with occasional fine to coarse gravel of slate, clay drain, limestone and carbonaceous materials and occasional limestone cobbles which represents localised demolition-type materials.

5.3.5 GRM reported that (unnumbered) trial pits excavated within the area of the former filter tank, that was located near to the existing sewage pumping station, did not encounter any made ground materials.

***Natural Strata***

5.3.6 Natural strata were encountered in all exploratory holes (except TP16) across the whole of the study site.

5.3.7 Natural sandy, silty clayey TOPSOIL was encountered across the site to depths ranging between 0.2-0.3m.

5.3.8 The natural topsoil was observed to be underlain by weathered Bee Low Limestone strata that were observed to consistently comprise orange brown, slightly sandy, silty to very silty CLAY with occasional, angular to sub-angular, fine to coarse gravel of limestone. Occasional cobbles and boulders of limestone were also present. The shear strength of the weathered Bee Low Limestone were recorded to be typically firm, but locally firm to stiff.

5.3.9 Less weathered (intact) Bee Low Limestone strata were typically encountered at depths ranging between 0.8-1.2bgegl and were recovered as grey strong to very strong, thinly to medium bedded, fine-grained LIMESTONE. Slightly weathering along sub-horizontal bedding was noted with fractures often containing gravelly clay infill. GRM reported that the Bee Low Limestone was excavated as gravel, cobbles and boulders.

## 5.4 Contamination

5.4.1 Only 4 samples of soils were selected by GRM for chemical testing and one sample for leachability testing. The localised made ground in TP19 and TP20 was noted to possess significantly elevated concentrations of arsenic, cadmium, copper, lead, zinc and PAHs and leachable metals. The topsoil was noted to be uncontaminated (2 samples).

5.4.2 Further discussion with respect to the significance of these chemical test results is presented in Sections 9 and 10 of this report.

5.4.3 Groundwater was not encountered and, therefore, not tested for chemical contaminants as part of the GRM investigation.

## 5.5 Ground Gas

5.5.1 The GRM investigation established temporary monitoring pipework within backfilled trial pits TP01-TP05.

5.5.2 The results of only two monitoring visits undertaken on the 24th May and 16th June 2006 were reported by GRM.

5.5.3 No methane gas was detected, however, carbon dioxide was detected at concentrations typically ranging between 1.9-3.9%v/v. TP01 recorded a maximum carbon dioxide concentration of 6.3%v/v on one occasion.

5.5.4 No gas flows were recorded.

5.5.5 GRM concluded that the gas monitoring results suggest that Carbon Dioxide is possibly being generated in the ground locally primarily as a result of the natural dissolution of the parent shallow limestone bedrock.

5.5.6 GRM recommended that gas protection measures conforming to 'Characteristic Situation 2' or 'Traffic Light Amber 1' should be considered for proposed new low-rise housing at the site with respect to the ground gases detected and in view of the fact that the site is located in an area where full radon gas protection measures would be required for new buildings.

## 5.6 Geotechnical Testing and Assessment

5.6.1 Geotechnical testing undertaken by GRM comprised 9 samples for Atterberg limit determination as well as pH and sulphate tests.

5.6.2 The weathered limestone strata was assessed to possess low to medium shrinkability potential.

5.6.3 Based on the recorded water soluble sulphate and pH levels in the soils below the site and assuming mobile groundwater conditions, in accordance with requirements of BRE Special Digest 1 (2005), 'Concrete in Aggressive Ground', GRM recommended that the Design Sulphate Class for buried concrete at the site should be assumed as DS-1 and the ACEC Class as AC-1.

5.6.4 Further discussion with respect to the significance of these test results is presented in Section 11 of this report.

5.6.5 With respect to proposed foundations, GRM concluded that the natural cohesive soils encountered (weathered Bee Low Limestone), overlying the rock strata, were generally at least firm and that a nett allowable bearing pressure of at least 125kN/m$^2$ for conventional strip or trench footings would be achievable. However, for ease of construction and to reduce the risk of differential settlement (due to varying thicknesses of clay) it was recommended that foundations throughout the site found onto the underlying strong to very strong Limestone strata.

## 5.7 In Situ Soakaway Tests

5.7.1 In situ soakaway tests undertaken in accordance with BRE Digest 365 were performed by GRM at five locations in Trial Pits STP01-SPT05 with two soakaway tests being performed in each test pit. The soil infiltration rates calculated by GRM were as follows (see Table 5).

**Table 5**
**Results of In Situ Soakaway Tests**
**Undertaken by GRM Development Solutions (2006)**

| Test Location | Test No. | Test Depth/Strata | Soil Infiltration Rate (m/sec) |
|---|---|---|---|
| STP1 | 1 | 1.95m/Limestone | $1.67 \times 10^{-3}$ |
| | 2 | | $1.22 \times 10^{-3}$ |
| STP2 | 1 | 2.10m/Limestone | $2.06 \times 10^{-4}$ |
| | 2 | | $1.17 \times 10^{-4}$ |
| STP3 | 1 | 1.95m/Limestone | $4.42 \times 10^{-4}$ |
| | 2 | | $3.30 \times 10^{-4}$ |
| STP4 | 1 | 1.95m/Limestone | $4.14 \times 10^{-4}$ |
| | 2 | | $2.88 \times 10^{-4}$ |
| STP5 | 1 | 2.10m/Limestone | $5.22 \times 10^{-5}$ |
| | 2 | | $4.71 \times 10^{-5}$ |

### 5.8 Comments on Previous Investigation Works and Recommendations

5.8.1 The overall scope of the 2006 GRM ground investigation is considered suitable given the nature of the study site and the 'exploratory' nature of the investigation required to be carried out at that time. However, ALM consider that the following additional works will be required to be carried out to expand upon the findings of the GRM investigation:

- Undertake additional trial pitting across the proposed development area to confirm ground conditions and, in particular, the depth to competent rock head to inform potential foundation zoning.
- Undertake additional chemical testing on topsoil and natural strata to further assess the suitability of these materials for reuse on, or off, site.
- Delineate the area of previously encountered made ground materials and undertake further chemical analysis of the made ground materials present.
- It is anticipated that given the existing topography of the site, regrading of site levels will be required prior to development. As such, the trial pits should also seek to ascertain the 'excavatability' of the upper limestone solid strata and to obtain representative samples of the weathered (soil) horizons to ascertain their suitability for compaction/re-engineering beneath roads and house plots.
- Undertake additional in situ soakaway tests in the area of the proposed attenuation pond (shown on Barratt Homes Manchester Drawing No. 1483/SK01 in Appendix B) to further determine the soil infiltration rate of the natural weathered and partially weathered limestone at this location to enable an appropriate SUDS drainage strategy to be designed. The existing soakaway tests performed by GRM suggests that the soil infiltration within the in situ limestone rock is high and that soakaways would, at this stage, be considered viable, however, the infiltration rate at a particular location will primarily be controlled by the degree of fracturing in the limestone.

5.8.2 With respect to gas monitoring, the existing gas monitoring information may be considered inadequate given that the monitoring was carried out in temporary standpipes installed within trial pits and consisted of only 2 reported monitoring visits over a 1 month period. However, ALM have consulted with Mr Matthew Rhodes, Contaminated Land Officer at High Peak Borough Council to discuss the requirement for any further gas monitoring at the site.

5.8.3 In view of the fact that the site has previously been determined to contain no specific sources of ground gas (i.e. significant areas of infilling), and that proposed properties will require Full radon gas protection measures, Mr Rhodes considered that additional gas monitoring would **not** be required at this site.

# 6 GROUND INVESTIGATION DESIGN

## 6.1 Anticipated Ground Conditions & Potential Issues

6.1.1 Based on the data reviewed in Sections 3, 4 and 5, anticipated ground conditions are expected to comprise:-

**Table 6**
**Anticipated Ground Conditions**

| Anticipated Condition | Remarks |
|---|---|
| Made Ground | Shallow made ground comprising reworked and disturbed topsoil previously identified to be localised within the site (GRM TP19 and GRM TP20) and confined to areas of former building footprints or located in the area where granular materials have locally been placed to store agricultural plant in the northwest of the site. Localised made ground deposits may also be present in the vicinity of former filter tank and small infilled quarry feature. |
| Natural Soils | Natural topsoil anticipated to be present across the site.<br>Drift strata previously observed to be absent at the site.<br>Weathered Limestone strata (sandy silty clay) anticipated to be present across the whole site. |
| Bedrock | Bee Low Limestone previously observed to be present at shallow (typically 0.8-1.2m) depth. |
| Mineworkings/ Quarry Workings | The site is not located in an area that has previously been mined for coal. However, extensive quarrying activity has taken place in the vicinity of the site.<br>A small (possibly infilled) quarry feature was present immediately to the south of the proposed development area and further small and shallow quarry workings within the site cannot be ruled out.<br>More recent and current large quarry operations have/are taking place to the northwest and south of the site. These are opencast limestone extraction operations and the likelihood of mining having taken place beneath the site is low. |
| Groundwater | Anticipated to be present at considerable depth beneath the site. |

6.1.2 Based on the data above and that in Sections 2 and 3, potential ground-related issues associated with this site are likely to include:

**Table 7**
**Anticipated Ground Related Issues**

| Type of Issue | Specific Issue | Remarks |
|---|---|---|
| Potential on-site contamination sources | 1. Former building (and trackway)<br>2. Former filter tank<br>3. Made Ground<br>4. Infilled small quarry feature | 1. Presence of demolition type materials previously noted in GRM TP20 to 0.6m depth. Metals and PAH contamination previously noted. Asbestos fibres may also be present.<br>2. Presence of demolition type materials may locally be present to shallow depth. Potential for metal and organic contamination to be present.<br>3. Previously noted in the extreme northwest of the site (GRM TP19). Miscellaneous materials (soils, rock, demolition materials) are currently, and may have previously been stored, in this location. Metal, organic and asbestos contamination may be present<br>4. Noted on historical maps to be present to the south of the proposed development area. Possibly backfilled with miscellaneous materials of unknown type or origin. |

Continued…

….Table 7 Continued

| Type of Issue | Specific Issue | Remarks |
|---|---|---|
| Potential off-site contamination sources | 1. Landfill (Burlow Works Landfill)<br>2. Abattoir | 1. Located ca. 160m to the north containing inert soil/rock wastes. Potential for significant gas generation considered to be relatively low.<br>2. Located ca. 150m to the north. Operations controlled by an IPC permit. Risks associated with any below ground mobile contamination considered to be low. |
| Potential geotechnical hazards | 1. Relict foundations/floorslabs<br>2. Deep Made Ground<br>3. Infilled pits/quarry workings<br>4. Shallow rock<br>5. Sloping ground | 1. Potentially present within the footprint of the former building and filter tank that were historically present on site. Not previously encountered during the 2006 GRM investigation.<br>2. Not previously encountered during the 2006 GRM investigation.<br>3. Small quarry feature historically present to the south of the proposed developed area (possibly infilled). The potential presence of other similar historical features cannot be completely ruled out.<br>4. Rockhead identified during the 2006 GRM investigation to be present at shallow (ca. 0.8-1.0m) depth. Possible requirement to use hydraulic pointed tools and overbreak in trench excavations. Possible ripping required if site regrade levels conflict with rockhead.<br>5. Existing site topography may necessitate site regrading works and/or the use of retaining walls. |
| Other potential constraints | 1. Foul sewers and pressurised sewer main | 1. Approximate locations shown on Drawing No. 30156/B/2 in Appendix B. Diversion of sewers may be required or development layout may require incorporation of easements. |

### 6.2 Preliminary Conceptual Site Model

6.2.1 A preliminary conceptual site model, presented as Drawing No 30156/B/6 in Appendix B, has been prepared after consideration of all the data presented in Sections 2 to 6.1 inclusive, of this report.

6.2.2 Potential pollutant linkages are shown on the preliminary conceptual site model.

6.2.3 The site currently exists as a field used for the grazing of livestock. Historical maps indicate that the site has remained in similar agricultural use since the mid 19$^{th}$ Century and the likelihood of any significant contamination arising from such activities is considered to be very low.

6.2.4 Localised development has, however, taken place on the site. This has comprised the construction of a building (presumably for agricultural use) and an associated trackway within the centre of the site and the construction of a filter tank within the northeast of the site which may have been used for the treatment of sewage from nearby residential development. These features were present in the first half of the 20$^{th}$ Century and were relatively minor in scale and extent.

6.2.5 The extreme north/north-western part of the site is currently used for the storage of agricultural machinery and trailers and this area has also been observed be used for the storage of small quantities of soils, rock and crushed demolition materials that are used by the local farmer/current landowner for various applications, such as the construction/maintenance of trackways and external storage areas.

6.2.6 In terms of contamination sources, the previous 2006 GRM ground investigation found only localised and shallow (0.2-0.6m depth) made ground materials (reworked/disturbed topsoil) within the extreme northwest of the site and within the footprint of a former building. Although this made ground was noted to be localised and shallow in extent, previous chemical tests undertaken on these materials indicate that metal and organic contamination is present. Other areas where potential contamination could be present is in the footprint of a former trackway, which lead to the former building, and in the vicinity of the former filter tank. In these areas, granular materials (possibly demolition-type materials) could be present and may represent a source of metal, organic and asbestos contamination. A small quarry feature was also present immediately to the south of the proposed development area which may have been infilled with various materials derived from local sources.

6.2.7 In terms of off-site sources of contamination, these comprise a former inert landfill and an abattoir, both of which are located ca. 150m to the north and northwest of the site respectively. Both of these are considered to be located at a sufficient distance away from the study site to not present any significant risk to the proposed development.

6.2.8 The development proposals comprise residential properties with areas of hard standing (e.g. car parking), domestic gardens and areas of soft landscaping/public open space. The primary human health receptors are end users of the completed development and construction workers. The primary pathways of concern include dermal contact with contaminated soil and soil dust, the ingestion of contaminated soil and soil dust, ingestion of homegrown produce that have taken up the contamination, indoor and outdoor inhalation of ground gas and soil vapours, and migration of contamination into water supply pipes.

6.2.9 For controlled waters, the primary receptor for the site is the underlying Principal aquifer (Bee Low Limestone Formation). The primary pathways of concern are leaching of contaminants and vertical migration to the groundwater. Although groundwater is anticipated to be present at significant depth, the presence of fractures within the shallow rock could lead to relatively rapid transmission of mobile and leachable contaminants within the subsurface.

6.2.10 A small surface water pond is located 25m to the north of the site but is located upgradient of the site and is probably clay or concrete lined used for the collection of rainwater for the watering of livestock and is not considered a viable or significant environmental receptor.

6.2.11 For construction materials, the primary receptors are water pipes and buried concrete. The primary pathways of concern are the migration of contamination leading to degradation of pipe materials and sulphate and/or acid attack on buried concrete.

### 6.3 Ground Investigation Design & Strategy

6.3.1 The preliminary conceptual site model has been used as a basis for design of an appropriate ground investigation, the scope of which is summarised below.

**Table 8**
**Proposed Supplementary Ground Investigation Strategy**

| Exploratory Holes | Purpose |
|---|---|
| Trial Pits (Machine Excavated) | To determine and confirm the general nature of soils underlying the site, including the:<br>• Nature, distribution and thickness of made ground<br>• Nature, degree and extent of contamination<br>• Proportion of any undesirable elements e.g. biodegradable matter, foundations etc<br>• Suitability of the ground for founding structures and highways<br>• The depth to and nature of rockhead |
| Trial Pits (Machine Excavated | To enable the performing of in situ soakaway tests within the area of a proposed attenuation pond/soakaway chamber to determine/confirm whether soakaways could be utilised for surface water drainage at this location. |

6.3.2 Proposed exploratory hole locations will be selected to provide a representative view of the strata beneath the site to expand upon, and supplement the findings of, the previous 2006 GRM investigation. A nominal 50m grid spacing is proposed. Additional exploratory locations would be scheduled by the site engineer in light of the ground conditions actually encountered.

6.3.3 Selected trial pits will be specifically designed to target former historical site features that have been identified in Sections 3 and 6.1 above and to target areas previously identified to contain made ground materials, as noted in Section 5.3.

6.3.4 An assessment of potential contaminants associated with the former uses has been undertaken and with reference to the previous GRM ground investigation findings. As a consequence of this assessment, anticipated potential contaminants, within soil include:

- pH, metals (As, Cd, Cr, Pb, Hg, Se, Cu, Ni and Zn).
- Leachable metals (selected samples).
- 2:1 water soluble sulphate, total sulphate (selected samples).
- Asbestos screen (selected samples).
- Total Organic Carbon/Soil Organic Matter (selected samples, particularly topsoil materials to enable assessment of the significance of PAH/TPH determinands)
- Speciated PAH.
- Speciated TPH and BTEX (selected samples) – these will be required by Severn Trent Water Ltd to enable pipeline risk assessments to be subsequently prepared.
- Speciated SVOC and VOCs (selected samples) – these will be required by Severn Trent Water to enable pipeline risk assessments to be subsequently prepared

6.3.5 The site is located in an area where full radon gas protection measures will be required for new buildings. As the site is anticipated to contain no significant on site or nearby off site sources of other hazardous ground gases, no additional ground gas monitoring has been deemed to be required.

# 7 FIELDWORK

## 7.1 Objectives

7.1.1 The original investigation strategy is outlined in Section 6.3 above.

## 7.2 Exploratory Hole Location Constraints

7.2.1 Existing gravity and pressurised foul sewer mains are present in the northeast, north and northwest of the study site, at the locations indicatively shown on Drawing No. 30156/B/2 in Appendix B. The presence of these underground utilities prevented the excavation of exploratory holes in these locations.

## 7.3 Scope of Works

7.3.1 Fieldwork was supervised by ALM between 29th-31st August 2017 and comprised the exploratory holes listed below.

**Table 9**
**Scope of Ground Investigation Works**

| Technique | Exploratory Holes Nos. | Final depth(s) | Remarks |
|---|---|---|---|
| Trial pitting (machine dug) | TB101 – TB124 | 0.8 – 1.8m | Vane tests in cohesive soils. |
| Trial pitting (machine dug) | TB101 | 1.3m | Excavated to target made ground materials previously noted in GRM TP19 |
| Trial pitting (machine dug) | TB110 | 1.8m | Excavated to target an historical trackway |
| Trial pitting (machine dug) | TB116 and TB117 | 1.3 – 1.6m | Excavated to target an historical infilled quarry feature |
| Trial pitting (machine dug) | TB120 | 1.5m | Excavated to target an historical filter tank structure |
| Trial pitting (machine dug) | TB122 | 1.5m | Excavated to target an historical building and to additionally target made ground previously noted in GRM TP20 |
| Soakaway Tests | SAB1 and SAB2 | 1.3 – 1.5m | Soakaway tests carried out in accordance with BRE Digest 365 in the location of a proposed attenuation pond/soakaway chamber |

7.3.2 Notes describing ground investigation techniques, in-situ testing and sampling are included in Appendix A to this report.

7.3.3 Exploratory hole logs are presented in Appendix H to this Report. These logs include details of the:

- Samples taken
- Descriptions of the soil strata, and any groundwater encountered.
- Results of the in-situ testing

7.3.4 Photographs of selected trial pits are also present in Appendix H.

7.3.5 The locations of the exploratory holes were set out by ALM and their respective OS coordinates established by means of a hand held GPS devise. The exploratory hole locations are shown on Drawing No. 30156/B/5 in Appendix B.

# 8 GROUND CONDITIONS

## 8.1 General

8.1.1 A complete record of strata encountered beneath the proposed development site is given on the various exploratory hole records, presented in Appendix H. However, a summary of the ground conditions encountered in the ALM exploratory holes is provided below.

## 8.2 Made Ground

8.2.1 Localised made ground deposits were encountered in the following exploratory holes:

- **Trial Pit TB116** – This trial pit was excavated just to the south of the proposed development area and targeted a former small (infilled) quarry feature. The quarry infill materials were observed to a depth of 1.4m and comprised reworked topsoil overlying granular materials of fine to coarse gravel of limestone and brick fragments with boulders of reinforced concrete with rare wire, clay tile and glass fragments. No degradable materials were observed within the quarry infill materials. Trial Pit TB117 was excavated immediately to the north of the quarry feature and no made ground materials were encountered.
- **Trial Pit TB120** – This trial pit was excavated within the footprint of a former 'filter tank' shown to have existed near to the current pumping station. The made ground materials at this location were observed to 0.5m depth and comprised reworked topsoil containing limestone gravel overlying clayey fine to coarse gravel of limestone (possible filter bed gravels).
- **Trial Pit TB122** - This trial pit was excavated within the footprint of a former building. The made ground materials at this location were observed to 0.3m depth and comprised reworked topsoil overlying clayey fine to coarse gravel of limestone and brick fragments and represents localised demolition type fill materials derived from the former building, similar to that observed in GRM TP20. No relict floor slab or foundations were observed.

8.2.2 Trial Pit TB101 was excavated near to GRM TP19 to assess the nature of the shallow made ground previously identified at this location. However, no made ground materials were encountered which suggests that the previously observed made ground materials are either very localised or have since been removed from the site.

8.2.3 Trial Pit TB110 was excavated within the footprint of a former trackway which is shown on historical maps to have crossed the central portion of the site. No made ground materials were encountered at this location.

## 8.3 Obstructions

8.3.1 Trial pits TB120 and TB122 were excavated at locations where relict foundations to former buildings that have been present on site were anticipated (based on superimposition of the OS maps on the current site topographical survey). No relict foundations, floor slabs or other obstructions were encountered.

## 8.4 Natural Ground

8.4.1 Natural strata were encountered in the all of the ALM exploratory holes. Ground conditions were observed to be relatively uniform across the site and the strata observed comprised the following.

***Topsoil***

8.4.2 The natural topsoil typically comprised a dark brown clayey topsoil with rootlets. The average thickness of the topsoil was recorded as 0.3m.

***Completely Weathered Bee Low Limestone***

8.4.3 All of the trial pits, with the exception of TB114 and TB116, encountered Completely Weathered Bee Low Limestone strata.

8.4.4 Within the context of this report, 'Completely Weathered' strata are defined as:

> Rock has completely changed to a soil in which the original rock fabric is completely destroyed, or the original rock fabric may still be locally preserved and may contain lithorelicts.

8.4.5 Completely Weathered Bee Low Limestone was observed directly beneath the natural topsoil and typically comprised a soft, becoming firm, (friable) slightly sandy very silty CLAY with rare fine to coarse gravel of limestone.

8.4.6 These materials were recorded to depths of between 0.6-1.6mbgl (average 1.05mbgl) and possessed a thickness of 0.3-1.25m (average 0.7m).

8.4.7 The undrained shear strength of this stratum was ascertained by means on a hand vane – the test results are presented on the respective trial pit logs in Appendix H. Hand vane tests were problematic due to the friable nature of the materials but gave undrained shear strength values ranging between 27 and 74kN/m$^2$ (48.6kN/m$^2$ average).

***Moderately Weathered Bee Low Limestone***

8.4.8 All of the trial pits encountered Moderately Weathered Bee Low Limestone Strata.

8.4.9 Within the context of this report, 'Moderately Weathered' strata are defined as:

> Original rock fabric is preserved but discontinuities may be open and have discoloured surfaces with alteration penetrating inwards.

8.4.10 Moderately Weathered Bee Low Limestone Strata comprised strong to very strong pale grey fine grained thinly to medium bedded LIMESTONE. The sub-horizontal bedding surfaces were observed to be weathered and discontinuities were observed to be filled with soft brown clay.

8.4.11 This stratum was very hard to excavate and trial pits were required to terminate at the stratum surface that was recovered as angular cobbles and boulders (see Section 8.5).

8.4.12 The depth to the top of the Moderately Weathered Bee Low Limestone ranged between 0.35mbegl (TB114) and 1.60mbegl (TB110), but was typically encountered at depths ranging between 0.8-1.2mbegl (average depth to rockhead – 1.0m)

8.4.13 Drawing No. 30156/B/7 in Appendix B presents a summary of the depth/level to the Moderately Weathered Limestone rockhead encountered in both the GRM and ALM exploratory holes.

8.4.14 As the depth to rockhead was generally observed to be relatively uniform across the site, the levels of the rockhead closely mirror the surface topography. The level of the top of rockhead is at its lowest in the vicinity of the sewage pumping station in the northeast of the site (337mAOD) and steadily increase to levels of 347-348mAOD towards the south, southwest and west.

## 8.5 Excavatability of Solid Strata

8.5.1 All of the trial pits were excavated using a JCB 3CX excavator using a 600mm wide toothed bucket.

8.5.2 The Completely Weathered Bee Low Limestone was excavated as a residual soil (slightly sandy very silty clay) and was easily excavated.

8.5.3 The change from Completely to Moderately Weathered Bee Low Limestone was noted to be very abrupt, with the Moderately Weathered Limestone strata (in situ rock) proving very difficult to excavate. The trial pits were forced to be terminated ca. 0.2-0.5m into this stratum with the rock being excavated as angular cobbles and boulders. The degree to which the rock was able to be excavated was generally dependent on the presence of rock discontinuities aligned transverse to the direction of dig.

8.5.4 Drawing No. 30156/B/8 in Appendix B presents a plot of the estimated compressive strength of the encountered moderately weathered limestone strata against the stratum discontinuity spacing to provide a general assessment of the 'excavatability' of the encountered rock strata based on the assessment method presented by Pettifer and Fookes (1994)[3].

8.5.5 The limestone was noted to be strong to very strong and was typically thinly to medium bedded. Excavation of the limestone would be expected to be problematic and would be categorised as 'hard-extremely hard ripping/hydraulic breaking'. As such, the use of pointed hydraulic breaker tools will be required to excavate into the limestone in trench excavations and ripping and breaking will be required in more open excavations.

## 8.6 Visual & Olfactory Evidence of Organic Contamination

8.6.1 None of the exploratory holes encountered any visual or olfactory evidence of any hydrocarbon (petroleum/solvent etc) contamination.

## 8.7 Groundwater

8.7.1 No groundwater seepages were encountered in any of the exploratory holes

## 8.8 Stability

8.8.1 The stability of trial pit excavations within was observed to be generally good. However, there was a tendency for cobbles and boulders loosened by excavation activity within the Moderately Weathered Bee Low Limestone to fall into the pits.

8.8.2 The excavation within the quarry infill materials in trial pit TB116 was noted to be unstable due to the granular nature of the fill materials encountered.

## 8.9 Revised Conceptual Ground Model (Ground Conditions)

8.9.1 The Preliminary Conceptual Site Model has been revised in light of data obtained during the ground investigation, most notably with respect to:

- the nature and distribution of made ground;
- the strength, nature and depth of underlying natural strata; and
- the nature and distribution of contamination (based on visual/olfactory evidence only)

8.9.2 Further refinement of the Conceptual Site Model is presented in Section 10, where the results of laboratory testing for contaminants have been considered.

[3] Pettifer G.S and P.G Fookes (1994) "A Revision of the Graphical Method for Assessing the Excavatability of Rock". Quat. Journal of Engineering Geology. 24. 145-164

# 9 CONTAMINATION (ANALYSIS)

## 9.1 General

9.1.1 Notes outlining current guidance with respect to the interpretation of analytical data are included in Appendix A to this report.

9.1.2 The study site has been, and has remained, in agricultural use since the mid 19th Century. Only modest development has historically taken place within the site, this has comprised a small (agricultural) building and an associated trackway and a small sewage filter tank. These features were present on site in the first half of the 20th Century. A small quarry feature was present immediately to the south of the proposed development area in the late 19th Century.

9.1.3 The supplementary ground investigation has encountered granular fill materials within the small quarry feature to 1.4m depth (TB116) which typically comprise concrete, brick and limestone rubble which may have been derived from local demolition sources. Within the footprints of the former building and filter tank, only shallow reworked/disturbed topsoil materials were present which contained entrained fragments of demolition type materials such as brick and gravel (TB120 and TB122). No other made ground materials were encountered across the site during the ALM investigations.

9.1.4 The above materials have the potential to be contaminated. An assessment of potential contaminants and contamination sources associated with the former use of the site has been undertaken; see Sections 6.2 an d 6.3 above.

## 9.2 Testing Scheduled

9.2.1 Based on the above assessment, an ALM Engineer submitted a test schedule (summarised in Table 10 below) to a UKAS accredited laboratory (Exova Jones Environmental, Deeside).

**Table 10**
**Summary of Chemical Tests Scheduled**

| Type of Sample | No. of Samples | Determinands |
|---|---|---|
| Made Ground (Quarry Fill, Reworked/ Disturbed Topsoil and Filter Gravels) | 4 | pH and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc and water soluble boron) |
| | 2 | Speciated PAH |
| | 3 | Total organic carbon |
| | 4 | Asbestos (screen) |
| | 1 | Speciated TPH+BTEX |
| | 2 | Speciated VOC + SVOC (incl. PAH) |
| | 3 | Leachable pH and metals (arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) |
| Natural Topsoil | 10 | pH and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc and water soluble boron) |
| | 10 | Speciated PAH |
| | 10 | Total organic carbon |
| | 4 | Asbestos (screen) |
| | 2 | Speciated TPH+BTEX |

Continued….

…. Table 10 Continued

| Type of Sample | No. of Samples | Determinands |
|---|---|---|
| Natural Strata (Completely Weathered Bee Low Limestone) | 7 | pH and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc and water soluble boron) |
| | 3 | Speciated PAH |
| | 7 | pH and Total and Water Soluble Sulphate |
| | 5 | Speciated VOC |
| | 4 | Speciated SVOC (incl PAH) |
| | 2 | Speciated TPH+BTEX |

9.2.2 Notes describing the various organics analyses are included in Appendix A to this report.

### 9.3 Soil Contamination Results

9.3.1 The soil contamination test results are summarised in Tables 11, 12 and 13 on pages 25 to 29.

9.3.2 It should be noted that the results of chemical tests previously obtained as part of the GRM 2006 investigation are **additionally presented** in Tables 11, 12 and 13.

9.3.3 Laboratory test certificates as received from the laboratory(ies) are presented in Appendices I(1) and I(2) to this report.

## Table 11 - Summary of Degree of Ground Contamination (Inorganics) at Burlow Road, Buxton – Southern Site (Site B).

| Hole ID | Depth (m) | Material | Concentrations in mg/kg unless otherwise stated. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are Shown in Brackets and assume a **residential with gardens** end-use. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % TOC | pH | As (37)$ | Cd (11)$ | Cr (910) $+ | Pb (200) # | Hg (40)$ | Se (250) $ | Cu (135) ♣ x | Ni (130) $ | Zn (200) ♣ x | B (3)^ | Asbestos | Total $SO_4$ (2,400) ◊ | Sol $SO_4$ (0.5 g/l) ◊ |
| TP19 | 0.1 | MG: R/W Topsoil | 3.35 | 6.9 | 37 | **14** | 124 | **6202** | 0.17 | 0.73 | **331** | 96 | **7446** | | | | 0.01 |
| TB120 | 0.1 | MG: R/W Topsoil | 3.28 | 7.83 | 27 | 5.3 | 89 | 121 | 0.2 | 1 | 61 | 78 | **312** | 1 | NAD | | |
| TB120 | 0.4 | MG: Filter Gravel | 6.0 | 7.62 | 22 | 4.1 | 83 | **376** | 1.2 | 1 | **151** | 43 | **737** | 1.8 | NAD | | |
| TP20 | 0.2 | MG: Demolition | 3.62 | 7.13 | 20 | 4.0 | 44 | **588** | 1.6 | 0.99 | **580** | 41 | **705** | | | | 0.02 |
| TB122 | 0.2 | MG: Demolition | | 7.98 | 9.9 | 1.6 | 55 | 87 | <0.1 | <1 | 32 | 30 | 116 | 0.4 | NAD | | |
| TB116 | 0.8 | MG: Quarry Fill | 1.44 | 7.97 | 8.4 | 1.7 | 41 | 42 | <0.1 | <1 | 22 | 28 | 99 | 0.4 | NAD | | |
| TP06 | 0.1 | Natural Topsoil | 4.47 | 6.72 | 12 | 1.3 | 39 | 84 | 0.2 | 0.78 | 28 | 25 | 143 | | | | 0.03 |
| TP18 | 0.1 | Natural Topsoil | 2.21 | 6.34 | 18 | 3.3 | 45 | 115 | 0.15 | 0.81 | 39 | 39 | **291** | | | | 0.02 |
| TB101 | 0.2 | Natural Topsoil | 3.21 | 7.42 | 17 | 4.6 | 65 | 93 | <0.1 | 2 | 36 | 46 | **349** | 1 | NAD | | |
| TB104 | 0.2 | Natural Topsoil | 3.72 | 6.64 | 21 | 2.6 | 93 | 118 | <0.1 | 2 | 36 | 36 | **268** | 1 | | | |
| TB106 | 0.2 | Natural Topsoil | 4.94 | 6.59 | 16 | 1.7 | 86 | 129 | <0.1 | 2 | 30 | 30 | **215** | 1.2 | | | |
| TB108 | 0.2 | Natural Topsoil | 4.61 | 5.98 | 12 | 1.5 | 1.1 | 98 | <0.1 | 1 | 31 | 26 | 187 | 1.2 | NAD | | |
| TB110 | 0.2 | Natural Topsoil | 6.83 | 7.12 | 15 | 2.3 | 83 | **588** | 1.4 | 1 | **187** | 29 | **469** | 2 | | | |
| TB112 | 0.2 | Natural Topsoil | 3.73 | 6.38 | 15 | 1.3 | 88 | 83 | <0.1 | <1 | 31 | 32 | 147 | 1 | NAD | | |
| TB114 | 0.2 | Natural Topsoil | 5.67 | 6.5 | 17 | 2.9 | 85 | 140 | 0.2 | 2 | 37 | 40 | **261** | 1.6 | | | |
| TB118 | 0.2 | Natural Topsoil | 6.33 | 6.61 | 15 | 2.6 | 90 | 120 | <0.1 | 2 | 36 | 41 | **225** | 1.5 | | | |
| TB121 | 0.2 | Natural Topsoil | 4.26 | 6.44 | 15 | 1.4 | 67 | 93 | 0.1 | 2 | 28 | 23 | 144 | 1.1 | NAD | | |
| TB123 | 0.2 | Natural Topsoil | 4.89 | 7.43 | 13 | 1.5 | 67 | 90 | <0.1 | 2 | 25 | 22 | 173 | 1.2 | | | |

| **Key** | | | |
|---|---|---|---|
| **BOLD** | Parameter is in excess of screening level concentration | ◊ | BRE Special Digest 1, Concrete in aggressive ground (2005) |
| ♣ | Trigger level concentration is pH dependent | ^ | ICRCL Guidance Note 59/83, Second Edition (1987) – (Boron Phytotoxic only) |
| $ | LQM/CIEH (2015) 'S4UL' for 'Residential with Homegrown Produce' land use | x | BS3882:2015 'Specification for Topsoil and Requirements for Use'. BS8601:2013 'Specification for Topsoil and Requirements for Use' |
| + | LQM/CIEH (2015) 'S4UL' for Chromium III for 'Residential with Homegrown Produce' land use | NAD | No Asbestos Detected |
| # | 'Category 4 Screening Level' (DEFRA 2014) | | |

## Table 11 (Cont.) - Summary of Degree of Ground Contamination (Inorganics) at Burlow Road, Buxton – Southern Site (Site B).

| Hole ID | Depth (m) | Material | Concentrations in mg/kg unless otherwise stated. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are Shown in Brackets and assume a **residential with gardens** end-use. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % TOC | pH | As (37)$ | Cd (11)$ | Cr (910) $+ | Pb (200) # | Hg (40)$ | Se (250) $ | Cu (135) ♣ x | Ni (130) $ | Zn (200) ♣ x | B (3)^ | Asbestos | Total $SO_4$ (2,400) ◊ | Sol $SO_4$ (0.5 g/l) ◊ |
| TP02 | 0.5 | CW Bee Low L'st | | 7.2 | | | | | | | | | | | | | 0.04 |
| TP08 | 0.3 | CW Bee Low L'st | | 6.7 | | | | | | | | | | | | | 0.08 |
| TP10 | 0.3 | CW Bee Low L'st | | 7.8 | | | | | | | | | | | | | 0.03 |
| TP19 | 0.3 | CW Bee Low L'st | | 6.8 | | | | | | | | | | | | | 0.03 |
| STP01 | 0.3 | CW Bee Low L'st | | 7.4 | | | | | | | | | | | | | 0.05 |
| STP04 | 0.3 | CW Bee Low L'st | | 7.0 | | | | | | | | | | | | | 0.03 |
| TB105 | 0.5 | CW Bee Low L'st | | 7.42 | 8 | 1.9 | 76 | 86 | <0.1 | 2 | 16 | 40 | 198 | 0.4 | | 443 | 0.0205 |
| TB107 | 0.6 | CW Bee Low L'st | | 6.79 | 8 | 3 | 74 | 26 | <0.1 | <1 | 25 | 64 | 197 | 0.3 | | 200 | 0.0165 |
| TB109 | 0.5 | CW Bee Low L'st | | 6.97 | 13 | 8 | 69 | 81 | <0.1 | 2 | 33 | 77 | **286** | 0.2 | | 222 | 0.0159 |
| TB111 | 0.6 | CW Bee Low L'st | | 6.94 | 6.4 | 0.2 | 65 | 25 | <0.1 | 1 | 11 | 29 | 86 | 0.2 | | 267 | 0.0245 |
| TB113 | 0.5 | CW Bee Low L'st | | 7.46 | 7.2 | 3 | 91 | 41 | <0.1 | 2 | 30 | 105 | 141 | 0.3 | | 199 | 0.0144 |
| TB121 | 0.6 | CW Bee Low L'st | | 7.4 | 6.2 | 1.5 | 65 | 21 | <0.1 | <1 | 18 | 60 | 106 | 0.2 | | 182 | 0.0162 |
| TB123 | 0.4 | CW Bee Low L'st | | 7.63 | 6.3 | 1.3 | 50 | 22 | <0.1 | 1 | 6 | 34 | 104 | 0.3 | | 272 | 0.0059 |
| TP06 | 1.0 | Limestone Rock | | 8.1 | | | | | | | | | | | | | 0.03 |
| TP11 | 1.1 | Limestone Rock | | 7.1 | | | | | | | | | | | | | 0.04 |
| TP16A | 2.1 | Limestone Rock | | 8.0 | | | | | | | | | | | | | 0.07 |
| STP05 | 1.2 | Limestone Rock | | 7.1 | | | | | | | | | | | | | 0.04 |

| Key | | | |
|---|---|---|---|
| **BOLD** | Parameter is in excess of screening level concentration | ◊ | BRE Special Digest 1, Concrete in aggressive ground (2005) |
| ♣ | Trigger level concentration is pH dependent | ^ | ICRCL Guidance Note 59/83, Second Edition (1987) – (Boron Phytotoxic only) |
| $ | LQM/CIEH (2015) 'S4UL' for 'Residential with Homegrown Produce' land use | x | BS3882:2015 'Specification for Topsoil and Requirements for Use'. BS8601:2013 'Specification for Topsoil and Requirements for Use' |
| + | LQM/CIEH (2015) 'S4UL' for Chromium III for 'Residential with Homegrown Produce' land use | NAD | No Asbestos Detected |
| # | 'Category 4 Screening Level' (DEFRA 2014) | | |

**Table 12 - Summary of the Leachability Testing on samples from Burlow Road, Buxton – Southern Site (Site B).**

| Hole ID | Depth (m) | Material | Concentration in μg/litre unless otherwise Shown. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are Shown in Brackets. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | pH | As | Cd | Cr | Cu | Pb | Hg | Ni | Zn | Se | B |
| | | | (6.5-9.5)* | (10)* | (5)* | (50)* | (2000)* | (10)* | (1)* | (20)* | (5,000)* | (10)* | (1000)* |
| TP19 | 0.1 | MG: R/W Topsoil | 7.47 | 2.7 | 0.4 | 11 | 26 | **31** | <0.01 | 4.7 | 533 | 2.1 | |
| TB120 | 0.4 | MG: Filter Gravel | 8.1 | <2.5 | <0.5 | 1.5 | 16 | <5 | <1 | 3 | 23 | <3 | <12 |
| TB122 | 0.2 | MG: Demolition | 8.31 | <2.5 | <0.5 | <1.5 | <7 | <5 | <1 | <2 | 7 | <3 | 14 |
| TB116 | 0.8 | MG: Quarry Fill | 8.25 | <2.5 | <0.5 | <1.5 | <7 | <5 | <1 | <2 | 7 | <3 | <12 |

| **Key** | | | |
|---|---|---|---|
| **BOLD** | Parameter in excess of trigger level concentration | * | Water Supply (Water Quality) Regulations 2000, as amended |

## Table 13 - Summary of Degree of Ground Contamination (Organics) at Burlow Road, Buxton – Southern Site (Site B).

| Hole ID | Depth (m) | Material | Concentrations in mg/kg. Results are quoted to 2 decimal places if <10, and whole numbers if >10. Trigger Level Concentrations are shown in brackets and assume a **residential with gardens** end use | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | TOC | Benzene | Toluene | Ethyl Benzene | Xylenes | Phenols | VOC | PAH | | TPH - $C_6$ to $C_{40}$ | | |
| | | | % | (0.087) +♣ | (130)+♣ | (47)+♣ | (56)+♣ | (120)+♣ | | BaP (2.2) +♣ | Naphthalene (2.3) +♣ | GRO $C_6$ to $C_{10}$ (0.087) ♣◇ | DRO $C_{10}$ to $C_{20}$ (74)~ ♣ | LRO $C_{20}$ to $C_{40}$ (1100)~ ♣ |
| TP19 | 0.1 | MG: R/W Topsoil | 3.35 | | | | | 0.12 | | <0.01 | <0.01 | | | |
| TB120 | 0.1 | MG: R/W Topsoil | 3.28 | | | | | | | 0.47 | <0.04 | | | |
| TB120 | 0.4 | MG: Filter Gravel | 6.0 | <5 | <5 | <5 | <5 | <0.01 | | **3.78** | <0.01 | <0.1 | **115** | 757 |
| TP20 | 0.2 | MG: Demolition | 3.62 | | | | | 0.30 | | <0.01 | <0.01 | | | |
| TB122 | 0.2 | MG: Demolition | | | | | | | | 0.13 | <0.04 | | | |
| TB116 | 0.8 | MG: Quarry Fill | 1.44 | <3 | <3 | <3 | <5 | <0.01 | <LoD | **3.17** | <0.01 | | | |
| TP06 | 0.1 | Natural Topsoil | 4.47 | | | | | <0.01 | | <0.01 | <0.01 | | | |
| TP18 | 0.1 | Natural Topsoil | 2.21 | | | | | 0.06 | | <0.01 | <0.01 | | | |
| TB101 | 0.2 | Natural Topsoil | 3.21 | <5 | <5 | <5 | <5 | | | 0.24 | <0.04 | <0.1 | <7 | <7 |
| TB104 | 0.2 | Natural Topsoil | 3.72 | | | | | | | <0.04 | <0.04 | | | |
| TB106 | 0.2 | Natural Topsoil | 4.94 | | | | | | | <0.04 | <0.04 | | | |
| TB108 | 0.2 | Natural Topsoil | 4.61 | | | | | | | 0.11 | <0.04 | | | |
| TB110 | 0.2 | Natural Topsoil | 6.83 | <5 | <5 | <5 | <5 | | | 1.52 | <0.04 | <0.1 | 23 | 166 |
| TB112 | 0.2 | Natural Topsoil | 3.73 | | | | | | | 0.08 | <0.04 | | | |
| TB114 | 0.2 | Natural Topsoil | 5.67 | | | | | | | <0.11 | <0.04 | | | |
| TB118 | 0.2 | Natural Topsoil | 6.33 | | | | | | | 0.12 | <0.04 | | | |

| Key | | | |
|---|---|---|---|
| **BOLD** | Parameter in excess of trigger level concentration | ♣ | Trigger level is dependent on Soil Organic Matter content. The Tier 1 values used here are the most conservative, and in the event of exceedances, reference should be made to TOC analysis. |
| BaP | Benzo(a)pyrene | + | LQM/CIEH (2015) 'S4UL' for 'Residential with Homegrown Produce' land use @ 1% SOM |
| ◇ | Conservative value – assumes all $C_6$ to $C_{10}$ is benzene @ 1% SOM. In the event of exceedances, reference should be made to TOC analysis and TPH composition. | ~ | Conservative value – assumes all of DRO is Aromatic C10-C12 @ 1% SOM and all of LRO is Aromatic C21-C35 @ 1%SOM. In the event of exceedances, reference should be made to TOC analysis and TPH composition |

**Table 13 (Cont.) - Summary of Degree of Ground Contamination (Organics) at Burlow Road, Buxton – Southern Site (Site B).**

| Hole ID | Depth (m) | Material | Concentrations in mg/kg. Results are quoted to 2 decimal places if <10, and whole numbers if >10. Trigger Level Concentrations are shown in brackets and assume a **residential with gardens** end use | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | TOC | Benzene | Toluene | Ethyl Benzene | Xylenes | Phenols | | PAH | | TPH - $C_6$ to $C_{40}$ | | |
| | | | % | (0.087) +♣ | (130)+♣ | (47)+♣ | (56)+♣ | (120)+♣ | | BaP (2.2) +♣ | Naphthalene (2.3) +♣ | GRO $C_6$ to $C_{10}$ (0.087) ♣◇ | DRO $C_{10}$ to $C_{20}$ (74)~ ♣ | LRO $C_{20}$ to $C_{40}$ (1100)~ ♣ |
| TB121 | 0.2 | Natural Topsoil | 4.26 | | | | | | | 0.13 | <0.04 | | | |
| TB123 | 0.2 | Natural Topsoil | 4.89 | | | | | | | 0.26 | <0.04 | | | |
| TB105 | 0.5 | CW Bee Low L'st | | | | | | | | <0.04 | <0.04 | | | |
| TB107 | 0.6 | CW Bee Low L'st | | <3 | <3 | <3 | <5 | <0.01 | <LoD | <0.01 | <0.01 | <0.1 | <7 | <7 |
| TB109 | 0.5 | CW Bee Low L'st | | <3 | <3 | <3 | <5 | <0.01 | <LoD | <0.01 | <0.01 | | | |
| TB111 | 0.6 | CW Bee Low L'st | | <3 | <3 | <3 | <5 | <0.01 | <LoD | <0.01 | <0.01 | <0.1 | <7 | <7 |
| TB113 | 0.5 | CW Bee Low L'st | | | | | | | | <0.04 | <0.04 | | | |
| TB121 | 0.6 | CW Bee Low L'st | | <3 | <3 | <3 | <5 | <0.01 | <LoD | <0.01 | <0.01 | | | |
| TB123 | 0.4 | CW Bee Low L'st | | | | | | | | <0.04 | <0.04 | | | |

| Key | | | |
|---|---|---|---|
| **BOLD** | Parameter in excess of trigger level concentration | ♣ | Trigger level is dependent on Soil Organic Matter content. The Tier 1 values used here are the most conservative, and in the event of exceedances, reference should be made to TOC analysis. |
| BaP | Benzo(a)pyrene | + | LQM/CIEH (2015) 'S4UL' for 'Residential with Homegrown Produce' land use @ 1% SOM |
| ◇ | Conservative value – assumes all $C_6$ to $C_{10}$ is benzene @ 1% SOM. In the event of exceedances, reference should be made to TOC analysis and TPH composition. | ~ | Conservative value – assumes all of DRO is Aromatic C10-C12 @ 1% SOM and all of LRO is Aromatic C21-C35 @ 1%SOM. In the event of exceedances, reference should be made to TOC analysis and TPH composition |

9.3.4 Test results are highlighted in Tables 10 and 11 where a specific concentration of a determinand exceeds the following screening values (also see Note 04 in Appendix A):

- Published LQM/CIEH 'Suitable For Use Levels' (S4ULs) or DEFRA 'Category 4 Screening Levels' (C4SLs) with respect to a 'residential end use with homegrown produce'. pH dependent soil concentrations for phytotoxic copper and zinc, as published in BS3882:2015, have also been used as appropriate screening values.
- Soil Leachability – leachate concentrations have been screening against published UK drinking water standards.

9.3.5 Of the 25 samples of natural soils and made ground analysed for inorganic parameters as part of both GRM and ALM investigations, 12 of the samples possessed concentrations of determinands in excess of their respective screening values (see Table 11 on pages 25-26).

9.3.6 Those determinands that have been detected in excess of their respective screening values are as follows:

- **Cadmium** - detected in excess of the S4UL of 11mg/kg in:
  - 1 sample of 'Reworked Topsoil' from TP19 @ 0.1m (14mg/kg).
- **Lead** – detected in excess of the C4SL of 200mg/kg in:
  - 1 sample of 'Reworked Topsoil' from TP19 @ 0.1m (6202mg/kg)
  - 1 sample of 'Filter Gravel' from TB120 @ 0.4m (376mg/kg)
  - 1 sample of 'Demolition Fill' from TP20 @ 0.2m (588mg/kg)
  - 1 sample of 'Natural Topsoil' from TB110 @ 0.2m (588mg/kg)
- **Copper** – detected in excess of the screening value of 135mg/kg in:
  - 1 sample of 'Reworked Topsoil' from TP19 @ 0.1m (331mg/kg)
  - 1 sample of 'Filter Gravel' from TB120 @ 0.4m (151mg/kg)
  - 1 sample of 'Demolition Fill' from TP20 @ 0.2m (580mg/kg)
  - 1 sample of 'Natural Topsoil' from TB110 @ 0.2m (187mg/kg)
- **Zinc** – detected in excess of the screening value of 200mg/kg in:
  - 2 samples 'Reworked Topsoil' from TP19 @ 0.1m (7446mg/kg) and TB120 @ 0.1m (312mg/kg).
  - 1 sample of 'Filter Gravel' from TB120 @ 0.4m (737mg/kg)
  - 1 sample of 'Demolition Fill' from TP20 @ 0.2m (7.5mg/kg)
  - 7 samples of 'Natural Topsoil'. The maximum concentration detected was in the sample from TB110 @ 0.2m (469mg/kg)
  - 1 sample of completely weathered Bee Low Limestone from TB109 @ 0.5m (286mg/kg)

9.3.7 Statistical analysis of test results has been carried out in general accordance with the methods outlined in "*Guidance on Comparing Soil Contamination Data with a Critical Concentration*" CIEH\CL:AIRE (2008) (see comments in Appendix A, Contamination Testing). The results of the statistical analysis are presented in Appendix I(2) and are summarised in Table 14 below.

9.3.8 It should be noted that statistical analysis is only meaningful where more than 6 test results are available for any given determinand from any given stratum. As such, statistical analysis has only been performed for those determinands detected in excess of their respective screening values within the natural topsoil and completely weathered Bee Low Limestone strata.

**Table 14**
**Results of Statistical Analysis of Soil Contamination Data**

| Stratum | $US_{95}$ Values for Contaminants that have yielded one or more Tier 1 exceedances for a given soil type (where No. of samples >6) | | |
|---|---|---|---|
| | Lead (SV = 200) | Copper (SV=200) | Zinc (SV=200) |
| Natural Topsoil | 116.35 **(218.73)** | 34.94 (68.57) | **289.64** |
| Completely Weathered Bee Low Limestone | NA | NA | **212.15** |

Notes: SV = Screening Value
NA = Not Applicable (no results in excess of Screening Value)
Values are bolded where the US95 value exceeds the relevant Tier 1 value.
Values in brackets are US95 values inclusive of any outliers.

9.3.9 The statistical analysis indicates that the upper 95th percentile bound value (US95) for Lead in the Natural Topsoil is below the relevant current guidance (C4SL) threshold value for residential with homegrown produce end use of 200mg/kg. However, the test result from TB110 @ 0.2m (588mg/kg) has been determined to be a statistical outlier.

9.3.10 The statistical analysis indicates that the US95 value for Copper in the Natural Topsoil material is below the relevant guidance threshold value for residential with homegrown produce end use of 135mg/kg. The test result from TB110 @ 0.2m (187mg/kg) has been determined to be a statistical outlier.

9.3.11 The statistical analysis indicates that the US95 value for Zinc in the Natural Topsoil material is in excess of the relevant guidance threshold value for residential with homegrown produce end use of 200mg/kg. The data set contains no statistical outliers.

9.3.12 The statistical analysis indicates that the US95 value for Zinc in the Completely Weathered Bee Low Limestone material is in excess of the relevant guidance threshold value for residential with homegrown produce end use of 200mg/kg. The data set contains no statistical outliers.

***Asbestos***

9.3.13 No asbestos fibres were identified in any of the samples of made ground and natural topsoil screened.

***Leachablity***

9.3.14 Four samples of made ground materials have been subjected to leachability tests for metal determinands (10:1 soil extract – NRA method).

9.3.15 The results of the Leachability tests presented in Table 12 on Page 27 indicate that the made ground materials possess a low leachability potential. No determinands were detected in excess of UK Drinking Water Standards with the exception of lead in the sample from GRM TP19 (31ug/l) which was in excess of the Drinking Water Standard of 10ug/l.

***Organic Determinands***

9.3.16 The results of chemical tests performed on soil samples for organic determinands have been compared to Published LQM/CIEH 'Suitable For Use Levels' (S4ULs) with respect to a 'residential end use with homegrown produce'.

9.3.17 Table 13 on Pages 28-29 presents a summary of the results of the chemical tests for organic determinands.

9.3.18 None of the determinands analysed were detected in excess of their respective screening values in any of the samples tested, with the exception of the following:

- **Benzo(a)pyrene and Benzo(b)fluoranthene** – Detected in excess of the S4ULs of 2.2mg/kg and 2.6mg/kg in:
  - 1 sample of 'Filter Gravel' material in TB120 @ 0.4m (3.78 and 4.93mg/kg respectively)
  - 1 sample of 'Quarry Fill' material in TB116 @ 0.8m (3.17 and 4.15mg/kg respectively)
- **Chrysene** – Detected in excess of the respective S4UL of 15mg/kg in:
  - 1 sample of 'Demolition' materials in GRM TP20 @ 0.2m (27.95mg/kg)
- **Diesel Range Organic Compounds (DRO)** – Detected in excess of the screening value of 74mg/kg in:
  - 1 sample of 'Filter Gravel' material in TB120 @ 0.4m (115mg/kg)

9.3.19 Due to the limited number of samples tested, the statistical significance of the above noted results cannot be undertaken.

9.3.20 However, with respect to the DRO contamination noted in TB120 @ 0.4m, the screening value adopted in this case assumes that all of the noted contamination is within the most toxic equivalent carbon (EC) fraction found in diesel fuel (aromatic EC10-12). Comparison of actual EC fractions detected in this sample are significantly below the S4ULs for 'residential end use with homegrown produce'

9.3.21 No SVOC (non-PAH) compounds were detected in excess of the limit of laboratory detection in any of the samples tested with the exception of the following:

- 2-Methylnaphthalene – 172ug/kg in TB120 @ 0.4m (Filter Gravel)
- Carbazole – 296ug/kg in TB116 @ 0.8m (Quarry Fill) and 166ug/kg in TB120 @ 0.4m (Filter Gravel)
- Dibenzofuran – 105ug/kg TB116 @ 0.8m (Quarry Fill) and 59ug/kg in TB120 @ 0.4m (Filter Gravel).

9.3.22 No VOC compounds were detected in excess of the limit of laboratory detection in any of the samples tested.

# 10 CONTAMINATION (QUALITATIVE RISK ASSESSMENT & REMEDIATION)

## 10.1 Assessment of Contamination Test Results

10.1.1 Notes outlining current guidance with respect to the interpretation of analytical data are included in Appendix A to this report.

***Topsoil***

10.1.2 Natural clayey Topsoil materials are present at surface across the whole of the study site and which possess an average thickness of 0.3m.

10.1.3 The natural topsoil has been observed to be free of any deleterious materials, however chemical test results indicate that these materials locally contain elevated lead and copper contamination and widespread elevated concentrations of zinc. With respect to lead and copper, statistical analysis indicates that, where these have been detected in excess of screening concentrations, they are statistical outliers ('hotspots') and the upper 95th percentile bound value (US95) for these determinands are below their respective screening values.

10.1.4 With respect to zinc, the widespread nature of this contamination means that the US95 concentration is in excess of the screening value of 200mg/kg. However, of particular note is that fact that the underlying Completely Weathered Bee Low Limestone clay strata have also been observed to possess a US95 concentration for zinc in excess of 200mg/kg. As such, the elevated zinc concentrations observed within the natural topsoil materials are considered to be a reflection of the naturally occurring presence of zinc within the underling parent material.

10.1.5 Zinc (and copper) are considered to be phytotoxic contaminants. However, observations made on site suggest that there is no evidence of any vegetation dye-back or stress and the typically alkaline nature of the soils will reduce the potential phytotoxic effects of these contaminants. Furthermore, the S4UL for zinc with respect to human health-related risks within a 'residential with homegrown produce' end use is 3700mg/kg and the S4UL for copper is 2400mg/kg, which are considerably in excess of the concentrations detected on site.

10.1.6 As such, it is considered that the natural topsoil materials present on site are considered suitable for use within the proposed residential development in private garden areas. Additional sampling and analysis of the topsoil materials may still be required to satisfy the requirements of the Local Planning Authority prior to their re-use.

10.1.7 However, given the localised presence of elevated lead, the existing topsoil materials present in the vicinity of the existing small brick structure (in the vicinity of TB110) should not be used in private garden areas. It is, however, noteworthy that this part of the site is proposed to be retained as public open space (Barratt Homes Manchester Drawing 1483/SK01 in Appendix B). The DEFRA C4SL for lead in residential public open space areas is 630mg/kg (see Appendix A), which is excess of the 588mg/kg maximum concentration of lead detected in the topsoil. As such, the in situ natural topsoil materials in this part of the site would still be considered suitable for use on the assumption that public open space is ultimately adopted in this area as part of the proposed development.

***Completely Weathered Bee Low Limestone***

10.1.8 As noted above, the Completely Weathered Bee Low Limestone (slightly sandy very silty clay) has been observed to possess a US95 concentration for zinc in excess of the screening value of 200mg/kg. However, this is considered to be naturally occurring within the local geology and these materials are not considered to present a risk to plants or human health within the context of the proposed development and are, therefore, considered suitable to be left in situ or be reused as subsoil within private garden areas.

***Made Ground***

10.1.9 Only very localised (and shallow) deposits of made ground have been identified as part of the GRM and ALM ground investigations. The made ground deposits are restricted to the following areas:

- Reworked/disturbed topsoil (containing ash and metal fragments) in the vicinity of GRM TP19 in the extreme northwest of the site.
- Reworked/disturbed topsoil overlying filter bed gravel in the vicinity of TB120 within the footprint of the former filter tank near to the present day sewage pumping station.
- Reworked/disturbed topsoil overlying/mixed with demolition-type granular materials within the footprint of the former building that was present in the centre of the site (GRM TP20 and TB122).
- Granular fill materials used to infill a small quarry feature located to the south of the proposed development area (TB116).

10.1.10 With respect to the reworked topsoil noted in GRM TP19, these materials have been noted to contain significantly elevated concentrations of total and leachable lead and zinc, as well as cadmium and copper that would make them unsuitable for reuse within landscaped or garden areas of the proposed development. However, these materials were not encountered in trial pit TB101 and would be expected to be very limited in extent, or may have even been removed from site during the intervening period between the GRM and ALM investigations.

10.1.11 The Filter Bed materials (and overlying reworked topsoil) have been noted to contain elevated concentrations of lead, copper, zinc, PAH compounds, detectable trace concentrations of some SVOC compounds and also contains gravel fractions which will also make these materials unsuitable for use at surface in private garden areas. However, the reworked topsoil noted in trial pit TB120 would be considered suitable for use as topsoil in proposed areas of public open space, where these materials may be required to be mixed with other natural topsoil materials prior to placement.

10.1.12 The Demolition materials (and overlying reworked topsoil) have also been noted to contain elevated concentrations of lead, copper and zinc and also contain gravel fractions and other miscellaneous demolition-derived materials which will make these materials unsuitable for use at surface in private garden areas.

10.1.13 The former small quarry feature has been observed to have been infilled with concrete, limestone and brick rubble to a depth of ca 1.4m. These materials have been observed to contain minor contamination by some PAH compounds and trace concentrations of some SVOC compounds. This former quarry feature is located outside, and to the south, of the proposed development area and would, for all intents and purposes be located in an area that would be used as public open space. It is considered that the concentrations of the PAH and SVOC compounds detected would not present a risk to future site users on the assumption that this feature is not proposed to be developed upon.

## 10.2 Revised Conceptual Ground Model (Contamination)

10.2.1 The Conceptual Site Model has been amended in light of data obtained during the ground investigation, most notably with respect to the distribution of made ground and contaminants.

10.2.2 The Conceptual Site Model includes the contaminant sources described in Section 10.1 above, and potential pollutant linkages (summarised below in Section 10.4) to receptors.

## 10.3 Environmental Setting & End Use

10.3.1 As discussed in Section 10.1 above, localised contamination exists in localised made ground materials within near surface/shallow reworked topsoil and Demolition Fill and Filter Gravel materials. In order to assess the significance of this contamination, consideration must be given to the site's environmental setting and the proposed end use.

10.3.2 The site is not located in close proximity to a surface water course or other significant surface water feature.

10.3.3 The site is located over Bee Low Limestone strata that are classified as a 'Primary' aquifer. Groundwater is commercially exploited in the area for potable (bottled) water and other commercial, industrial and public amenity uses. The western half of the site is situated within a Groundwater Source Protection Zone (Inner Zone I) with respect to the potable and public amenity groundwater abstractions.

10.3.4 Overall, the site's environmental setting is considered to be of moderate to high sensitivity.

10.3.5 With respect to human health, the proposed end use (residential) is considered to be sensitive. Transient risks to construction workers can be addressed by the adoption of appropriate health and safety measures, see Section 14.3.

## 10.4 Pollutant Linkages

10.4.1 In terms of a proposed development of this site, plausible pollutant linkages can be summarised as follows.

***Sources***

10.4.2 Contaminant sources have been discussed above in Section 10.1 above and comprise:

- Reworked/disturbed topsoil (containing ash and metal fragments) in the vicinity of GRM TP19 – cadmium, lead, copper, zinc, leachable lead.
- Reworked/disturbed topsoil overlying filter bed gravel in the vicinity of TB120 – lead, copper, zinc, PAH, trace SVOCs
- Reworked/disturbed topsoil overlying/mixed with demolition-type granular materials within the footprint of the former building that was present in the centre of the site (GRM TP20 and TB122) – lead, copper, zinc.
- Quarry infill materials located to the south of the proposed development area (TB116) – PAH and trace SVOCs

***Pathways***

10.4.3 Potential contaminant pathways include:

- Ingestion
- Dermal contact
- Inhalation of contaminated particulates
- Surface water run-off, including existing drainage infrastructure
- Downward infiltration of leachable/mobile contaminants to groundwater

***Receptors***

10.4.4 Potential contaminant receptors include:

- Bee Low Limestone Aquifer
- End users of the site (critical receptor – female child residents)

10.4.5 It can be concluded that there are plausible pathways between actual contaminant sources and potential receptors. Consequently, some Remediation action will be required, either treatment/removal of the source, or "breakage" of the pathway.

## 10.5 Potential Remediation Options

### *General*

10.5.1 Approval of the recommendations given below should be sought from the appropriate regulatory authorities prior to commencement of site redevelopment.

### *Topsoil Re-Use and Stripping*

10.5.2 All reasonable effort has been made during this investigation to chemically characterise the natural topsoil materials that are present extensively across the site.

10.5.3 Chemical tests (12 samples from both GRM and ALM investigations) indicate that the topsoil materials locally contain lead and copper contamination, but also contains more widespread zinc contamination. The zinc contamination is also present within the underlying natural Completely Weathered Bee Low Limestone strata and is considered to be naturally occurring and present within the soil parent material in the area. As such, the topsoil materials are deemed suitable for re-use in private gardens as part of the proposed development. Where copper and lead have locally been noted to be present in trial pit TB110, this is located in an area that is to be retained as an area of public open space and the concentrations detected are below appropriate assessment criteria for this end use and the topsoil is considered suitable to be left at surface given the proposed use of this part of the site.

10.5.4 The existing topsoil materials should be carefully stripped and stockpiled prior to any development and such works should be carried out in accordance with DEFRA '*Construction Code of Practice for the Sustainable Use of Soils on Construction Sites*' (2009).

10.5.5 Due to the clayey nature of the topsoil deposits, particular consideration should be given to prevailing weather conditions during the topsoil stripping exercise and stockpiles should be created to a suitable size so as to minimise 'compaction' of the materials.

### *Reworked/Disturbed Topsoil*

10.5.6 The reworked/disturbed topsoil encountered in GRM TP19 contains ash and metal fragments and significant contamination (in particular cadmium, lead and zinc) at concentrations that could present a risk to human health and plants. As such, these materials at this location should be excavated and disposed off site as part of the site preparation works prior to development. As noted above, ALM trial pit TB101 did not encounter these materials, so they are either extremely localised and of very limited volume or have, in fact, since been removed from site during the intervening period between the GRM and ALM investigations. During site preparation works, particular care should be employed to identify any remaining reworked/disturbed topsoil materials present in this area during topsoil stripping works to ensure that these materials are not incorporated into the uncontaminated natural topsoil materials.

10.5.7 The reworked/disturbed topsoil materials present in the area of the former building (TP20/TB122) contain elevated lead, copper and zinc contamination but also contain entrained demolition materials (brick, slate etc). Although it may be possible to potentially screen these potentially deleterious materials the very limited volume of materials present may make this uneconomic and would not necessarily remove the contamination noted. As such, it is recommended that the reworked/disturbed topsoil materials at this location be excavated and removed from site prior to development works.

10.5.8 The reworked topsoil in the vicinity of the former filter tank (TB120) contains only marginally elevated copper contamination and only minor entrained fractions of gravel. It is considered that the reworked topsoil at this location would be suitable for re-use, particularly if mixed with other natural topsoil materials and used in areas of proposed public open space.

### *Filter Gravels and Demolition Fill*

10.5.9 The filter gravels noted in TB120 and demolition fill noted in TP20 are only limited in thickness and extent but locally contain lead, copper and zinc contamination. Where any such residual made ground remains beneath proposed garden and landscaped areas it is recommended that a suitably thick surface cover of "clean" soil comprising subsoil (e.g. site won Completely Weathered Bee Low Limestone deposits) and a minimum 150mm of topsoil be placed over the made ground. This cover will break potential pollutant linkages between the contaminated made ground and future end-users and would additionally provide a suitable amenity and growing medium for plants.

10.5.10 The thickness of the soil cover can typically fall into one of three classes:

- Option A - 300mm (comprising 150mm subsoil and 150mm topsoil), where soils beneath proposed garden areas are "clean" (i.e. yield no elevated concentrations of contaminants), but include "unsuitable" materials such as proportions of demolition rubble. This thickness is in accordance with NHBC Standards, Chapter 9.2.
- Option B - 600mm (comprising 450mm subsoil and 150mm topsoil), where soils beneath proposed garden areas yield moderately elevated concentrations (i.e. in excess of relevant screening level criteria) of inorganic and organic contaminants. This cover thickness is in line with current UK guidance provided in the *Cover Systems for Land Regeneration.* This document, published by the BRE in 2004, concluded: "*any disturbance or intermixing of soils is unlikely to exceed 600mm depth*".
- Option C - 1,000mm (comprising 850mm subsoil and 150mm topsoil), where shallow soils beneath proposed garden areas yield the presence of significant concentrations of contaminants and asbestos fibres, for example.

10.5.11 At this stage, soil cover **Option B** is considered suitable for this site, subject to the finalised earthworks scheme, regrading works and finalised proposed development levels. Alternatively, it may prove more practical to remove the filter gravels and demolition fill materials from site prior to site development works.

### *Quarry Fill*

10.5.12 The infilled quarry feature encountered in trial pit TB116 is located outside of the proposed development area. Contamination noted in the granular quarry fill materials comprises marginally elevated PAH compounds and trace concentrations of some SVOCs but these concentrations would be suitable for residential public open space end use. As such, the concentrations present are not considered to present a risk to future site users or the environment and could be left in situ.

### *Organic Contamination*

10.5.13 No areas of gross organic contamination were encountered during the GRM and ALM ground investigations. However, localised areas of more onerous contamination than that identified to date may be present on site. If any "oily", odorous, brightly coloured etc. materials are encountered further, advice should be sought from ALM.

### *Groundwater*

10.5.14 Groundwater was not encountered during the GRM and ALM ground investigations and the groundwater table would be expected to be present at considerable depth.

10.5.15 It is therefore considered unlikely that any significant groundwater seepages would be encountered in shallow excavations. If/where groundwater is encountered, the inherent nature of the site would mean that any treatment or works to mitigate any potential soil leachate would not be warranted.

10.5.16 However, the cohesive nature of the Completely Weathered Bee Low Limestone strata would mean that surface water could collect in shallow excavations during periods of inclement weather.

10.5.17 Groundworkers should make all necessary arrangements to prevent off-site migration of groundwater/surface water (including suspended solids) via surface water run off and inadvertent groundwater disturbance.

10.5.18 Groundwater should be controlled in accordance with CIRIA report 113 "Control of Groundwater for Temporary Works", if/where required.

***Waste Classification***

10.5.19 Disposal of the excess soils off site is not considered appropriate, economically viable, nor in line with current Government philosophy regarding sustainable development. However, some excess arisings may be generated by excavations for foundations, sewers etc. Off site reuse of such arisings would be appropriate if redistribution and retention on site is not feasible.

10.5.20 Any off site reuse, on other nearby construction projects, for example, would be subject to waste management controls and should be carried out in accordance with the CL:AIRE *'Definition of Waste: Development Industry Code of Practice Version 2'* (March 2011) and additionally following consultation with the Environment Agency.

10.5.21 Notes outlining the interpretation of analytical data with respect to waste classification are included in Appendix A to this report, together with notes about Waste Acceptance Criteria (WAC)

10.5.22 Soil arisings generated by excavations at this site are likely to be classified as follows (see Table 15):

**Table 15**
**Anticipated Waste Classifications**

| Soil Type | Waste Classification | Remarks |
|---|---|---|
| Reworked/Disturbed Topsoil (TP19, TP20/TB122) | Non-Hazardous | |
| Filter Gravels (TB120) and Demolition Fill (TP20/TB122) | Non-Hazardous | |
| Natural Topsoil | Non-Hazardous | Due to TOC concentration >3% but considered suitable for off site reuse. |
| Completely Weathered Bee Low Limestone | Inert | |
| Moderately Weathered Bee Low Limestone (rock) | Inert | |

## 10.6 Summary of Potential Pollutant Linkages & Mitigation

10.6.1 In terms of the proposed redevelopment plausible pollutant linkages, and feasible remediation options, can be summarised as follows (see Table 16 on next page):

**Table 16**
**Summary of Potential Remediation Options**

| Receptors | Pathways | Contaminants | Remediation Options |
|---|---|---|---|
| Human Health (Future residents) ◇ | Consumption of contaminated vegetables | Cd, Pb, Cu, Zn in made ground | - Stripping of Disturbed/Reworked Topsoil from area of TB120 and disposal off site or, alternatively, reuse in areas of public open space.<br>- Off site disposal of Disturbed/Reworked Topsoil from the area of TP19.<br>- Placement of 600mm soil cover layer in areas possessing residual made ground filter gravel (TB120) and/or demolition materials (TP20/TB122) to provide suitable amenity in garden/landscaped areas. Alternatively, dispose off site. |
| | Ingestion | | |
| | Inhalation (dust and/or fibres) | | |
| | Dermal contact | | |
| | Migration & accumulation of hazardous gas | Radon, Carbon dioxide | Adoption of appropriate gas protection measures – see Section 11 |
| | Infiltration of water supply pipes | BTEX, Hydrocarbons (especially halogenated hydrocarbons), | Adoption of appropriate water supply pipework in accordance with Severn Trent Water pipeline risk assessments. No special precautions anticipated, particularly if water supply pipework lain in natural strata – see Section 14.5 |
| Buildings | Migration & accumulation of explosive gas | Methane | Adoption of appropriate gas protection measures – see Section 11 |
| | Contact with "aggressive" soil and/or groundwater | Sulphate in the made ground and natural strata | Adoption of appropriate concrete class (see Section 12.3) |
| Plants | Uptake of phytotoxic elements | Cu and Zn in the made ground | - Stripping of Disturbed/Reworked Topsoil from area of TB120 and disposal off site or, alternatively, reuse in areas of public open space.<br>- Off site disposal of Disturbed/Reworked Topsoil from the area of TP19<br>- Placement of 600mm soil cover layer in areas possessing residual made ground filter gravel (TB120) and/or demolition materials (TP20/TB122) to provide suitable amenity in garden/landscaped areas. Alternatively, dispose off site. |
| Groundwater | Migration of leachable components | Pb in the made ground | Off site disposal of Disturbed/Reworked Topsoil from the area of TP19 |
| | Surface water run-off | Inorganic contaminants in the made ground | Adoption of surface water management controls during enabling works |

◇ transient risks to construction workers will be addressed by the adoption of appropriate health and safety measures in accordance with the Health and Safety at Work Act 1974 and regulations made under the Act including for example the COSHH Regulations.

# 11 HAZARDOUS GAS

## 11.1 General

11.1.1 Information from historical OS plans indicates that the site has remained as Greenfield land in agricultural use since the mid 19th Century. A small (infilled) quarry feature was present in the late 19th Century to the south of the proposed development area and other small and shallow quarry features were present on land to the northeast and north of the site. No former ponds or other potentially infilled features are indicated on historical maps to have been present on site.

11.1.2 The GRM and ALM ground investigations have encountered only localised and shallow areas of made ground materials within the footprints to former small structures that were present in the site in the first half of the 20th century. The small quarry feature located to the south of the proposed development area has been observed to have been infilled to 1.4m depth, but these fill materials are minerogenic in nature containing concrete, brick and limestone containing no degradable materials.

11.1.3 A former landfill site is present ca. 160m to the north of the site ('Burlow Works' Landfill). This landfill site is now substantially restored to agricultural land and only accepted inert soil and rock materials and is not considered to represent a significant source of ground gas with respect to the study site.

11.1.4 The site is located in an area where 'Full' Radon protection measures will be required for new properties.

11.1.5 The site is not located in an area that was historically worked for coal.

11.1.6 Consideration of the above conceptual site model has enabled a qualitative assessment of risks associated with gas to be developed as summarised in Table 17 below (see next page) :-

**Table 17**
**Hazardous Gas Conceptual Site Model**

| Source | Receptors | Hazard | Pathway | Initial Risk |
|---|---|---|---|---|
| On-site made ground (Shallow | Human Health | Asphyxiation & explosion. | Vertical migration, ingress & accumulation | **Very Low**: made ground is shallow, of limited volume, essentially inert, with little/no degradable matter. |
| | Buildings | Explosion. | | |
| Off-site Historical Landfill | Human Health | Asphyxiation & explosion. | Lateral migration, ingress & accumulation | **Low**: Landfill now substantially restored. Known to have accepted only inert wastes |
| | Buildings | Explosion. | | |
| Mineworkings | Human Health | Asphyxiation & explosion. | Lateral migration, ingress & accumulation | **Not applicable** |
| | Buildings | Explosion. | | |
| Radon | Human Health | Carcinogenic risks. | Vertical migration, ingress & accumulation | **Applicable** : Full Radon protection Measures will be required for new developments |

## 11.2 Scope of Works

11.2.1 Temporary gas monitoring standpipes were installed by GRM within trial pits TP01-TP05 as part of the 2006 investigation works to provide an initial assessment of ground gases.

11.2.2 The results of only two monitoring visits undertaken on the 24th May and 16th June 2006 were reported by GRM.

### 11.3 Monitoring Results

11.3.1 The results of the gas monitoring reported by GRM are summarised below, the full results are presented in Appendix K.

**Table 18**
**Summary of Gas Monitoring Results Obtained by GRM (2006)**

| Hole ID | Range of Methane Concentrations (% v/v) | Range of Carbon Dioxide Concentrations (% v/v) | Range of Positive Flow Rates (litre/hour) |
|---|---|---|---|
| TP01 | 0.0 | 1.9 – 6.3 | 0.0 |
| TP02 | 0.0 | 2.7 – 3.8 | 0.0 |
| TP03 | 0.0 | 2.9 – 3.9 | 0.0 |
| TP04 | Installation damaged – no results | | |
| TP05 | 0.0 | 3.8 | 0.0 |

### 11.4 Discussion

11.4.1 No methane gas was detected, however, carbon dioxide was detected at concentrations typically ranging between 1.9-3.9%v/v. TP01 recorded a maximum carbon dioxide concentration of 6.3%v/v on one occasion.

11.4.2 No gas flows were recorded.

11.4.3 GRM concluded that the gas monitoring results suggest that Carbon Dioxide is possibly being generated in the ground locally primarily as a result of the natural dissolution of the parent shallow limestone bedrock.

11.4.4 Notes outlining how gas monitoring results are interpreted are presented in Appendix A of this report.

11.4.5 Viewing the gas measurements obtained from across the site as a whole, and based on the maximum detected gas concentrations and a default gas flow rate of 0.1l/hr, the following Gas Screening Values are as follows:

- 'Worst Case GSV' – Methane – **0.0 l/hr**
- 'Worst Case GSV' – Carbon Dioxide – **0.0063 l/hr**

11.4.6 These values would usually indicate a NHBC traffic light 'Green' classification for low rise residential properties. However, as the maximum carbon dioxide concentration was observed to be >5%, consideration potentially needs to be given to upgrading the classification to 'Amber 1' in accordance with CIRIA Report C665.

11.4.7 The site is, however, located within an area where full radon gas protection measures will be required to be installed in accordance with Building Research Establishment (BRE) Report BR211 (2015) which would nominally be required to conform to the NHBC classification 'Amber 1'. The full radon protection measures would therefore seek to mitigate any risks associated with carbon dioxide.

11.4.8 Based on the current set of gas monitoring data, the site characterisation noted above, the likely foundation solutions, and with reference to BRE BR 211 (2015) and the gas protection "scoring" system outlined in BS 8485:2015 for various site Characteristic Gas Situations, ALM would recommend that the following protective measures should be incorporated in all new dwellings at the site (see Table 19).

**Table 19**
**Recommendations for Gas Protection Measures**
**(Low Rise Residential Housing**
**BS 8485:2015 'TYPE A'**
**Building in Private Ownership with Small Rooms)**

| Traffic Light Class (NHBC – 10627_R01, 2007) | Characteristic Situation (Wilson & Card 1999) | Gas "score" req'd by BS 8485 | Floor Slab (BS 8485 "score") | Protective Measures: Sub-floor ventilation (BS 8485 "score") | Protective Measures: Membrane Type (BS 8485 "score") |
|---|---|---|---|---|---|
| **Amber 1** | **CS2** | **3.5** | *Select one from:*<br>i. Block & Beam – **(0)**.<br>ii. Cast in-situ ground bearing slab (with only nominal mesh reinforcement) **(0.5)**.<br>iii. Cast in-situ monolithic reinforced ground bearing raft or cast in-situ suspended floor slab with minimal penetrations **(1.0)** or **(1.5)** if well reinforced to control cracking and have minimal penetrations cast in.<br>iv. Basement floor and walls conforming to BS8102:2009, Grade 2 waterproofing **(2.0)**<br>v. Basement floor and walls conforming to BS8102:2009, Grade 32 waterproofing **(2.5)** | *Select one from:*<br>Pressure relief pathway, usually formed of low fines gravel, or with a thin composite blanket or strips, terminating in a gravel trench external to the building **(0.5)**.<br>Passive sub-floor dispersal layer:<br>i. Very Good Performance **(2.5)**<br>e.g. min 100mm Clear Void[4] or polystyrene void former[5] with an equivalent clear void depth of at least 60mm, with 1,500mm² side ventilation[6] per 1m run of wall on at least two opposite sides. The venting area through any downstand beam should be 4 to 5 times greater that provided by the side ventilation<br>ii. Good Performance **(1.5)**<br>e.g. 25mm geo-composite blanket[7], with 1,500mm² side ventilation per 1m run of wall on at least two opposite sides.<br>or<br>300mm thick gravel dispersal layer[8 & 9] with 'good performance' (BS 8485) | Waterproof DPM (1200g polyethylene) **(0)**<br>Gas resistant membrane[10 & 11] **(2.0)** |

**Footnotes:**

1. Integral garages with occupied rooms above, or direct access through a doorway from the garage to the house, should be provided with the same protective measures as the rest of the dwelling. Buildings with basement car parks (with ventilation in accordance with Building Regulations) may not require gas resistant membranes.
2. There should be minimum penetration of floor slab by services; any penetrations should be suitably sealed.
3. For radon, CS2 protection is required for 'basic' radon measures (but sub-floor ventilation not essential), and protection as per AMBER 1 for 'full' radon measures (minimum membrane requirement 1200g polyethylene).
4. An open void space provides the most effective gas dispersal layer and is suitable for gas regimes up to and including CS4.
5. The maximum point score of 2.5pts should only be applied to the thicker void formers with an equivalent clear void depth of at least 60mm. For thinner polystyrene void formers a maximum point score should be 2pts unless calculations demonstrate a very good performance.
6. For small to medium width buildings (up to 15m wide) the minimum area of side ventilation for open void space and void formers should be 1,500mm² per meter run on at least two opposite sides. For larger buildings, side ventilation should be at least 2,000mm² per meter run of wall for gas regimes up to and including CS3, and 4,500mm² per meter run of wall for gas regime CS4. If the amount of side ventilation or internal cross openings are less than those recommended for a good performance, then the score should be reduced to 2pts or 1.5pts.
7. The minimum thickness of a geo-composite blanket passive gas dispersal layer should be 25mm. As a guide, a score of 1.5pts can be applied for a 25mm thick geo-composite blanket for a building up to 15m wide, but for larger buildings or thinner blankets, the points score should be reduced to 1pt or 0.5pts. For small to medium buildings, the minimum area of side ventilation should be 1,500mm² per meter run of wall on at least two opposite sides, increasing to at least 2,000mm² for larger width buildings. Geo-composite blankets are not suitable for CS4 sites unless the width of the building is small (<5-8m). Geo-composite blankets thinner than 25mm should not be specified for CS3 or above.
8. A point score of between 0.5-2.5pts can be achieved for gravel dispersal layer depending on the material used and construction detail. A gravel layer should typically be a minimum of 300mm thick, have high porosity (>40%), and have a minimum particle size of 20mm. The minimum side ventilation should be the same as for geo-composite blankets (see Note 7). Well graded aggregates such as MOT Type 1 and Type 2 are unsuitable.
9. The dispersal characteristics of granular layers can be improved by the introduction of drains, which may typically be either perforated plastic pipe of >75mm diameter, or geo-composite strips greater than 1m wide and 12.5mm thick. Granular layers should be at least 200mm thick and drains should be no further than 3m apart. Side ventilation for granular layers with drains should be provided at no more than 10m centres and have an area equivalent to 1,500mm² per meter run on at least two opposite sides. Granular layers with drains are not suitable for CS4 or above.
10. There are a wide variety of gas resistant membranes with different properties and performance characteristics but should comply with all of the requirements of Table 7 of BS5485:2015 and possess an average methane gas transmission rate of <40.0 ml/day/m²/atm. The choice of membrane should consider factors such as; resistance/permeability to methane and/or carbon dioxide, durability, strength, flexibility for installation, resistance to degradation by other contaminants that may be present (i.e. hydrocarbons). The chosen membrane should be manufactured from virgin polymer and not from re-cycled materials.
11. In all cases a gas membrane should be well installed, with no punctures and with all joints sealed correctly. The membrane should always be lapped and sealed and verified in accordance with CIRIA Report C735 *"Good Practice on the Testing and Verification of Protection Systems for Buildings Against Hazardous Ground Gases"* (2014). The membrane should be continuous across cavity walls, and there should be a cavity tray in external walls. If a membrane is installed that does not meet the requirements of Table 7 of BS5485:2015, then the score is 'zero'.

# 12 GEOTECHNICAL TESTING

## 12.1 General

12.1.1 Selected samples of natural soils were delivered to suitably accredited laboratories with schedules of geotechnical testing drawn up by GRM as part of their 2006 and ALM as part of this present investigation.

12.1.2 The geotechnical laboratory test results are presented in Appendices J(1) and J(2) to this report.

## 12.2 Atterberg Limits

12.2.1 Fourteen selected samples of natural Completely Weathered Bee Low Limestone (clay) strata were selected by GRM and ALM as part of their 2006/2017 ground investigations for Atterberg Limit determination tests (see Appendices J(1) and J(2)).

12.2.2 The results of the Atterberg Limit tests are summarised in Table 20 below.

**Table 20**
**Summary of Atterberg Limit Tests**

| Soil type | Range of Plasticity Indices* (Average) | Shrinkability |
|---|---|---|
| Completely Weathered Bee Low Limestone | 7.9% - 42.9% (17.2%) | Low to High (Average = Low) |

* Modified where appropriate in accordance with revised Chapter 4.2 of the NHBC Standards.

**Note.** The term Shrinkability is equivalent to the term Volume Change Potential used in Chapter 4.2.

12.2.3 The average modified plasticity index (PI) has been calculated to be 17.2%, however, modified PIs within the range of low shrinkability (<20%) to high shrinkability (>40%, one sample) have also been recorded.

12.2.4 For the purposes of foundation design, it is recommended that the completely weathered Bee Low Limestone strata be regarded as being of 'Moderate' shrinkability.

## 12.3 Soluble Sulphate and pH

12.3.1 In accordance with BRE Special Digest 1 (2005), this site has been classified as 'Greenfield' with a mobile groundwater regime (to a reflect worst case scenario).

12.3.2 It is envisaged foundations will extend to through made ground and into natural strata and samples taken from this depth range have been submitted by both GRM and ALM for pH and water-soluble sulphate (2:1 soil/water extract).

12.3.3 The concentrations of sulphate in the aqueous natural soil extracts were determined using the gravimetric method. The pH value of each sample was determined by the electrometric method.

12.3.4 The highest water-soluble sulphate concentration and the lowest pH value for each soil type analysed are shown in the Table 21 below.

**Table 21**
**Summary of Sulphate and pH results**

| Soil Type / Water Body | Lowest pH values | Highest Soluble Sulphate Concentration (g/l) |
|---|---|---|
| Made Ground: Demolition fill | 7.13 | 0.02 |
| Completely Weathered Bee Low Limestone (Clay) | 6.76* | 0.057# |
| Moderately Weathered Bee Low Limestone (Rock) | 7.1 | 0.07 |

* Average of the lowest 20% of test results
# Average of the highest 20% of test results

12.3.5 In accordance with Table C1 of Special Digest 1, subsurface concrete should be sub-surface concrete should be Design Sulphate Class DS-1, with the site allocated an ACEC Classification of AC-1.

## 12.4 Compaction Tests

12.4.1 Laboratory compaction tests are useful wherever ground improvement, to provide a satisfactory CBR beneath proposed highways, or site regrading, is anticipated.

12.4.2 Engineered fill is defined as material which is selected, placed and compacted to an appropriate specification so that it will exhibit the required engineering behaviour.

12.4.3 Grading and moisture content control the degree to which materials can be effectively compacted. If the grading or moisture content of an in-situ material is not suitable to facilitate its compaction then screening, wetting, or lime addition may be required.

12.4.4 Three samples of the Completely Weathered Bee Low Limestone were scheduled for laboratory compaction testing (using a 2.5kg rammer) and particle size distribution analysis to determine their suitability for re-engineering.

12.4.5 Laboratory compaction tests are only appropriate if the material grading demonstrates that:

- At least 70% of the material passes the 20mm sieve and/or
- At least 90% of the material passes the 37.5mm sieve

12.4.6 If particle sizes are only slightly in excess of the above limits, compaction tests can be useful in order to indicate target densities, but the results should be treated with caution and used for guidance only. However, if a particular material type is significantly coarser than the above limits allow, the results of laboratory compaction testing would be meaningless and a field trial would be necessary.

12.4.7 The material particle density (Gs) is required in order to plot the 0, 5 and 10% air voids lines on the compaction graph for each material type.

12.4.8 The results are presented in Appendix J(2) and are summarised in Table 22 below:

**Table 22**
**Summary of Particle Size Distribution and Compaction Tests**

| Sample location & depth | Material description | % passing 37.5mm sieve | % passing 20mm sieve |
|---|---|---|---|
| TB106 @ 0.6m | Sandy silty Clay | 100 | 100 |
| TB108 @ 0.7m | Sandy silty Clay | 100 | 100 |
| TB121 @ 0.80 | Sandy silty Clay | 100 | 100 |

| Sample location & depth | $G_s$ (Mg/m$^3$) | MDD (Mg/m$^3$) | OMC (%) | Allowable mc range for 95% MDD & <5% air voids | In-situ moisture content (%) |
|---|---|---|---|---|---|
| TB106 @ 0.6m | 2.59 | 1.66 | 17 | 21.8 - 25 | 26.3 |
| TB108 @ 0.7m | 2.61 | 1.71 | 12 | 20.5 - 24 | 28.4 |
| TB121 @ 0.80 | 2.60 | 1.71 | 15 | 20 – 23.5 | 32 |

12.4.9 In addition, the moisture contents of a further 5 samples of the completely weathered Bee Low Limestone were determined. The results for these samples were in the range 26.3 to 33%.

12.4.10 The test results show that the completely weathered Bee Low Limestone material is suitable for compaction testing. However, it is apparent that the in-situ moisture content of these materials is significantly in excess of the Optimum Moisture Content (OMC) and in excess of the allowable moisture content range that will be required to achieve 95% Maximum Dry Density (MDD) and <5% air voids. On this basis it is considered that the completely weathered Bee Low Limestone is suitable for re-engineering for use beneath highways and hardstanding, subject to drying prior to re-engineering works.

### 12.5 Laboratory California Bearing Ratio (CBR) Tests

12.5.1 Two samples of completely weathered Bee Low Limestone strata were scheduled by ALM for laboratory California Bearing Ratio (CBR) Tests (BS1377:Part 4:Cl7)

12.5.2 Each sample was subjected to re-compaction (using a 2.5kg rammer) at natural (as received) moisture content.

12.5.3 The results of the laboratory CBR tests are summarised in Table 23.

**Table 23**
**Summary of Laboratory CBR Tests**

| Sample location & depth | Material description | Bulk Density ($Mg/m^3$) | Natural Moisture Content (%) | Mean CBR (%) |
|---|---|---|---|---|
| TB112 @ 0.6m | Brown silty clay | 1.91 | 27 | 1.5 |
| TB122 @ 0.6m | Brown silty clay | 1.82 | 32 | 1.6 |

12.5.4 It is considered prudent to assume a design CBR of 1.5% following re-compaction of the natural Completely Weathered Limestone materials beneath proposed roadways.

### 12.6 Soakaway Tests

12.6.1 General notes about soakaways, including their location, design, and ALM's test methodology are presented in Appendix A.

12.6.2 Two soakaway tests were carried out in accordance with BRE Digest 365 "Soakaway Design" within Test Pit Nos. SAB1 and SAB2. The locations of the soakaway tests were designed to test the infiltration of the strata in the area of a proposed 'attenuation pond'/soakaway as shown on Barratt Homes Manchester Drawing No. 1483/SK01 presented in Appendix B (test locations are shown on Drawing No. 30156/B/5 presented in Appendix B to this report).

12.6.3 Records of the soakaway tests are presented in Appendix J(3) to this report.

12.6.4 The calculated infiltration rates for each test are summarised in the Table 24 below.

**Table 24**
**Summary of Soakaway Infiltration Rates**

| Soakaway No. | Stratum | Infiltration Rate |
|---|---|---|
| SAB1 | Completely and Moderately Weathered Bee Low Limestone | 1.99 $x10^{-2}$ m/s (theoretical)<br>(Unable to fill test pit due to rapid percolation of water through fissures within rock. Measured water injection rate 6.7litres/sec) |
| SAB2 | Completely and Moderately Weathered Bee Low Limestone | Test 1 – 9.54 x $10^{-5}$ m/s<br>Test 2 – 9.87 x $10^{-5}$ m/s |

12.6.5 For test pit SAB1, water was injected into this pit as quickly as possible using a pressurised water bowser, however it proved impossible to fill the pit with water and only a water level of ca. 20mm above the base of the pit was possible due to the rapid percolation of water through fissures within the Limestone bedrock. A 'theoretical' soil infiltration of the bedrock has been calculated to be 1.99 $x10^{-2}$ m/s based on the approximate time it took for the pit to drain completely of water. Subsequent tests were carried out to determine the water injection rate used in the attempt to fill pit SAB1 with water by recording the time taken to fill a 1000 litre capacity IBC container. The measured water injection rate used to fill test pit SAB1 was 6.7litres/sec.

12.6.6 The infiltration rate at a particular location has been observed to primarily be controlled by the degree of fracturing in the limestone. However, the infiltration rates noted above are broadly comparable to those recorded by GRM in 2006 (see Table 5 on page 13).

12.6.7 Based on the above it is, therefore, considered that soakaways are a practical drainage solution for surface water management at the site within the limestone deposits.

# 13 GEOTECHNICAL ISSUES

## 13.1 Conceptual site Model

### *Made Ground*

13.1.1 Both GRM and ALM ground investigations have identified the presence of only very localised and shallow made ground materials within the site.

13.1.2 In general terms, the made ground typically comprises a reworked/disturbed topsoil which resembles the natural topsoil that is present across the site but contains minor constituents of gravel (demolition materials or filter gravels). The presence of the made ground is typically confined to the footprints of a former building and a filter tank that were present on site – the locations of which are shown on Drawing No. 301546/B/4 in Appendix B.

13.1.3 An additional localised area of shallow reworked/disturbed topsoil was encountered during the 2006 GRM investigation in trial pit TP19, but were not encountered in ALM Trial Pit TB101.

13.1.4 A small former quarry feature was present to the south of the proposed development area. Trial Pit TB116 targeted this feature and was observed to contain made ground materials to 1.4m depth. The quarry fill materials are granular in nature and comprise limestone, concrete and brick gravel, cobbles and boulders.

### *Natural Strata*

13.1.5 Natural clayey topsoil materials are present across the entire development area to an average depth of 0.3m.

13.1.6 The topsoil is underlain by a horizon of completely weathered Bee Low Limestone which was recovered as a friable, soft becoming firm sandy silty clay. The completely weathered limestone was absent in trial pit TB114 but elsewhere was observed to vary in thickness between 0.3-1.25m (average 0.7m) and extended to depths of between 0.6-1.6mbgl (average 1.05mbgl)

13.1.7 Moderately Weathered Bee Low Limestone Strata (rock) was encountered in all exploratory holes and comprised strong to very strong pale grey fine grained thinly to medium bedded Limestone. The sub-horizontal bedding surfaces were observed to be weathered and discontinuities were observed to be filled with soft brown clay.

13.1.8 The depth to the top of the Moderately Weathered Bee Low Limestone ranged between 0.35mbegl (TB114) and 1.60mbegl (TB110), but was typically encountered at depths ranging between 0.8-1.2mbegl (average depth to rockhead – 1.0mbegl). Drawing No. 30156/B/7 in Appendix B presents a summary of the depth/level to the Moderately Weathered Limestone rockhead encountered in both the GRM and ALM exploratory holes. The levels of the rockhead closely mirror the surface topography and is at its lowest in the vicinity of the sewage pumping station in the northeast of the site (337mAOD) and steadily increase to levels of 347-348mAOD towards the south, southwest and west.

### *Groundwater*

13.1.9 No groundwater seepages were encountered in any of the GRM and ALM exploratory holes.

## 13.2 Mining & Quarrying

13.2.1 The site is not in an area that has historically been mined for coal.

13.2.2 Limestone has, and continues to be widely extracted by opencast methods in the vicinity of the site, but the presence of limestone workings beneath the site is considered unlikely.

13.2.3 Historical maps do not show the presence of any quarries within the development area, although a small quarry feature was present to the south of the development boundary and which has been observed to have been infilled with granular inert materials.

13.2.4 Although the presence of similar small and shallow quarry features within the development area cannot be completely discounted, the likelihood of the presence of such features is considered to be very low.

### 13.3 Site Regrade and/or Ground Improvement

13.3.1 Ground levels vary significantly across the site and it is anticipated that regrading of the proposed development area will be required. It is anticipated that this regrading will comprise 'cut and fill' beneath individual house plots, particularly where proposed in the western, southwestern and southern parts of the site with the requirement for retaining walls along plot boundaries. Based on an initial assessment of existing ground levels and proposed finished floor levels undertaken by Barratt Homes Manchester, it is anticipated that some retaining walls of between ca. 1.5-4.5m height may locally be required.

13.3.2 The Completely Weathered Bee Low Limestone materials will be suitable for re-engineering/compaction, however, existing geotechnical tests suggest that the natural moisture contents of these materials are considerably in excess of the optimum moisture content and are also in excess of the range of moisture contents that would enable 95% of maximum dry density and <5% air voids to be achieved following re-compaction.

13.3.3 It is therefore considered that optimum re-engineering of the completely weathered Bee Low Limestone clay strata could be problematic during the winter months or during periods of inclement wet weather, and consideration should be given for the drying of the completely weathered strata in windrows or the use of lime stabilisation techniques. If the latter is adopted, field trials will be required to determine the appropriate lime ratio required to achieve optimum (or close to optimum) moisture content.

13.3.4 The near surface soils also have the potential to be disturbed by weathering and site traffic. Precautions should be taken to avoid this, as excessive disturbance may entail more onerous road subbase thickness and increased amounts of off-site disposal etc. The near surface soils may need treatment or reinforcing to allow safe movement of construction plant and labour. An assessment by the contractor should be undertaken once the type of machinery/plant needed to complete the development is known.

### 13.4 Foundation Recommendations

#### *General*

13.4.1 Consideration is being given to the development of the site with 132 No. 2-3 storey domestic dwellings, associated gardens, public open space and adoptable roads and sewers. Barratt Homes Manchester Drawing No. 1483/SK01 presented in Appendix B presents a 'Feasibility Sketch' of the proposed development.

13.4.2 Foundation recommendations assume that development will be two-three storey and that line loads will not exceed 60kN/m run. If this is not the case significant alteration to these recommendations will be required.

13.4.3 Foundation recommendations presented below take into consideration the anticipated difference between existing site levels and indicative proposed finished floor levels of the development, as provided by Barratt Homes Manchester. Any modification to the proposed finished floor levels will require amendments to the foundation recommendations provided.

13.4.4 Shallow made ground materials have been observed to be locally present in some parts of the site. Made ground is not considered a suitable foundation material and foundations should therefore be taken through these materials into underlying natural strata of adequate bearing capacity.

13.4.5 The in situ firm Completely Weathered Bee Low Limestone (sandy silty clay) is considered a suitable load bearing stratum.

13.4.6 Assuming a strip foundation of 10m length and 0.6m width, founding at 0.90m depth, the Completely Weathered Mudstone/Sandstone stratum is generally considered to have a safe bearing capacity of at least 165kN/m$^2$, where the typical 'worst case' shear strength of the 'firm' clays (50kN/m$^2$) recorded in hand vanes tests is assumed. With respect to the above foundation geometry and a maximum line load of 60kN/m run, settlements in the order of 4-8mm would be anticipated. This is considered likely to be acceptable, however further advice should be sought from the Structural Engineer responsible for design.

13.4.7 However, the Completely Weathered Bee Low Limestone was observed to be friable and locally soft in nature. Therefore, for ease of construction and to reduce the risk of any unacceptable total and/or differential settlement it is recommended that foundations found onto the underlying strong to very strong Moderately Weathered Limestone (rock) strata. A nett allowable bearing pressure of in excess of 1000 kN/m$^2$ for conventional strip or trench footings will be achievable on the rock.

13.4.8 The Completely Weathered Limestone (clay) strata can be easily excavated using a backhoe excavator. However, the Moderately Weathered Limestone (rock) was very very hard to excavate in trial pits, but it should still be possible to excavate the upper horizons of the rock using a backhoe excavator with the assistance of hydraulic pointed tools and will be excavated as angular coarse gravel, cobbles and boulders.

13.4.9 A suspended floor construction should be used wherever the depth of made ground or infill beneath a plot exceeds 600mm. However, due to the requirement for full radon protection and the likelihood of other ground gases (carbon dioxide) being present it is recommended that an allowance be made for suspended floors for all house plots with an appropriate ventilated sub-floor void (e.g. "beam-and-block").

13.4.10 Barratt Homes or their groundworker should seek further advice from ALM if unexpected ground conditions are encountered in foundation or sewer excavations, including any conflict between soft ground associated with a backfilled trial pit excavation and the line of a proposed footing.

13.4.11 Sub-surface concrete in contact with the made ground and with the natural weathered Limestone should be Design Sulphate Class DS-1, with the site allocated an ACEC Classification of AC-1.

13.4.12 No relict floor slabs or foundations are anticipated to still be present within the site. However, should these features be encountered they will require breaking out prior to re-development. However, relict foundations could probably be left in-situ and an allowance made for local breaking out where these conflict with new foundations.

13.4.13 Foundations of plots placed over relict foundations should be taken to greater depth than the relict foundations and into natural ground of adequate bearing capacity.

13.4.14 Over-deepened foundations should be stepped in accordance with NHBC Standards, Chapter 4.4.

13.4.15 Foundations will be required to be placed below a line drawn up at 45$^0$ from the base of any service or similar excavation.

13.4.16 The foundation solution for two or three storey residential properties constructed on this site is discussed below.

### *Strip/Trench Fill Footings*

13.4.17 It is considered that strip footings/deep strip footings will be the most suitable foundation solution for the two or three storey houses proposed to be constructed at the site. This solution is viable where the depth to competent strata beneath proposed finished floor levels is less than about 2m and firm Completely Weathered Limestone or Moderately Weathered Limestone rock are the founding material.

13.4.18 As noted above, due to potential variability of the bearing capacity of the Completely Weathered (clay) strata, it is recommended that <u>all</u> foundations found upon the Moderately Weathered Limestone rock. The rockhead will be expected to contain significant amounts of coarse granular (cobbly/bouldery) weathered rock with some clay infill within discontinuities, therefore reinforcement of footings is recommended as a precaution against differential settlement.

13.4.19 Reinforcement, as a precaution against differential settlement, is recommended only where foundation excavations encounter significant lateral and vertical variations in strata.

13.4.20 Foundations on rock should be placed entirely on rock and not partially on rock and partially on residual soil. This may, depending on surface gradient of the rock strata, necessitate localised over-deepening of foundations and over-break of the rockhead will be anticipated for a number of house plots.

13.4.21 Clay classification tests suggest that the Completely Weathered Limestone at the site should be regarded as being of medium shrinkabilty. A minimum founding depth of 900mm is therefore recommended for all soils on the site where strip footings are proposed or foundations be seated on bedrock whichever is the shallower depth.

13.4.22 Foundations should be deepened near trees in accordance with NHBC Standards Chapter 4.2. This may affect a number of properties located in centre of the site.

13.4.23 Founding depths are from original or finished ground level, whichever is the lower, to the underside of the footing.

13.4.24 In order to minimise softening and swelling of the cohesive soils, it is recommended that as soon as formation level is reached, it should be blinded. The blinding should consist of concrete with as low a water:cement ratio as possible.

13.4.25 In addition to the above, Barratt Homes should review proposed plot designs and layouts, since deeper excavations for trench fill are likely to be unstable where the centre-lines of parallel trenches are closer than about 2m (assuming 600mm widths). Barratt Homes should supervise their groundworker to ensure footings are excavated in a controlled and safe manner.

## 13.5 Excavations

13.5.1 Based on the results of the investigations it is unlikely that major groundwater flows will be encountered in shallow excavations. However, shallow excavations terminating within the Completely Weathered Limestone would have a tendency to hold surface waters during periods of rainfall, as such, provision should be made for the dewatering of foundation and service trench excavations. The extent to which dewatering of excavations will be required will, in part, depend on the time of year and preceding and prevailing weather conditions at the time of development works.

13.5.2 Excavations within made ground materials (i.e. regrade infill beneath house plots) would be expected to be unstable and will require shoring, whereas excavations in natural ground should remain stable in the short term but if left open for any significant period of time, may require shoring.

13.5.3 The Completely Weathered Limestone would be excavated as a residual soil (sandy silty clay).

13.5.4 Excavations within the Moderately Weathered Limestone rock strata will be expected to be difficult. As such, it would be prudent to allow for excavation of hard rock in all excavations that will require the use of pointed hydraulic breaker tools to excavate the limestone in trench excavations and ripping may be required in more open excavations.

13.5.5 Drawing No. 30156/B/7 in Appendix B presents the approximate levels of rockhead observed within the site.

13.5.6 Drawing No. 30156/B/8 in Appendix B presents a plot of the estimated compressive strength of the encountered moderately weathered limestone strata against the stratum discontinuity spacing to provide a general assessment of the 'excavatability'.

### 13.6 Drainage

13.6.1 The site is underlain at shallow depth (average depth 1mbegl) by Moderately Weathered Bee Low Limestone rock. In situ soakaway tests performed by GRM as part of their 2006 investigation and ALM indicate that the in situ limestone rock possesses an in situ infiltration rate that would make the use of soakaways as part of a sustainable surface water management system feasible. The 'soil infiltration rates' measured at the site by GRM and ALM varied between $4.71 \times 10^{-5}$ and $1.99 \times 10^{-2}$ m/s (average soil infiltration rate = $1.914 \times 10^{-3}$ m/s)

13.6.2 The measured soil infiltration rates were dictated by the presence of fractures within the rock and also the presence of weathered clay infill within rock discontinuities. The highest recorded infiltration rate of $1.99 \times 10^{-2}$ m/s in test pit SAB1 is only a theoretical rate, as a water injection rate into the test pit of 6.7 l/s was unable to exceed the percolation through the rock discontinuities at this location. If this soakaway test is ignored, the average soil infiltration rate recorded across the site was $4.15 \times 10^{-4}$ m/s.

13.6.3 It should be noted that the western part of the site is located within a Groundwater Source Protection Zone (Inner Protection Zone I) with respect to potable water abstractions and water abstractions for public amenity use which are of major significance in the area. Although the location of the proposed soakaway within the proposed development is indicated on Barratt Homes Manchester Drawing No. 1483/SK01 to be outside of the Groundwater Source Protection Zone (see Appendix F), consultations should be held with the Environment Agency with respect to confirming their acceptance for the use of soakaway drainage and determining the requirements for any precautions required, such as the use of oil/water interceptors. Oil/water interceptors are likely to be required for soakaways for highway drainage. The highway adopting authority should be consulted at the earliest opportunity regarding the use of soakaways for highway drainage.

13.6.4 All soakaways should be designed in accordance with BRE Digest 365 "Soakaway Design".

13.6.5 It is recommended that Barratt Homes Manchester contact Severn Trent Water Limited with respect to identifying the capacity in existing foul and surface water sewers and the existing sewage pumping station in the vicinity of the development area.

### 13.7 Highways

13.7.1 Where the Completely Weathered Limestone (clay) strata are exposed at road formation level and are to be used as road subgrade, these strata should first be proof rolled and any soft spots removed and replaced with suitable engineered fill.

13.7.2 Based on visual inspection of the natural materials and the recorded plasticity indices at the site, published tables (Highways Agency 'Design Manual for Roads and Bridges' – Volume 7, Section 2 – Design Guidance for Road Pavement Foundations Interim Advice Note 73/06, 2009) indicate that the Completely Weathered Limestone strata could be expected to have a CBR value of at least 3%.

13.7.3 However, laboratory CBR tests indicate that, due to the relatively high moisture content of the Completely Weathered Limestone materials, laboratory determined CBRs were typically 1.5%.

13.7.4 It is therefore considered prudent to assume a design CBR of 1.5% following re-compaction of the natural Completely Weathered Limestone materials beneath proposed roadways. Actual CBR values should be verified prior to or during construction.

13.7.5 The adopting authority should be consulted at the earliest opportunity to confirm any local requirements regarding sub grade requirements. Incorporation of a biaxial geogrid into sub-base layers may allow for reduced capping thickness.

### 13.8 External Works

13.8.1 Any digital terrain modelling undertaken, or commissioned by Barratt Homes should be made available to their Engineering Designer prior to issue of an External Works Drawing.

13.8.2 Based on indicative finished floor levels for proposed house plots that have initially been prepared by Barratt Homes Manchester it is anticipated that retaining wall structures will be required to be constructed at plot boundaries. Within the western margins of the site, earth retaining structures may be required to be 2.5-4.5m in height.

13.8.3 The presence of shallow rock at the site may preclude the use of any cantilever retaining wall design. As such it is strongly recommended that a structural engineer be consulted at an early stage with respect to the design of these structures and to identify any preparatory foundation works that will be required to be carried out during site regrading operations.

# 14 REDEVELOPMENT ISSUES

## 14.1 General

14.1.1 This report has presented options with respect to foundation solutions, treatment of contamination etc that are considered technically feasible and in line with current good practice. Consequently, we would expect to obtain regulatory approval for whichever option is adopted, although this cannot be guaranteed. Copies of this report should be forwarded to the relevant regulatory authorities (NHBC & Local Authority) for their comment/approval.

## 14.2 Enabling Works Strategy

14.2.1 Redevelopment of this site may be subject to planning conditions relating to remediation and validation. Once a specific, preferred development strategy has been decided, ALM could liaise with local Planning Authority and NHBC and prepare an Enabling Works Strategy document for approval.

14.2.2 The Enabling Works/Remediation Strategy document would include:

- General background information, including site location, site description and a summary of ground investigation data
- An overview of existing constraints on development and the aims of the proposed Remediation works
- Specific details of the anticipated site Remediation/preparatory works
- Details of site supervision and verification
- A summary of implications for redevelopment

14.2.3 The anticipated enabling works are summarised below:

- Identification/fencing of existing trees that are to be retained and protected.
- Identification of the location of existing sewers present within the site.
- Clearance of pre-existing vegetation and removal of any unprotected trees.
- Perform an intrusive 'Pre-Demolition and Refurbishment Asbestos Survey' to the existing building that is to be demolished (brick structure located within the centre of the site).
- Demolish existing brick structure and removal of floor slab and associated foundations.
- General site clearance of any materials that may be present within the extreme northwest of the site
- Strip existing natural and 'reworked' topsoil materials and relocate to stockpiles in accordance with DEFRA '*Construction Code of Practice for the Sustainable Use of Soils on Construction Sites*' (2009) for subsequent reuse in garden and landscaped areas. 'Reworked' topsoil should be carefully segregated and stockpiled separately for use within proposed area of public open space.
- Excavation and off site disposal of made ground materials noted in GRM Trial Pit TP19, if still present.
- If/where required, screening of any oversize fractions from demolition materials noted to be present in GRM trial pit TP20 and ALM trial pit TB122 with crushing and screening of any oversize fractions to produce a suitably graded secondary aggregate for reuse on site.
- Undertake phased regrading of the site to appropriate lines and levels to achieve finalised development levels. Earthworks associated with the regrading operation may require to use of lime stabilisation techniques to permit optimum compaction of the completely weathered limestone strata beneath house plots and/or adoptable roads.

- The crushing and screening to a suitable grading of limestone rock arisings derived from any overbreak in site regrading works and/or foundation excavations.
- Prepare adoptable road footprints using selected granular materials (reengineered to specification).
- Placement of a suitable minimum 600mm soil cover layer (150mm subsoil/450mm topsoil) in proposed garden areas to plots that possess any residual made ground at surface. Elsewhere, placement of site won subsoil and topsoil materials in garden and landscaped areas
- Supervision of the works by a suitably qualified consultant to include detailed records, testing requirements, where required etc
- Validation of the remediated site in the form of a detailed Completion Statement confirming that the works set out in this document and agreed were completed and that the site is suitable for its intended use

14.2.4 It is recommended that the 'Enabling Works Strategy' includes a volumetric assessment of the anticipated earthworks and types of materials to be used to create a sustainable development scheme, and a suitable development platform to required finished development levels.

14.2.5 The finalised earthworks strategy would be required to be documented within a detailed 'Materials Management Plan' prepared in accordance with CL:AIRE *'Definition of Waste: Development Industry Code of Practice Version 2'* (March 2011).

## 14.3 Health & Safety Issues - Construction Workers

14.3.1 Only localised and shallow made ground materials have been identified within the proposed development boundary, however, this made ground contains contaminants at concentrations above the guidance threshold values for an end use that includes domestic gardens. Workers involved in excavations for foundations, drainage, utilities etc are likely to come into direct contact with the made ground, where present.

14.3.2 Although workers will only be exposed to the contaminated soil for a relatively short time, the contaminants represent a risk, and simple precautionary measures are required, i.e. good personal hygiene and basic personnel protective equipment.

14.3.3 Consequently, during the remediation and construction phases of the site development it will be necessary to protect the health and safety of site personnel. General guidance on these matters is given in the Health and Safety Executive (HSE) document "Protection of Workers and the General Public during the Redevelopment of Contaminated Land". In summary, the following measures are suggested to provide a minimum level of protection:

- All ground workers should be issued with protective clothing, footwear and gloves. Personnel should be instructed in why and how they are to be used.
- Hand-washing and boot-washing facilities.
- Good practices relating to personal hygiene should be adopted on the site.
- The contractor should satisfy the Health & Safety Executive with regard to any other matters concerning the health, safety and welfare of persons on the site.

14.3.4 Access into excavations etc. must be controlled and only undertaken in accordance with the Confined Spaces Regulations 1997. The atmosphere in all trenches should be monitored for oxygen and hazardous gas (methane & carbon dioxide), prior to personnel entering such excavations. Monitoring should continue whilst personnel are working in excavations.

14.3.5 Before site operations are started, the necessary COSHH statements and Health & Safety Plan should be drafted in accordance with the CDM regulations.

## 14.4 Control of Excavation Arisings

14.4.1 Excavations into made ground are likely to yield contaminated arisings. The groundworker should carefully segregate (and stockpile separately) made ground arisings from arisings of "clean" natural soils, in order that an excessive volume of unsuitable material is not generated.

14.4.2 Made ground arisings could be:

- Redistributed beneath areas of hardstanding, where they would be satisfactorily isolated from end users. This option should not be used if the made ground is potentially compressible, such as organic 'reworked' topsoil.
- Isolated beneath the 600mm thick cover layer in garden or landscaped areas.
- 'Reworked' topsoil could be blended with natural topsoil materials and relocated to areas of public open space.
- Exported from site to a suitably licensed landfill facility

## 14.5 New Utilities

14.5.1 It is anticipated that new utilities will be lain within natural Completely Weathered Limestone or reworked Completely Weathered Limestone (following site regrading works). In view of the uncontaminated nature of the natural strata, trenches for services including site drainage and water supply would not be required to be cut over size. However, it is strongly recommended that all statutory service bodies are consulted at an early stage with respect to the ground conditions within which they will lay services in order to assess at an early stage any potential abnormal costs.

14.5.2 Given the nature of the ground conditions identified, it is not anticipated that Severn Trent Water Limited will require contamination resistant water supply pipework to be used in the proposed development. However, the findings of this ground investigation should be submitted to Severn Trent Water Limited for their review, once development proposals have been finalised.

## 14.6 Potential Development Constraints

14.6.1 Existing foul sewers (225mm diameter gravity sewers and a 100mm pressurised sewer) are present within the site leading to and from the adjacent Severn Trent Water Limited sewage pumping station. The approximate alignments of these sewers are indicatively shown on Drawing No. 30165/B/2 in Appendix B.

14.6.2 The lines of these sewers will have a significant impact on the plot layout at the site. Consultations should be held at an early stage with Severn Trent Water Limited with respect to ascertaining the potential to re-align these sewers and the associated costs. Alternatively, consultations should seek to ascertain restrictions with respect to development in the vicinity of the sewers and the easements required.

14.6.3 The site is underlain by shallow rock, the depth to which is typically 1mbegl and the rockhead typically mirrors the surface topography of the site (see Drawing No. 30156/B/7 in Appendix B). It is recommended that foundations utilise the rock as the founding stratum, however the surface gradient of the rockhead will locally necessitate significant overbreak to form development platforms or foundation trenches. The appointed groundworker will therefore require to utilise rock breaking equipment in the form of hydraulic breakers and rippers during site regrading works and/or during the construction of foundations. Crushing and screening of rock arisings will generate aggregate, which (subject to confirmatory testing) should be suitable for use as unbound pavement materials within the highways.

14.6.4 Indicative proposed development levels suggest that significant earth retaining structures will be required to be constructed as part of the proposed development. The shallow rock will preclude the use of more conventional cantilever retaining wall designs and consideration of alterative retaining wall designs will need to be carried out at an early design stage.

# 15 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

## 15.1 General

15.1.1 ALM were commissioned to carry out a Supplementary Geoenvironmental Appraisal of land at Burlow Road, Harpur Hill, Buxton in the context of the proposed development of the site for low rise residential housing.

15.1.2 The site exists as an irregular-shaped parcel of agricultural (pasture) land covering an area of approximately 4.72ha that is situated ca.3km to the south of Buxton town centre.

15.1.3 The primary aims of this 'supplementary' phase of investigation were to review the findings of the previous Desk Study and Ground Investigation works that were undertaken by GRM Development Solutions in 2006 and to carry out further investigation works, principally in order to:

- Confirm ground conditions beneath the site to provide further recommendations with respect to foundations for proposed structures.
- Undertake further assessment and analysis of localised made ground materials previously noted to be on site.
- Undertake additional sampling and chemical and geotechnical analysis of topsoil materials and natural strata to further assess their potential for re-use within the proposed development.
- Undertake an assessment of the depth of rock strata to assist in the formulation of a site regrading scheme and to further assess the 'excavatability' of the rock strata with respect to the site regrade works and proposed foundation/service trenches.
- Undertake additional in situ soakaway tests.

15.1.4 The above 'supplementary' investigation works have been designed to supplement, and be consolidated with, the findings of the previous GRM investigation to confirm and identify salient geoenvironmental issues affecting the site to enable the Client to obtain budget costs for the necessary site preparatory and remediation works

15.1.5 The supplementary ground investigation comprised the excavation of 24 No. Trial Pits, 2 No. in situ soakaway tests and associated chemical and geotechnical analysis of near surface soils.

15.1.6 Historical maps indicate that the site is 'Greenfield' in nature and has been in agricultural use since at least the mid 19th Century. Only modest development has taken place within the site. This has comprised the development of a small building and trackway in the centre of the site and a small sewage filter tank in the northeast of the site. These features were developed in the early 20th Century but were not present on site in the 1950s/70s. A small infilled quarry feature is shown to have been present in the late 19th Century immediately to the south of the proposed development area which was infilled in the past.

15.1.7 The ground investigations have identified the presence of a nominally 0.3m thick deposit of clayey topsoil across the whole of the study site.

15.1.8 Localised shallow Made Ground deposits have been noted within some parts of the site. These typically comprise 'reworked/disturbed' topsoil materials possessing minor inclusions of demolition materials (brick, concrete, slate etc) and filter gravels and would appear to be confined to the footprints of historical buildings/structures that were present within some parts of the site. Similar made ground materials containing ash and metal fragments were noted to be present in the extreme northwest of the study site during the GRM investigation, but these materials were not encountered as part of ALMs supplementary investigations.

15.1.9 The former small quarry feature to the south of the proposed development area has been noted to have been infilled to 1.45m depth with inert brick, concrete and limestone gravel, cobbles and boulders.

15.1.10 The natural and 'reworked/disturbed' topsoil materials have been observed to be underlain by Completely Weathered Bee Low Limestone strata which typically comprise a soft, becoming firm, (friable) slightly sandy very silty CLAY with rare fine to coarse gravel of limestone. These materials were recorded to depths of between 0.6-1.6mbgl (average 1.05mbgl) and possessed a thickness of 0.3-1.25m (average 0.7m).

15.1.11 The Completely Weathered strata are underlain by Moderately Weathered Bee Low Limestone Strata - strong to very strong pale grey fine grained thinly to medium bedded LIMESTONE. The sub-horizontal bedding surfaces were observed to be weathered and discontinuities were observed to be filled with soft brown clay.

15.1.12 The depth to the top of the Moderately Weathered Bee Low Limestone ranged between 0.35mbegl (TB114) and 1.60mbegl (TB110), but was typically encountered at depths ranging between 0.8-1.2mbegl (average depth to rockhead – 1.0m). The depth to the top of rockhead has been observed to be relatively uniform across the site and the levels of the rockhead closely mirror the surface topography. The level of the top of rockhead is at its lowest in the vicinity of the sewage pumping station in the northeast of the site (337mAOD) and steadily increase to levels of 347-348mAOD towards the south, southwest and west.

15.1.13 The change from Completely to Moderately Weathered Bee Low Limestone was noted to be very abrupt, with the Moderately Weathered Limestone strata (in situ rock) proving very difficult to excavate. The trial pits were forced to be terminated ca. 0.2-0.5m into this stratum with the rock being excavated as angular cobbles and boulders.

15.1.14 No groundwater was encountered during either the GRM or ALM investigations

## 15.2 Hazardous Gas

15.2.1 Initial gas monitoring undertaken by GRM in 2006 within temporary standpipes installed into backfilled trial pits noted the presence of slightly elevated background concentrations of carbon dioxide, which is considered to be as a result of the natural dissolution of the parent limestone bedrock.

15.2.2 The highest concentration of carbon dioxide recorded was 6.3%v/v, however no gas flow rates were recorded.

15.2.3 The concentration of carbon dioxide would lead to consideration of the adoption of NHBC 'Amber 1' gas protection measures. However, the site is located within an area where 'Full' radon gas protection measures will be required. As such 'Amber 1' gas protection measures (well installed gas proof membrane with a ventilated sub-floor void) will be required.

## 15.3 Mining and Quarrying

15.3.1 Limestone has, and continues to be widely extracted by opencast methods in the vicinity of the site, but the presence of limestone workings beneath the site is considered unlikely.

15.3.2 Historical maps do not show the presence of any quarries within the development area, although a small quarry feature was present to the south of the development boundary and which has been observed to have been infilled with granular inert materials. Although the presence of similar small and shallow quarry features within the development area cannot be completely discounted, the likelihood of the presence of such features is considered to be very low.

### 15.4 Contamination & Remediation

15.4.1 The shallow 'reworked/disturbed' topsoil containing ash and metal fragments encountered in GRM trial pit TP19 in the extreme northwest of the site was observed to contain significant concentrations of lead and zinc as well as copper and cadmium contamination which could present a risk to human health and plants and should be excavated and removed from site. However, ALM trial pit TB101 did not encounter these materials which either suggests that they are very localised, or have since been removed from site.

15.4.2 The shallow 'reworked/disturbed' topsoil containing small amounts of demolition materials noted in GRM TP20 and ALM TB122 is considered suitable for re-use within areas of public open space (i.e. it is not suitable for use in private gardens), particularly if blended with other natural topsoil materials. Alternatively, these reworked topsoil from this location could also be excavated and removed from site.

15.4.3 The localised demolition type materials noted in GRM TP20 and localised filter gravels noted in ALM TB120 contains lead, copper and zinc contamination. Should these materials be present at surface within proposed private garden or public open space areas they should be covered by a layer of uncontaminated subsoil and topsoil to 600mm thickness. Alternatively, these materials could be excavated and removed from site.

15.4.4 The natural topsoil contains localised lead and copper contamination (one sample – TB110). The topsoil from this area would, however, be considered suitable for use in residential public open space areas, particularly if mixed with other natural topsoil materials.

15.4.5 The natural topsoil has also been noted to contain widespread marginally elevated concentrations of zinc above the potential phytotoxic threshold concentration of 200mg/kg. However, of particular note is that fact that the underlying Completely Weathered Bee Low Limestone clay strata have also been observed to possess a US95 concentration for zinc in excess of 200mg/kg. As such, the elevated zinc concentrations observed within the natural topsoil materials are considered to be a reflection of the naturally occurring presence of zinc within the underling parent material.

15.4.6 It is considered that the natural topsoil (and completely weathered Bee Low Limestone) materials present on site are considered suitable for use within the proposed residential development in private garden areas

### 15.5 Foundations

15.5.1 It is considered that strip footings/deep strip footings will be the most suitable foundation solution for the two or three storey houses proposed to be constructed at the site.

15.5.2 Due to potential variability of the bearing capacity of the Completely Weathered (clay) strata, it is recommended that <u>all</u> foundations found upon the Moderately Weathered Limestone rock. The rockhead will be expected to contain significant amounts of coarse granular (cobbly/bouldery) weathered rock with some clay infill within discontinuities, therefore reinforcement of footings is recommended as a precaution against differential settlement.

15.5.3 Foundations on rock should be placed entirely on rock and not partially on rock and partially on residual soil. This may, depending on surface gradient of the rock strata, necessitate localised over-deepening of foundations and over-break of the rockhead will be anticipated for a number of house plots.

### 15.6 Flooding

15.6.1 The site is not located in an area that is prone to 1:100 year and 1:1000 year flood events.

15.6.2 However, the eastern/north-eastern margins of the site are indicatively shown to be prone to high (30 year recurrence interval), medium (100 year recurrence interval) and low (1000 year recurrence interval) risk of flooding by surface waters.

### 15.7 Drainage & Highways

15.7.1 The site is underlain at shallow depth (average depth 1mbegl) by Moderately Weathered Bee Low Limestone rock. In situ soakaway tests performed by GRM as part of their 2006 investigation and ALM indicate that the in situ limestone rock possesses an in situ infiltration rate that would make the use of soakaways as part of a sustainable surface water management system feasible.

15.7.2 It should be noted that the western part of the site is located within a Groundwater Source Protection Zone (Inner Protection Zone I) with respect to potable water abstractions and water abstractions for public amenity use which are of major significance in the area. Although the location of the proposed soakaway within the proposed development is indicated on Barratt Homes Manchester Drawing No. 1483/SK01 to be outside of the Groundwater Source Protection Zone, consultations should be held with the Environment Agency with respect to confirming their acceptance of the use of soakaway drainage. Oil/water interceptors are likely to be required for soakaways for highway drainage. The highway adopting authority should be consulted at the earliest opportunity regarding the use of soakaways for highway drainage.

15.7.3 It is recommended that Barratt Homes Manchester contact Severn Trent Water Limited with respect to identifying the capacity in existing foul and surface water sewers and the existing sewage pumping station in the vicinity of the development area.

15.7.4 Where the Completely Weathered Limestone (clay) strata are exposed at road formation level and are to be used as road subgrade, these strata should first be proof rolled and any soft spots removed and replaced with suitable engineered fill.

15.7.5 Laboratory CBR tests indicate that, due to the relatively high moisture content of the Completely Weathered Limestone materials, laboratory determined CBRs were typically 1.5%. It is therefore considered prudent to assume a design CBR of 1.5% following re-compaction of the natural Completely Weathered Limestone materials beneath proposed roadways. Actual CBR values should be verified prior to or during construction.

15.7.6 The adopting authority should be consulted at the earliest opportunity to confirm any local requirements regarding sub grade requirements. Incorporation of a biaxial geogrid into sub-base layers may allow for reduced capping thickness.

### 15.8 External Works

15.8.1 Given the existing topography of the site, and based on indicative finished floor levels for proposed house plots, it is anticipated that retaining wall structures will be required to be constructed at plot boundaries. Within the western margins of the site, earth retaining structures may be required to be 2.5-4.5m in height.

15.8.2 The presence of shallow rock at the site may preclude the use of any cantilever retaining wall design. As such, it is strongly recommended that a structural engineer be consulted at an early stage with respect to the design of these structures and to identify any preparatory foundation works that will be required to be carried out during site regrading operations.

### 15.9 Further Works

15.9.1 The following further works are recommended to be carried out:

- Consultations should be held at an early stage with Severn Trent Water Limited with respect to ascertaining the potential to re-align existing sewers that are present within the northern part of the site. Alternatively, consultations should seek to ascertain restrictions with respect to development in the vicinity of the sewers and the easements required.
- It is recommended that an 'Enabling Works Strategy' be prepared to include a volumetric assessment of the anticipated earthworks and types of materials to be used to create a sustainable development scheme, and a suitable development platform to required finished development levels.
- The finalised earthworks strategy would be required to be documented within a detailed 'Materials Management Plan' prepared and approved in accordance with CL:AIRE *'Definition of Waste: Development Industry Code of Practice Version 2'* (March 2011).

# APPENDIX A

## General Notes

# Generic Notes – ALM Geoenvironmental Investigations

## 01 - Environmental Setting

### General

Third party information obtained from the British Geological Survey (BGS), the Coal Authority, the Local Authority etc is presented in the Correspondence Appendix of this Geoenvironmental Report.

### Geology, Mining & Quarrying

In order to establish the geological setting of a site, ALM refer to BGS maps for the area, and the relevant geological memoir.

Borehole records held within the BGS archive are additionally obtained where such records are available or are considered relevant to the study site. It should be noted that the exact locations of boreholes held within the BGS archive are not always known and the quality of information presented within the borehole records may vary, depending on the age and nature of the borehole record and the reason for why the borehole was drilled.

A coal mining report is obtained from the Coal Authority where the study site is located within a Coal Authority Search Area. Further information is sourced from the Local Authority and by reference to current and historical OS plans.

### Landfills

ALM obtain data from the Landmark Information Group/Emapsite, the Environment Agency and the Local Authority with respect to known areas of landfilling within 250m of the proposed development site. Reference is also made to historical OS plans, which are inspected for evidence of backfilled quarries, railway cuttings, colliery spoil tips etc.

### Radon

Radon is a colourless, odourless gas, which is radioactive. It is formed in strata that contain uranium and radium (most notably granite), and can move though fissures eventually discharging to atmosphere, or the spaces under and within buildings. Where radon occurs in high concentrations, it can pose a risk to health.

In order to assess potential risks associated with radon gas, ALM refer to BRE Report BR211, 2015: "*Radon: guidance on protective measures for new buildings*".

The level of protection needed is site-specific and is determined by reference to the maps contained in Annex A of BR211. These maps are derived from the Radon Atlas of England and Wales (2007), and indicate the highest radon potential within each 1km grid square.

If the site falls within a light grey square on the relevant map in Annex A then basic radon protection should be installed in new buildings; if the site falls within a dark grey square then full radon protection should be installed. **If the site is in an un-shaded square then no radon protection is needed.**

BR211 provides a preliminary indication of the measures required for a particular site, but it is also often beneficial to request a BR211 Radon Report from the BGS. The Annex A maps indicate the highest geological radon potential within each 1km grid square, but in many cases the radon potential varies considerably within the grid square. The BR211 Radon Report gives definitive guidance on the requirement for radon protective measures, and therefore may allow the adoption of a lower level of protection than that indicated in the Annex A maps.

ALM typically obtains a BR211 Radon Report for all sites that fall within a shaded square on the relevant Annex A map.

When requesting a BR211 Radon Report from the BGS ALM selects the search radius carefully, since too large a search radius may result in the inclusion of areas of higher geological radon potential, and therefore in the recommendation of too high a level of protection.

Further details of the protective measures required, if appropriate, are provided in the Hazardous Gas section of this Geoenvironmental Report.

**Hydrogeology**

ALM obtain information from the Environment Agency (EA) and the Landmark Information Group/Emapsite with respect to:

- groundwater quality
- recorded pollution incidents
- licensed groundwater abstractions

Reference is also made to the EA document "*Policy and Practice for the Protection of Groundwater*" (V1.1 August 2013) and the relevant Groundwater Vulnerability Map.

Since 1st April 2010 the Environment Agency's *Groundwater Protection Policy* uses aquifer designations that are consistent with the Water Framework Directive and represent a slight modification to those aquifer designations which have been used in the past. These new designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply) but also their role in supporting surface water flows and wetland ecosystems.

The aquifer designation data is based on geological mapping provided by the British Geological Survey and will be updated from time to time based on the ongoing programme of improvements to these maps.

The Solid and any overlying Drift deposits are classified and defined by the Environment Agency as follows:

**'Principal Aquifers' (formerly known as Major Aquifers):**

*"Layers of rock or drift deposits that have high intergranular and/or fracture permeability which can usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as a major aquifer"*

**'Secondary Aquifers' (generally formerly known as Minor Aquifers):**

These include wide range of rock layers or drift deposits with an equally wide range of water permeability and storage. Secondary Aquifers are sub-divided into two types:

- **Secondary A**: *"Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers".*

- **Secondary B**: *"Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of layers formally classifies as non-aquifers"*

- **Secondary Undifferentiated***: "Layers of rock or drift where it has not been possible to attribute either Secondary A and Secondary B classification. This means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to variable characteristics of the rock or drift type"*

**'Unproductive Strata' (formerly known as Non-aquifers)**:

"*These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow".* NB: Groundwater flow through Unproductive Strata although imperceptible, does take place and needs to be considered in assessing the risk associated with persistent pollutants. Some non-aquifers can yield water in sufficient quantities for domestic use.

Groundwater vulnerability is determined by 4 variables:

1. The presence and nature of overlying soil (the weathered zone affected by living organisms; soil in the UK can extend up to 2m in depth). Physical properties of the soil affect the downward passage of water and it's ability to attenuate pollutants. The EA make reference to a three-fold classification of soil types:-

   - Soils of **low** leaching potential are defined as *"soils in which the pollutants are unlikely to penetrate the soil layer because either water movement is largely horizontal, or they have the ability to attenuate diffuse pollutants".*

   - Soils of **intermediate** leaching potential are defined as *"soils which have a moderate ability to attenuate diffuse source pollutants or in which it is possible that some nonadsorbed diffuse source pollutants and liquid discharges could penetrate the soil layer".*

   - Soils of **high** leaching potential are defined as *"soils with little ability to attenuate diffuse source pollutants and in which non-adsorbed diffuse source pollutants and liquid discharges have the potential to move rapidly to underlying strata or to shallow groundwater".*

In urban areas and restored mineral workings the soil information is based on fewer observations than elsewhere. A worst-case vulnerability (H) is therefore assumed for these areas and for current mineral workings by the EA. All are given a designation of **HU** unless proved otherwise.

2. The presence and nature of Drift, which often overlies bedrock. Where Drift is of substantial thickness and low permeability, it can provide an effective barrier to surface pollutant migration. Permeable Drift is classified as a Minor Aquifer except where it is in probable hydraulic continuity with a Major Aquifer, where it is regarded as part of the Major Aquifer unless proven otherwise by site investigation.

3. The nature of the geological strata (bedrock). Rocks that contain groundwater in exploitable quantities are called aquifers.

4. The depth of the unsaturated zone; i.e. that part of the aquifer which lies above the water Table The EA have also designated Source Protection Zones, which are based on proximity to a groundwater source (springs, wells and abstraction boreholes). The size of a Source Protection Zone is a function of the aquifer, volume of groundwater abstracted, groundwater flow travel times and the effective rainfall, and may vary from tens to several thousand hectares.

**Hydrology**

ALM obtains information from the Environment Agency and the Landmark Information Group/Emapsite with respect to:

- surface water quality
- recorded pollution incidents
- licensed abstractions (groundwater & surface waters)
- licensed discharge consents
- site susceptibility to flooding

The EA have set **water quality** targets for all rivers. These targets are known as River Quality Objectives (RQOs). The water quality classification scheme used to set RQO planning targets is known as the River Ecosystem scheme. The scheme comprises five classes (RE1 to RE5) which reflect the chemical quality requirements of communities of plants and animals occurring in our rivers.

General Quality Assessment (GQA) grades reflect actual water quality. They are based on the most recent analytical testing undertaken by the EA. There are six GQA grades (denoted A to F) defined by the concentrations of biochemical oxygen demand, total ammonia and dissolved oxygen.

The susceptibility of a site to **flooding** is assessed by reference to a Flood Map on the Environment Agency's website. These maps provide show natural floodplains - areas potentially at risk of flooding if a river rises above its banks, or high tides and stormy seas cause flooding in coastal areas.

There are two different kinds of area shown on the Flood Map:

1. Dark blue areas could be flooded by the sea by a flood that has a 0.5% (1 in 200) or greater chance of happening each year, or by a river by a flood that has a 1% (1 in 100) or greater chance of happening each year

2. Light blue areas show the additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with up to a 0.1% (1 in 1000) chance of occurring each year.

These two colours show the extent of the natural floodplain if there were no flood defences or certain other manmade structures and channel improvements.

The maps also show all flood defences built in the last five years to protect against river floods with a 1% (1 in 100) chance of happening each year, or floods from the sea with a 0.5% (1 in 200) chance of happening each year, together with some, but not all, older defences and defences which protect against smaller floods.

The Agency's assessment of the likelihood of flooding from rivers and the sea at any location is based on the presence and effect of all flood defences, predicted flood levels, and ground levels.

It should also be noted that as the floodplain shown is the 1 in 100 year (or 1 in 200 year as appropriate), areas outside this may be flooded by more extreme floods (e.g. the 1 in 1000 year flood). Also, parts of the areas shown at risk of flooding will be flooded by lesser floods (e.g. the 1 in 5 year flood). In some places due to the shape of the river valley, the smaller floods will flood a very similar extent to larger floods but to a lesser depth.

If a site falls within a floodplain, it is recommended that a flood survey be undertaken by a specialist consultant who can advise on appropriate mitigating measures; i.e. raising slab levels, provision of storage etc.

**COMAH & Explosive Sites**

ALM obtain information from the Landmark Information Group with respect to COMAH or explosive sites within 1km of the proposed development site. ALM's report refers to any that are present, and recommends that the Client seeks further advice from the HSE.

Areas around COMAH sites (chemical plants etc) are zoned with respect to the implementation of emergency plans. The HSE are a statutory consultee to the local planning authority for all COMAH sites. The COMAH site may have to revise it's emergency action plan if development occurs. This might be quite straightforward or could entail significant expenditure. Consequently, the COMAH site may object to a proposed development (although it is the Local Authority who have final say, and they are likely to place more weight on advice from the HSE).

**Preliminary Conceptual Ground Model**

The site's environmental setting (and proposed end use) is used by ALM to assess the significance of any contamination encountered during the subsequent ground investigation.

Assessment of contaminated land is based on an evaluation of pollutant linkages (source-pathway-receptor). Contaminants within the near surface strata represent a potential source of pollution. The environment (most notably groundwater), site workers and end users are potential targets.

Potential pollutant linkages are shown on a preliminary conceptual site model, presented as a Drawing in an Appendix to this Geoenvironmental Report. The preliminary model is revised in light of data arising from the subsequent ground investigation.

ALM CONSULT

# Generic Notes – ALM Geoenvironmental Investigations

## 02 - Ground Investigation Fieldwork

### General

ALM Ground Investigations are undertaken in accordance with current UK guidance including:

- BS5930:2015 "*Code of practice for ground investigation*"
- BS10175:2013 "*Code of practice for the identification of potentially contaminated sites*".
- "*Technical Aspects of Site Investigation*" – EA R&D Technical Report P5-065/TR (2000)
- "*Development of appropriate soil sampling strategies for land contamination*" – EA R&D Technical Report P5-066/TR (2001)
- Contaminated Land Reports 1 to 6, most notably CLR Report No. 4 "*Sampling strategies for contaminated land*"
- "*Guidance on the protection of housing on contaminated land*" – NHBC & EA R&D Publication 66 (2000)
- AGS: 1996 "*Guide to the selection of Geotechnical Soil Laboratory Testing*"
- BS1377:1990 "*British Standard Methods of Test for Soils for Civil Engineering Purposes"*

Exploratory hole logs are presented in Appendices to this Geoenvironmental Report. These logs include details of the:

- Investigation technique adopted .
- Samples taken.
- Descriptions of the strata and any groundwater encountered.
- Results of any in-situ testing.
- Any gas\groundwater monitoring well installed.

### Exploratory Hole Locations

Exploratory hole locations are selected by ALM prior to commencement of fieldwork to provide a representative view of the strata beneath the site and to target potential contaminant sources identified during the preliminary investigation (desk study). Additional exploratory locations are often determined by the site engineer in light of the ground conditions actually encountered; this enables better delineation of the depth and lateral extent of organic contamination, poor ground, relict structures etc.

### Investigation Techniques

Ground conditions can be investigated by a number of techniques; the procedures used are in general accordance with BS5930:2015 and BS1377:1990. Techniques most commonly used by ALM include:

- Machine excavated trial pits, usually equipped with a backactor and a 0.6m wide bucket.
- Cable percussive (Shell & Auger) boreholes, typically using 150mm diameter tools and casing.

- Window or Windowless Sampling boreholes. Constraints associated with existing buildings, operations and underground service runs can render some sites partly or wholly inaccessible to a mechanical excavator. In such circumstances, window sampling is often the most appropriate technique. A window sampling drilling rig can be manoeuvred in areas of restricted access and results in minimal disturbance of the ground (a 150mm diameter tarmac/concrete core can be lifted and put to one side). However, it should be noted that window sampling allows only a limited inspection of the ground (especially made ground with a significant proportion of coarse material).
- Rotary percussive open-hole probeholes are typically drilled using a tricone rock roller bit with air as the flushing medium. Probeholes are generally lined through made ground with temporary steel casing to prevent hole collapse.

Where installed, gas\groundwater monitoring wells typically comprise a lower slotted section, surrounded by a filter pack of 10 mm non-calcareous gravel and an upper plain section surrounded in part by a bentonite seal and in part by gravel or arisings. The top of the plain pipe is cut off below ground level and the monitoring well protected by a square, stopcock type manhole cover set in concrete, or the plain pipe is cut off just above ground level and the well protected by 100mm diameter steel borehole helmet set in concrete.

Monitoring well details, including the location of the response zone and bentonite seal are presented on the relevant exploratory hole logs.

## In-situ Testing

Where relative densities of granular materials given on the trial pit are based on visual inspection only, they do not relate to any specific bearing capacities. However, wherever possible ALM employ a Mackintosh probe to assess relative density. Mackintosh probe results can be related to approximate allowable bearing capacities.

The relative densities of granular materials encountered in cable percussive boreholes and window sample boreholes are based on Standard Penetration Test (SPT) results. SPT's are carried out in boreholes, in accordance with BS 1377:1990,:Part 9 Section 3.3. Where full penetration (600mm) is not possible, N values are calculated by linear extrapolation and are shown on the logs as N* = x.

The strength of cohesive deposits is determined using a hand shear vane.

Shear strength test results reported on trial pit logs are considered to be more reliable than those reported on window sample logs. Significant sample disturbance occurs during window sampling and consequently shear strength results on disturbed window samples are generally lower than results obtained during trial pitting, in-situ or in large excavated blocks.

## Sampling

Representative soil/fill samples are taken at regular intervals from the exploratory holes to assist in description of the ground and to allow selected laboratory testing to be performed. The type of sample taken is dependent on the nature of the stratum and the purpose of the analysis.

Where the soils encountered contain a significant proportion of coarse grained material, truly representative samples are not typically obtained - only the finer fraction is placed in sample containers. However, a visual estimate of the amount of coarse material is made on site.

NB: Coarse constituents not sampled are defined as: coarse gravel, cobbles and boulders. (i.e. any 'particles' with an average diameter greater than 20mm).

Occasionally, unrepresentative 'spot' samples are also taken from some exploratory locations for contaminant analysis, typically where unusual, localised pockets of materials are encountered.

Samples of soil for chemical testing are placed into 1 litre plastic tubs prior to delivery to the selected laboratory. Samples of water are taken in one litre, brown glass bottles and stored in cool boxes, at a temperature of <5ºC, until delivery to the selected laboratory. Soil\fill samples for organic analysis are also stored in cool boxes.

### Groundwater

Where encountered during fieldwork, groundwater is recorded on the exploratory hole log. If monitoring wells are installed, groundwater levels are also recorded on one or more occasions after completion of the fieldwork.

It should be borne in mind that the rapid excavation rates used during a ground investigation may not allow the establishment of equilibrium water levels. Water levels are likely to fluctuate with season/rainfall and could be substantially higher at wetter times of the year than those found during this investigation.

Long-term monitoring of standpipes or piezometers is always recommended if water levels are likely to have a significant effect on earthworks or foundation design.

### Description of Strata

The soils encountered during an ALM ground investigation are described in general accordance with BS 5930. The descriptions and depth of strata encountered are presented on the exploratory hole logs and summarised in the Ground Conditions section within the main body of text.

The materials encountered in trial pits are logged, samples taken, and tests performed on the in-situ materials in the excavation faces, to depths of up to 1.2m; below this depth these operations are conducted at the surface on disturbed samples recovered from the excavation.

### Key to Exploratory Hole Logs

Keys to logs are presented in the Appendix(ces) containing the logs. There are two Keys – Symbols & Legends and Terms & Definitions.

# Generic Notes – ALM Geoenvironmental Investigations

## 03 - Geotechnical Laboratory Tests

### General

Soil samples are delivered to the laboratory for testing along with a schedule of testing drawn up by ALM. All tests are carried out in accordance with BS 1377:1990.

The test results are presented as received in an Appendix to this Geoenvironmental Report.

The following laboratory tests are routinely carried out on a selection of samples:

- Atterberg limits (Plastic Limit, Liquid Limit, Plasticity Index) & Moisture Content
- Soluble sulphate & pH
- Quick Undrained Triaxial Shear Stength (on undisturbed 100mm diameter samples)

The additional tests are typically only scheduled where significant earthworks regrade is anticipated:

- Particle Size Distribution
- Five Point Compaction
- Particle Density
- California Bearing Ratio (CBR) on either undisturbed or re-compacted disturbed samples

### Atterberg Limits & Moisture Content

The Liquid and Plastic Limits of samples of natural in-situ clay are determined using the cone penetrometer method and the rolling thread test. These tests enable determination of an average Plasticity Index (PI) for each "type" of clay, although judgement is applied where variable results are reported.

PI can be related to shrinkability (low, medium or high) and then to minimum founding depth. ALM typically only consider a soil to be shrinkable if the proportion finer than 63µm is >35%.

PI results are compared against guidance given in the NHBC Standards, Chapter 4.2 (revised April 2003), which advocates the use of modified Plasticity Index (I'p), defined as:

I'p = Ip * (%< 425µm/100)
i.e. if PI is 30%, but the soil contains 80% < 425µm, then: I'p = 30 * 80/100 = 24%.

It should be noted that in accordance with the requirements of BS 1377, the % passing the 425µm sieve is routinely reported by testing labs.

ALM apply engineering judgment where PI results are spread over a range of classifications. Consideration is given to:

- the average values for each particular soil type (i.e. differentiate between residual soil and alluvium),
- the number of results in each class and
- the actual values.

Unless the judgment strongly indicates otherwise, ALM typically adopt a conservative approach and recommend assumption of the higher classification.

**Soluble Sulphate and pH**

Sulphates in soil and groundwater are the chemical agents most likely to attack sub-surface concrete, resulting in expansion and softening of the concrete to a mush. Another common cause of concrete deterioration is groundwater acidity.

The rate of chemical attack depends on the concentration of aggressive ions and their replenishment at the reaction surface. The rate of replenishment is related to the presence and mobility of groundwater.

ALM refer to BRE Special Digest 1 (SD1) "*Concrete in aggressive ground. Part 1: Assessing the aggressive chemical environment*" (2001). SD 1 provides definitions of:

- the nature of the site (greenfield, brownfield or pyritic)
- the groundwater regime (static, mobile or highly mobile)
- the Design Sulphate Class (DC Class) and
- the Aggressive Chemical Environment for Concrete (ACEC Class)

ALM reports clearly state each of the above for the site being considered.

The concentrations of sulphate in aqueous soil/fill extracts are determined in the laboratory using the gravimetric method. The results are expressed in terms of $SO_4$ for direct comparison with BS 5328:1997. The pH value of each sample was determined by the electrometric method.

SD1 also discusses determination of "representative" sulphate concentration from a number of tests. Essentially if <10 samples of a given soil-type have been tested, the highest measured sulphate concentration should be taken. If >10 samples have been tested, the mean of the highest 20% of the sulphate test results can be taken. With respect to groundwater, the highest sulphate concentration should always be taken.

With respect to pH (soil & groundwater) the value used is the lowest value if <10 samples have been tested and the mean of the lowest 20% if >10 samples have been tested.

## Generic Notes – ALM Geoenvironmental Investigations

### 4A. Contamination Laboratory Analysis & Interpretation (including WAC)

**Waste Classification & Waste Acceptance Criteria (WAC)**

In the context of waste soils generated by remediation and\or groundworks activities on brownfield sites, the following definitions (from the Landfill Regulations 2002) apply:

- Inert (e.g. uncontaminated 'natural' soil, bricks, concrete, tiles & ceramics).
- Non-Hazardous (e.g. soil excavated from a contaminated site which contains dangerous substances, but at concentrations below prescribed thresholds).
- Hazardous (e.g. soil excavated from a contaminated site which contains dangerous substances at concentrations above prescribed thresholds).

Dangerous substances include compounds containing a variety of determinants commonly found in contaminated soils on brownfield sites, for example arsenic, lead, chromium, benzene etc.

Since 16th July 2005, landfill operators require Waste Acceptance Criteria (WAC) laboratory data, if soil waste is classified as **hazardous**, and such waste must have been subjected to pre-treatment. However, subject to WAC testing it may be possible to classify it as stable, non-reactive hazardous waste, which can be placed within a dedicated cell within the non-hazardous landfill.

ALM typically only include WAC analysis in site investigation proposals and reports, if significant off-site disposal (of soil classified as hazardous waste) is anticipated, for example where redevelopment proposals include basement construction etc.

If off-site disposal of soils classified as hazardous waste were undertaken during redevelopment, then WAC analysis should be scheduled at an early stage in the remediation programme.

However, organic compounds (BTEX, TPH, PAH, asbestos etc) are the most common contaminants that result in soils being classed as hazardous. These contaminants can often be dealt with by alternative technologies (e.g. by bioremediation or stabilisation) and consequently retention on site is often possible.

It should be noted that **non-hazardous** soil waste can go to a non-hazardous landfill facility; no further testing (eg WAC) is required.

**Contamination Laboratory Analysis & Interpretation**

An assessment of potential contaminants associated with the former usages of the site is undertaken with reference to DEFRA/Environment Agency R&D Publication CLR8 "*Potential contaminants for the assessment of land*" (2002) and the relevant DETR/DoE Industry Profile(s), where published.

<u>Common Inorganic Contaminants</u>

These can include:

- metals, most notably cadmium, copper, chromium, mercury, lead, nickel, and zinc.
- semi-metals, most notably arsenic, selenium, and (water soluble) boron
- non-metals, most notably sulphur
- inorganic anions, most notably cyanides (free & complex), sulphates, sulphides, and nitrates.

With respect to the terminology used by most analytical laboratories:

Total cyanide = Free cyanide + Complex cyanide

Total cyanide (CN) is determined by acid extraction; whereas free cyanide is the water soluble fraction.

Complex cyanide is "bound" in compounds and is hard to breakdown. Laboratory determination of complex CN involves subjecting the sample to uv digestion for determination of both free and total CN.

Thiocyanate (SCN) is a different species combined with sulphur.

Elemental sulphur (S) and free sulphur are the same. Total sulphur is all forms, including that present in sulphates ($SO_4$), sulphides etc

There are 2 forms of chromium (Cr), chromium VI and chromium III. Chromium VI is the more toxic of these. In soils, total chromium is determined by a strong aqua regia acid digestion. Chromium VI is an empirical method based on a water extract test.

Common Organic Contaminants

*Petroleum hydrocarbons* are a mixture of hydrocarbons produced from the distillation of crude oil. They include aliphatics (alkanes, alkenes and cycloalkanes), aromatics (single or multi benzene ringed compounds) and hydrocarbon-like compounds containing minor amounts of oxygen, sulphur or nitrogen.

Petroleum hydrocarbons can be grouped based on the carbon number range:-

- GRO – Gasoline Range Organics (typically $C_6$ to $C_{10}$). Also commonly referred to as PRO – Petroleum Range Organics
- DRO – Diesel Range Organics (typically $C_{10}$ to $C_{28}$)
- LRO - Lubricating Oil Range Organics (typically $C_{28}$ to $C_{40}$)
- MRO – Mineral Oil Range Organics (typically $C_{18}$ to $C_{44}$)

However, it should be borne in mind that the terms “GRO”, “DRO”, “LRO” analysis are purely descriptive terms, the exact definition of which varies.

*Total Petroleum Hydrocarbons (TPH)* is also a poorly defined term; some testing laboratories regard TPH as hydrocarbons ranging from $C_5$-$C_{44}$, whereas others define TPH as $C_{10}$-$C_{30}$. TPH cannot be assessed as a single “total” value, and reference has been made to the Environment Agency’s document P5-080/TR3, “*The UK approach for evaluating human health risks from petroleum hydrocarbons in soils*”. This document supports the assumptions and recommendations made by the US Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG). This approach is in line with the TPHCWG documents volumes 1[(1)], 2[(2)], 3[(3)] and 4[(4)].

The TPHCWG assessed “TPH” into thirteen representative constituent fractions or “Equivalent Carbon (EC) Bandings”. EC Bandings are based around Equivalent Carbon numbers and the TPHCWG have derived a series of physiochemical and toxicological parameters for each of the thirteen EC bandings.

The composition of a TPH plume migrating through the ground can vary significantly; this is primarily dictated by the nature of the source (e.g. petrol, diesel, engine oil etc). Furthermore, different hydrocarbons are affected differently by weathering processes, and this can result in further variation in the chemical composition of the TPH.

*Gasoline* contains light aliphatic hydrocarbons (especially within the $C_5$ to $C_{10}$ range) that will rapidly evaporate. The aromatic hydrocarbons in gasoline are primarily benzene, toluene, ethylbenzene and xylenes, referred to as BTEX that are relatively volatile and soluble. Small amounts of polyaromatic hydrocarbons (PAHs) such as naphthalene may also be present.

*Diesel and light fuel oils* have higher molecular weights than gasoline. Consequently, they are less volatile and less water soluble. About 25 to 35% of diesel/light fuel oil is composed of aromatic hydrocarbons. BTEX concentrations are generally low.

*Heavy Fuel Oils* are typically dark in colour and considerably more viscous than diesel. They contain 15 to 40% aromatic hydrocarbons. Polar nitrogen, sulphur and oxygen-containing compounds (NSO) compounds are also present.

*Lubricating Oils* are relatively viscous and relatively insoluble in groundwater. They may contain 10 to 30% aromatics, including the heavier PAHs. NSO compounds are also common.

*Polycyclic Aromatic Hydrocarbons* (PAHs) have more than two fused benzene rings as a structural characteristic. PAH compounds are present in both petrol and diesel, although in significantly lower concentrations than in coal tars and heavier oils. Certain PAH compounds are carcinogenic (e.g. benzo(a)pyrene) and\or more mobile in the environment (e.g. naphthalene). PAH cannot be assessed as a single “total” value, as each individual PAH compound has different toxicity and mobility in the environment. Speciated analysis is required to determine the concentrations of the various compounds, most notably the key PAHs: benzo(a)Pyrene (considered the most toxic of the PAHs); and naphthalene (the most mobile and volatile of the PAHs).

*Volatile (& Semi) Organic Compounds (VOCs/SVOCs)* include a variety of compounds which have relatively low boiling points. However, VOC’s are much more volatile than SVOC’s. Examples of VOC’s include benzene, chloroform and trichloroethene (e.g. chlorinated solvents); SVOC’s include phenol, fluorine and ‘lighter’ PAHs. Both groups of chemicals are readily absorbed through skin and some, such as benzene, are believed to be linked to tumour growth.

*Phenols* are compounds that have a hydroxyl group attached to an aromatic ring (i.e. include a benzene ring and an –OH group). Most are colourless solids. A solution of phenol in water is known as carbolic acid, and is a powerful antiseptic. However, phenol vapour is toxic, and skin contact can result in burns.

*Polychlorinated Biphenyls (PCBs)* were used in pre-1974 transformers as dielectric fluids. PCB’s possess increasing toxicity relative to the degree of chlorination, they do not degrade in the environmental and can bio-accumulate. Acute symptoms of PCB poisoning are irritation of the respiratory tract leading to coughing and shortness of breath. Nausea, vomiting and abdominal pain are caused by ingestion of PCB’s.

*Dioxins and furans* (polychlorinated dibenzodioxins and polychlorinated dibenzofurans) are some of the most toxic chemicals known. In the environment, they tend to bio-accumulate in the food chain. Dioxin is a general term that describes a group of hundreds of chemicals that are highly persistent in the environment. The most toxic compound is 2,3,7,8 tetrachlorodibenzo–p-dioxin or TCDD.

Dioxin is formed by burning chlorine-based chemical compounds with hydrocarbons. The major source of dioxin in the environment comes from waste-burning incinerators and also from uncontrolled burning (e.g. bonfires). Dioxin pollution is also affiliated with paper mills which use chlorine bleaching in their process and with the production of Polyvinyl Chloride (PVC) plastics and with the production of certain chlorinated chemicals (like many pesticides).

## Methods of Analysis (Organic Compounds)

**TPH by GC-FID** is an analytical technique which only detects hydrocarbons (aliphatic and aromatic) in the range $C_{10}$ to $C_{40}$ (volatiles, heavy tars, humic material and sulphur are not detected). The laboratory can provide a breakdown of the TPH results into gasoline range organics (**GRO**), diesel range organics (**DRO**) and heavier lubricating oil range organics (**LRO**).

**GRO (PRO) by GC-FID** analysis detects the more volatile $C_6$-$C_9$ hydrocarbons (aliphatic and aromatic), including those organic compounds present in petrol.

**Speciated VOC (by GC-MS)** analysis quantifies the concentrations of 30 USA-EPA priority compounds. These include chlorinated alkanes and alkenes (in the molecular weight range chloroethane to tetrachloroethane); trimethylbenzenes; dichlorobenzenes; and the 4 BTEX compounds (benzene, ethyl-benzene, toluene & xylene).

**Speciated SVOC by (GC-MS)** analysis quantifies the concentrations of a variety of organic compounds, including the chlorinated compounds 16 USA-EPA priority PAHs, phenolic compounds, 7 USA EPA priority PCB congeners, herbicides & pesticides.

*Note: PAHs are hydrocarbons and consequently (where present) will be picked-up when testing TPH by GC-FID. Naphthalene (the lightest PAH) is also one of the 58 US EPA VOCs.*

**Speciated TPH by GC-MS** provides a "banded" TPH, initially split into aromatic and aliphatic fractions and then further divided into fraction specific carbon bandings based upon behavioural characteristics and includes speciated BTEX compounds.

*Note: Risk assessment models require physiochemical properties (solubilities, toxicities etc) of compounds in order to model their behaviour in the environment. These physiochemical properties cannot be derived from a single "TPH", "GRO" or "DRO" value. However, the carbon banded fractions can be used in risk assessment models.*

## Current UK Guidance

The UK approach to contaminated land is set out in Environment Agency Contaminated Land Report (CLR) No. 11 (2004) "*Model Procedures for the Management of Land Contamination*". The approach is based upon risk assessment, where risk is defined as the combination of the probability of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

In the context of land contamination, there are three essential elements to any risk: (1) a contaminant source, (2) a receptor (e.g. controlled water or people) and (3) a pathway linking the (1) and (2). Risk can only exist where all three elements combine to create a pollutant linkage. Risk assessment requires the formulation of a conceptual model which supports the identification and assessment of pollutant linkages.

ALM adopts a tiered approach to risk assessment, consistent with UK guidance and best practice. The initial step of such a risk assessment (or **'Tier 1'**) is the comparison of site data with appropriate UK guidance levels, ALM risk-derived screening values, or remedial targets.

Groundwater

Tier 1 **groundwater** risk assessments are undertaken by comparing soil leachate or groundwater concentrations with the appropriate water quality standard. Depending upon the specific characteristics and environmental setting of the site the appropriate standard is likely to be one of the following:

- Water Supply (Water Quality) Regulations 1989
- Environmental Quality Standards (for Freshwater)
- The Surface Waters (Abstraction for Drinking Water) Regulations

Hazardous Gas

Tier 1 risk assessment of **hazardous gas** is undertaken through reference to the following documents:

- Approved Document C, Building Regulations 2000
- Boyle & Witherington (2006) – 'Guidance on evaluation on development proposals on sites where methane and carbon dioxide are present, incorporating "traffic lights"'. Report Ref. 10627-R01-(02), for NHBC
- CIRIA C665 (2007) – 'Assessing risks posed by hazardous ground gases to buildings'
- BS 8485:2015 – 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'.
- BRE Report 211 (2007) – 'Radon: Guidance on protective measures for new buildings', Building Research establishment

Further information with respect to hazardous gas assessments is presented in 'Generic Note No. 5 – Hazardous Gas'.

Soil Contamination – Human Health

In March 2002 DEFRA and the Environment Agency published a series of technical documents (R&D Publications CLR 7, 8, 9 and 10) outlining the UK approach to the assessment of risk to **human health** from land contamination and which replaced previously published guidance. In March 2004 DEFRA and the Environment Agency published a further four documents ('Briefing Notes 1-4') which expanded, or where necessary revised, the original R&D Documents.

Publications CLR 7, 8, 9 and 10 and Briefing Notes 1-4 set out the UK's quantitative modelling approach to contaminated land (the *Contaminated Land Exposure Assessment* (CLEA) model). The CLEA model set out exposure frequency and duration assumptions, together with technical algorisms for the modelling of human health-related risks to contaminated land. The CLEA model lead to the publication of Soil Guidance Values (SGVs) for certain contaminants of concern ('SGV Reports'), based on collated published toxicity data for the contaminant in question ('TOX Reports')

In 2008 R&D Publications CLR 7, 9 and 10 and all corresponding SGV and TOX reports were withdrawn and superseded by new guidance including:

- Guidance on Comparing Soil Contamination Data with a Critical Concentration - CL:AIRE and CIEH, May 2008 [(5)] (effectively replaced CLR7)
- Evaluation of models for predicting plant uptake of chemicals from soil - Science Report – SC050021/SR [(6)]
- Human health toxicological assessment of contaminants in soil - Science Report: SC050021/SR2 [(7)] (effectively replaced CLR9)
- Updated technical background to the CLEA model - Science Report: SC050021/SR3 [(8)] (effectively replaced CLR10)
- CLEA Software (Version 1.05) Handbook Science report: SC050021/SR4 [(9)] (replaced pre-existing CLEA software models released prior to 2009)
- Compilation of data for priority organic pollutants for derivation of Soil Guideline Values - Science Report: SC050021/SR7 [(10)] (presents a technical physiochemical reference for contaminants of concern)

The revised approach set out in the above documents represented current scientific knowledge and thinking; and included the revised Contaminated Land Exposure Model (CLEA version 1.06). The Environment Agency/DEFRA are intending to use this updated approach to regenerate a selection of Soil Guideline Values (SGVs) under Environment Agency Science Report SC050021 for Residential, Allotment and Commercial end use scenarios.

At the time of writing this report, SGV's are only available for a limited number of contaminants, the development of both the CLEA model and additional SGV's is ongoing, albeit probably now on hold in view of more recent guidance published by DEFRA in 2014 (see below). Where published, SGV's can be utilised as 'intervention values' for the purpose of an initial 'Tier 1' assessment.

In 2015 Land Quality Management and the Chartered Institute of Environmental Health (LQM/CIEH) published Tier 1 soil screening thresholds for assessing risks posed to human health from soil contamination (11). These soil screening thresholds are called 'Suitable For Use Levels' or 'S4ULs'. The S4ULs have been published in the absence of any forthcoming additional SGVs published by the Environment Agency/DEFRA.

The S4ULs have been developed using a modified version of the CLEA model for a wider variety of landuses in line with revised human exposure to soil contamination assumptions and landuse classes recommended by DEFRA (2014)(12) (also see below) to reduce the over-conservatism that is commonly attributed to SGVs. However, the S4ULs remain based on the principles of 'minimal' or 'tolerable' risk enshrined in Science Report SC050021/SR2(7) in that they utilise appropriate Health Criteria Values in their derivation. Thus the S4ULs are essentially equivalent to SGVs for the use of generic risk assessment under both the planning and Part 2A regimes.

The LQM/CIEH (2015)(11) publication presents S4ULs for 85 substances including 11 metals, 4 BTEX compounds, 16 TPH fractions, 16 PAH compounds, 8 chloroalkanes/alkene compounds, 2 explosive compounds, 7 pesticide compounds, 6 chlorobenzene compounds and additional isomers, 3 phenol and chlorophenol compounds and other organic compounds.

The development of S4ULs has been carried out under a peer review process and in accordance with prevailing UK government guidelines that in no way undermines the validity of the existing guidance in SC050021/SR2(7), SR3(8), SR4 or the existing CLEA software(9). As such **ALM chooses to adopt the use of S4ULs with respect to the assessment of soil contamination posed to human health**. The appropriate S4UL for any given chemical determinand used in the Tier 1 screening process is presented in the various summary tables presented in this report for the appropriate landuse being considered.

It should be noted that exceedance of 'Tier 1' S4UL does not necessarily mean that remedial action will be required.

ALM's use of S4ULs as Tier 1 values is, however based on a number of assumptions, most notably:

a. Contamination identified is located in the top 0.5m of soil on site. The CLEA model assumes that all exposure pathways are relevant within 0.6m of ground level.
b. A conservative **Soil Organic Matter** of 1% is initially assumed.
(Note: TOC = SOM x 0.58; and FOC = TOC/100).
Hydrocarbons tend to be "bind" with SOM, and therefore become less mobile. Consequently, Tier 1 values can be revised if the amount of organic matter within the soil exceeds 1%.
c. Some determinands reach **residual saturation** before a vapour risk is predicted to occur. Prior to residual saturation, as the concentration of a contaminant in soil increases, so does the concentration of the same contaminant in the associated vapour phase. However, once saturation is reached, the concentration of contaminant in the vapour phase remains constant (for any given atmospheric conditions – temperature and

pressure).

However, ALM recognise that it is unacceptable to leave free product in the ground and therefore arbitrary Tier 1 values have been ascribed to such contaminants. These values have been selected on the basis that they are below the limit of olfactory detection (i.e. at concentrations below Tier 1, odours are not readily identified).

Soil Contamination - Phytotoxity

With respect to the assessment of potential **phytotoxic effects** of contaminants, ALM refer to BS3882:2015 for copper and zinc(13). Nickel is also regarded as a phytotoxin, however, ALM adopts the S4UL for nickel due to its human health effects.

Soil Contamination – Building Fabric and Combustibility

The potential risk to **building materials** is considered through reference to relevant BRE Digests, with particular emphasis on BRE Special Digest 1, 'Concrete in aggressive ground', 2005.

With respect to the interpretation of the **calorific values**, at present there are no accepted methods to assess whether a sample is combustible and under what circumstances it might smoulder. Some guidance is given in ICRCL Note 61/84 "Notes on the fire hazards of contaminated land" which states that:

> "*In general...it seems likely that materials whose CV's exceed 10MJ/kg are almost certainly combustible, while those with values below 2MJ/kg are unlikely to burn".*

**Possible Action in Event of Tier 1 Exceedance**

Should any of the Tier 1 criteria detailed above be exceeded, then three potential courses of action are available. (The first is only applicable in terms of human health, but the second and third could also be applied to groundwater or hazardous gas).

- Undertake further statistical analysis following the approach set out in CL:AIRE/CIEH 2008[5] in order to determine whether contaminant concentrations of contaminants within soil\fill actually present a risk (only applicable to assessing the risk to human health).
- Carry out a more detailed quantitative risk assessment in order to determine whether contamination risks actually exist.
- Based on a qualitative risk assessment, advocate an appropriate level of remediation to "break" the pollutant linkage - for example the removal of the contaminated materials or the provision of a clean cover.

Prior to undertaking any statistical analysis contamination across the entire site needs to be characterised by reference to the Conceptual Site Model. Consequently, ALM gather and analyse sample results by soil/fill type, and/or by former use in a given sub-area of the site, before undertaking statistical analysis; i.e. the statistical data set is associated with the extent of a particular fill type, or an area affected by spillage\leakage.

In terms of brownfield redevelopment, this is considered a more appropriate methodology which provides a more representative sample population for statistical analysis.

Analysis by soil/fill type is appropriate for essentially immobile contaminants associated with a particular fill type, for example arsenic in colliery spoil, metals in ash & clinker, sulphate in plaster-rich demolition rubble etc.

Analysis by former use is appropriate where more mobile contaminants have entered the ground, for example diesel associated with leakage from a former fuel tank, downward migration of leachable metals through granular materials, various soluble contaminants present in a wastewater leaking into the ground via a fractured sewer etc. In these circumstances, it may be appropriate to undertake statistical analysis of sample results from a variety of different soil\fill types. However, consideration would have to be given to factors such as porosity which might influence impregnation of a mobile contaminant into the soil mass; i.e. contamination would normally be more pervasive and significant in granular soils than cohesive soils.

**Category 4 Screening Levels (C4SLs)**

In March 2014, DEFRA published the findings of a research project relating to the development of 'Category 4 Screening Levels' (C4SLs)(12) for assessing soil contamination with respect to human health risks. The project was carried out within the context of the revised Statutory Guidance to support Part 2A of the Environment Protection Act 1990 that was published in April 2012. The revised Statutory Guidance introduced a new four-category system for classifying land under Part 2A for cases of a Significant Possibility of Significant Harm to human health, where 'Category 1' includes land where the level of risk is clearly unacceptable and 'Category 4' includes land where the level of risk is acceptably low.

An impact assessment that accompanied the revised Part 2A Statutory Guidance identified that the current practice of 'generic' ('Tier 1') screening of soil contamination concentrations against published SGVs or other generic assessment criteria derived from the CLEA model, was too conservative and identified a potential new role for C4SLs in providing a simple test for deciding whether land is suitable for use and definitely not contaminated land.

The C4SLs are proposed to be more pragmatic (whilst still strongly precautionary) compared to the existing 'generic' screening levels (e.g. SGVs). The development of C4SLs used marginally less conservative human exposure assumptions associated with a wider variety of land use classes as well as modified assumptions on levels of tolerable doses. It is intended by DEFRA that the C4SLs will be used as new generic screening criteria, albeit describing a higher level of risk than the currently available SGVs.

Six substances were selected within the C4SL project because of their ubiquity within contaminated land risk assessments and a draft methodology for the derivation of C4SLs was subjected to peer review.

The final C4SLs derived for the 6 initially modelled contaminants of concern are presented in Table 5 below.

**Table 5 – Final C4SLs (after DEFRA 2014 (12))**

| Substance | Residential (with home grown produce) | Residential (without home grown produce) | Allotments | Commercial | Public Open Space (Residential) | Public Open Space (Park) |
|---|---|---|---|---|---|---|
| Arsenic | 37 | 40 | 49 | 640 | 79 | 168 |
| Benzene | 0.87 | 3.3 | 0.18 | 98 | 140 | 230 |
| Benzo(a)pyrene | 5 | 5.3 | 5.7 | 76 | 10 | 21 |
| Cadmium | 26 | 149 | 4.9 | 410 | 220 | 880 |
| Chromium VI | 21 | 21 | 170 | 49 | 23 | 250 |
| Lead | 200 | 310 | 80 | 2330 | 630 | 1300 |

Note - All C4SLs are expressed as mg/kg

With respect to the applicability of use of the C4SLs, the DEFRA 2014 report states:

> *"The Part 2A Statutory Guidance...(was) developed on the basis that Category 4 Screening Levels could be used under the planning regime... However policy responsibility for the National Planning Policy Framework and associated Planning Practice Guidance falls to the Department for Communities and Local Government"*

*"Where a valid SGV exists for a contaminant where a C4SL has been derived, it is anticipated that risk assessors will use the C4SL…In the absence of a suitable C4SL, risk assessors should identify and select appropriate GAC criteria in accordance with established good practice. It is for the Environment Agency to decide whether or not any of the SGVs will be updated in the light of more recent toxicological data or whether any particular SGV should be withdrawn."*

Until such time as C4SLs are formally adopted by the Department for Communities and Local Government into the National Planning Policy Framework and associated Planning Practice Guidance, ALM will adopt the use of the published LQM/CIEH S4ULs for 'generic' ('Tier 1') screening of soil contamination concentrations for the assessment of human health, unless otherwise advised by the Local Planning Authority in question that the use of C4SLs is appropriate. This is with the exception of lead, where ALM will adopt the C4SL presented in Table 5 above given that no recognised/published criteria (SGV or S4UL) for lead are available.

## References


(1) Total Petroleum Criteria Working Group Series, Volume 1 Analysis of Petroleum Hydrocarbons in Environmental Media, 1998.

(2) Total Petroleum Criteria Working Group Series, Volume 2 Composition of Petroleum Mixtures, 1998.

(3) Total Petroleum Criteria Working Group Series, Volume 3. Selection of Representative TPH Fractions Based on Fate and Transport Considerations, 1997

(4) Total Petroleum Criteria Working Group Series, Volume 4. Development of Fraction Specific Reference Doses (RfDs) and Reference Concentrations (RfCs) for Total Petroleum Hydrocarbons (TPH), 1998.

(5) Guidance on Comparing Soil Contamination Data with a Critical Concentration. CL:AIRE/Chartered Institute of Environmental Health, May 2008

(6) Evaluation of models for predicting plant uptake of chemicals from soil Science Report – SC050021/SR, 2008

(7) Environment Agency Science Report – SR2 Human health toxicological assessment of contaminants in soil, 2008

(8) Environment Agency Science Report - SC050021/SR3 Updated Technical Background to the CLEA Model (as amended 2009)

(9) Environment Agency Science Report - SC050021/SR4 CLEA Software (Version 1.05) Handbook, 2009

(10) Environment Agency Science Report – SR7 Compilation of Data for Priority Organic Pollutants for the Derivation of Soil Guidelines Values, 2008

(11) The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Management/Chartered Institute of Environmental Health. 2015

(12) DEFRA. SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination – Policy Companion Document. Department for Environment Food and Rural Affairs. March 2014

(13) BS3882:2015 – Specification for Topsoil. British Standards Institution

## Generic Notes – ALM Geoenvironmental Investigations

### 05 - Hazardous Gas

**General**

Hazardous gas is considered to be any mixture of potentially explosive, toxic or asphyxiating gases, most notably methane, carbon dioxide and oxygen (deficiency).

In addition, radon, a naturally occurring radioactive gas is also considered. Further information about radon is included in 'Generic Notes 01 – Environmental Setting' in Appendix A of this report.

An 'initial' assessment of potential risks associated with hazardous gas are based on a review of data obtained from desk study searches, such as a review of historical maps and other historical records (for evidence of backfilled quarries, railway cuttings, colliery spoil tips etc), information held by the Environment Agency and the Local Authority (current and historical landfill sites etc) as well as a review information obtained from the British Geological Survey and the Coal Authority. Such information is used to develop a Preliminary Conceptual Site Model to identify potential on site and off site gas sources and potential gas migration pathways.

Where landfilling of wastes has occurred within 250m of the site boundary, the Local Planning Authority may request a hazardous gas investigation in accordance with the Town and Country Planning General Development Order 1988.

**Sources**

Potential sources of hazardous gas are:

- Landfill sites
- Made ground, especially where significant depths are present.
- Shallow mineworkings associated with coal extraction.
- Geological strata, including peat, organic silts, coal-bearing strata and limestone (reaction with acidic waters), granite (radon).
- Groundwater can sometimes act as a "carrier" for dissolved hazardous gas.
- Leakages from pipelines or storage tanks
- Sewers, septic tanks and cess pits

**Generation**

Wherever biodegradable material is deposited, hazardous gas (principally a mixture of methane and carbon dioxide) is likely to be generated by microbial activity. Carbon dioxide is an asphyxiant and is toxic; methane is flammable and a mixture containing between 5% and 15% methane by volume in air can be explosive. Such gas in the ground is unlikely in itself to pose a significant risk, though it may cause vegetative stress to some plants. However, the migration/accumulation of these gases into confined spaces within buildings (e.g. cellars, services, etc) may give rise to significant risk.

The composition, concentration and length of time gas is produced depends on a number of factor including the organic fraction/nature of organic fraction present, the depth of fill materials, the moisture content of the materials, groundwater conditions etc.

**Migration**

Gas migration from a gas source may occur in several ways. It may migrate through adjacent strata; the distance of migration being dependent on the pressure gradients, volume of gas and permeability of the strata. Where there are faults, cavities and fissures within the strata, gas may move considerable distances. Other migration pathways for gas include man-made features such as mine shafts, roadways and underground services.

Gas migration can be influenced by a number of climatic factors, such as atmospheric pressure variations, water table level variations and the influence of a covering of snow or ice over the surface of the site and surrounding area.

**Gas Monitoring Procedure**

ALM adopts a gas monitoring procedure in accordance with guidance contained within CIRIA Report C665 (2007) "*Assessing Risks Posed By Hazardous Ground Gases to Buildings*". This procedure involves the measurement, in the following order of:

- Atmospheric temperature, pressure and ambient oxygen concentration on site immediately prior to and on completion of monitoring.
- Gas emission rate.
- Methane, oxygen and carbon dioxide concentrations using an infra-red gas analyser.
- Standing water level using an electronic dipmeter.

In addition, ground conditions at each sampling location are recorded together with prevailing weather conditions and any other observations such as any vandalism.

Where samples of gas are required for laboratory analysis, Gresham Tubes or Tedlar bags are used. Gas concentrations in the well are typically recorded immediately before and after retrieval of a sample.

**Site Characterisation - Current Guidance**

CIRIA Report 151 (1995)[i] identified that there was inadequate guidance on trigger concentrations for ground gases. CIRIA concluded that the most important aspect of a gas regime below or adjacent to a site was the surface emission rate, i.e. how quickly the gas is coming out of the ground. The lower the surface emission rate, the lower the risk.

CIRIA Report C665 (2007)[ii] advocates two methodologies for characterising sites:

**Situation A** – All developments except low rise housing. The advocated methodology is that proposed by Wilson & Card, 1999[iii].

**Situation B** – Low rise housing. An alternative ('traffic light') methodology, derived by Boyle and Witherington, 2006[iv] for the NHBC

Both methodologies refer to 'Gas Screening Values' (GSV) (previously known as limiting borehole gas volume flow).

*'Situation A' – All developments except low rise housing.*

Wilson & Card, (1999)[iii] revised Table 28 of CIRIA Report 149[v] in terms of a Gas Screening Value (GSV) based on the detected gas concentration and gas flow rate (l/hr) in order to achieve a more consistent design of protection measures. This was done to reflect the importance of recognising the gas surface emission rate.

Wilson & Card then developed a method for classifying gassing sites (Table 1 below), which took into account the combined gas concentration and GSV.

**Table 1 – Site Classification (Wilson & Card)**

| Characteristic Situation (Wilson & Card, 1999) | Gas Screening Value, CH4 or CO2 (l/hr) | Additional limiting factors | Typical source of generation |
|---|---|---|---|
| 1 | <0.07 | Methane not to exceed 1%v/v and carbon dioxide not to exceed 5%v/v | Natural soils with high organic content |
| 2 | <0.7 | Borehole air flow rate not to exceed >70ltr/hr otherwise increase to Characteristic Situation 3 | Natural soils with high peat/organic content |
| 3 | <3.5 | | Old landfill, inert waste, flooded mineworkings |
| 4 | <15 | Quantitative Risk Assessment required to evaluate scope of protection measures | Mineworkings susceptible to flooding, completed landfill, inert waste (WMP 26B criteria) |
| 5 | <70 | | Mineworkings, unflooded, inactive |
| 6 | >70 | | Recent landfill sites |

Notes:
Borehole flow rate = volume of gas (regardless of composition) which is escaping from well (l/hr).
Gas Screening Value (litre/hour) = gas concentration (%) / 100 x borehole flow rate (l/hr).
To facilitate design implementation, the limiting values for both methane and carbon dioxide are identical.

*'Situation B' – Low rise housing*.

The NHBC developed a characterisation system similar to that of Wilson & Card above, but specific to low-rise housing development (Boyle and Witherington[iv]) (see Table 2). This approach compares measured gas emission rates with generic risk-based "Traffic Lights". The Traffic Lights include "Typical Maximum Concentrations" of gas for initial screening, and risk-based Gas Screening Values (GSVs) for consideration of situations where the Typical Maximum Concentrations are exceeded. Calculations are carried out for both methane and carbon dioxide and the worse case adopted in order to establish the appropriate gas protection measures to be adopted within the low rise housing development.

**Table 2 - NHBC Traffic light system for 150 mm void (From CIRIA Report C665, Table 8.7)**

| Traffic light | Methane[1] | | Carbon dioxide[1] | |
|---|---|---|---|---|
| | Typical maximum concentration[5] (% v/v) | Gas screening value (GSV)[2,4,6] (litres per hour | Typical maximum concentration[5] (% v/v) | Gas screening value (GSV)[2,3,4,5] (litres per hour |
| Green | | | | |
| | 1 | **0.16** | 5 | **0.78** |
| Amber 1 | | | | |
| | 5 | **0.63** | 10 | **1.56** |
| Amber 2 | | | | |
| | 20 | **1.56** | 30 | **3.13** |
| Red | | | | |

**Notes:**

1. The **worst gas-regime** identified at the site, either methane or carbon dioxide, recorded from monitoring in the worst temporal conditions, will be the decider for which Traffic Light and GSV is allocated.
2. Generic GSVs are based on guidance contained within "The Building Regulations: Approved Document C" (2004) and assume a **sub-floor void** of 150 mm thickness.
3. The **small room** is considered to be a downstairs toilet, with dimensions of 1.50 × 1.50 × 2.50 m, with a soil pipe passing into the sub-floor void.
4. The **GSV**, in litres per hour, is as defined in Wilson and Card (1999) as the borehole flow rate multiplied by the concentration in the air stream of the particular gas being considered.
5. The Typical Maximum Concentrations can be exceeded in certain circumstances should the conceptual site model indicate it is safe to do so. This is where professional **judgment** will be required, based on a thorough understanding of the gas regime identified at the site where monitoring in the worst temporal conditions has occurred.
6. The GSV thresholds should not generally be exceeded without completion of a detailed gas risk assessment taking into account site-specific conditions.

## Type And Design Of Gas Protection Measures

BS 8485:2015[vi] gives recommendations on the choice of solutions for the design of integral gas protective measures for new buildings to prevent entry of carbon dioxide and methane to provide a safe internal environment.

BS 8485:2015 utilises 'Characteristic Gas Situations' (CS), as determined by the calculated Gas Screening Value (GSV) as presented in CIRIA Report C665 (Table 1 above). The appropriate CS for the site (or site zone) is used to determine the type and nature of gas protection systems within any given building utilising a **Gas Protection Score** – see Table 3.

**Table 3**
**Gas Protection Score By CS and Type of Building**
**(Modified from Table 4 of BS 8485:2015)**

| CS | Minimum Gas Protection Score High Risk | Medium Risk | | Low Risk |
|---|---|---|---|---|
| | Type A Building[1] | Type B Building[2] | Type C Building[3] | Type D Building[4] |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 3.5 | 3.5 | 2.5 | 1.5 |
| 3 | 4.5 | 4 | 3 | 2.5 |
| 4 | 6.5[A] | 5.5[A] | 4.5 | 3.5 |
| 5 | - [B] | 6.5[A] | 5.5 | 4.5 |
| 6 | - [B] | - [B] | 7.5 | 6.5 |

Notes:

| | |
|---|---|
| 1 | Private ownership with no structural management controls on alterations to the internal structure and use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms present. Probably conventional building construction (rather than civil engineering).Examples include private housing and some retail premises. |
| 2 | Private or commercial property with central building management control of any alterations to the building or its uses but limited or no central building management control of the maintenance of the building, including the gas protection measures. Multiple occupancy. Small to medium size rooms with passive ventilation of rooms and other internal spaces throughout ground floor and basement areas. May be conventional building or civil engineering construction. Examples include managed apartments, multiple occupancy offices, some retail premises and parts of some public buildings (such as schools, hospitals, leisure centres) and parts of hotels. |
| 3 | Commercial building with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, including the gas protection measures. Single occupancy of ground floor and basement areas. Small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas. Probably civil engineering construction. Examples include offices, some retail premises, and parts of some public buildings (such as schools, hospitals, leisure centres and parts of hotels). |
| 4 | Industrial style building having large volume internal space(s) that are well ventilated. Corporate ownership with building management controls on alterations to the ground floor and basement areas of the building and on maintenance of ground gas protective measures. Probably civil engineering construction. Examples are retail park sales buildings, factory shop floor areas, warehouses. (Small rooms within these style buildings should be separately categorised as Type B or Type C). |
| A | Residential buildings should not be built on CS4 or higher sites unless the type of construction or site circumstances allow additional levels of protection to be incorporated, e.g. high-performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system, e.g. in institutional and/or fully serviced contractual situations. |
| B | The gas hazard is too high for this empirical method to be used to define the gas protection measures. |

Having determined the minimum Gas Protection Score for the building, an element, or combination of elements, of gas protection should be chosen to achieve a combined score achieving the minimum level of recommended gas protection.

The elements of gas protection are essentially categories into three components each providing a corresponding score:

| | Score * |
|---|---|
| 1. Structural Barrier (floor slab or basement slab/walls) | 0 – 2.5 |
| 2. Sub Floor Ventilation Measures | 0.5 - 4.0 |
| 3. Gas Resistant Membrane | 2 |

* Scores vary depending on relative performance of differing systems or elements, as presented in Tables 5-7 of BS 8485:2015

## Site Characterisation Without Gas Monitoring

ALM would always advocate an appropriate programme of gas monitoring, undertaken in general accordance with CIRIA C665 (2007), specific to the nature of development proposed and identified gas sources and pathway. However, in some circumstances, gas monitoring may not be deemed appropriate or warranted, for example where only shallow materials possessing a low degradable content are present on site.

Annex D of BS 8485:2015 provides guidance for an empirical approach to characterizing sites without gas monitoring data where the source(s) of ground gas on the site is made ground with a low degradable organic content.

In this approach the representative gas regime (CS) is assigned based on:

- The conceptual site model, derived by updating the preliminary conceptual site model to take into account geological, hydrogeological and geotechnical data of an adequate ground investigation conducted to inform the design of the development.

- Knowledge of the Total Organic Carbon (TOC) content of potential ground gas generating made ground.

- A detailed examination of the made ground soil material.

This approach should be adopted with caution and should not be applied on its own to assess off-site sources or materials associated with waste disposal, and should only be used to define sites with very low to moderate hazard potential.

Table 4 below presents the limiting factors that are presented in BS 8485:2015 in assigning a Characteristic Gas Situation (CS) without gas monitoring.

**Table 4**
**Limiting Values of Thickness and Organic Content in Assigning a Characteristic Gas Situation Without Gas Monitoring (Adapted from Table D.1 BS 8584: 2015)**

| Thickness of Made Ground | Maximum Total Organic Carbon Content of Made Ground - TOC | | Site Characteristic Situation (CS) to be Assumed |
|---|---|---|---|
| | Made Ground in place for <20 years % | Made Ground in place for >20 years % | |
| Maximum 5m<br>Average <3m | ≤ 1.0 | ≤ 1.0 | CS1 |
| Maximum 5m<br>Average <3m | ≤ 1.5 | ≤ 3.0 | CS2 |
| Maximum 5m<br>Average <3m | ≤ 4.0 | ≤ 6.0 | CS3 |

Notes:
The above is for guidance only.
Gas monitoring would be required where TOC is greater than 4% (or 6% in old made ground).
ALM would always advocate gas monitoring where made ground is present at the thicknesses presented above.
ALM consider that where <1.0m of made ground is present the CS may be subject to revision due to the reduced potential for ground gas generation.

i CIRIA Report 151 (1995). Interpreting measurements of gas in the ground. Harries CR, Witherington PJ and McEntee JM

ii CIRIA Report C665 (2007), Assessing risks posed by hazardous ground gases to buildings.

iii Wilson SA and Card GB Reliability and Risk in Gas Protection Design. Ground Engineering, 32 **2** February 1999

iv Boyle & Witherington (2006) – Guidance on evaluation on development proposals on sites where methane and carbon dioxide are present, incorporating "traffic lights". Report Ref. 10627-R01-(02), for NHBC

v CIRIA Report 149 (1995). Protecting Development from Methane. Card GB

vi BS 8485:2015 Code of Practice for the Design of Protection Measures for Methane and Carbon Dioxide Ground Gases for New Buildings. British Standard Institution.

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# Generic Notes – ALM Geoenvironmental Investigations

## 06 - Soakaways

### Background

Soakaways have been the traditional way to dispose of storm water from buildings and paved areas from a public sewer or watercourse. In recent years, soakaways have been used within urban, fully-sewered areas, to limit the impact of discharge of new upstream developments and to avoid costs of sewer up-grading outside of a development.

Soakaways are seen increasingly as a more widely applicable option alongside other means of storm water control and disposal. Soakaways must store the immediate storm water run-off and allow its efficient infiltration into the soil. They must discharge their stored water sufficiently quickly to provide the necessary capacity to receive run-off from a subsequent storm. The time taken for discharge depends upon the soakaway shape and size, and the surrounding soil's infiltration characteristics. Soakaways can be constructed in many different forms and from a range of materials.

**BRE Digest 365: 1991** (revised 2007) describes design and construction procedures and explains how to calculate rainfall design values and soil infiltration rates. Further advice is provided in **NHBC Standards Chapter 5.3**.

Soakaways should generally be built on land lower than, or sloping away from, buildings and be sited at least 5m from the foundations of a building.

Made Ground (and ground within 5m of made ground) is not generally regarded as suitable for soakaways, due to potential for inundation settlement and the leaching of contaminants.

It should be noted that due to possible structural instability and modification of Chalk when wetted, CIRIA Report 11 'Foundations in Chalk' states that "Soakaways should be avoided it at all possible but, if unavoidable, should be sited at least 20m away from any structure".

### Test Methodology

ALM undertake in situ soakaway tests in general accordance with BRE Digest 365 'Soakaway Design'. The BRE Digest recommends that each soakaway pit is filled and allowed to drain three times to near empty; the three fillings to be on the same or consequent days. However, each test can take several hours to complete and therefore pits are often filled and allowed to drain on one occasion, due to time constraints imposed by the investigation.

Three fillings/drainage cycles are more important where drainage is primarily by fissures, most notably within a rock mass. Initial drainage within the rock mass may be high, as the fissures fill with water, giving the impression (if only one cycle is undertaken), that soakways would be suitable drainage solution. If infiltration though the matrix of the rock is low, the drainage from the test pit becomes slow as the fissures become saturated.

For non-fissile, granular soils, infiltration is via the soil matrix and, consequently, one filling/drainage cycle is generally considered sufficient.

Soakaway pits are typically excavated to a depth of ca. 2.5m using a mechanical excavator equipped with a 0.3-0.5m wide bucket.

The soakaway test pits are rapidly filled with water to the top of the test section. The fall in water level is then monitored at regular intervals.

**Infiltration Rates**

Infiltration rates for each soakaway test are calculated, where possible, in accordance with BRE Digest 365. This takes into account the time of emptying the soakaway pit between 25% and 75% of the effective depth. The effective depth is calculated from the starting water level to the soakaway pit base. Where the water level does not fall to 25% effective depth, the data may be extrapolated to obtain a representative infiltration rate.

**Soakaway Design**

Soakaway design is carried out in accordance with BRE Digest 365 using the infiltration rates calculated above; assuming a rainfall ratio of 0.39; and that each soakaway will have the capacity to handle storm water from an impermeable area of $100m^2$.

Two soakaway types can be designed using BRE Digest 365:

- Perforated concrete ring in a square pit with granular backfill (chamber type)
- Trench with granular backfill (trench type)

The design for the perforated ring type soakaway assumes that the chamber comprises a permeable 900mm internal diameter 'hollow' chamber set in a square pit with granular material around the chamber possessing a void space of 30%.

The design for the trench type soakaway assumes that the trench is 600mm wide filled with granular material, possessing a void space of 30%.

It is generally assumed that the soakaways become impracticable on residential developments when:

- The chamber type design requires a square pit with a side length in excess of 1.8m, or an effective depth greater than 1.5m.
- The trench type design requires a length greater than about 10m, or an effective depth greater than 1.5m.

Increasing the soakaway effective depth might be a solution, but consideration should be given to:

- The standing groundwater level.
- The depth to base of permeable strata.
- Cost of excavation.

Soakaway percolation in some rock types is predominantly via the vertical joints within the rock mass. The relatively small-scale soakaway test pits may not intercept such joints and this can result in variable test results. As such, considerable caution should be adopted when assessing in situ soakaway tests within rock strata.