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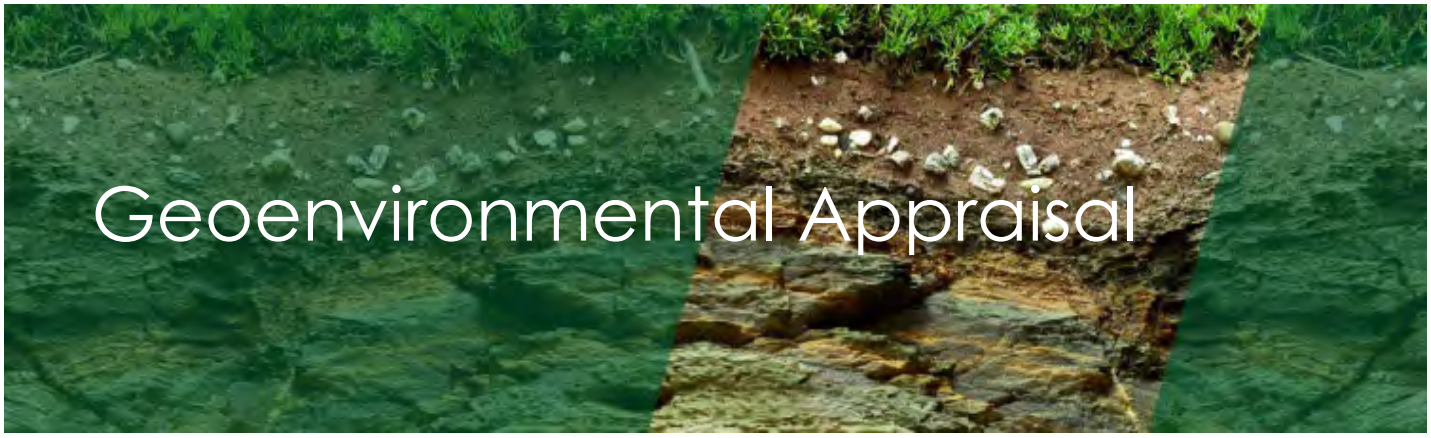

Geoenvironmental Appraisal

Land at Cudworth Parkway, Barnsley

For Fenwood Estates Limited

Report no: 4674/1

Date: June 2024

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SUMMARY OF GEOENVIRONMENTAL ISSUES

Job No.	4674	**Site area/ha**	6.2
Client:	Fenwood Estates Limited	**NGR:**	SE 390 103
Site:	Cudworth Parkway, Barnsley	**Nearest postcode:**	S72 8FG

The site is located off the A628 (Cudworth Parkway), approximately 6km northeast of Barnsley town centre, and currently comprises agricultural grassland in the west with dense trees/vegetation in the centre and east. The centre has previously been occupied by houses and allotments, with a former sandstone quarry in the east which was used as a landfill between 1947 and 1984. The west of the site has remained undeveloped throughout history.

Lithos were commissioned by Fenwood Estates to provide a geoenvironmental appraisal of the site, which it is understood is to be redeveloped with two storey domestic dwellings, associated gardens, community orchard, POS, adoptable roads and sewers. Lithos' investigation included a review of the site's history and environmental setting, and a ground investigation comprising 49 trial pits (with soakaway testing in 8 pits), 15 trial trenches, 19 rotary openhole probeholes, 15 window sample boreholes and 3 rotary cored boreholes.

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

Issue	Remarks
Made ground	Made Ground Topsoil is present in the centre to c. 0.3m depth. Deep made ground is present in the east within a backfilled quarry and predominantly comprises Cohesive and Granular Made Ground (clay/gravel of mixed lithologies with cobbles and boulders) with lesser amounts of Ash & Clinker, Quarry Waste and Landfill Material. The base of the quarry has been identified at between 1.6m and 5.2m depth (average 3.1m).
Natural ground	Natural ground typically comprises Topsoil (east only) over Cohesive Residual Soil (firm/stiff clay) and Granular Residual Soil (sand/gravel). Sandstone bedrock is present across the area at shallow depth (<2.5m).
Contamination	Testing suggests the Topsoil in Area A is suitable for re-use. Made Ground Topsoil in Area B is not suitable for reuse in gardens and therefore should be stripped, stockpiled separately from the "clean" Topsoil in Area A, and redistributed in areas of POS or as the lowermost 150mm of cover in proposed garden areas in Area C. Where any residual made ground remains in Area B beneath garden and landscaped areas (i.e. not beneath hardstanding), a 450mm thick surface cover of "clean" soil is recommended. Within Area C a cover layer should be placed comprising: • a minimum 600mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 750mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base in garden areas and community orchard areas (750mm in total) • a minimum 300mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 450mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base in landscaped areas (450mm in total) The Landfill Material encountered in the northeast of Area C has yielded significantly elevated concentrations of a number of inorganic determinands and is therefore not considered suitable for retention on site. Consequently, this material should be delineated by excavation, stockpiled separately from other material types and disposed of off-site.
Mining	The far northeast corner of the site is recorded to be underlain by the Shafton Coal although it is understood no development is proposed in this area. The majority of the site is underlain at depth by sandstone bedrock and the shallowest coal seam (Royston Coal, 0.8m thick) is anticipated to lie at c. 20m depth in the far west (although no mining has been recorded in this seam). Whilst the site lies within a Coal Authority Low Risk area, no significant risks have been identified, and an intrusive mining investigation will not be required.
Quarrying	A former sandstone quarry is recorded in the east of the site which was shown to be disused in 1962. The quarry was subsequently used as a landfill accepting waste until 1984. Lithos' quarrying investigation found the extent of the quarry to be similar to that recorded on the 1962 OS map (see Drawing 4674/8). The base of the quarry has been found to be between 1.6m and 5.2m deep (average 3.1m). The majority of "highwalls" encountered have been within the residual soil with only localised highwalls observed within bedrock which are generally of a shallow gradient (<25°). The depth to bedrock is typically similar (within c. 1m) both inside and outside the quarry. It appears the quarry mainly extracted the residual soil (sand/gravel) with only the uppermost c. 1m of sandstone removed.

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Job No.	4674	**Site area/ha**	6.2
Client:	Fenwood Estates Limited	**NGR:**	SE 390 103
Site:	Cudworth Parkway, Barnsley	**Nearest postcode:**	S72 8FG

Issue	Remarks
Hazardous gas	The site is in an area where less between 1% and 3% of homes are estimated to be above the radon action level. Therefore, basic radon protection measures are not required in new dwellings. Given the east of the site is underlain by a significant thickness of made ground, gas monitoring is currently underway to determine the need for special precautions against methane / carbon dioxide gas in new plots.
Preparatory works	General site clearance of vegetation and surface materials. Topsoil strip in Area A and stockpile for re-use. Strip of Made Ground Topsoil in Area B and separate stockpiling for re-use in POS. Turnover of full thickness of made ground in Area C with off-site disposal of unsuitable materials followed by processing and engineering in to an End Product specification.
Foundations	New plots constructed in the centre and west of the site will be founded on traditional strip/trench-fill foundations in residual soils or bedrock, deepened where necessary due to tree influence. Plots constructed in the east over the backfilled quarry will be founded on either rafts/stiffened strips on engineered fill or piles embedded in sandstone bedrock.
Groundwater & excavations	Groundwater is unlikely to be encountered at shallow depth (<1m) and has typically been recorded at greater than 2m depth in monitoring wells. Excavations in the centre and west should remain stable in the short term but if left open for any significant period of time may require shoring most notably in granular soils and localised made ground. The stability of even shallow excavations in made ground is likely to be poor (within the former quarry), and therefore allowance should be made for shoring in this area. Bedrock was encountered in the majority of the exploratory holes, especially beyond the backfilled quarry. Based on the exploratory hole logs, excavation greater than 2.5m is likely to prove difficult across about 65% of the site (beyond quarry). It would therefore be prudent to allow for excavation/ripping of hard rock in any deep excavations such as those that may be required for drainage etc.
Flooding & drainage	The majority of the site lies in Flood Zone 1, where the risk of flooding from rivers or the sea is classified as low. However, the east of the site lies in Flood Zone 2, where the risk of flooding is classified as moderate. Given the significant thicknesses of made ground encountered in the east, on-site soakaway construction in this area will be highly problematic. It should be noted that soakaways cannot be allowed to infiltrate into made ground due to the risk of settlement caused by wash out of fine soil particles. However, in the centre and west of the site where sandstone bedrock is present, soakaways constructed in natural granular soils or weathered bedrock might provide a suitable drainage solution for surface water run-off at this site. However, CIRIA C753 states that: "A minimum distance of 1m between the base of the infiltration system and the maximum likely groundwater level should always be adopted.
Highways	Based on visual inspection of the shallow natural materials in the centre and west, and published guidance, the Residual Soils should provide a CBR value of at least 3%. This value should be verified prior to or during construction. However, made ground is present across the east of the site, typically to depths of around 3m, and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended. Where made ground is present it should be excavated and either replaced with suitable aggregate, or screened, to allow selection of suitable material, before being replaced in engineered layers. Where the made ground is re-engineered it is considered that a CBR value of at least 3% should be achievable. However, this should be verified by field trials.

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

- Ground improvement – turnover of the full thickness of made ground in the former quarry in order to deal with contamination, remove buried obstructions and prepare the ground for plot/highway construction.

Some further work is required, most notably:

- Preparation of a Remediation Strategy and Earthworks Specification

CONTENTS

APPENDICES

Appendix A - General notes

01	Environmental setting
02	Ground investigation fieldwork
03	Geotechnical testing
04	Contamination laboratory analysis & interpretation
05	Hazardous gas
06	Soakaways

Appendix B - Drawings

Drawing	Revision	Title
4674/1	-	Site Location Plan Poss
4674/2	-	Proposed Layout
4674/3	-	Site Features
4674/4	-	Site Photographs
4674/5	-	Preliminary Conceptual Site Model
4674/6	-	Exploratory Hole Locations
4674/7	-	Revised Conceptual Site Model
4674/8	-	Site Geology & Mining
4674/9	-	Sandstone Quarry Investigation Findings
4674/10	-	Indicative Remediation Requirements
4674/11	-	Indicative Foundation Zoning Plan

Appendix C - Commission

Appendix D - Historical OS plans#

Appendix E - Search Responses and other Correspondence#

From	Date	Content
Landmark	18th December 2023	Environmental search data
Coal Authority	18th December 2023	Mining report
Environment Agency	30th January 2024	Environmental search data
BGS Radon Report	31st May 2024	Radon classification

Appendix F to J - Exploratory records

Appendix F	TP01 to TP49
Appendix G	TT01 to TT15
Appendix H	WS01 to WS15
Appendix I	PH01 to PH19
Appendix J	RC01 to RC03

Appendix K - Soakaway calculation sheets

Appendix L - Chemical test results

Appendix M - Geotechnical test results

Appendix N - Gas monitoring results

Some of this data is not included within the paper or PDF copies of this report but can be provided on request.

FOREWORD (GEOENVIRONMENTAL APPRAISAL REPORT)

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 Lithos Consulting Limited (Lithos); 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.

This report has been reviewed by a Competent Person, as defined in the National Planning Policy Framework. We ensure that all projects are managed by individuals with necessary experience, relevant qualifications, and current membership of a relevant professional organisation. Records of engineers, project managers and reviewers involved in this project are maintained by us. Lithos QA/QC procedures for all our work forms an integral part of our ISO9001 accreditation and as such is regularly audited.

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 Lithos prior to significant revision of the development proposals.

The report should be read in its entirety, including all associated drawings and appendices. Lithos cannot be held responsible for any misinterpretations arising from the use of extracts that are taken out of context. However, it should be noted that in order to keep the number of pages to a minimum, some information (e.g. full copy of the Landmark/Groundsure Report) is not included in the PDF; by request it can be provided.

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 Lithos believes are reliable. Reasonable care and skill has been applied in examining the information obtained. Nevertheless, Lithos cannot and does not guarantee the authenticity or reliability of the information it has relied upon.

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 Lithos, 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.

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

The report represents the findings and opinions of experienced geoenvironmental consultants. Lithos does not provide legal advice and the advice of lawyers may also be required.

Lithos standard terms and conditions apply to the report, a copy of the terms and conditions is available on request or can be found with our proposal in Appendix C.

GEOENVIRONMENTAL APPRAISAL
of land at
CUDWORTH PARKWAY, BARNSLEY

1 INTRODUCTION

1.1 The commission and brief

1.1.1 Lithos Consulting Limited were commissioned by Fenwood Estates Limited to carry out a geoenvironmental appraisal of land off Cudworth Parkway, Barnsley.

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

- A site walkover and inspection
- An assessment of the land use history
- Determination of the site's environmental setting
- A mining risk assessment in accordance with Coal Authority guidance
- An intrusive ground investigation comprising 49 trial pits (with soakaway testing in 8 pits), 15 trial trenches, 19 rotary openhole probeholes, 15 window sample boreholes and 3 rotary cored boreholes
- Assessment of the geotechnical properties of the near surface deposits to enable provision of foundation and highway recommendations
- A qualitative assessment of contamination risks
- Recommendations for the necessary site preparatory and remediation works

1.1.3 Primary aims of this investigation were to identify salient geoenvironmental issues affecting the site to support the submission of a planning application, and also to enable Fenwood Estates to obtain budget costs for: foundations; gas protection measures; and site preparatory and remediation works.

1.1.4 Supplementary investigation to satisfy the Local Planning Authority, develop a Remediation Strategy and enable refinement of budget abnormals is anticipated.

1.2 The proposed development

1.2.1 It is understood that consideration is being given to redevelopment of the site with two storey domestic dwellings, associated gardens, community orchard, POS, adoptable roads and sewers.

1.2.2 A site layout has been provided by Fenwood Estates (Drawing reference 22-04-001-01-02, dated 14th February 2023) which is reproduced as Drawing 4674/2 in Appendix B to this report. However, it is understood the layout is to be revised in light of the findings of this investigation.

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
- Geotechnical testing
- Contamination testing
- Hazardous gas

- Soakaways

1.3.2 General notes and limitations relevant to all Lithos 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.

1.3.3 In accordance with the agreed scope of works, the ground investigation reported here is not fully compliant with Eurocode 7 (EC7) and this report does not purport to be a Ground Investigation Report, nor a Geotechnical Design Report as defined by EC7. The ground appraisal, parametric assessment and preliminary design guidance presented are intended to assist others as they prepare the design of the proposed works.

2 SITE DESCRIPTION

2.1 General

2.1.1 The site's location is shown on Drawing 4674/1 presented in Appendix B to this report. Site details are summarised in the table below.

Detail	Remarks
Location	6 km northeast of Barnsley town centre
NGR	SE 390 103
Approximate area	6.2ha (15.3 acres)
Known services	Underground electric, gas, fibre optic & water Overhead telecom

2.2 Site features

2.2.1 Lithos completed a walkover survey of the site on 4th January 2024.

2.2.2 Existing salient features, at the time of the walkover are presented on Drawing 4674/3 in Appendix B to this report and summarised in the table below. A selection of site photographs is included on Drawing 4674/4.

Feature	Remarks
Current access	Off A628 (Cudworth Parkway) in the northeast or Three Nooks Lane in the south
Topography	Land slopes gently (c. 1 in 15) towards the north Steep slope (c. 1 in 3) immediately beyond the northwest boundary with land falling towards the A628 to the northwest
Approximate areas	33,000m^2 dense vegetation 26,700m^2 grass 2,400m^2 tarmac hardstand
Nature of boundaries	North & east – dry stone walls South – no physical boundary West - post & rail fence, dense vegetation
Surrounding land uses	North & east – Cudworth Parkway (A628) with housing and fields beyond South – housing and allotments West – Cudworth Parkway (A628) with arable farmland beyond

2.2.3 The site can be accessed via locked gates off Three Nooks Lane in the south or from Cudworth Parkway (A628) in the northwest and currently comprises agricultural grassland in the west with dense trees/vegetation in the centre and east.

2.2.4 A short tarmac track slopes up from a roundabout on the A628 beyond the northwest boundary into the westernmost field which appears to be used for silage, along with a smaller field to the east of the bridleway. Trodden footpaths are present along the perimeters of these fields with dog walkers noted during the walkover. The field boundaries are marked by timber fences with semi-mature trees/hedgerows.

2.2.5 The centre and east of the site are heavily overgrown with dense brambles, bushes and semi-mature trees, with dense trees and vegetation present along the north adjacent to Cudworth Parkway. Areas of rough grass are present in the centre and south with sporadic bushes/trees present.

2.2.6 A public bridleway (tarmac track) runs north-south through the centre from Three Nooks Lane towards the A628, before turning east and crossing the north of the site roughly parallel to the A628. Pedestrian access points to the bridle way are present in the south, north and far east of the site.

2.2.7 An overhead telecom cable on wooden telegraph poles runs north-south along the bridleway.

3 SITE HISTORY

3.1 Site centred extracts from Ordnance Survey (OS) plans dating back to 1854 have been examined. Some of these plans are presented in Appendix D to this report.

3.2 The table below provides a summary of the salient points relating to the history of the site. 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.

Date	Site	Surrounding land
1854	**West Shaw Lane** crosses the north trending approx. east-west and **Three Nooks Lane** crosses the west trending approx. north-south Open fields beyond the roads	Open fields in all directions Bind Hole (old quarry – sandstone) recorded 250m east Shafton village 700m north **Shafton Colliery** 750m northeast
1893	**West Shaw Houses** in the centre north adjacent to West Shaw Lane **Old quarry** shown in the centre south	Housing 70m east
1894	No significant changes	Shafton Colliery no longer shown
1906	Footprint of old quarry in the south changed slightly **Allotment Gardens** shown in the centre **Brickworks** buildings shown in the far north with associated **Marl Pit** spanning northern boundary	**Crane** immediately south adjacent to old quarry **Sand Pit** 10m south Timber Yard 70m south Housing from 100m south
1917	**Quarry** appears to be active with a larger footprint **Chimney** shown in the far north associated with the brickworks	Significant expansion of residential area to the south Slight expansion of pit associated with the brickworks to the north Sand pit to the south no longer shown
1933	Further **expansion** of quarry across the centre of the site Brickworks in the north no longer present with a possible **spoil heap/tip** in its place	Allotment gardens immediately southeast and southwest, and 100m northeast Slight expansion of residential area to the east
1948	No significant changes	No significant changes
1962	Quarry shown to be **disused**	**Spoil heap** shown immediately north Timber yard to the south no longer labelled

Date	Site	Surrounding land
	Allotment gardens reduced in size with small building and an access track shown in the centre	
1977	West Shaw Houses in the centre north no longer present Allotments and small buildings now shown in the centre south	Spoil heap to the north labelled playing fields Further housing shown immediately southeast Allotment gardens to the northeast replaced by housing Builder's Yard immediately southeast
1993	No significant changes	No significant changes
2006		Expansion of residential area to the north and southeast
2023	Footprint of former quarry no longer shown and labelled as '**Workings**' Allotment gardens in the south no longer shown Path crosses the centre of the site	Cudworth Parkway immediately beyond north and west boundaries Further expansion of residential area to the north

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. Reference has been made to publicly available Government held digital data via QGIS (an Open Source Geographic Information System). Extracts from the response received from Landmark, and responses from the Coal Authority and the Environment Agency are presented in Appendix E. These responses are summarised below, together with the findings of our own "desk study" investigation.

Issue	Data reviewed	Summary
Geology	1:50,000 BGS map (Sheet 87) 1:10,000 BGS map (Sheet SE31SE) BGS Sheet 87 Explanation	Drift soils – None mapped although Made Ground (colliery spoil tips, embankments and landfill sites) shown in the centre. Solid (bedrock) – predominantly Mexborough Rock (sandstone) with Pennine Lower Coal Measures (mudstone, siltstone & sandstone) in the far east. Shallowest coal seam – Shafton Coal outcrops in the east dipping northeast. Further details in Section 5 below. Strata dip – c. 6° to the northeast. Faults – northeast-southwest trending fault crosses the far southeast.
Mining	Coal Authority	The centre and east of this site are located within a Coal Mining Development High Risk Area. Further details in Section 5 below.
Quarrying	Historical OS plans	Quarry shown on site from 1892 until 1962.
Landfills	Envirocheck Report	Further details in Section 4.2.
Radon	UK Health Security Agency	The site lies in an area where 3% to 5% of homes are estimated to be above the action level. Further details in Section 13.
Hydrogeology	Environment Agency electronic open data via QGIS Envirocheck Report	Groundwater Source Protection Zone? No. Aquifer. Secondary A (Solid). Groundwater abstractions? None within 1km. Soil leaching potential - High. Pollution incidents? None recorded within 500m.
Hydrology		Nearest watercourse(s) – unnamed stream/drain 40m north flowing northwest. Water quality – Located within Cudworth Dyke from Source to River Dearne catchment area currently achieving poor ecological status. Pollution incidents? Category 3 (minor) incident recorded 35m south with oils (waste oil) entering unnamed freshwater stream. Abstractions? None within 1km. Discharge consents? Consent on site with sewage discharges (final/treated) entering the land via a soakaway.
Flood risk		The east of the site lies in Flood Zone 2, where the risk of flooding from rivers or the sea is classified as moderate. The remaining site are lies within Flood Zone 1 where the risk is low. In accordance with Chapter 14 of the National Planning Policy Framework, a site-specific flood risk assessment is required for new development in Flood Zones 2 and 3.

4.2 Landfills

4.2.1 Known or suspected areas of landfill in the vicinity of the proposed development site are summarised below:

Location	NGR (proximity to site)	Remarks	Source of data
Quarry off Weetshaw Lane	SE 391 103 (centre of site)	Licenced landfill operated between 1947 and 1984 accepting inert and commercial waste, including construction/demolition wastes and excavated natural materials. Currently occupied by rough grass and dense vegetation/trees	EA electronic open data via QGIS* Envirocheck Report Environment Agency OS plans
Weetshaw Lane	SE 390 104 (spans northern boundary)	Dates of operation and accepted waste types unknown. Currently occupied by trees/dense vegetation, POS and the A628 (Cudworth Parkway)	

* QGIS is an Open Source Geographic Information System.

4.2.2 Enquiries were made of Barnsley Metropolitan Borough Council (BMBC) with regards to the recorded landfills although no response was received.

4.2.3 Given the likely presence of deep made ground on and immediately adjacent to the site, gas monitoring and risk assessment is proposed (see Section 13) to determine the need for protection measures in new dwellings.

4.3 Potential issues associated with historic landfill

4.3.1 Both quarries present on the site are recorded as historic landfill. The presence of recorded historic landfills may have implications for preparatory earthworks. If the landfilled material was placed under a Waste Management License (or similar) it cannot be retained and re-used in accordance with the CL:AIRE Code of Practice because the Environment Agency have indicated they would consider such material waste, irrespective of its suitability for reuse. It is likely the EA would require a recovery of waste permit (or similar) to control reuse; application for such a permit would have both financial and time implications and approval is by no means certain.

4.3.2 It is worth noting that the description of these sites as **historic landfill** is the reason re-use on site is more problematic than it would be on a 'traditional' Brownfield site which contains made ground. This is because the EA indicate that where material has been placed in any landfill, the material has clearly being discarded and is therefore waste, irrespective of age. Lithos do not agree with this stance and as such could discuss with the EA.

4.3.3 An alternative option might be to send the excavated material to a permitted treatment facility regulated under the Environmental Permitting regime where it could be processed/treated and returned to the site for use. Further advice on this should be sought from an appropriately qualified and experienced earthworks contractor.

4.3.4 The nature of the landfilled material is a critical factor; if it is essentially inert and suitable for retention / re-use (it could reasonably be considered not to be waste), however if it contains a significant proportion of putrescible / degradable matter or material that could be classified as hazardous waste (road planings, asbestos, plaster board etc) it is clearly not suitable for re-use, in which case it would still be considered waste.

5 MINERAL EXTRACTION

5.1 Coal & mining

5.1.1 In July 2011 the Coal Authority (CA) formalised their requirements in relation to planning applications and introduced some new terminology relating to coal mining development areas. This Section (and Section 15.2) provides the necessary mining risk assessment required by the proposed planning application.

5.1.2 Geological maps suggest that the Shafton Coal (c. 1.6m thick) outcrops in the northeast corner dipping northeast. Given dip and topography, this seam is expected to underlie an area of approximately 0.4 hectares in the far northeast.

5.1.3 In addition to the above, the Royston Coal (c. 0.8m thick) and Sharlston Top Coal (c. 1.0m thick) underlie the west of the site at approximately 20m and 30m depth respectively. The BGS sheet explanation[1] for the 1:50,000 geological map indicates the Royston Coal has not been worked and the Sharlston Top Coal has only been extracted via opencast.

5.1.4 Approximate outcrops are shown on Drawing 4674/8. It should be noted that seam outcrops plotted on geological maps have been known to be inaccurate by distances in excess of 100m.

5.1.5 The south and east of the site are located within a Coal Mining Development **High Risk Area** - an area with specific mining legacy risks to the surface, including mine entries; shallow coal workings etc).

5.1.6 However, the Coal Authority indicates the High Risk Area in the south is due to the presence of a shallow, workable coal seam outcropping across the site roughly northeast-southwest. This conflicts with the geological maps which show all coal outcrops in the local area trending northwest-southeast.

5.1.7 Consequently, enquiries were made with the Coal Authority (included in Appendix E) to clarify the discrepancy between BGS recorded geology and the Coal Authority's recorded coal outcrop. It was determined that this was an error on the CA's mapping system and the High Risk Area is isolated to land in the northeast where the Shafton Coal is conjectured to outcrop.

5.1.8 A CA mining report states that:

- Mineworkings are recorded beneath the site at between 265m and 748m depth, the shallowest being in the Winter Coal last worked in 1957.
- There are probable unrecorded shallow workings beneath the site. *This is associated with the Shafton Coal in the far northeast.*
- There are no recorded spine roadways at shallow depth.
- There are no recorded mine entries within 100m of the site.
- An area of opencast mining is recorded 100m south.
- There are no damage notices or claims for mining subsidence on or within 50m of the site.
- There are no recorded of mine gas within 500m.

5.1.9 The table below summarises the potential risks associated with coal mining legacy issues at this site.

Coal mining issue	Yes	No	Remarks
Underground coal mining (recorded at shallow depths)		X	

[1] *Geology of the Barnsley District: a brief explanation of the geological map sheet 87 Barnsley (2007).*

Coal mining issue	Yes	No	Remarks
Underground coal mining (probable at shallow depths)	X		In the far northeast only (Shafton Coal)
Mine entries (shafts and adits)		X	
Coal mining geology (fissures)		X	
Record of past mine gas emissions or potential	X		
Recorded coal mining surface hazard		X	
Surface mining (opencast workings)		X	

5.1.10 For those issues identified as "yes" in the above table, a more detailed discussion and assessment of the risks, both individually and cumulatively, to the application site and the proposed development is provided below.

5.1.11 Risks include:

- Mines gas
- Combustion
- Collapse of shallow mineworkings, with consequent subsidence affecting surface stability

5.1.12 Current UK guidance, CIRIA C758D[2], provides information and guidance for engineers and geologists with respect to the design of: mining investigations; foundations; and remedial measures.

Mining risks – gas

5.1.13 Gas monitoring and a hazardous gas risk assessment will be required and is proposed (see Section 13).

Mining risks – combustion

5.1.14 Where coal is exposed during any site preparatory earthworks, or within excavations, care should be taken to avoid the potential for spontaneous coal combustion.

5.1.15 If any foundation excavation comes into contact with coal, the foundation should be taken through the coal seam, into underlying natural in-situ strata of adequate bearing. The full thickness of coal should then be sealed with mass concrete fill placed as soon as possible after exposing the seam to prevent the ingress of air.

5.1.16 Any ground investigation and\or drilling for grouting purposes should be carried out to HSE and Coal Authority guidelines to minimise the risk of coal combustion and potential for migration of mine gases into neighbouring properties.

Mining risks – shallow underground mineworkings

5.1.17 Mineworkings which could affect surface stability are probably present beneath the far northeast of the site, although as noted in Section 5.1.8 above, there are **no recorded** mineworkings. Additionally, at this stage it is understood no development will take place in this area.

5.1.18 The Shafton Coal would likely have been extracted via bell pits and/or pillar and stall methods, and if present these could result in unpredictable subsidence.

5.1.19 Individual pillars may collapse at any time, leading to settlement in the overlying strata. As the mine roof degrades and collapse the void migrates upwards, sometimes causing a surface collapse or crown hole.

[2] *CIRIA C758D:2019. Abandoned mine workings manual*

5.1.20 The vertical distance through which a void can migrate is difficult to assess. Made ground and superficial deposits are considered to have no inherent strength and the assumption is generally made that if a void reaches the base of these formations, it will reach the surface.

5.1.21 CIRIA C758D notes that given the limited evidence of structural damage caused by pillar failure, compared with that resulting from roof collapses, engineering assessment of the potential for surface instability has focused on the latter. Failure of roof strata results in the progressive transmission of the void upwards through overlying rock. The extent of 'void migration' can be influenced by factors such as: strata dip; bulking characteristics of the collapsed rock or soil; capability for arching of the collapsed zone; groundwater flow and the presence of strong and intact rock layers with the ability to span that may attenuate the upward movement.

5.1.22 The limit height on the void migration, where no appreciable surface subsidence results, is often termed 'acceptable cover', with its determination based upon a criterion reflecting the worked thickness of the seam and the rock cover. The acceptable cover criterion is generally represented as ht, where 'h' is the thickness of rock above the workings expressed as a multiple of t, the worked thickness. This has been a popular approach because the two elements can be reasonably well determined via conventional ground investigation.

5.1.23 Most evaluations of required bedrock cover come from the examination of Coal Measures mines. In these, it has been observed that the height of migration in bedrock might, exceptionally, extend to 10 times the height of the original extraction. Consequently, the 10t criterion has, for over 30 years, been adopted by the industry as providing reasonable assurance against surface subsidence resultant from roof collapse in old, room and pillar mines. However, collapses might attenuate within a lesser cover and there will be circumstances where using the 10t criterion could be considered overly conservative.

5.1.24 That said, a Coal Authority Technical Guidance Note[3] which describes a subsidence event that affected a number of properties on a housing estate in north-east England in 2016, concluded that the 10 times rock cover guidance is only a 'rule of thumb' for crown hole collapses. Other subsidence mechanisms can occur, such as pillar failure, for which the 10 times rock cover rule of thumb is not an appropriate guide.

5.1.25 Should **any** developed be proposed in areas underlain by possible shallow mineworkings, mitigation of the risks posed may be required, and this could be achieved in one of two ways:

- Extraction of the remaining coal
- Consolidation, via drilling & grouting

5.1.26 Alternatively, the proposed development layout could be designed with areas of Public Open Space (as is the currently the case) in the northeast to avoid construction in this area.

5.2 Mexborough Rock

5.2.1 Geological maps suggest the Mexborough Rock, a major sandstone unit within the Pennine Middle Coal Measures, underlies the majority of the site (see Drawing 4674/8). The BGS sheet explanation[4] for the 1:50,000 geological map indicates the unit is up to 56m thick and has been quarried in the region for building stone.

5.2.2 Examination of historical mapping (see Section 3) shows that a large quarry formerly covered c. 9,500m^2 in the centre of the site, as shown on Drawing 4674/8.

[3] *Coal Authority, TGN01/2019. Findings from a large subsidence event on a residential estate.*

[4] *Geology of the Barnsley District: a brief explanation of the geological map sheet 87 Barnsley (2007).*

5.2.3 It is understood that on completion of the quarrying, the excavation was used as a landfill (see Section 4.2) with construction/demolition waste and excavated natural materials used to backfill the former quarry.

Potential issues associated with deep quarry backfill

5.2.4 At this stage, and subject to the findings of an intrusive ground investigation it is considered likely that the presence of deep quarry backfill beneath this site will have implications for:

- Foundations – likely possibly rafts/reinforced strips following ground improvement; possibly piled if backfill is less than c. 10m thick.
- Drainage – likely need for placement at maximum possible gradients using flexible connections to prevent any backfalls should differential settlement of the fill occur. Potential need for piling of manholes.
- New utilities – should be constructed of flexible materials. Electricity and communications cabling should also be laid with sufficient 'slack' to accommodate a degree of movement. The use of flexible joints is recommended where possible, particularly where service connections extend across a rigid/flexible structure interface (e.g. from a piled foundation into a garden area).
- Highways - a specification will need to be agreed with the adopting authority, but reinforcement of the road construction over highwalls will probably be required.

5.2.5 Geotechnical characteristics of quarry backfill are typically related to the nature of the excavated overburden, how it becomes mixed, how it is placed, and any compaction applied.

5.2.6 All quarry backfill is subject to some settlement caused by self-weight which is partly governed by initial thickness. The characteristics of each backfill will be unique and its potential capabilities, at the time of development, depend on many factors.

5.2.7 The foundation solution should allow for the consequences of recovery of internal groundwater levels within the quarry backfill. Precautions may also be required to avoid detrimental effects from surface water infiltration. The location and detailing of drains and other trenches, and the provision of hardstanding aprons, requires attention to prevent extraneous waters deteriorating the fill.

5.2.8 If piled foundations are adopted for plots underlain by quarry backfill there should be a reduced need for further significant geotechnical analysis / modelling, although specialist piling contractors will require more data (i.e. cable percussion boreholes, possibly with rotary core follow-on).

5.2.9 Conversely, if reinforced strips (or rafts) are preferred, significant further investigation and assessment will be required. This should commence with a review of the data obtained during this investigation, and case study data relating to other deep backfill sites, to enable preliminary estimates of anticipated settlement.

High walls

5.2.10 It is generally considered wise not to build over high walls and such areas are usually reserved for non-critical uses such as landscaping. Utility routes in the vicinity of high walls need careful selection.

5.2.11 However, building in the crest region might be possible if split foundation types are used to reach undisturbed natural ground.

5.2.12 It will be necessary to ensure the construction of a reliable rock socket at the high wall. This could be problematic if there are concerns about slope strata integrity (which can occur where a fault has determined the extraction boundary).

5.2.13 Furthermore, if there are unrecorded workings in the sandstone that was extracted, these could influence surface stability in the vicinity of the highwall.

5.2.14 Away from the crest, and over the buried slope, it should be expected that shallow foundations on quarry backfill will tilt due to differential settlement. The zone of potential unacceptably large tilt of foundations will be dependent upon:

- the angle of the opencast slope
- depth below development level at which the crest is buried
- depth below development level to the toe of the slope
- the mass modulus of the fill/made ground

5.3 Mineral safeguarded areas

5.3.1 The site is underlain by **sandstone** and **coal** and might therefore be considered by the Local Authority to lie within a Mineral Safeguarding Area (MSA).

5.3.2 MSAs are areas of known mineral resources that are of sufficient economic or conservation value to warrant protection for generations to come. The purpose of MSAs is not to preclude automatically other forms of development, but to make sure that mineral resources are adequately and effectively considered in land-use planning decisions.

5.3.3 Specialist guidance on Mineral Safeguarding "A Guide to Mineral Safeguarding in England" has been produced by The Coal Authority and the British Geological Survey.

5.3.4 Chapter 17 of the National Planning Policy Framework (NPPF) requires Local Authorities to facilitate the sustainable use of minerals, and planning policies should:

- Safeguard mineral resources by defining Mineral Safeguarding Areas and Mineral Consultation Areas; and adopt appropriate policies so that known locations of specific minerals resources of local and national importance are not sterilised by non-mineral development where this should be avoided (whilst not creating a presumption that the resources defined will be worked.
- Set out policies to encourage the prior extraction of minerals, where practicable and environmentally feasible, if it is necessary for non-mineral development to take place.

5.3.5 NPPF Chapter 17 notes that when determining planning applications, local planning authorities should give great weight to the benefits of the mineral extraction.

5.3.6 As a consequence of the NPPF, and the presence of sandstone and coal beneath the site, the Local Authority may require Fenwood Estates to consider the opportunity to recover (extract) the sandstone and/or coal. Applicants submitting planning applications may need to demonstrate to the Local Authority that they will extract the sandstone and/or coal, unless:

- It can be shown it is not economically viable to do so, or
- It is not environmentally acceptable to do so, or
- The need for the development outweighs the need to extract the coal, or
- The coal will not be sterilised by the development

5.4 Agriculture

5.4.1 Historical plans show that the west of the site has been occupied by arable farmland. Generally farming is not considered likely to have caused significant ground contamination. However, activities such as slurry spreading, the discharge of chemicals to ground, and unregulated burial are known to have occurred on farmland. Potential contaminants associated with farming activity could include any of the following.

Agricultural activity	Potential contaminant
Sewage farming, slurry spreading	Methane, metals, nitrates, oxygen depletion
Tracks (if built up with crushed demolition rubble etc)	Metals, asbestos, hydrocarbons
Plant & animal protection	Pesticides & herbicides
Soil conditioners	Metals, sulphates, PAH
Field sports	Lead shot
Waste burial, land levelling, backfilling ponds/quarries	Methane, metals, PAH etc
Naturally occurring contaminants	Arsenic, metals

5.4.2 Whilst it is likely that pesticides have been applied during arable use of the land, these are not likely to include the persistent organochloride pesticides such as Dieldrin, Aldrin, DDT etc. Pesticides routinely used on arable crops the UK (Phenoxy Acetic acid herbicide or PAAH) rapidly degrade in soils or leach via rainwater infiltration to groundwater. It is highly unlikely these would be detected by soil sampling and therefore it is not proposed to undertake analysis of these.

6 PRELIMINARY CONCEPTUAL SITE MODEL

6.1 An assessment of potential contaminants associated with the former uses has been undertaken with reference to CLR8. As a consequence of this assessment, anticipated potential contaminants, within soil and/or groundwater include:

- Inorganics (metals associated with made ground associated with the former uses, and reworked topsoil)
- Asbestos &/or ACMs within the made ground associated with from the former buildings etc
- TPH & PAH (associated with made ground in the former quarry)

6.2 Historical plans show the presence of a former quarry, houses and allotments which should be targeted during the ground investigation.

6.3 A preliminary conceptual site model, presented as Drawing 4674/5 in Appendix B, has been prepared after consideration of all the data presented in Sections 2 to 5.4 inclusive of this report.

6.4 Potential contaminant linkages are shown on the preliminary conceptual site model.

6.5 The conceptual model will likely be subject to modification in light of data arising from the proposed intrusive ground investigation; see Section 9.9.

7 GROUND INVESTIGATION DESIGN

7.1 Anticipated ground conditions & potential issues

7.1.1 Based on the data reviewed in Sections 4 (Environmental Setting) and 5 (Mineral Extraction), anticipated ground conditions are expected to comprise:

Anticipated condition	Remarks
Made ground	Veneer of made ground possible across the centre (former houses and allotments) with deep made ground likely in the former quarry
Natural soils	Topsoil underlain by residual soil (gravelly clay/clayey gravel) from the weathering of bedrock
Bedrock	Predominantly sandstone at shallow depth (<3m) beyond the former quarry

Anticipated condition	Remarks
Mineworkings	No shallow mineworkings anticipated across the majority of the site (possible in the far northeast beyond the Shafton Coal outcrop)
Groundwater	Perched water in made ground with true groundwater likely at depth in bedrock

7.1.2 Based on the data above and that in Sections 2 (Site Description) and 3 (History), potential ground-related issues associated with this site are likely to include:

Type of issue	Specific issue	Remarks
Potential on-site contamination sources	1. Reworked topsoil (inorganics, & organics) 2. Former buildings 3. Backfilled quarry/landfill (inorganics, organics & gas)	1. Associated with farming 2. Asbestos &\or ACMs 3. Unknown material type
Potential off-site contamination sources	1. Landfill/backfilled ground	1. Migration of hazardous gas
Potential geotechnical hazards	1. Relict buried obstructions 2. Deep made ground 3. steep slopes 4. shallow workings	1. Foundations associated with former buildings and boulder in the former quarry 2. Depth of former quarry unknown 3. Beyond northwest boundary sloping down towards A628 4. Possible workings in the Shafton Coal in the far northeast
Other potential constraints	1. Underground and overhead utilities 2. Public bridleway	1. Underground electric, gas, fibre optic & water and overhead telecom 2. Likely to require inclusion in any proposed layout

7.2 Ground investigation design & strategy

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

Exploratory holes	Purpose
About 45 trial pits	To determine the general nature of soils underlying the site, including the: • Nature, distribution and thickness of made ground • Nature, degree and extent of contamination • Proportion of undesirable elements e.g. biodegradable matter, foundations etc • Suitability of the ground for founding structures and highways
8 trial pits	To determine whether soakaways could be utilised for storm water drainage
14 trial trenches	To determine the line and geometry of the opencast highwall
3 cable percussion boreholes	To retrieve geotechnical data from depth including confirming the strength (density) of quarry backfill via SPTs To install monitoring wells in the former quarry in order to determine groundwater levels
18 window sample boreholes	To install monitoring wells across the site in order to: • Monitor for hazardous gas • Determine groundwater levels and assess flow direction
3 rotary cored boreholes	To recover rock samples from beneath the base of the quarry for geotechnical testing

7.2.2 Proposed exploratory hole locations were selected to provide a representative view of the strata beneath the site and to target potential areas of interest identified in Section 7.1 above. A nominal 30m grid spacing was proposed. Additional exploratory locations might be scheduled by the site engineer in light of the ground conditions actually encountered.

7.2.3 The number of representative samples taken will be reflective of the geological complexity actually encountered. However, in general about 3 samples will be taken from most trial pits.

8 FIELDWORK

8.1 Objectives

8.1.1 The original investigation strategy is outlined in Section 7.2 above.

8.1.2 Given initial findings of the trial pitting within the former quarry (significantly shallower than anticipated with obstructions), the method of drilling to determine the depth of the quarry was changed from cable percussion to rotary. Additionally, a number of monitoring wells were installed with rotary methods (c.f. window sampling) due to shallow rock beyond the quarry and obstructions in the quarry backfill.

8.1.3 The additional exploratory holes listed below were advanced in light of ground conditions actually encountered.

Exploratory holes	Purpose
PHs 01 to 13 & 15 to 19	To determine the depth to rockhead within and around the former quarry
PHs 04 & 14	To enable installation of monitoring wells

8.2 Exploratory hole location constraints

8.2.1 No access was available in the far east due to woodland/dense vegetation. Additionally, limited investigation of the quarry was possible in the north again due to the presence of trees.

8.3 Scope of works

8.3.1 Fieldwork was supervised by Lithos between 25th March and 9th April 2024 and comprised the exploratory holes listed below.

Technique	Exploratory holes	Final depth(s)	Remarks
Trial pitting (machine dug)	TPs 01 to 49	1.5m to 3.9m	Vane tests in cohesive soils
Soakaway tests	Within TPs 16 to 19, 29 & 31 to 33	1.8m to 2.9m	-
Trial trenching (machine dug)	TTs 01 to 15	1.6m to 3.8m	To delineate the quarry highwall
Rotary openhole probeholes	PHs 01 to 19	3.0m to 12.0m	Monitoring wells installed in PHs 01, 02, 04, 05, 07, 12 & 14
Rotary cored boreholes	RCs 01 to 03	8.9m to 11.8m	-
Window sample boreholes	WSs 01 to 15	0.8m to 2.0m	Monitoring wells installed in all holes except WS03

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

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

- Samples taken
- Descriptions of the solid strata, and any groundwater encountered.
- Results of the in-situ testing
- The monitoring wells installed

8.3.4 Exploratory hole locations are shown on Drawing 4674/6 presented in Appendix B; exploratory holes were picked-up by a surveyor and co-ordinates/ground levels are included on the logs.

9 GROUND CONDITIONS

9.1 General

9.1.1 A complete record of strata encountered beneath the proposed development site is given on the various exploratory hole records, presented in Appendices F to J.

9.1.2 The site can be divided into 4 areas based on ground conditions. These areas are shown on Drawing 4674/10 and are summarised below:

Site area	General location	Area (m^2)
A	Agricultural land in the west	10,500
B1	Former allotments in the centre	20,000
B2	Densely vegetated land in the northeast	3,300
C	Former quarry/landfill in the east	17,000

Land inaccessible during the investigation (far north and east) are not included.

9.1.3 Typical ground conditions encountered at the site are described below in Sections 9.2 (made ground) and 9.4 (natural ground), with a summary provided in the table on pages 17 to 19.

9.2 Made ground

9.2.1 The made ground on site is a heterogeneous mixture of materials and it is unlikely, even with a huge amount of sampling, that it could be accurately characterised. Nonetheless, the bulk of the made ground can be categorised as one of 7 broad types:

- **Made Ground Topsoil:** clay/sand with gravel of mixed lithologies including sandstone, brick, ceramic, glass, coal, plastic, clinker and slate encountered in Areas B1 and B2 to between 0.2m and 0.4m depth.
- **Ash & Clinker:** encountered locally in Area C only as a thin surface layer in TPs 09 and 10, with a 2.1m thick bed in TP12.
- **Granular Made Ground:** encountered across Area C (locally in Areas B1 and B2) comprising sandy Gravel of predominantly sandstone, brick, concrete, tarmac and clinker with lesser amounts of metal, wood, coal, glass, paper, plastic and ceramic. Variable cobble and boulder content of brick, sandstone, concrete and tarmac.
- **Cohesive Made Ground:** typically comprises Clay with gravel of mixed lithologies (including brick, sandstone, mudstone, slate, coal, clinker and wood) to between 0.3m and 3.3m depth (average 1.8m) in Area C only.
- **Quarry Waste:** Gravel of sandstone (rare brick) with variable cobble content encountered in Area C only to between 1.2m and 3.2m (average 2.1m).
- **Reworked Natural Ground:** encountered locally at shallow depth in Areas A and B1 to between 0.5m and 1.2m depth (average 0.8m) typically comprising sandstone Gravel with cobbles and boulders of sandstone.
- **Landfill Material:** brightly coloured (purplish red, purplish blue and white) sandy Clay and clayey Sand encountered at variable depths within trenches excavated in the northeast of Area C, as shown (red hatching) on drawing 4674/10.

9.2.2 Review of the trial pit logs suggest made ground thicknesses beneath the site vary between 0.2m (Area B1) and greater than 3.6m (Area C). The approximate thickness of made ground in and adjacent to the quarry is shown on Drawing 4674/9.

9.2.3 The thickest made ground was encountered in the Area C (former quarry/landfill), with made ground in excess of 2m deep encountered in 14 of the 20 trial pits and window sample boreholes advanced within this area.

9.2.4 Whilst not encountered during this investigation, the possibility of 'burial pits' beyond the former quarry cannot be entirely discounted.

9.3 Obstructions

9.3.1 It is apparent from a review of historical OS Plans (see Section 3) that buildings have been present on about 300m^2 in the centre north. Furthermore, a former sandstone quarry (subsequently used as a landfill) is shown to be present across 15% of the site area in the east. Drawing 4674/3 shows the footprints of the former structures and quarry.

9.3.2 A trial pit (TP34) excavated in the footprint of former terrace housing (as shown on the 1962 OS Plan) in the centre north encountered a brick wall extending to 0.7m depth which is likely a relict foundation. Consequently, it is considered likely that further below ground obstructions associated with former buildings will be present.

9.3.3 In addition to the obstructions described above, large oversize materials such as sandstone boulders and concrete kerb stones (up to 2m across) were encountered within the former quarry in the east (most notably in the Granular Made Ground). It is estimated that within this made ground type up to 40% of the material is coarser than a house brick.

9.4 Natural ground

9.4.1 Natural ground was encountered in the majority of the exploratory holes, and typically comprised:

- **Topsoil:** predominantly clayey sand with gravel of sandstone was identified across Area A, and locally in Areas B1 and B2, to a typical depth of 0.3m.
- **Cohesive Residual Soil:** firm to stiff sandy/gravelly Clay encountered locally to shallow depth (typically <1.2m) beyond Area C.
- **Granular Residual Soil:** encountered across beyond Area C as gravelly Sand/sandy Gravel of sandstone to between 0.8m and 3.0m depth (average 1.7m).
- **Mexborough Rock:** typically comprises medium strong Sandstone (locally siltstone and/or mudstone) encountered at shallow depth (c. 1.7m) in Areas A, B1 and B2. Within Area C (former quarry), bedrock was encountered at between 1.8m and 5.1m depth (average 2.8m).

Summary of ground conditions

Area	Hole	Final depth (m)	Depth to Base of Made Ground (m)	Depth to Base of (m)									Depth to bedrock (m)
				Made Ground						Natural Soils			
				Made Ground Topsoil	Ash & Clinker	Granular Made Ground	Cohesive Made Ground	Quarry Waste	Reworked Natural Ground	Topsoil	Cohesive Residual Soil	Granular Residual Soil	
A	TP01	2.1	0.5	-	-	-	-	-	0.5	0.3	-	1.2	1.2
	TP02	1.7	0.9	-	-	-	-	-	0.9	0.3	-	0.9	0.9
	TP03	2.4	-	-	-	-	-	-	-	0.3	-	2.3	2.3
	TP04	2.4	-	-	-	-	-	-	-	0.2	0.5	1.7	1.7
B1	TP05	1.6	-	-	-	-	-	-	-	0.2	-	1.4	1.4
	TP06	2.1	0.5	-	-	0.5	-	-	-	-	-	1.7	1.7
C	TP07	2.6	>2.6	-	-	0.6	-	>2.6	-	-	-	-	-
	TP08	3.3	3.2	-	-	1.5	2.3	3.2	-	-	-	-	3.2
	TP09	3.3	3.3	-	0.2	2.5	3.3	-	-	-	-	-	3.3
	TP10	2.5	1.2	-	0.1	-	0.7	1.2	-	-	-	2.0	2.0
	TP11	2.9	2.8	-	-	2.8	-	-	-	-	-	-	2.8
	TP12	2.9	2.8	-	2.5	-	2.8	-	-	-	-	-	2.8
	TP13	2.5	2.3	0.2	-	1.0, then 2.3	2.0	-	-	-	-	-	2.3
	TP14	3.4	3.0	-	-	2.6	-	3.0	-	-	-	>3.4	-
	TP15	3.1	2.7	-	-	1.1, then 2.3	2.7	1.6	-	-	-	3.0	3.0
A	TP16	1.8	-	-	-	-	-	-	-	0.2	-	1.5	1.5
	TP17	2.5	-	-	-	-	-	-	-	0.2	0.6	2.0	2.0
	TP18	2.5	-	-	-	-	-	-	-	0.3	1.1	1.8	1.8
B1	TP19	2.4	0.3	0.3	-	-	-	-	-	-	-	2.2	2.2
A	TP20	2.0	-	-	-	-	-	-	-	0.4	1.7	-	1.7
C	TP21	1.9	0.2	0.2	-	-	-	-	-	-	-	1.7	1.7
	TP22	2.4	2.2	-	-	2.2	-	-	-	-	-	-	2.2
B2	TP23	2.3	-	-	-	-	-	-	-	0.2	-	1.6	1.6
C	TP24	2.9	2.7	-	-	2.7	0.6	1.6	-	-	-	-	2.7
	TP25	2.6	2.5	-	-	-	2.5	-	-	-	-	-	2.5

Area	Hole	Final depth (m)	Depth to Base of Made Ground (m)	Depth to Base of (m)									Depth to bedrock (m)
				Made Ground						Natural Soils			
				Made Ground Topsoil	Ash & Clinker	Granular Made Ground	Cohesive Made Ground	Quarry Waste	Reworked Natural Ground	Topsoil	Cohesive Residual Soil	Granular Residual Soil	
	TP26	2.0	0.7	-	-	0.7	-	-	-	-	-	1.7	1.7
	TP27	3.9	3.8	-	-	3.8	-	-	-	-	-	-	3.8
B1	TP28	2.2	-	-	-	-	-	-	-	0.3	-	1.7	1.7
	TP29	1.8	0.3	-	-	-	-	-	-	-	1.2	1.6	1.6
C	TP30	2.0	1.4	-	-	1.4	0.3	-	-	-	-	1.8	1.8
B1	TP31	2.9	1.2	0.2	-	-	-	-	1.2	-	>2.9	2.2	-
	TP32	2.5	0.3	0.3	-	-	-	-	-	-	0.7	2.0	2.0
	TP33	2.0	-	-	-	-	-	-	-	0.2	0.6	1.4	1.4
	TP34	2.3	0.5	-	-	-	0.5	-	-	-	0.9	1.6	1.6
	TP35	1.9	0.2	0.2	-	-	-	-	-	-	-	1.6	1.6
	TP36	1.8	-	-	-	-	-	-	-	0.3	-	1.6	1.6
	TP37	2.2	0.3	0.3	-	-	-	-	-	-	1.0	1.6	1.6
	TP38	2.0	-	-	-	-	-	-	-	0.3	-	1.8	1.8
	TP39	2.0	0.2	0.2	-	-	-	-	-	-	-	1.6	1.6
	TP40	1.9	0.2	0.2	-	-	-	-	-	-	-	1.7	1.7
	TP41	1.8	0.7	-	-	0.3	-	-	0.7	-	1.5	-	1.5
C	TP42	3.4	1.7	-	-	1.7	-	-	-	-	-	3.0	3.0
B2	TP43	1.9	-	-	-	-	-	-	-	0.2	1.8	-	1.8
	TP44	2.1	-	-	-	-	-	-	-	0.2	1.0	1.9	1.9
	TP45	2.2	-	-	-	-	-	-	-	0.2	1.4	1.7	1.7
	TP46	2.0	-	-	-	-	-	-	-	0.2	0.6, then 1.6	1.3, then 1.9	1.9
C	TP47	3.6	3.3	-	-	3.3	-	-	-	-	-	-	3.3
	TP48	3.6	>3.6	0.2	-	>3.6	-	-	-	-	-	-	-
B1	TP49	1.5	-	-	-	-	-	-	-	0.2	0.6	1.3	1.3
A	WS01	2.0	-	-	-	-	-	-	-	0.5	-	2.0	2.0
	WS02	1.5	-	-	-	-	-	-	-	0.4	-	1.5	1.5

Area	Hole	Final depth (m)	Depth to Base of Made Ground (m)	Depth to Base of (m)									Depth to bedrock (m)
				Made Ground						Natural Soils			
				Made Ground Topsoil	Ash & Clinker	Granular Made Ground	Cohesive Made Ground	Quarry Waste	Reworked Natural Ground	Topsoil	Cohesive Residual Soil	Granular Residual Soil	
	WS03	0.8	-	-	-	-	-	-	-	0.3	-	0.8	0.8
	WS03A	0.5	-	-	-	-	-	-	-	0.3	-	0.9	0.9
	WS03B	0.8	-	-	-	-	-	-	-	0.3	-	0.8	0.8
	WS04	1.7	-	-	-	-	-	-	-	0.4	-	1.7	1.7
B1	WS05	1.5	-	-	-	-	-	-	-	0.2	-	1.5	1.5
	WS06	1.4	-	-	-	-	-	-	-	0.3	-	1.4	1.4
	WS07	1.5	0.4	0.4	-	-	-	-	-	-	-	1.4	1.4
	WS08	2.0	-	-	-	-	-	-	-	0.3	2.0	1.9	2.0
	WS09	1.9	-	-	-	-	-	-	-	-	1.9	1.7	1.9
	WS10	1.6	0.3	0.3	-	-	-	-	-	-	-	1.6	1.6
	WS11	1.5	0.3	0.3	-	-	-	-	-	-	-	1.5	1.5
B2	WS12	1.8	0.7	0.3	-	0.7	-	-	-	-	1.8	1.0	1.8
	WS13	1.8	0.3	0.3	-	-	-	-	-	-	1.8	1.0	1.8
C	WS14	2.0	1.2	-	-	1.2	-	-	-	-	-	2.0	2.0
B2	WS15	1.4	0.3	0.3	-	-	-	-	-	-	-	1.4	1.4

9.5 Visual & olfactory evidence of organic contamination

9.5.1 No evidence of significant organic contamination was noted in any of the exploratory holes.

9.5.2 A slight hydrocarbon (tar) odour was noted in TP08 from 1.0m depth although this is likely associated with the presence of tarmac within the made ground.

9.5.3 Selected samples of potentially contaminated materials were scheduled for chemical testing to determine the nature and extent of any contamination, and to confirm the suitability of existing topsoil for re-use; see Section 11.

9.6 Groundwater

9.6.1 No significant inflows of groundwater were encountered in natural ground beyond the quarry during the investigation. Inflows and seepages were noted in a number of pits/trenches excavated within the quarry, typically towards the base of the made ground.

9.6.2 Groundwater levels recorded in the monitoring wells are summarised below.

Hole	Response zone (depth range & strata)	Groundwater body	Typical standing water level	
			m bgl	m AoD#
PH01	2.7m – 3.7m (Made Ground & Granular Residual Soil)	Perched	N.D.	N.D.
PH02	2.5m – 3.5m (Made Ground)		3.4	77.6
PH04	1.5m – 3.0m (Sandstone)	Shallow (Solid)	N.D.	N.D.
PH05	1.0m – 2.0m (Made Ground)	Perched	2.4	76.4
PH07	1.0m – 2.5m (Made Ground)		N.D.	N.D.
PH12	1.0m – 2.0m (Made Ground)		N.D.	N.D.
PH14	1.0m to 3.0m (Granular Residual Soil and Sandstone)	Shallow (Solid)	N.D.	N.D.
WS01	1.0m to 2.0m (Granular Residual Soil)		N.D.	N.D.
WS02	0.5m to 1.5m (Granular Residual Soil)		N.D.	N.D.
WS04	0.7m to 1.7m (Granular Residual Soil)		N.D.	N.D.
WS05	0.5m to 1.5m (Granular Residual Soil)		N.D.	N.D.
WS06	0.7m to 1.4m (Granular Residual Soil)		N.D.	N.D.
WS07	0.5m to 1.5m (Granular Residual Soil and Sandstone)		N.D.	N.D.
WS08	1.0m to 2.0m (Granular & Cohesive Residual Soil)		N.D.	N.D.
WS09	0.9m to 1.9m (Granular & Cohesive Residual Soil)		1.8	82.2
WS10	0.6m to 1.6m (Granular Residual Soil)		N.D.	N.D.
WS11	0.5m to 1.5m (Granular Residual Soil)		1.2	74.2
WS12	1.0m to 1.8m (Granular & Cohesive Residual Soil)		1.6	72.8
WS13	0.8m to 1.8m (Granular & Cohesive Residual Soil)		1.6	73.3
WS14	0.5m to 1.0m (Granular Made Ground)	Perched	N.D.	N.D.
WS15	0.5m to 1.4m (Granular Residual Soil)	Shallow (Solid)	N.D.	N.D.

levelled-in by survey
N.D. none detected

9.6.3 Dip data to date suggests groundwater is typically greater than 2.0m depth (i.e. beyond base of most wells). However, groundwater was particularly shallow (within 1.5m of ground level) in WS11.

9.6.4 These results will be required by the foundation designer, drainage designer, and groundworker (especially if/where deep excavation is required).

9.7 Stability

9.7.1 Stability of excavations within natural ground was generally good. However, significant instability occurred during excavation through the made ground within the former quarry.

9.8 Quarrying investigation

9.8.1 It is clear from the desk study that the west of the site is likely to be underlain by deep made ground associated with a backfilled sandstone quarry. Consequently, a quarrying investigation has been undertaken comprising the excavation of 24 trial pits and 15 trenches, and the drilling of 13 rotary open-hole probeholes and 3 cored boreholes. Exploratory hole locations are shown on Drawing 4674/6.

9.8.2 The depth of the quarry has been investigated with a combination of trial pitting and rotary drilling which identified rockhead predominantly at shallow depth. The ground conditions encountered during drilling are summarised in the table below.

Hole	Final depth (m)	Depth to Base of Made Ground (m)	Depth to bedrock (m)	Remarks
PH01	10.5	3.5	3.8	-
PH02	9.0	5.1	5.1	-
PH03	10.5	2.5	2.5	-
PH04	3.0	1.3	1.3	Drilled beyond quarry
PH05	10.5	2.3	2.3	-
PH06	9.0	2.5	2.5	-
PH07	6.0	2.7	3.0	-
PH08	9.0	-	1.9	Drilled beyond quarry
PH09	9.0	1.8	2.5	-
PH10	6.0	1.3	2.3	Drilled beyond quarry
PH11	6.0	2.7	3.0	-
PH12	9.0	2.4	2.8	-
PH13	6.0	1.5	2.1	Drilled beyond quarry
PH14	3.0	-	3.0	-
PH15	12.0	3.3	4.8	-
PH16	9.0	2.5	2.5	-
PH17	12.0	3.8	3.8	-
PH18	12.0	2.0	5.2	-
PH19	6.0	1.0	1.7	Drilled beyond quarry
RC01	11.8	4.2	4.7	-
RC02	8.9	2.9	2.9	-
RC03	9.1	3.1	3.1	-

9.8.3 It should be noted that detailed logging of the ground is not possible in the rotary probeholes due to the nature of the drilling method and quality/quantity of material returned to the surface. Consequently, it can be difficult to distinguish reworked soils from natural ground, and residual soils from very weak bedrock and as such, a degree of caution is required when interpreting the depth of the quarry encountered in the probeholes.

9.8.4 The depth of made ground encountered in PH02 is different (>1.5m deeper) to adjacent exploratory holes. It is likely that the base of made ground is shallower than recorded, although given the nature of the made ground and uppermost weathered bedrock it was not possible to accurately identify the interface.

9.8.5 Trial trenches have been advanced at 15 locations to expose the quarry highwall in order to determine the location, orientation and gradient. Trenches were excavated roughly perpendicular to the quarry highwall as shown on historical OS maps.

9.8.6 Details obtained from the trenches are outlined in the table below.

Hole	Depth to rockhead beyond quarry (m)	Depth to rockhead within quarry (m)	Notable highwall in bedrock?	Angle of highwall (from horizontal)	Remarks
TT01	-	1.9 to 2.7	-	-	Trench excavated wholly within quarry
TT02	1.7	2.3	N	<5°	
TT03	1.9	2.0	N	<5°	
TT04	1.6	2.2	N	<5°	
TT05	1.7	2.6	N	6°	
TT06	2.0	2.4	N	5°	
TT07	2.1	2.9	N	8°	
TT08	1.6	3.8	Y	23°	
TT09	2.1	2.2	N	<5°	
TT10	1.8	2.3	N	<5°	
TT11	1.6	1.6	N	<5°	
TT12N	2.2	2.4	N	<5°	Spur of rock in trench with 'highwalls' on either side
TT12S	2.2	2.4	N	6°	
TT13N	1.6	2.6	N	8°	Spur of rock in trench with 'highwalls' on either side
TT13S	1.6	2.7	Y	23°	
TT14	1.6	2.8	Y	19°	
TT15	1.8	2.8	N	14°	

9.8.7 The locations of the trial trenches and observed/inferred lines of highwalls are shown on Drawing 4674/9. The extent of the quarry is broadly similar to that shown on the 1962 OS map with the notable exceptions being in the far southeast and west. Spurs within the quarry as shown on the historical map have been identified at similar locations.

9.8.8 It should be noted that due to the presence of trees/dense vegetation, only limited trenching has been possible in the north of the quarry although trial pits excavated immediately beyond the anticipated quarry did encounter natural ground at shallow depth. Consequently, it can be tentatively assumed that the line of the highwall will be in the anticipated location based on historical mapping. However, further trenching in this area following vegetation clearance would be considered prudent.

9.8.9 Analysing the data obtained from the quarrying investigation, it is apparent that:

- The base of the quarry is between 1.6m and 5.2m depth (average 3.1m) below existing ground levels. The deepest made ground is present in the southwest.
- The depth to rockhead is typically similar (within 1m) both inside and outside the quarry.
- The majority of 'highwalls' encountered were observed in the Residual Soils with only localised highwalls in bedrock identified.
- Where highwalls in bedrock were noted, they were typically of a shallow gradient (<25°).

9.8.10 It appears the quarry mainly extracted the residual soil with only the uppermost c. 1m of sandstone removed. This may be related to the material type required by those undertaking the quarrying (e.g. sand/gravel for construction) or the nature of the sandstone bedrock (too hard to excavate or not meeting certain quality standards etc.).

9.9 Revised conceptual ground model (ground conditions)

9.9.1 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, including the presence of significant buried obstructions
- The strength, nature and depth of underlying natural strata
- The nature and distribution of contamination (based on visual/olfactory evidence only)

9.9.2 Further refinement of the Conceptual Site Model is presented in Sections 12.3, where the results of laboratory testing for contaminants have been considered.

10 SOAKAWAY TEST RESULTS

10.1 UK guidance

10.1.1 General notes about soakaways, including their location, design, and Lithos' test methodology are presented in Appendix A.

10.1.2 UK guidance does not explicitly state that soakaways cannot be constructed in made ground, but such construction is not generally considered good practice. There may be a risk of settlement caused by wash out of fine soil particles if soakaway waters are allowed to infiltrate into made ground. Furthermore, UK guidance does state that the soakaways should not be built where the presence of contamination could result in pollution of groundwater.

10.1.3 CIRIA C753[5] recommends that soakaways should not be constructed 'in ground where the water table reaches a level within 1m below the base of the soakaway at any time of the year'.

10.1.4 BRE DG365[6] "Soakaway Design" advises that each soakaway pit should be filled and allowed to drain three times to near empty on the same or consecutive days.

10.2 Field tests

10.2.1 Soakaway testing was carried out in 8 pits in the centre and west (away from areas of deep made ground), in general accordance with BRE DG365 "Soakaway Design". The locations of the soakaways are shown on Drawing 4674/6 presented in Appendix B to this report.

10.2.2 Infiltration rates for each soakaway test have been calculated (where possible) in accordance with BRE DG365. This design takes into account time for the water level to fall from 75% to 25% of its effective depth. The effective depth is the difference between the starting water level and the soakaway pit base depth.

10.2.3 Where the water level did not fall to 25% effective depth within 5 hours, the test was not considered suitable for calculation of an infiltration rate; this was the case for unsuccessful tests in TPs 17 & 31.

[5] *CIRIA C753. The SuDS Manual (2015).*
[6] *BRE DG365. Soakaway Design (2016).*

10.2.4 Variable infiltration rates meant that between 1 and 3 filling cycles were possible in the pits where successful tests occurred.

10.2.5 Calculated infiltration rates for each successful test are summarised in the table below, and copies of the associated calculations are presented in Appendix K to this report.

Hole	Test	Stratum	Infiltration rate (m/s)	Remarks
TP16	1	Granular Residual Soil (0.6m to 1.5m) Siltstone (1.5m to 1.8m)	2.14×10^{-5}	-
	2		1.65×10^{-5}	-
TP17	1	Granular Residual Soil (0.6m to 2.0m) Siltstone (2.0m to 2.5m)	N/A	Still c. 100% full after 5 hrs
TP18	1	Cohesive Residual Soil (0.5m to 1.1m), Granular Residual Soil (1.1m to 1.8m) Sandstone (1.8m to 2.5m)	7.34×10^{-5}	-
	2		7.38×10^{-5}	-
TP19	1	Granular Residual Soil (0.6m to 2.2m) Sandstone (2.2m to 2.4m)	1.01×10^{-4}	-
	2		9.73×10^{-5}	-
TP29	1	Cohesive Residual Soil (0.5m to 1.2m), Granular Residual Soil (1.2m to 1.6m) Sandstone (1.6m to 1.8m)	1.54×10^{-5}	-
	2		N/A	Insufficient time to complete test
TP31	1	Granular Residual Soil (1.2m to 2.2m) Cohesive Residual Soil (2.2m to 2.9m)	N/A	Plateaued after 0.5 hours; still c. 35% full after 5 hours
TP32	1	Granular Residual Soil (0.7m to 2.0m) Sandstone (2.0m to 2.5m)	1.06×10^{-5}	-
TP33	1	Granular Residual Soil (0.6m to 1.4m) Sandstone (1.4m to 2.0m)	7.78×10^{-5}	-
	2		1.29×10^{-4}	-
	3		1.24×10^{-4}	-

10.3 Discussion & conclusions

10.3.1 Drainage Engineers could use the infiltration rates reported above to determine the feasibility of soakaways as a solution for the discharge of surface water run-off.

10.3.2 Increasing the soakaway effective depth might offer a solution, but consideration should be given to the cost of excavation (especially given the strong nature of the bedrock).

10.3.3 It should be noted that soakaway percolation in bedrock is predominately via 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. It is possible that the larger surface area associated with soakaway construction during development will intercept such joints; although this cannot be guaranteed.

10.3.4 Soakaways are generally only considered to provide a satisfactory solution for the disposal of surface water where the vast majority of tests yield reasonable infiltration rates.

10.3.5 Consequently, soakaways might provide a suitable drainage solution where sandstone bedrock is present. Soakaways will not provide a suitable means of surface water disposal in the vicinity of the quarry and there is likely to be a need for surface water balancing in the west.

10.3.6 However, regard must be made to seasonal groundwater levels; UK guidance indicates that the seasonally high groundwater table must be at least 1m below the base the soakaway.

10.3.7 Drainage solutions are discussed further in Section 15.9.

11 CONTAMINATION (ANALYSIS)

11.1 General

11.1.1 The west of the site has remained undeveloped throughout history and appears to have been used as farmland. The centre has previously been occupied by allotment gardens and a number of terrace houses, with a former sandstone quarry in the west.

11.1.2 The use of the former quarry (east) as a landfill is likely to have given rise to some ground contamination. Furthermore, significant thicknesses of made ground were encountered in many of the exploratory locations in this area during the ground investigation.

11.1.3 The west of the site has not been the subject of a past potentially contaminative industrial land use. However, historical mapping suggests arable farming has been carried out on the site. Sampling of the topsoil has been undertaken to confirm its suitability for re-use.

11.1.4 An assessment of potential contaminants associated with the former uses has been undertaken; see Section 6.

11.1.5 In the context of risks to human health associated with residential redevelopment, the Tier 1 Soil Screening Values referenced in this report have been derived via the CLEA default conceptual site model (CSM) used for generating SGVs, but amended, where appropriate, to be more specific to redevelopment within the planning process.

11.1.6 Where available, Category 4 Screening Levels (C4SL) have also been referenced.

11.1.7 Generic Note 04 in Appendix A provides further details with respect to current guidance and the interpretation of analytical data.

11.2 Testing scheduled

11.2.1 Based on the above assessment, Lithos submitted a test schedule (summarised in the table below) to a UKAS accredited laboratory. Account has also been taken of visual evidence recorded during the ground investigation.

Type of sample	No. of samples	Determinands
Area A		
Topsoil	6	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID TOC, Speciated Polycyclic Aromatic Hydrocarbons (PAH)
	2	Clay/sand/silt content and visible contaminants, sharps (glass etc) to check compliance with BS3882:2015
Areas B & C		
Made ground	26	Asbestos ID
	23	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) Water soluble sulphate, chloride, nitrate and magnesium TOC, Speciated Polycyclic Aromatic Hydrocarbons (PAH), Banded Total Petroleum Hydrocarbons (TPH)
	15	Leachable metals: arsenic, boron, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc
	3	Calorific Value (CV)

Type of sample	No. of samples	Determinands
Area A		
	2	Speciated Total Petroleum Hydrocarbons (TPH) Volatile Organic Compounds (VOC), includes BTEX Semi-Volatile Organic Compounds (sVOC), includes PAHs Total cyanide
Topsoil/Made Ground Topsoil	13	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID TOC, Speciated Polycyclic Aromatic Hydrocarbons (PAH)
	4	Clay/sand/silt content and visible contaminants, sharps (glass etc) to check compliance with BS3882:2015

11.2.2 The soil contamination test results are summarised in the tables on pages 27 to 32.

11.2.3 Laboratory test certificates as received from the laboratory are presented in Appendix L to this report.

Summary of degree of soils contamination (Area A – Topsoil)

Expl Hole	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 BLUE and assume a **residential with gardens** end-use.												PAH		Asbestos I.D.
			pH	As ∞	B ~	Cd ∞	Cr x	Cu♣$	Pb ∞	Hg *	Ni	Se	Vn	Zn $	% TOC	B(a)P ∞	Naphthalene	
				37	5	26	4000	100	200	199	109	434	584	200		5	6	
TP01	0.1	Topsoil	7.1	9.7	< 0.2	0.2	8.7	15	21	< 0.1	13	< 0.5	16	60	1.4	< 0.1	< 0.1	N.D.
TP02	0.1	Topsoil	7.7	11	0.3	0.2	12	18	28	0.1	16	< 0.5	21	61	1.6	< 0.1	< 0.1	N.D.
TP04	0.1	Topsoil	7.4	11	< 0.2	0.3	14	20	36	0.1	15	< 0.5	22	73	1.9	< 0.1	< 0.1	N.D.
TP16	0.1	Topsoil	7.0	9.7	< 0.2	0.2	8.8	15	29	0.1	11	< 0.5	16	53	1.7	< 0.1	< 0.1	N.D.
TP17	0.1	Topsoil	6.7	11	0.3	0.3	12	19	33	0.1	13	< 0.5	18	73	2.3	< 0.1	< 0.1	N.D.
TP18	0.1	Topsoil	6.8	9.8	0.3	0.2	12	17	28	0.1	15	< 0.5	20	62	1.6	< 0.1	< 0.1	N.D.

Key	
36	Parameter tested for and found to be in excess of Tier 1 value.
179	Parameter tested for and found to be > 5 x Tier 1 value.
12	Parameter tested for but not found to be in excess of Tier 1 value.
-	Parameter not tested for.
♣	Tier 1 Value is pH dependent.
X	Assumes Cr is CrIII. If demonstrated Cr is CrVI Tier 1 would be 21mg/kg.
N.D.	No fibres detected (asbestos screen)

Source of guidance trigger level	
With the exception of those annotated with one of the symbols below (∞, $, ~), all Soil Screening Values in brackets above have been derived using CLEA v1.071. Values assume contaminants located in a sandy loam, with 6% soil organic matter (SOM).	
∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE/Defra).
$	MAFF. Code of Practice for Agricultural Practice for the Protection of Soil, 1998.
~	Engineering judgement (Lithos). Boron is a phytotoxic, although most phytotoxic compounds can pose a risk to human health if sufficient concentrations are present. However, plants represent the most sensitive receptor, and a Tier 1 value which is protective of flora is therefore also protective of human health.
*	Assumes mercury present as an inorganic compound (cf elemental metal or within organic compound). See Science Report SC050021/Mercury SGV.

Summary of degree of soils contamination (Areas B & C – inorganics)

Expl Hole	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 BLUE and assume a **residential with gardens** end-use.												
			pH	As ∞	B~	Cd ∞	Cr x	Cu♣$	Pb ∞	Hg*	Ni	Se	Vn	Zn$	CV	Asbestos
				37	5	26	4000	100	200	199	109	434	584	200	2	
TP23	0.1	Topsoil	6.0	12	0.3	0.2	14	19	36	0.1	14	< 0.5	21	68	-	N.D.
TP28	0.1	Topsoil	6.1	15	0.3	0.2	13	31	45	0.1	17	< 0.5	23	89	-	N.D.
TP38	0.1	Topsoil	6.2	12	0.3	0.3	15	29	51	0.1	14	< 0.5	22	130	-	**Chrysotile**
TP43	0.1	Topsoil	8.0	15	0.3	0.3	73	31	65	0.1	17	1.1	35	67	-	N.D.
TP05	0.1	Made Ground Topsoil	7.8	11	0.3	0.3	24	26	44	0.1	16	< 0.5	24	85	-	N.D.
TP19	0.1	Made Ground Topsoil	7.7	9.6	0.3	0.2	17	17	31	0.1	14	< 0.5	20	65	-	N.D.
TP21	0.1	Made Ground Topsoil	7.0	12	0.5	0.3	15	21	51	0.1	16	< 0.5	23	95	-	N.D.
TP29	0.1	Made Ground Topsoil	6.4	19	0.4	0.3	12	30	55	0.1	16	< 0.5	22	100	-	N.D.
TP31	0.1	Made Ground Topsoil	6.1	20	0.3	0.3	24	35	59	0.1	17	< 0.5	31	120	-	N.D.
TP32	0.1	Made Ground Topsoil	5.9	17	0.3	0.2	14	27	45	0.1	14	< 0.5	21	80	-	N.D.
TP35	0.1	Made Ground Topsoil	5.7	13	0.2	0.2	13	24	48	0.1	15	< 0.5	21	82	-	N.D.
TP37	0.1	Made Ground Topsoil	6.7	14	0.3	0.2	13	22	55	0.1	16	0.5	21	94	-	N.D.
TP40	0.1	Made Ground Topsoil	6.2	17	0.4	0.2	11	35	44	0.1	17	< 0.5	23	81	-	N.D.
TP09	0.1	Ash & Clinker	7.7	**49**	0.9	0.5	61	**210**	**200**	1.0	41	< 0.5	38	**370**	**7.3**	N.D.
TP10	0.4	Ash & Clinker	7.7	**42**	0.7	0.1	30	34	36	0.1	23	0.5	17	67	**4.7**	N.D.
TP12	0.5	Ash & Clinker	7.9	**54**	1.1	0.7	73	**600**	**240**	0.5	40	< 0.5	65	**370**	**6.8**	N.D.
TP34	0.2	Cohesive Made Ground	7.7	12	1.0	1.1	22	**200**	100	< 0.1	20	< 0.5	21	**530**	-	N.D.
TP24	0.4	Cohesive Made Ground	8.0	17	0.9	0.2	20	**100**	56	0.1	21	< 0.5	19	110	-	N.D.
TP13	1.5	Cohesive Made Ground	8.1	15	0.8	0.6	43	**120**	95	0.1	25	< 0.5	34	**330**	-	**Chrysotile**
TP08	1.8	Cohesive Made Ground	9.0	**42**	2.2	0.2	65	43	39	0.1	26	0.6	28	94	-	N.D.
TP15	2.4	Cohesive Made Ground	7.8	25	2.1	8.3	22	85	**240**	0.2	27	< 0.5	28	**4400**	-	**Chrysotile**
TP42	0.2	Granular Made Ground	8.1	15	0.6	0.5	48	56	81	0.1	19	0.5	38	160	-	**Chrysotile**
TP11	0.3	Granular Made Ground	8.5	13	1.4	2.0	250	48	99	0.1	18	1.4	85	**940**	-	N.D.
TP07	0.4	Granular Made Ground	9.5	5.6	0.9	0.1	53	18	19	< 0.1	8.6	< 0.5	38	54	-	N.D.
TP26	0.5	Granular Made Ground	10	6.9	1.0	0.3	150	36	33	< 0.1	22	1.0	69	140	-	N.D.
TP15	0.6	Granular Made Ground	8.0	15	0.6	0.3	45	29	**380**	0.1	17	< 0.5	31	130	-	N.D.

Expl Hole	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 BLUE and assume a **residential with gardens** end-use.												
			pH	As ∞	B~	Cd ∞	Cr x	Cu♣$	Pb ∞	Hg*	Ni	Se	Vn	Zn$	CV	Asbestos
				37	5	26	4000	100	200	199	109	434	584	200	2	
TP22	0.6	Granular Made Ground	9.0	25	0.9	0.2	42	48	55	0.1	26	< 0.5	45	120	-	N.D.
TP27	0.9	Granular Made Ground	11	6.3	1.8	0.4	220	24	36	< 0.1	12	1.8	110	97	-	**Chrysotile**
TP09	1.5	Granular Made Ground	8.6	13	0.7	0.3	110	36	**380**	0.1	23	< 0.5	58	110	-	N.D.
TP22	1.8	Granular Made Ground	8.7	17	0.8	2.0	29	59	79	0.2	19	< 0.5	34	**620**	-	N.D.
TP24	2.0	Granular Made Ground	8.6	11	1.5	0.3	160	75	77	0.1	23	0.9	55	140	-	N.D.
TP07	1.0	Quarry Waste	8.3	7.8	0.4	0.1	15	17	88	0.3	16	< 0.5	16	63	-	N.D.
TP10	1.6	Quarry Waste	7.3	16	0.2	< 0.1	15	11	11	< 0.1	16	0.7	16	51	-	N.D.
TP08	2.8	Quarry Waste	8.5	14	1.6	0.1	18	33	37	0.1	22	0.6	20	78	-	N.D.
TT04A	2.1	Landfill Material	6.9	**230**	0.8	0.8	180	**220**	**1200**	0.7	**130**	3.8	130	**380**	-	N.D.
TT12A	1.2	Landfill Material	4.8	**840**	< 0.2	**55**	4.3	39	**39000**	38	4.1	**4000**	6.3	50	-	N.D.
TP34	0.3	Cement Sheet	-	-	-	-	-	-	-	-	-	-	-	-	-	**Chrysotile**
TP42	0.3	Cement Sheet	-	-	-	-	-	-	-	-	-	-	-	-	-	**Chrysotile & Crocidolite**
TP09	1.7	Cement Sheet	-	-	-	-	-	-	-	-	-	-	-	-	-	**Chrysotile**

Key	
36	Parameter tested for and found to be in excess of Tier 1 value.
179	Parameter tested for and found to be > 5 x Tier 1 value.
12	Parameter tested for but not found to be in excess of Tier 1 value.
-	Parameter not tested for.
♣	Tier 1 Value is pH dependent.
X	Assumes Cr is CrIII. If demonstrated Cr is CrVI Tier 1 would be 21mg/kg.
N.D.	No fibres detected (asbestos screen)

Source of guidance trigger level	
With the exception of those annotated with one of the symbols below (∞, $, ~), all Soil Screening Values in brackets above have been derived using CLEA v1.071.	
∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE/Defra).
$	MAFF. Code of Practice for Agricultural Practice for the Protection of Soil, 1998.
~	Engineering judgement (Lithos). Boron is a phytotoxic, although most phytotoxic compounds can pose a risk to human health if sufficient concentrations are present. However, plants represent the most sensitive receptor, and a Tier 1 value which is protective of flora is therefore also protective of human health.
*	Assumes mercury present as an inorganic compound (cf elemental metal or within organic compound). See Science Report SC050021/Mercury SGV.

Summary of the leachability testing (Areas B & C)

Expl Hole	Depth (m)	Material	Concentration in **µg/litre** unless otherwise Shown. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Tier 1 Screening Concentrations are shown in **BLUE**.									
			pH	As ~	B ~	Cd ~	Cr ~	Cu ~	Pb ~	Hg ~	Ni ~	Se ~	Zn *
				10	1000	5	50	2000	10	1	20	10	3000
TP09	0.1	Ash & Clinker	6.7	1.2	57	0.3	**54**	2.4	3.4	0.1	0.8	2.0	20
TP10	0.4	Ash & Clinker	6.6	0.8	< 12	0.2	1.7	0.9	0.9	< 0.1	< 0.5	0.7	5.3
TP12	0.5	Ash & Clinker	6.6	0.7	21	< 0.1	0.5	1.6	0.6	< 0.1	< 0.5	0.5	5.5
TP34	0.2	Cohesive Made Ground	7.1	2.3	< 12	< 0.1	< 0.3	4.0	0.8	< 0.1	< 0.5	< 0.3	8.2
TP08	1.8	Cohesive Made Ground	6.8	1.8	< 12	< 0.1	< 0.3	1.7	0.5	< 0.1	< 0.5	0.3	2.0
TP11	0.3	Granular Made Ground	7.6	0.6	< 12	0.1	0.6	0.9	0.2	< 0.1	< 0.5	< 0.3	1.8
TP26	0.5	Granular Made Ground	7.8	2.7	< 12	< 0.1	1.6	1.5	0.4	< 0.1	< 0.5	< 0.3	3.2
TP15	0.6	Granular Made Ground	7.2	0.8	< 12	0.1	< 0.3	1.3	< 0.1	< 0.1	< 0.5	< 0.3	2.4
TP09	1.5	Granular Made Ground	7.3	1.4	24	< 0.1	0.6	1.8	0.4	< 0.1	< 0.5	0.4	6.4
TP22	1.8	Granular Made Ground	7.4	2.7	< 12	< 0.1	1.6	1.5	0.4	< 0.1	< 0.5	< 0.3	3.2
TP13	1.5	Quarry Waste	6.9	0.8	< 12	0.1	< 0.3	1.3	< 0.1	< 0.1	< 0.5	< 0.3	2.4
TP15	2.4	Quarry Waste	7.1	4.2	85	0.1	0.3	1.3	0.6	< 0.1	0.6	0.4	11
TP27	0.9	Quarry Waste	7.5	1.4	24	< 0.1	0.6	1.8	0.4	< 0.1	< 0.5	0.4	6.4
TT04A	2.1	Landfill Material	6.4	**13**	14	< 0.1	0.7	3.1	**23**	< 0.1	< 0.5	0.6	6.1
TT12A	1.2	Landfill Material	5.8	5.8	< 12	**10**	< 0.3	1.6	**2000**	< 0.1	0.9	**18**	89

Key		Source of guidance trigger level	
36	Parameter tested for and found to be in excess of Tier 1 concentration	~	Water Supply (Water Quality) Regulations 2018
0.3	Parameter tested for but not found to be in excess of Tier 1 concentration	*	The Surface Waters (Abstraction for Drinking Water) (Classification) Regulations 1996

Summary of degree of soils contamination (Areas B & C – organics)

Expl Hole	Depth (m)	Material	Concentrations in mg/kg. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in BLUE and assume a **residential with gardens and 600mm** cover end use					
			% TOC	PAH		TPH – C6 to C40		
				B(a)P ∞	Naphthalene	GRO~ C_6 to C_{10}	DRO◊ C_{10} to C_{21}	LRO C_{21} to C_{40}
				25	6	23	218	5000
TP23	0.1	Topsoil	2.2	< 0.1	< 0.1	-	-	-
TP28	0.1	Topsoil	5.0	< 0.1	< 0.1	-	-	-
TP38	0.1	Topsoil	2.6	< 0.1	< 0.1	-	-	-
TP43	0.1	Topsoil	4.7	0.1	< 0.1	-	-	-
TP05	0.1	Made Ground Topsoil	2.2	0.1	< 0.1	-	-	-
TP19	0.1	Made Ground Topsoil	2.4	< 0.1	< 0.1	-	-	-
TP21	0.1	Made Ground Topsoil	2.8	< 0.1	< 0.1	-	-	-
TP29	0.1	Made Ground Topsoil	4.4	< 0.1	< 0.1	-	-	-
TP31	0.1	Made Ground Topsoil	6.6	0.2	< 0.1	-	-	-
TP32	0.1	Made Ground Topsoil	4.0	< 0.1	< 0.1	-	-	-
TP35	0.1	Made Ground Topsoil	3.9	< 0.1	< 0.1	-	-	-
TP37	0.1	Made Ground Topsoil	2.1	< 0.1	< 0.1	-	-	-
TP40	0.1	Made Ground Topsoil	5.7	< 0.1	< 0.1	-	-	-
TP09	0.1	Ash & Clinker	19	0.4	< 0.1	< 0.1	13	43
TP10	0.4	Ash & Clinker	11	0.2	< 0.1	< 0.1	<10	<10
TP12	0.5	Ash & Clinker	18	0.2	< 0.1	< 0.1	16	76
TP34	0.2	Cohesive Made Ground	4.6	< 0.1	< 0.1	< 0.1	<10	<10
TP24	0.4	Cohesive Made Ground	8.1	0.1	< 0.1	< 0.1	<10	<10
TP13	1.5	Cohesive Made Ground	4.5	0.8	< 0.1	< 0.1	33	199
TP08	1.8	Cohesive Made Ground	12	0.3	0.12	< 0.1	<10	<10
TP15	2.4	Cohesive Made Ground	5.4	0.1	< 0.1	< 0.1	38	150
TP42	0.2	Granular Made Ground	4.4	0.2	< 0.1	< 0.1	22	110
TP11	0.3	Granular Made Ground	4.9	5.3	0.2	< 0.1	**226**	1340
TP07	0.4	Granular Made Ground	3.9	4.4	< 0.1	< 0.1	**662**	1810
TP26	0.5	Granular Made Ground	4.6	6.3	0.1	< 0.1	**766**	2430

Expl Hole	Depth (m)	Material	Concentrations in mg/kg. Results are quoted to 1 decimal place if <10, and whole numbers if >10. Trigger Level Concentrations are shown in **BLUE** and assume a **residential with gardens and 600mm** cover end use					
			% TOC	PAH		TPH – C6 to C40		
				B(a)P ∞	Naphthalene	GRO~ C_6 to C_{10}	DRO◊ C_{10} to C_{21}	LRO C_{21} to C_{40}
				25	6	23	218	5000
TP15	0.6	Granular Made Ground	4.6	0.2	< 0.1	< 0.1	15	110
TP22	0.6	Granular Made Ground	5.9	0.1	< 0.1	< 0.1	<10	21
TP27	0.9	Granular Made Ground	5.1	3.7	0.5	< 0.1	110	780
TP09	1.5	Granular Made Ground	4.0	0.1	< 0.1	< 0.1	<10	31
TP22	1.8	Granular Made Ground	6.0	0.1	< 0.1	< 0.1	149	299
TP24	2.0	Granular Made Ground	3.3	0.1	< 0.1	< 0.1	<10	38
TP07	1.0	Quarry Waste	1.2	0.4	< 0.1	< 0.1	70	332
TP10	1.6	Quarry Waste	0.8	< 0.1	< 0.1	< 0.1	<10	<10
TP08	2.8	Quarry Waste	12	0.2	0.2	< 0.1	111	325
TT04A	2.1	Landfill Material	3.0	0.1	< 0.1	< 0.1	< 10	<20
TT12A	1.2	Landfill Material	1.9	< 0.1	< 0.1	< 0.1	8.2	66

Key		Source of guidance trigger level	
60	Parameter tested for and in excess of Tier 1 concentration.	All Soil Screening Values in brackets above have been derived using CLEA v1.071. Values assume contaminants located in a sandy loam, with 6% soil organic matter (SOM).	
0.3	Parameter tested for but not in excess of Tier 1 concentration.	~	Assumes all GRO is aromatic fraction C7 to C8.
-	Contaminant not tested for.	◊	Assumes all DRO is aliphatic fraction C10 to C12.
		∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE/Defra).

11.3 Soil contamination results (Area A)

Inorganic determinands

11.3.1 Of the 6 samples of Topsoil analysed for inorganic parameters, all can be classified as uncontaminated.

11.3.2 These samples have been classified by comparison with Tier 1 Soil Screening Values for an end use including domestic gardens and any area where plants are to be grown (the most sensitive of proposed end-uses).

11.3.3 Current UK guidance regarding the statistical analysis of soil contamination data obtained during a site investigation is provided by CL:AIRE[7], and uses two-way confidence intervals and graphical summaries, to assist assessors when determining whether or not a dataset is adequate to answer the question posed; e.g. "is existing site topsoil suitable for retention & re-use?". To answer such a question, it is necessary to recover and test a large number of samples (a minimum of 10; ideally 20+) in order to undertake meaningful statistical analysis.

11.3.4 The difference between the old and new approaches, including how Lithos apply the statistical assessment is detailed in Generic Note 04, included as Appendix A to this report.

11.3.5 Lithos can confirm that statistical assessment of the Topsoil in Area A **is appropriate** because:

- There is a well understood, robust CSM which identifies possible source areas
- Sampling locations are relatively evenly spread across the site and only random sample data has been included in the assessment
- Samples are considered by strata type
- At least 6 samples have been taken from the strata and no significant past use of this area is apparent

11.3.6 Statistical analysis assumes that a given stratum is reasonably homogenous in terms of composition, the distribution of contaminants and the degree of contamination; the CSM indicates that this is a reasonable assumption at this site.

11.3.7 Selected Dot and Box Plots are presented in Appendix L and the results are summarised below.

Natural Ground – Topsoil

Contaminant	Critical concentration	Mean	Upper confidence level (95%)	Lower confidence level (5%)	Range of 'true' mean	Mean lies above critical concentration (Y/N)
Arsenic	37.0	10.4	11.1	9.8	9.8 to 11.1	N
Lead	200.0	28.8	34.1	24.7	24.7 to 34.1	N
Benzo(a)pyrene	5.0	0.1	0.1	0.1	0.1	N

All concentrations are in mg/kg

11.3.8 Statistical analysis indicates that the true mean for all determinands in the Topsoil in Area A are not elevated compared with relevant Lithos tier 1 screening values.

Asbestos

11.3.9 No visual evidence of asbestos-containing materials (ACMs), such as broken fragments of asbestos-cement sheeting, was noted during the excavation of trial pits in Area A.

[7] *CL:AIRE, 2020.Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration.*

11.3.10 No asbestos fibres were identified in any of the 6 samples screened.

Organic determinands

11.3.11 This area of the site is essentially greenfield and therefore for organic compounds, the Tier 1 Values used in this report have been derived with reference to a CSM that assumes a residential with gardens end use, with no clean soil cover will be placed in gardens/landscaped areas (Lithos Scenario A).

11.3.12 Lithos have used the CLEA model to derive risk-based screening values for hydrocarbons, in accordance with the methodology detailed by the TPHCWG, and reviewed by a UK workshop of experts with respect to UK adoption of the method.

11.3.13 However, these screening values assume a Soil Organic Matter (SOM) of 6% (equivalent to a TOC of 3.5%). Many organic contaminants are more mobile when the SOM is lower, and consequently comparison of soil results with lower screening values may be required.

11.3.14 In order to check the validity of Lithos' Tier 1 Soil Screening Values, the average TOC for each common fill type (beyond any areas of obvious hydrocarbon impact) have been determined.

Fill type	Typical TOC (%)	Comparison of soil results with revised screening value necessary?
Topsoil (Area A only)	1.8	Yes, but no significant organic contamination was recorded in this soil type. All determinands well below the most conservative "1%" screening value; most below limit of detection.

11.3.15 There are numerous PAH compounds. The USEPA identified 16 PAHs that are considered to represent the most problematic in terms of toxicology, fate and behaviour. The UK have also focused on these 16 and these are included in the laboratory report where speciated PAH analysis has been scheduled.

11.3.16 Speciated PAH analysis has been undertaken in order to determine concentrations of the key "marker" compounds: benzo(a)pyrene (considered the most toxic of the PAHs); and naphthalene (the most mobile and volatile of the PAHs).

11.3.17 Speciated analysis has confirmed the absence of significant concentrations of both benzo(a)pyrene and naphthalene in the Topsoil in Area A.

BS3882 Topsoil testing

11.3.18 The presence of visible contaminants, sharps (glass etc) was assessed by the Engineer in the field (inspection of initial trial pit arisings); none were identified. BS3882 considers visual contaminants to comprise 'undesirable potentially injurious foreign object(s) visible to the naked eye'.

11.3.19 The clay/sand/silt content of 2 topsoil samples have been determined to check compliance with BS3882[8] requirements.

11.3.20 It should be noted that this is a reduced suite of analysis, and no N-P-K etc. testing has been undertaken.

11.3.21 The results are summarised below:

Parameter	BS3882 Specification	TP01, 0.2m	TP02, 0.2m
Retained on 2mm sieve	< 30%	21	**37**

[8] *BS3882:2015. Specification for topsoil. Published by BSI Standards Limited.*

Parameter	BS3882 Specification	TP01, 0.2m	TP02, 0.2m
Retained on 20mm sieve	< 10%	8	**26**
Retained on 50mm sieve	0%	0	0
Clay content	5 to 35%	7	5
Silt content	0 to 65%	18	17
Sand content	0 to 90%	54	41
Visible contaminants	< 0.5%	0	0

Note: Values in **bold** type fail the required specification for multipurpose topsoil

11.3.22 The results indicate that the topsoil complies with the requirements for multipurpose topsoil, with the exception of gravel content in the sample from TP02. This is likely associated with the underlying natural weathered sandstone which is likely to have been mixed with the topsoil by ploughing.

11.4 Soil contamination results (Areas B & C)

Inorganic determinands

11.4.1 Of the 36 samples of Topsoil and Made Ground from Areas B & C analysed for inorganic parameters, 22 can be classified as uncontaminated and 14 could be classified as contaminated.

11.4.2 These samples have been classified by comparison with Tier 1 Soil Screening Values for an end use including domestic gardens and any area where plants are to be grown (the most sensitive of proposed end-uses).

11.4.3 The most common contaminants are:

- Ash & Clinker – arsenic, copper, lead and zinc
- Cohesive Made Ground – arsenic, copper, lead and zinc
- Granular Made Ground – lead and zinc
- Landfill Material – arsenic, cadmium, copper, lead, nickel, selenium and zinc

11.4.4 Current UK guidance regarding the statistical analysis of soil contamination data obtained during a site investigation is provided by CL:AIRE[9], and uses two-way confidence intervals and graphical summaries, to assist assessors when determining whether or not a dataset is adequate to answer the question posed; e.g. "is existing site topsoil suitable for retention & re-use?". To answer such a question, it is necessary to recover and test a large number of samples (a minimum of 10; ideally 20+) in order to undertake meaningful statistical analysis.

11.4.5 However, in the context of site investigation to assess the significance of contamination on brownfield sites which are typically underlain by heterogenous made ground, some remediation is almost always required (placement of soil cover, excavation of gross contamination etc). Consequently, in such circumstances, it is not usually necessary to demonstrate that made ground soils are "clean" and therefore there is no need to test large numbers of samples and undertake statistical analysis. Heterogenous made ground sample results can simply be compared directly with appropriate screening values (e.g. Lithos Tier 1 values).

11.4.6 The difference between the old and new approaches, including how Lithos apply the statistical assessment is detailed in Generic Note 04, included as Appendix A to this report.

[9] *CL:AIRE, 2020.Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration.*

11.4.7 Lithos can confirm that statistical assessment of all made ground types is **not appropriate** because:

- Made Ground is considered too heterogenous
- There are insufficient samples from each strata type to allow representative statistical assessment to be undertaken.

11.4.8 Elevated concentrations of zinc were recorded at a number of locations. **Zinc** is a phytotoxic metal; phytotoxicity describes the inhibitive and toxic effect high concentrations of some substances can have on plant growth.

11.4.9 Most substances are harmful to human health at lower concentrations than would be detrimental to plant growth. However, there are three notable exceptions – boron, copper and zinc. Plants are the more sensitive receptor to these elements i.e. detrimental effects are seen in plants at concentrations which do not present a risk to human health. Consequently, for zinc, consideration and protection of flora would also be protective of human health.

11.4.10 Allowable concentrations of heavy metals in arable soils are set out in Defra's Code of Good Agricultural Practice 2009[10]. The value for zinc is 200mg/kg, and is based on a continued annual application of heavy metal rich fertiliser (sludge); as such it is not representative of activity in a standard UK garden.

11.4.11 Lithos have also derived a value for zinc in relation to risks to human health, using the CLEA model, assuming a residential end use with consumption of home grown produce in a sandy loam soil with 6% SOM. The reported value is 2,170mg/kg, ten times greater than the potential phytotoxic concentration.

11.4.12 Based on the revised screening value a single elevated concentration of zinc has been recorded on the site (4,400mg/kg TP15 2.4m bgl). On balance, given the context of a residential development and the relatively typically low concentrations recorded, zinc is not considered significant and no special remedial measures are considered necessary.

11.4.13 Similar logic applies to **copper** (human health Tier of 2,400mg/kg), and consequently on balance, the slightly elevated concentrations of copper and zinc are not considered significant and no special remedial measures are considered necessary.

11.4.14 Whilst all made ground types contain elevated concentrations of arsenic and lead the **Landfill Material** also contains elevated concentrations of other contaminants (cadmium and selenium). Furthermore, the concentrations recorded within the Landfill Material are notably more elevated than within the other made ground types present.

Calorific value

11.4.15 The calorific value of 3 samples of Ash & Clinker have yielded CV results of between 4.7 MJ/kg and 7.3 MJ/kg (average 6.3 MJ/kg). Materials whose CVs exceed 10MJ/kg are almost certainly combustible, while those with values below 2MJ/kg are unlikely to burn.

Asbestos

11.4.16 Broken fragments of suspected asbestos cement sheeting were identified in a number of trial pits (TPs 09, 34 & 42). All fragments were subsequently identified as an asbestos-containing material (ACM).

[10] *Defra – Protecting our Water, Soil & Air – A Code of Good Agricultural Practice for farmers, growers and land managers. 2009*

11.4.17 Screening for asbestos identified fibres in 5 of the 36 samples of Topsoil/Made Ground tested with it being recorded within the Topsoil, Granular Made Ground and Cohesive Made Ground.

11.4.18 Further analysis (asbestos quantification) was undertaken with the results summarised in the table below.

Hole ID	Depth (m)	Strata	ACM Identified?	Results of Asbestos quantification analysis
TP38	0.1	Topsoil	No	0.002% chrysotile
TP13	1.5	Cohesive Made Ground	No	<0.001% chrysotile
TP15	2.4	Cohesive Made Ground	No	0.002% chrysotile
TP42	0.2	Granular Made Ground	Yes (insultation)	0.025%
TP27	0.9	Granular Made Ground	No	<0.001% chrysotile
TP34	0.3	Cement Sheet	Yes (cement sheet)	Chrysotile
TP42	0.3	Cement Sheet	Yes (cement sheet)	Chrysotile & Crocidolite
TP09	1.7	Cement Sheet	Yes (cement sheet)	Chrysotile

11.4.19 If during appropriate laboratory analysis only 1 or 2 fibres (or fibre bundles) are seen and identified as asbestos, HSG248[11] suggests that the term 'trace asbestos identified' can be used; the reported concentration will be < 0.001%. Consequently, 3 of the 5 results reported here whilst low, are more than a trace.

Leachables

11.4.20 Of the leachability tests conducted on 15 samples of made ground, 3 had concentrations of leachable contaminants above the maximum permissible concentrations as defined in the Water Supply (Water Quality) Regulations 1989, as amended in 2000.

11.4.21 A single sample of Ash & Clinker yielded a slightly elevated concentration of chromium (54ug/l compared to the Tier 1 value of 50ug/l) which is not considered significant given the isolated occurrence, the site's environmental setting (Secondary A aquifer and not within a groundwater SPZ), and proposed earthworks which will reduce infiltration of water through the made ground.

11.4.22 Both samples of Landfill Material tested yielded elevated concentrations of a number of metals (notably lead).

Organic determinands

11.4.23 Areas B & C are brownfield and underlain by made ground which has yielded elevated concentrations of a number of inorganic determinands. Consequently, for organic compounds, the Tier 1 Soil Screening Values used in this report have been derived with reference to a CSM that assumes a minimum 600mm of clean soil cover will be placed in gardens/landscaped areas (Lithos Scenario B).

11.4.24 Lithos have used the CLEA model to derive risk-based screening values for hydrocarbons, in accordance with the methodology detailed by the TPHCWG, and reviewed by a UK workshop of experts with respect to UK adoption of the method.

11.4.25 However, these screening values assume a Soil Organic Matter (SOM) of 6% (equivalent to a TOC of 3.5%). Many organic contaminants are more mobile when the SOM is lower, and consequently comparison of soil results with lower screening values may be required.

[11] *HSG:2021. Asbestos: The Analysts' Guide.*

11.4.26 In order to check the validity of Lithos' Tier 1 Soil Screening Values, the average TOC for each common fill type (beyond any areas of obvious hydrocarbon impact) have been determined.

Fill type	Typical TOC (%)	Comparison of soil results with revised screening value necessary?
Made Ground Topsoil	3.7	No
Ash & Clinker	>5	
Cohesive Made Ground	4.7	
Granular Made Ground	>5	
Quarry Waste	4.7	

Hydrocarbons (TPH & PAH)

11.4.27 Given the previous uses of the site (no hydrocarbon sources identified) and absence of visual/olfactory evidence of any hydrocarbon contamination, only a simple banded TPH (cf full speciation) was scheduled on 23 samples of made ground.

11.4.28 Elevated concentrations of DRO were recorded in three samples of granular made ground (TP11, 0.3m bgl, TP07 0.4m bgl & TP26 0.5m bgl).

11.4.29 TPH can be associated with a variety of sources and elevated TPH concentrations do not automatically infer a petroleum product is present; indeed the absence of petroleum products on this site is reflected in the preliminary conceptual model. TPH analysis will detect most hydrocarbons and is not restricted to those detailed within the TPHCWG reports.

11.4.30 Whilst not necessarily associated with a petroleum product, the significance of these hydrocarbons, with respect to health, should still be assessed. Providing no other sources are present on site (solvents, degreasers etc), it can be assumed that the most problematic compounds detected within the banded TPH screen are polycyclic aromatic hydrocarbons (PAHs).

11.4.31 The significance of PAHs can be determined by considering indicator compounds. In most cases, benzo(a)pyrene (BaP) is adopted as an indicator (due to the wealth of toxicological data available) and has been used by various authoritative bodies to assess the carcinogenic risk of PAHs in food.

11.4.32 Whilst classed as a PAH, naphthalene is more volatile and mobile in the environment than other PAHs. As such the significance of naphthalene cannot be considered within the surrogate marker approach. Consequently, naphthalene has been considered individually against Lithos' Tier 1 Value.

11.4.33 A C4SL toxicity assessment using the surrogate marker approach can be used to estimate the significance of a mixture of PAHs in soil, using toxicity data for indicator compounds within that mixture. Exposure to the indicator (or surrogate marker) is assumed to represent exposure to all PAHs in that matrix. The sample profiles here are sufficiently similar to the toxicity study adopted for the C4SL assessment.

11.4.34 Concentrations of B(a)P and naphthalene are both below their respective Tier 1 Values and consequently, the DRO hydrocarbons detected are unlikely to pose any unacceptable risk to end users, and no remediation is required (beyond what is necessary for the inorganic/asbestos contamination identified).

Volatile Organic Compounds (VOC) and Semi-Volatile Organic Compounds (sVOC)

11.4.35 The two samples of Landfill Material recovered from Area C were scheduled for a suite of Volatile Organic Compounds (VOC) and Semi-Volatile Organic Compounds (sVOC). No significant concentrations of any compounds were detected in either sample with the vast majority being at or below the limit of detection.

BS3882 Topsoil testing

11.4.36 The presence of visible contaminants, sharps (glass etc) was assessed by the Engineer in the field (inspection of initial trial pit arisings); gravel size fragments of anthropogenic materials (including glass and ceramic) were identified in a number of locations. BS3882 considers visual contaminants to comprise 'undesirable potentially injurious foreign object(s) visible to the naked eye'.

11.4.37 The clay/sand/silt content of 4 topsoil samples from Area B1 have been determined to check compliance with BS3882[12] requirements.

11.4.38 It should be noted that this is a reduced suite of analysis, and no N-P-K etc. testing has been undertaken.

11.4.39 The results are summarised below:

Parameter	BS3882 Specification	TP19, 0.2m	TP28, 0.2m	TP37, 0.2m	TP40, 0.2m
Retained on 2mm sieve	< 30%	**34**	12	18	11
Retained on 20mm sieve	< 10%	**25**	0	0	0
Retained on 50mm sieve	0%	0	0	0	0
Clay content	5 to 35%	7	10	11	9
Silt content	0 to 65%	19	25	25	11
Sand content	0 to 90%	40	53	46	58
Visible contaminants	< 0.5%	**0.5**	0	**1.5**	**0.5**

Note: Values in **bold** type fail the required specification for multipurpose topsoil

11.4.40 The results indicate that the topsoil complies with the requirements for multipurpose topsoil, with the following exceptions:

- The gravel content of one sample (TP19) tested slightly exceeded the maximum permissible level (34% *cf* upper threshold of 30% for 2mm and 25% *cf* upper threshold of 10% for 20mm). However, the average gravel content from the 4 samples is within the specified range.
- Visible contaminants were identified in 3 of the 4 samples tested above the maximum permissible level.

12 CONTAMINATION (QUALITATIVE RISK ASSESSMENT & REMEDIATION)

12.1 Topsoil (Area A)

12.1.1 Topsoil, typically 300mm thick underlies Area A. Testing suggests this material is suitable for re-use.

[12] *BS3882:2015. Specification for topsoil. Published by BSI Standards Limited.*

12.1.2 Given the nature of the topsoil present on this site it would be expected to be suitable to support plant growth.

12.1.3 No plausible contaminant linkages have been identified in this area of the site and therefore no remediation is required.

12.2 Summary of significant contamination (Areas B & C)

Made Ground Topsoil

12.2.1 Made Ground Topsoil is present across Area B1, and sporadically in Areas B2 & C, which is typically 300mm in thickness. Testing suggests this material is suitable for re-use although contains a significant proportion of anthropogenic materials (glass, ceramic, coal, brick, etc). Consequently, this is not considered suitable for re-use near surface in private gardens.

12.2.2 It is therefore recommended that the Made Ground Topsoil is stripped from Areas B & C and placed in areas of POS. Alternatively, it could be placed as the lowermost 150mm of the proposed "clean" cover in private gardens.

12.2.3 Given the compressible nature and gas-generating potential of this material if buried at depth, the Made Ground Topsoil should not be overlain by no more than 1m of soil.

Made Ground

12.2.4 An area of deep made ground (typically >2.5m thick) is present across Area C associated with a former sandstone quarry which was subsequently used as a landfill. The made ground predominantly comprises **Granular & Cohesive Made Ground** with localised occurrences of **Ash & Clinker** and **Quarry Waste**; isolated pockets of **Landfill Material** are also present.

12.2.5 This made ground contains elevated concentrations of a number of inorganic determinands and contains materials (e.g. brick, concrete, clinker, glass, metal, etc), which would generally be considered undesirable as a near-surface material in garden areas. Additionally, the made ground contains asbestos above 'trace amounts' along with ACMs (cement and insultation).

12.2.6 An area in the northeast of Area C also contains a variable material type (**Landfill Material**) identified by bright colours (red, purple & white) which has yielded significantly elevated concentrations of inorganic determinands (notably arsenic, lead and selenium).

12.2.7 The approximate location where Landfill Material has been encountered is shown on Drawing 4674/10 (red hatching) which is based on observations made during Lithos' ground investigation, combined with the laboratory test results.

12.2.8 Given the above, remediation earthworks are required in order to render the site suitable for redevelopment.

12.2.9 No areas of significant organic (hydrocarbon) contamination have been identified to date although given the site's former use as a landfill, the possible presence of grossly contaminated fill cannot be discounted.

12.3 Revised conceptual ground model (contamination)

12.3.1 The Preliminary 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.

12.3.2 A revised Conceptual Site Model is presented as Drawing 4674/7 in Appendix B. The Model includes the contaminants described in Section 12.2 above, and potential contaminant linkages (summarised below in Section 12.5) to receptors.

12.4 Environmental setting & end use

12.4.1 As discussed in Section 12.2 above, contamination exists in the soil beneath this site. In order to assess the significance of this contamination, consideration must be given to the site's environmental setting and the proposed end use.

12.4.2 The underlying sandstone bedrock is classified as a Secondary A aquifer. The nearest surface watercourse is an unnamed stream, which flows in a northeast direction, approximately 40m beyond the site's northern boundary. Therefore, the site's environmental setting is considered to be **moderate sensitivity**.

12.4.3 With respect to human health, the proposed end use (residential) is considered **sensitive**.

12.4.4 Transient risks to construction workers can be addressed by the adoption of appropriate health and safety measures, see Section 16.7.

12.5 Contaminant linkages

12.5.1 In terms of a proposed redevelopment of this site, plausible contaminant linkages can be summarised as follows.

Contaminants

12.5.2 Contaminants have been summarised in Section 12.2 above.

Pathways

12.5.3 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

12.5.4 Potential contaminant receptors include:

- The environment – Secondary A aquifer
- End users of the site (residents)

12.5.5 It can be concluded that there are plausible pathways between the soil contaminants summarised in Section 12.2 above and potential receptors. Consequently, some remediation will be required; either treatment/removal of the contaminant, or "breakage" of the pathway.

12.6 Potential remediation options

General

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

12.6.2 Given the constraints discussed in Section 8.2 (dense vegetation in Area C), some additional investigation will be required before definitive recommendations are provided. However, at this stage it is considered unlikely that anything more than placement of soil cover in garden/landscaped areas, and removal of significantly contaminated soils (**Landfill Material**) will be required.

Combustibility

12.6.3 The Ash & Clinker encountered in Area C yielded an average CV of 6.3 MJ/kg (maximum 7.3 MJ/kg) and is considered potentially combustible.

12.6.4 Given the need for significant preparatory earthworks, it should be ensured that the Ash & Clinker is redistributed at greater than 1m depth to mitigate against the risk of spontaneous combustion.

12.6.5 As further mitigation against the risk of spontaneous combustion, the ash could be excavated, replaced in approximate 300mm thick layers, wetted and subjected to nominal compaction, comprising at least 2 passes with a towed vibratory roller of at least 2,900 kg per metre width. Compaction will help to prevent the material drying out and reduce the ingress of oxygen.

12.6.6 Alternatively, if the Ash & Clinker is left on site, the following remediation measures could be adopted:

- Services: utility trenches (especially those carrying potential heat sources e.g. electric cables) should be cut oversize and backfilled with clean, inert material. This applies to any utility trenches that run beneath estate roads or extend under houses. It is strongly recommended that further advice be sought from all statutory service bodies with respect to the ground conditions within which they will lay services.
- Estate roads: no action required (although generally less than 1,000mm thick, the road construction is considered to provide adequate isolation as there will be no heat source). Local Authority Highways approval should be sought.
- Houses: no action required (the floor slab will include insulation and therefore heat transfer into the ground will be negligible). Local Authority Building Control and Warranty Provider approval should be sought.

Asbestos

12.6.7 CL:AIRE has published a Joint Industry Working Group (JIWG) guidance[13] document with the support of the Health & Safety Executive which provides an explanation of how legal requirements of the Control of Asbestos Regulations 2012 have been interpreted to be more directly applicable to the risks associated with asbestos contaminated soil and construction & demolition materials.

12.6.8 Samples of soil and/or construction & demolition material recovered from brownfield sites may exhibit a wide range of concentrations of asbestos contamination. Due consideration should therefore be given to the interpretation of any 'trace' concentrations in the wider context of the site. Guidance prepared by the JIWG asbestos suggests that judgements on the nature, degree and significance of contamination present should not be made on the basis of individual samples alone.

[13] *Control of Asbestos Regulations 2012: Interpretation for Managing and Working with Asbestos in Soil and Construction & Demolition materials: Industry Guidance. CL:AIRE, 2016.*

12.6.9 As discussed in Section 11.4, an asbestos ID (screen) was scheduled on 36 samples of Topsoil and made ground recovered from Areas B & C, with asbestos identified in 5 samples. Additionally, fragments of asbestos cement sheeting were identified in 3 trial pits. Supplementary analysis (asbestos quantification) of the samples yielded 3 of the 5 results above the limit of measurement (<0.001%).

12.6.10 Made ground soils with only a trace of asbestos still have the potential to be hazardous to human health. This is because soil with a low asbestos content of say 0.001% may contain thousands, possibly hundreds of thousands, of potentially respirable asbestos fibres per gram of soil. However, asbestos fibres only pose a risk if they are allowed to become airborne, and release from soil to air can only occur if the soil is dry and then agitated (e.g. by vehicle movement, excavation, wind etc).

12.6.11 Provided soils are kept damp the risk of airborne fibre release, even during disturbance associated with excavation, should be negligible, and certainly below the control limit (as set by the Control of Asbestos Regulations 2012) of 0.1 f/cm^3 airborne fibres averaged over a 4-hour period.

12.6.12 In our experience, damp soils do not allow the release of asbestos fibres, even from soils that contain concentrations in excess of the hazardous waste threshold (0.1%).

12.6.13 Consequently, in line with the principles of sustainable development, there should be no need to export any soil from site.

12.6.14 There may be transient risks during the excavation of made ground soils. Exposure to asbestos of personnel involved in these excavation works is considered likely to be sporadic and of low intensity (provided soils are kept damp). Therefore in accordance with Regulation 3(2) of the Control of Asbestos Regulations (2012), exemption from Regulations: 9 (notification of work with asbestos); 18(1)(a) (asbestos areas); and 22 (health records and medical surveillance) should apply, provided it is 'clear from a suitable and sufficient risk assessment that the control limit of 0.1 f/cm3 airborne fibres averaged over a 4-hour period will not be exceeded'.

12.6.15 Nonetheless, risks must be mitigated by appropriate measures (principally damping down), working procedures, and PPE. Method Statements and Risk Assessments should be prepared by the Contractor, and then be reviewed by the Client and Lithos.

12.6.16 Any fragments of asbestos cement sheeting encountered during the excavation works, should be gathered by hand and placed in double sealed bags. Personnel involved in this activity must be equipped with an appropriate respirator (i.e. a FFP3 or better), in addition to their "standard" PPE. The bags of asbestos waste should be placed in a sealed skip for off-site disposal at a suitably licensed landfill site; such material will be classified as hazardous waste.

12.6.17 Made ground where asbestos has been positively identified and considered representative of near-surface soils, should ultimately be isolated beneath any of the following:

- a minimum 600mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 750mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base in **garden and areas** (**750mm** in total). This would also apply to the community orchard where made ground is present.
- a minimum 300mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 450mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base in **landscaped areas** (**450mm** in total)
- hardstand (parking areas)
- floor slabs (buildings)

12.6.18 The above measures will ensure there is no risk of release of asbestos fibres from the ground.

12.6.19 New utilities should be laid in trenches reinstated with 'clean' backfill in order to prevent exposure to maintenance workers in the future.

12.6.20 See also comments in the 'Waste Classification' Section 12.8 below.

Inorganic contamination

Area B

12.6.21 With the exception of a single sample (TP38 at 0.1m), the Made Ground Topsoil in Areas B1 & B2 has been found to be essentially "clean" (i.e. it has not yielded elevated concentrations of any contaminants), but it does include "unsuitable" materials (e.g. they contain a significant proportion of glass, ceramic, brick, coal, etc).

12.6.22 Therefore, the Made Ground Topsoil should be stripped, stockpiled separately from the "clean" Topsoil in Area A, and redistributed in areas of POS or as the lowermost 150mm of cover in proposed garden areas in Area C.

12.6.23 Where any residual made ground remains in Area B beneath garden and landscaped areas (i.e. not beneath hardstanding), a **450mm** thick surface cover of "clean" soil is recommended. This thickness is in accordance with NHBC Standards, Chapter 10.2.

Area C

12.6.24 The bulk of the made ground in Area C has yielded elevated concentrations of a number of metals; most notably lead and arsenic and asbestos has been identified. Where residual made ground remains beneath garden and landscaped areas the following surface cover is recommended:

- a minimum 600mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 750mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base in **garden areas** (**750mm** in total). This would also apply to the community orchard where made ground is present.
- a minimum 300mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 450mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base in **landscaped areas** (**450mm** in total)

12.6.25 This cover will break potential contaminant linkages between the contaminated made ground and future end-users.

12.6.26 The **Landfill Material** encountered in the northeast of Area C has yielded significantly elevated concentrations of a number of inorganic determinands and is therefore not considered suitable for retention on site. Consequently, this material should be delineated by excavation, stockpiled separately from other material types and disposed of off-site.

Organic contamination

12.6.27 No areas of gross organic contamination were encountered during the site works. However, localised areas of more onerous contamination than that identified to date may be present on site.

12.6.28 Given the site's former use as a landfill, it would be prudent to allow for the off-site disposal of some grossly contaminated soil. Further advice should be sought from a specialist contractor, with experience of brownfield remediation, regarding an appropriate contingency.

12.7 Summary of potential contaminant linkages & mitigation

12.7.1 In terms of the proposed redevelopment plausible contaminant linkages, and feasible remediation options, can be summarised as follows:

Receptors	Pathways	Contaminants	Plausible contaminant linkage? (and remediation options where required)
Human health (Future residents) ◊	Consumption of contaminated vegetables	Metals & asbestos in the made ground (Area C)	**Yes** – isolation beneath clean soil cover, plus hard dig layer, in garden and landscaped areas
	Ingestion		
	Dermal contact		
	Inhalation (dust and/or vapours)		
Buildings	Migration & accumulation of explosive and asphyxiating gases	Methane, carbon dioxide	To be assessed on completion of monitoring and gas risk assessment
Groundwater	Leaching of inorganic determinands from Landfill Material	Metals in the made ground	**Yes** – off-site disposal of Landfill Material
	Surface water run-off		**Yes** – Silt and surface water management plan (SWMP) required

◊ 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.

12.8 Waste classification

12.8.1 Disposal of the made ground off site is generally 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. Disposal to landfill (or an appropriate soil / aggregate transfer station) may be the most practical solution, if redistribution and retention on site is not feasible.

12.8.2 Following excavation and stockpiling, sampling will be required prior to disposal.

12.8.3 As there is no WRAP protocol for soils, the characterisation, sampling and classification of soils arising from brownfield sites has been incorporated within the Environment Agency's Technical Guidance WM3[14]. Classification of soils as non-hazardous or hazardous in accordance with WM3 is quite a complex process, although it ultimately results in a simple classification as hazardous or non-hazardous. Note: inert is not a class under WM3; WAC testing is required to determine whether a waste soil can be considered inert.

12.8.4 If waste soil is classed as hazardous following classification under WM3, and destined for landfill, waste acceptance criteria (WAC) leachate testing will need to be undertaken. Similarly, if waste soil destined for landfill is classed as non-hazardous under WM3, and suspected to be inert, WAC leachate testing will need to be undertaken. However, non-hazardous soil waste can go to a non-hazardous landfill facility; no further testing (e.g. WAC) is required.

[14] *Technical Guidance WM3 – Guidance on the classification and assessment of waste. Environment Agency 2015*

12.8.5 WAC analysis is different to the 'routine' laboratory testing (such as that included earlier in this Section) undertaken in order to determine hazardous properties. Lithos typically only include WAC analysis if significant off-site disposal (of soil classified as hazardous waste) is anticipated.

12.8.6 It is critical if material is to be exported from site that this is allocated an appropriate waste code, following the steps within WM3. Waste carriers transporting, and sites accepting, this material should have a corresponding code within their permits. It is the responsibility of those generating the waste (i.e. the Developer), to ensure that the waste is handled and disposed of appropriately.

12.8.7 Soil treatment facilities (STFs) provide an alternative to landfill. STFs are regulated by the Environment Agency and allow soils to be treated and screened (effectively recycled to be used at other sites). Export to an STF does not require WAC testing and suitability of various soil types will be dependent on material waste codes, which may be allocated after consideration of the data in Section 12 but will often need supplementing with further testing after soils have been stockpiled (see also advice in Section 16.3).

12.8.8 Most STFs are permitted to accept soils with waste code 17 05 04 (i.e. soils which do not exhibit hazardous properties). Lithos has a list of permitted STFs and can help identify one local to this development site.

12.8.9 With respect to **asbestos**, waste soils will be classed hazardous if the soil mass contains more than 0.1% asbestos fibres that are free and dispersed. However, WM3 states that where the waste contains identifiable pieces of asbestos (i.e. any particle of a size that can be identified as potentially being asbestos by a competent person if examined by the naked eye), then the waste is hazardous if the concentration of asbestos in the pieces alone is 0.1%. If a stockpile of soil contained rare fragments of broken asbestos-cement sheeting, the whole stockpile would be classed as hazardous unless all the fragments could be picked-out (even though the concentration of asbestos in the soil mass might be orders of magnitude less than 0.1%).

12.8.10 As discussed in Section 9.2, tarmac hardstand is present in the form of a public bridle way running through the centre and north of the site.

12.8.11 If off-site disposal is anticipated, tarmac assessment is based on the amount of coal tar present, this will vary depending on the age of the tarmac. The assessment is based on the amount of benzo(a)pyrene and has a concentration limit of 50mg/kg.

12.8.12 Contractors exporting waste from the site should review the site investigation data and make their own assessment. Alternatively, Lithos could undertake this assessment once exported waste streams have been identified.

13 HAZARDOUS GAS

13.1 General

13.1.1 Consideration of the conceptual site model and potential linkages has enabled a preliminary qualitative assessment of risks associated with gas:

Source	Receptors	Hazard	Pathway	Initial risk
On-site made ground/landfill	Human health	Asphyxiation & explosion	Lateral/vertical migration, ingress & accumulation	**Low**: made ground essentially inert, with little degradable matter
	Buildings	Explosion		
	Human health	Asphyxiation & explosion		**Low**: nature of made ground unknown (although likely inert) and

Source	Receptors	Hazard	Pathway	Initial risk
Off-site landfill (immediately north)	Buildings	Explosion	Lateral migration, ingress & accumulation	shallow natural strata predominantly granular (weathered sandstone)
Deep mineworkings	Human health	Asphyxiation & explosion	Vertical migration, ingress & accumulation	**Moderate**: bedrock comprises sandstone which is permeable and faults are mapped in the local area providing plausible pathways
	Buildings	Explosion		

13.1.2 Given the above gas monitoring wells have been installed in 21 boreholes across the site. Details of the installations are given on the borehole logs presented in Appendices H & I to this the report.

13.1.3 The generation potential of the gas source was initially considered to be Moderate and this has been confirmed by the monitoring results obtained. Consequently, in accordance with CIRIA Report C665[15], given the proposed residential end use, 12 visits have been scheduled over a 6-month period.

13.2 Scope of works

13.2.1 To date, the wells have been monitored on two occasions for groundwater levels and soils-gases, and the results are presented in Appendix N.

13.2.2 A standard procedure was followed, in accordance with CIRIA guidance:

- Ambient oxygen concentration
- Atmospheric temperature & pressure
- Methane, oxygen and carbon dioxide concentrations and flow rates using a Gas Data GFM436 infra-red gas analyser
- Standing water level using a dipmeter
- Ambient oxygen concentration (check for instrument drift)

13.3 Monitoring results

13.3.1 The results of the monitoring completed to date are summarised below.

Well	Response zone	Range of methane concentrations (% v/v)	Range of carbon dioxide concentrations (% v/v)	Range of steady flow rates (litre/hour)
PH01	2.7m – 3.7m (Made Ground & Granular Residual Soil)	N.D	2.3	N.D
PH02	2.5m – 3.5m (Made Ground)	N.D	2.1 to 2.9	N.D
PH04	1.5m – 3.0m (Sandstone)	N.D	1.3 to 2.1	N.D
PH05	1.0m – 2.0m (Made Ground)	N.D	2.3 to 3.3	N.D
PH07	1.0m – 2.5m (Made Ground)	N.D	4.9 to 7.2	N.D
PH12	1.0m – 2.0m (Made Ground)	N.D	5.6 to 8.5	N.D

[15] *CIRIA C665: Assessing risks posed by hazardous ground gases to buildings (2007).*

Well	Response zone	Range of methane concentrations (% v/v)	Range of carbon dioxide concentrations (% v/v)	Range of steady flow rates (litre/hour)
PH14	1.0m to 3.0m (Granular Residual Soil and Sandstone)	N.D	5.3 to 6.2	N.D
WS01	1.0m to 2.0m (Granular Residual Soil)	N.D	1.4 to 3.3	N.D
WS02	0.5m to 1.5m (Granular Residual Soil)	N.D	4.2 to 5.6	N.D
WS04	0.7m to 1.7m (Granular Residual Soil)	N.D	2.3 to 4.2	N.D
WS05	0.5m to 1.5m (Granular Residual Soil)	N.D	2.2	N.D
WS06	0.7m to 1.4m (Granular Residual Soil)	N.D	1.6 to 3.1	N.D
WS07	0.5m to 1.5m (Granular Residual Soil and Sandstone)	N.D	1.0 to 3.3	N.D
WS08	1.0m to 2.0m (Granular & Cohesive Residual Soil)	N.D	4.6 to 6.1	N.D
WS09	0.9m to 1.9m (Granular & Cohesive Residual Soil)	N.D	2.2 to 2.9	N.D
WS10	0.6m to 1.6m (Granular Residual Soil)	N.D	1.5 to 2.3	N.D
WS11	0.5m to 1.5m (Granular Residual Soil)	N.D	2.0 to 2.8	N.D
WS12	1.0m to 1.8m (Granular & Cohesive Residual Soil)	N.D.	0.4 to 2.2	N.D.
WS13	0.8m to 1.8m (Granular & Cohesive Residual Soil)	N.D.	1.5 to 3.1	N.D.
WS14	0.5m to 1.0m (Granular Made Ground)	N.D.	2.0 to 3.2	N.D.
WS15	0.5m to 1.4m (Granular Residual Soil)	N.D.	1.4	N.D.

N.D. - none detected

13.4 Discussion (methane & carbon dioxide)

13.4.1 Generic Note 05 in Appendix A outlines how monitoring results are interpreted.

13.4.2 A hazardous gas risk assessment incorporating all of the results will be issued on completion of monitoring in November 2024.

13.5 Radon

13.5.1 Requirements with respect radon measures are set out in Building Regulations Approved Document C. Probability bandings (based on the proportion of properties in a given area that exceed the Action Level; currently 200 $Bq.m^{-3}$) are used to determine whether a property requires no, basic or full measures.

13.5.2 At present Approved Document C advocates basic measures for the probability banding 3% to 10% (full measures if >10%). However, the UK Health Security Agency (HSA) would like to see all new build include basic measures.

13.5.3 In December 2022, the British Geological Survey (BGS), deployed a revised dataset which increased accuracy and also the number of properties falling within radon affected areas. This revised dataset is now referenced by maps on the HSA website.

13.5.4 The HSA website radon map indicates that the site is in an area where **3% to 5%** of homes are estimated to be above the action level. However, a site specific radon report was obtained and this confirms that the site itself is in an area where **1% to 3%** of homes are estimated to be above the action level, meaning **no radon** specific protection measures are required in new dwellings.

14 GEOTECHNICAL TESTING

14.1 General

14.1.1 A total of 19 samples of natural soil were delivered to a suitably accredited laboratory with a schedule of geotechnical testing drawn up by Lithos.

14.1.2 The geotechnical laboratory test results are presented in Appendix M to this report.

14.2 Atterberg limits

14.2.1 The plasticity indices of 19 samples of made ground and natural soil have been determined; results are summarised below.

Soil type	No. samples tested	Moisture content range % (average)	Range of Plasticity Indices % * (average)	Shrinkability
Made Ground	8	15 to 41 (22)	NP to 20 (13)	Low to medium
Cohesive Residual Soil	8	15 to 33 (21)	NP to 18 (15)	Low
Granular Residual Soil	3	11 to 18 (16)	NP to 14 (12)	Low

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

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

14.2.2 For the purposes of foundation design, it is recommended that the natural cohesive soils be regarded as being of **low** shrinkability.

14.2.3 Of the 8 samples of made ground tested, only one sample of Cohesive Made Ground returned a modified Plasticity Index of 20% or greater (i.e. medium shrinkability). Therefore, the made ground can be considered to be of low shrinkability.

14.3 Particle size distribution

14.3.1 The grading of 8 samples of made ground and 6 samples of natural strata has been determined by wet sieving and the results are summarised in the table below:

Sample & depth	Strata	Field description	% passing 37.5mm sieve	% passing 20mm sieve	% passing 2mm sieve	% fines	Material description (based on grading & plasticity)
Made Ground							
TP10, 0.6m		Slightly sandy gravelly CLAY	100	100	69	36	Slightly sandy slightly gravelly CLAY

Sample & depth	Strata	Field description	% passing 37.5mm sieve	% passing 20mm sieve	% passing 2mm sieve	% fines	Material description (based on grading & plasticity)
Made Ground							
TP25, 1.2m	Cohesive Made Ground	Sandy gravelly CLAY	97	94	85	51	Slightly gravelly slightly sandy CLAY
TP09, 0.7m	Granular Made Ground	Sandy clayey GRAVEL with low cobble content	46	37	30	15	COBBLES with much sandy clayey gravel
TP13, 0.9m		Sandy clayey GRAVEL with low cobble content	96	92	72	37	Slightly gravelly sandy CLAY
TP22, 1.0m		Sandy clayey GRAVEL with high cobble content	94	94	57	25	Very sandy very clayey GRAVEL
TP47, 1.3m		Gravelly clayey SAND	100	94	84	26	Slightly gravelly very sandy CLAY
TP24, 0.9m	Quarry Waste	Sandy very clayey GRAVEL with medium cobble content	94	87	62	22	Very gravelly very clayey SAND
TP07, 1.6m		Sandy slightly silty GRAVEL with medium cobble content	79	52	37	12	Very sandy silty GRAVEL
Natural strata							
TP34, 0.7m	Cohesive Residual Soil	Slightly gravelly sandy CLAY	88	76	62	35	Slightly sandy gravelly CLAY
TP44, 0.9m		Slightly gravelly sandy CLAY	93	92	68	35	Slightly sandy slightly gravelly CLAY
TP29, 1.0m		Sandy gravelly CLAY	83	73	50	14	Very sandy clayey GRAVEL
TP46, 1.0m	Granular Residual Soil	Gravelly silty SAND	100	100	94	43	Slightly gravelly very sandy CLAY
TP17, 1.3m		Sandy very clayey GRAVEL	100	100	87	29	Slightly gravelly very sandy CLAY
TP36, 1.4m		Sandy slightly clayey GRAVEL with low cobble content	66	41	24	6	Sandy clayey GRAVEL with high cobble content

14.3.2 NHBC Chapter 4.2 considers shrinkable soils to be those containing more than 35% fines and having a Modified Plasticity Index greater than 10%.

14.3.3 Based on the grading results, the Granular Made Ground locally contains enough fines (up to 37%) to act as a cohesive soil. However, the average fines content is 23% and therefore the Granular Made Ground encountered in the backfilled quarry can therefore on the whole be regarded as non-shrinkable.

14.3.4 Additionally, sampling bias during the investigation will have removed the largest fractions (cobbles and boulders) of which this material type contains a significant proportion.

14.3.5 Locally, the residual soil is encountered as sandy clay/clayey sand which can be difficult to distinguish in the field. Where this is the case (i.e. clearly not gravel), it would be prudent to assume this material is a clay and therefore should be regarded as shrinkable.

14.4 Soluble sulphate and pH

14.4.1 In accordance with BRE SD1[16], this site has been classified as brownfield with a mobile groundwater regime.

14.4.2 It is envisaged foundations will extend to depths of about 1m through made ground and natural strata and samples taken from this depth range have been submitted for pH and water-soluble sulphate (2:1 soil/water extract). Within the quarry, samples have been taken from between c. 0.5m and 3m depth, which covers the likely range of turnover earthworks.

14.4.3 The concentrations of sulphate in the aqueous natural soil extracts of 18 samples were determined. In addition, 15 samples of made ground were tested as part of the contamination suite. The pH value of each sample has also been determined.

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

Soil type	No. samples tested	Lowest pH values	Highest soluble sulphate concentration (mg/l)
Made Ground	15	7.7	1700
Cohesive Residual Soil	6	5.0	24
Granular Residual Soil	12	6.0	190

14.4.5 Only a single sample yielded a pH of less than 5.5 and therefore concentrations of chloride and nitrate are considered insignificant.

14.4.6 In accordance with Tables C1 and C2 of SD1, sub-surface concrete should be Design Sulphate Class **DS-1**, with the site allocated an ACEC Classification of **AC-3z** where in contact with natural strata only.

14.4.7 This should be increase to **DS-3 AC-5** where subsurface concrete is also in contact with made ground.

14.5 Compaction tests

14.5.1 Laboratory compaction tests are useful wherever ground improvement is anticipated, for example to provide a satisfactory CBR beneath proposed highways.

14.5.2 In accordance with BS5930[17] 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.

14.5.3 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.

14.5.4 Laboratory compaction testing was scheduled on 8 samples of made ground and 6 samples of natural strata (using a 4.5kg rammer) to determine their suitability for re-engineering.

14.5.5 Laboratory compaction tests are only appropriate if:

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

[16] *BRE Special Digest 1 (2005) – Concrete in aggressive ground.*
[17] *BS5930 (2015) - Code of practice for ground investigations.*

14.5.6 As shown in the table in Section 14.3, 5 of the 14 samples tested do not conform to the requirements detailed above.

14.5.7 It should also be noted that a significant proportion of the made ground within Area C contained cobbles and boulders which were not sampled/tested for compactions due to non-conformity and practicality reasons.

14.5.8 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.

14.5.9 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.

14.5.10 The results are summarised in the tables below:

Sample location & depth	Strata	Material description	Gs (Mg/m^3)	MDD (Mg/m^3)	OMC (%)	Allowable mc range for 95% MDD & <5% air voids	Typical in-situ moisture content (%)
Made Ground							
TP10, 0.6m	Cohesive Made Ground	Slightly sandy slightly gravelly CLAY	2.22	1.70	12	11 to 17	18
TP25, 1.2m		Slightly gravelly slightly sandy CLAY	2.46	1.64	19	18 to 23	
TP09, 0.7m	Granular Made Ground	COBBLES with much sandy clayey gravel	2.52	1.85	12	12 to 16	18
TP13, 0.9m		Slightly gravelly sandy CLAY	2.21	1.55	18	16 to 22	
TP22, 1.0m		Very sandy very clayey GRAVEL	2.13	1.25	32	30 to 36	
TP47, 1.3m		Slightly gravelly very sandy CLAY	2.42	1.77	13	12 to 17	
TP24, 0.9m	Quarry Waste	Very gravelly very clayey SAND	2.62	1.93	12	11 to 16	13
TP07, 1.6m		Very sandy silty GRAVEL	2.59	1.91	12	11 to 16	
Natural strata							
TP34, 0.7m	Cohesive Residual Soil	Slightly sandy gravelly CLAY	2.63	1.85	14	13 to 18	21
TP44, 0.9m		Slightly sandy slightly gravelly CLAY	2.62	1.87	13	13 to 18	
TP29, 1.0m		Very sandy clayey GRAVEL	2.61	1.94	11	11 to 16	
TP46, 1.0m	Granular Residual Soil	Slightly gravelly very sandy CLAY	2.59	1.91	12	11 to 16	16
TP17, 1.3m		Slightly gravelly very sandy CLAY	2.58	1.91	12	11 to 16	
TP36, 1.4m		Sandy clayey GRAVEL with high cobble content	2.65	2.00	11	10 to 15	

14.5.11 It is apparent that the in-situ moisture content of the Cohesive Made Ground, Quarry Waste and Granular Residual Soil is generally within the allowable moisture content range to achieve 95% MDD and less than 5% air voids. On this basis it is considered that these material types are suitable for re-engineering.

14.5.12 The in-situ moisture content of the Cohesive Residual Soil is typically slightly too wet to achieve 95% MDD and less than 5% air voids. Therefore, the natural cohesive soils are likely to require some drying out before they can be utilised for engineered fill.

14.5.13 Drying out of these soils will require careful management on site. They should be placed in sealed stockpiles during periods of wet weather, or while the site is unattended. During periods of favourable weather (ideally warm & windy) the soils should be spread in thin layers over as wide an area as possible and aerated by turning with an excavator. Alternatively, consideration could be given to lime modification.

14.5.14 Given the **highly variable** nature of the Granular Made Ground, the in-situ moisture content of this material type is locally **too wet or dry** and therefore additional testing will be required. However, it should be noted that this material type contains a significant proportion of very coarse material (cobbles and boulders) which will not have been included in the samples tested.

14.5.15 The majority of the made ground will need to be screened and processed in order to remove any unsuitable and oversize materials.

14.5.16 Acceptability of the made ground and natural soils for use in the proposed controlled earthworks will need detailed appraisal by the Earthworks Designer in light of the required performance characteristics.

14.6 Undrained shear strength testing

Hand shear vane testing

14.6.1 Hand shear vane testing was undertaken within trial pits in-situ to around 1.2m depth. However, given the localised occurrence and nature of the Cohesive Residual Soil (sandy/gravelly clay) only a limited number of hand vane shear tests could be undertaken (6 no.).

14.6.2 Where testing was possible, the undrained shear strength of the Cohesive Residual Soil was typically greater than 55kPa.

14.7 Point load & UCS rock testing

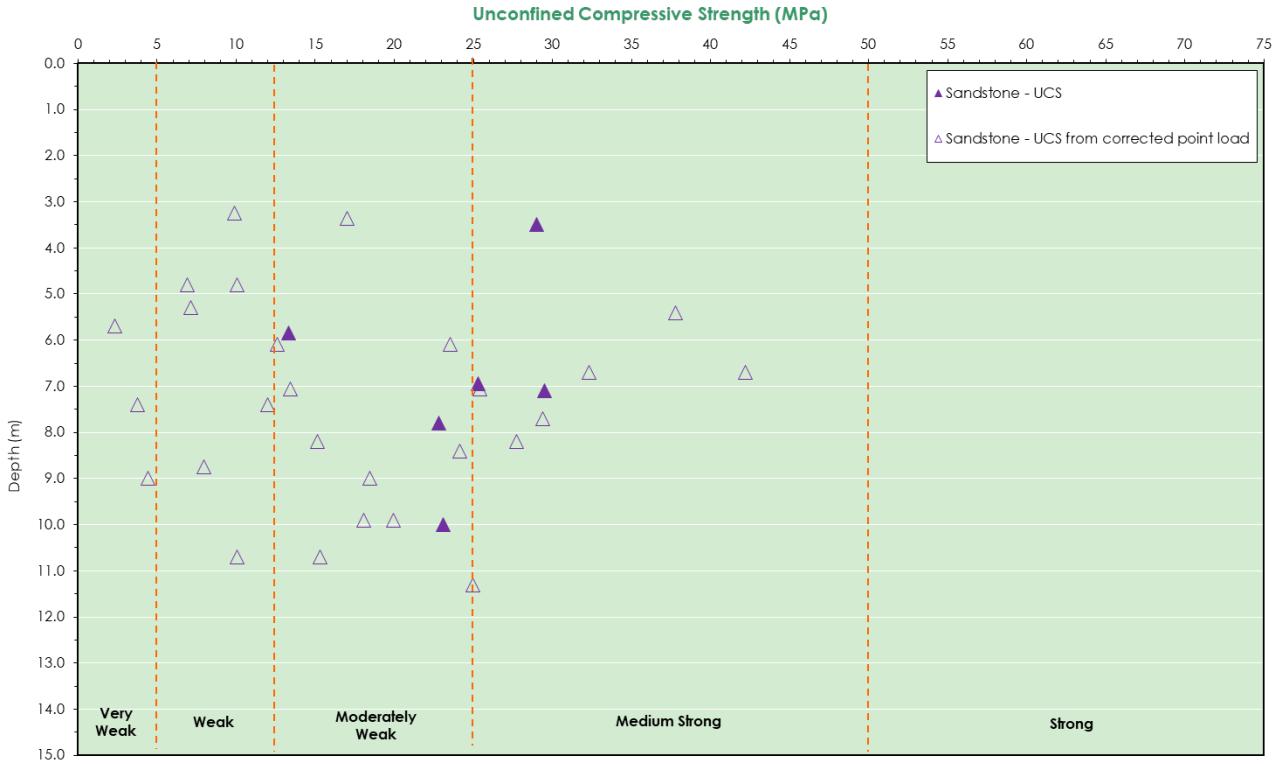
14.7.1 Unconfined Compressive Strength (UCS) testing was undertaken on 6 samples of rock. In addition to each UCS value, the density of each sample has also been reported. Point load testing was undertaken in 18 samples of rock with each test undertaken along axial and diametral orientations where possible.

14.7.2 Point load testing in an axial orientation (i.e. vertical/perpendicular to bedding) produces a value for Is50 in MPa. This value is not a direct reflection on the strength of the in-situ rock due to the concentrated area of force applied to the sample by the testing tool (the point). In order to gain a value in MPa comparable to the strength of the rock sample, and directly equivalent to the unconfined compressive strength, a conversion factor must be applied.

14.7.3 Whilst a variety of correction factors have been published. Mark and Rusnak[18] published a conversion factor of 21 following a case study of Coal Measures bedrock across North America.

14.7.4 Therefore, Lithos have adopted a correction factor of 21 to convert the Is50 into a uniaxial Compressive Strength equivalent in MPa.

14.7.5 The UCS from direct measurement and UCS derived from the point load data is shown in the graph below. The derived UCS for the sandstone shows a similar range to the UCS range from direct measurement and broadly correlates with the field description presented on the borehole logs (weak to medium strong).



15 GEOTECHNICAL ISSUES

15.1 Conceptual site model

15.1.1 The site can be divided into 3 broad areas based on site history and ground conditions (see Drawing 4674/10:

- Area A (west) – greenfield and no significant made ground
- Area B (centre) – former allotments with localised made ground
- Area C (east) – former quarry and subsequent landfill with deep made ground

15.1.2 Ground in Area A typically comprises Topsoil over Cohesive Residual Soil (firm/stiff clay) and Granular Residual Soil (sand/gravel). Sandstone bedrock is present across the area at shallow depth (<2.5m).

[18] *Using the point load test to determine the uniaxial compressive strength of Coal Measure Rock. J Rusnak & C Mark. August 200. Proceedings on the 19th international conference on ground control in mining. Pgs. 362 - 371*

15.1.3 Ground conditions in Area B are similar although the Made Ground Topsoil is not considered suitable for re-use at shallow depth in proposed gardens. Additionally, localised areas of made ground are present likely associated with past use (allotments, former terraced housing, adjacent quarry, etc).

15.1.4 Made ground is present across the majority of Area C predominantly comprising Cohesive and Granular Made Ground (clay/gravel of mixed lithologies with cobbles and boulders) with lesser amounts of Ash & Clinker, Quarry Waste and Landfill Material. The base of the quarry has been identified at between 1.6m and 5.2m depth (average 3.1m).

15.1.5 The majority of "highwalls" encountered have been within the residual soil with only localised highwalls observed within bedrock which are generally of a shallow gradient (<25°). The depth to bedrock is typically similar (within c. 1m) both inside and outside the quarry.

15.2 Mining & quarrying

15.2.1 This far northeast of the site is located within a Coal Mining Development High Risk Area although it is understood no development is proposed in this area.

15.2.2 The majority of the site is underlain at depth by sandstone bedrock and the shallowest coal seam is anticipated to lie at c. 20m depth in the far west (although no mining has been recorded in this seam). Whilst the site lies within a Coal Authority Low Risk area, no significant risks have been identified, and an intrusive mining investigation will not be required.

15.2.3 There is a former sandstone quarry recorded in the east of the site which was shown to be disused in 1962. The quarry was subsequently used as a landfill accepting waste until 1984.

15.2.4 Lithos' quarrying investigation found the extent of the quarry to be similar to that recorded on the 1962 OS map (see Drawing 4674/8). The base of the quarry has been found to be between 1.6m and 5.2m deep (average 3.1m). It should be noted the deepest made ground was recorded in rotary probeholes which can be difficult to interpret due to the nature of drilling.

15.2.5 The majority of "highwalls" encountered have been within the residual soil with only localised highwalls observed within bedrock which are generally of a shallow gradient (<25°). The depth to bedrock is typically similar (within c. 1m) both inside and outside the quarry.

15.2.6 It appears the quarry mainly extracted the residual soil (sand/gravel) with only the uppermost c. 1m of sandstone removed.

15.3 Ground improvement

15.3.1 Made ground currently underlies Area C, and locally Area B1, to an average depth of about 3.1m; maximum of 5.2m. This made ground is of variable and poor strength and is therefore not considered a suitable foundation material. It has also yielded elevated concentrations of a number of inorganic determinands and contains materials (e.g. brick, concrete, clinker, coal, etc), which would generally be considered undesirable as a near-surface material in garden areas.

15.3.2 Given the substantial volume of made ground present, export to landfill is not considered economically viable.

15.3.3 Consideration should be given to turnover (excavation, screening and replacement in engineered layers) of the full thickness of made ground beneath the site. Turnover is considered an appropriate ground improvement solution since significant excavation of the made ground will be required in any case to remove the Landfill Material which has yielded significantly elevated concentrations of inorganic determinands.

15.3.4 Because turnover enables inspection of the full thickness of fill, the developer and their prospective property purchasers, are provided with the reassurance that no significant hazard is left undetected. This is considered advantageous from a perception viewpoint. Furthermore, any potential for surface water infiltration, which would drive potential leaching of contaminants, should be reduced by compaction.

15.3.5 Screened and engineered fill should yield CBR values in excess of 3%, thereby reducing abnormals associated with the construction of estate roads and car parking areas. Excavations through the engineered fill, for drainage etc and foundations will not encounter significant obstructions or grossly contaminated ground and should be stable with little overbreak.

15.3.6 Excavation of the uppermost 500mm or so of natural soils beneath made ground could be undertaken in order to generate a sufficient volume of 'clean' subsoil for placement across the proposed development in gardens and landscaped areas. This subsoil would be best placed during the construction phase; i.e. it should be left in stockpile(s) on completion of the site preparatory works.

15.3.7 Prior to placement of any fill, the excavation base should be **surveyed**, in order that fill thicknesses can be plotted and appropriate foundation solutions determined.

15.3.8 There are a number of advantages to such a 'soil inversion' operation; most notably:

- Ground levels will remain essentially as existing (i.e. there is no need to raise levels by 600mm to accommodate soil cover).
- Reduced traffic movements - there should be no need to export any significant volume of made ground off-site, and no need to import subsoil to site.

15.3.9 The above solution is considered to be in line with current government philosophy regarding sustainable development. Turnover works should be undertaken in accordance with the CL:AIRE Code of Practice (v2, March 2011), and a Materials Management Plan (MMP) should be prepared prior to commencement.

15.4 Excavatability

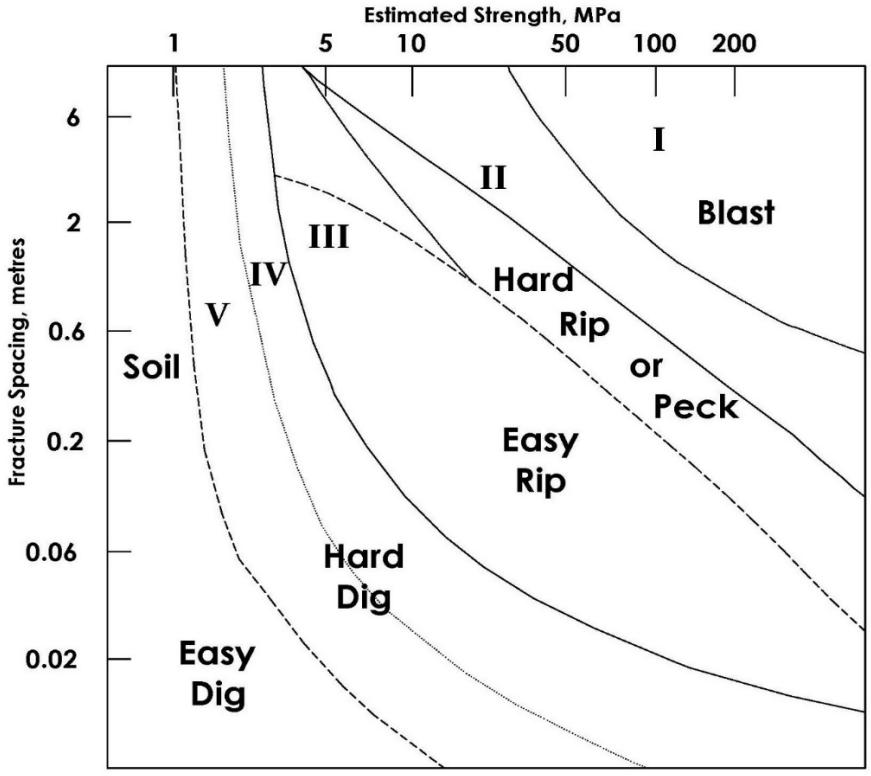
15.4.1 The west and centre of the site are underlain by Residual Soil (firm clay and sand/gravel) with sandstone bedrock from between 0.8m and 3.0m depth (average 1.7m). Consequently, if any deep excavations are required (i.e. for deep drainage, attenuation basins, etc) these are likely to encounter competent bedrock.

15.4.2 To date, site wide strength testing of the sandstone has not been undertaken although samples of bedrock recovered from the base of the former quarry (east) have been tested (see Section 14.7). The strength results obtained from this testing are likely to broadly similar for the sandstone bedrock encountered across the wider site.

15.4.3 Additionally, trial pitting using a 20-tonne tracked excavator equipped with a 0.6m wide toothed bucket has been carried out across the wider site and observations from this have also been used to estimate the excavatability of the bedrock.

15.4.4 Based on the results of this investigation and an excavation method chart adapted from Waltham[19] (shown below), the upper surface of the sandstone bedrock can be excavated using an appropriately sized excavator. However, more competent sandstone (strength of greater than 10MPa) below c. 2.5m depth (from existing ground level) is likely to require ripping using a tractor or dozer mounted ripper or a concrete breaker.

[19] *Adapted from: T Waltham. Foundations of Engineering Geology. Third edition. 2009. Pg 80.*



15.5 Foundation recommendations

General

15.5.1 It is understood that consideration is being given to redevelopment of the site with two storey domestic dwellings, associated gardens, POS, adoptable roads and sewers.

15.5.2 A site layout has been provided by Fenwood Estates (Drawing reference 22-04-001-01-02, dated 14th February 2023) which is reproduced as Drawing 4674/2 in Appendix B to this report. However, it is understood the layout is to be revised in light of the findings of this investigation.

15.5.3 Foundation recommendations assume that development will be two or three storey construction and that line loads will not exceed 90kN/m run. If this is not the case significant alteration to these recommendations will be required.

15.5.4 We have assumed that final development levels will not differ significantly from ground levels existing at the time of investigation. Any digital terrain modelling undertaken, or commissioned, by Fenwood Estates should consider implications for the foundation recommendations outlined below.

15.5.5 Foundation depths (and types) will depend on thicknesses of fill following the anticipated earthworks regrade.

15.5.6 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.

15.5.7 Sub-surface concrete in contact with the natural ground should be Design Sulphate Class DS-1, with the site allocated an ACEC Classification of AC-3z, increased to DS-3 AC-5 where in contact with made ground.

15.5.8 It is considered that the following foundation solution options will be most appropriate for two or three storey residential properties constructed on this site:

- Traditional strip/trench-fill foundations in Areas A & B
- Rafts/stiffened strips on engineered fill or piles in Area C

15.5.9 Further discussion of these foundation types is presented below.

Strip/trench fill footings

15.5.10 It is considered that shallow strip or deepened trench fill footings will be the most suitable foundation solution for two or three storey houses constructed in Areas A & B (i.e. beyond the former quarry). This solution is viable where the made ground is less than about 2.5m thick, and firm clay or competent rock is the founding material.

15.5.11 Reinforcement, as a precaution against differential settlement, is recommended only where foundation excavations encounter significant lateral and vertical variations in strata. One layer of B385 mesh placed 75mm above the base of the footing is likely to provide suitable reinforcement, but further advice should be sought from the Structural Engineer.

15.5.12 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.

15.5.13 Foundations will be required to be placed below a line drawn up at 45^{o} from the base of any service or similar excavation.

15.5.14 Deepened foundations should be stepped in accordance with NHBC Standards, Chapter 4.3.

15.5.15 In order to minimise softening and swelling of cohesive soils or loosening of granular soils, it is recommended that footings are cast as soon as formation level is reached (or alternatively formation could be blinded using concrete with as low a water:cement ratio as possible).

15.5.16 Fenwood Estates 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). Fenwood Estates should supervise their groundworker to ensure footings are excavated in a controlled and safe manner.

15.5.17 Fenwood Estates or their groundworker should seek further advice from Lithos 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.

Cohesive Residual Soil

15.5.18 Atterberg tests suggest that natural cohesive soils at the site are of low shrinkability. A minimum founding depth of 750mm (not accounting for any existing or proposed vegetation) is therefore required for all soils on the site where strip footings are proposed.

15.5.19 In accordance with NHBC Standards, founding depths in cohesive soils should be taken from original or finished ground level, whichever is the lower, to the underside of the footing.

15.5.20 Foundations should be deepened near trees in accordance with NHBC Standards Chapter 4.2. It is estimated that up to 70% of the site may be affected by trees.

15.5.21 The current layout suggests some plots will be built on ground from which tree/hedgerows will be removed. Whilst the hedgerows at the site are relatively low (<2.5m height) and appear to have been maintained at that height by trimming, it is often difficult to definitively prove that they have not desiccated soils to significant depth. In theory, if mature Hawthorn is removed from within the footprint of a plot, founding depth (in low shrinkability clay) would be around 2.5m.

15.5.22 Trench fill foundations should be designed in accordance with NHBC Standards, Chapter 4.2. Heave precautions (a suitable approved compressible void former) should be used on the internal face of all external walls where the foundation is within the zone of influence of trees and greater than 1.5m deep.

15.5.23 Any trench fill foundation deeper than 2.5m will need to be designed by a Chartered Engineer, whose status is accepted by NHBC (NHBC Standards, Technical Requirement R5); however, it is likely that the **presence of bedrock** will result in few, if any, foundations being deeper than 2.5m.

15.5.24 It would therefore be prudent to prepare a detailed foundation schedule and seek approval from NHBC in order to determine likely foundation abnormals.

15.5.25 A safe bearing capacity of around 150kPa, allowing a maximum foundation line load of 90kN/m run, can be assumed if the following are true:

- A foundation length of 8m
- A foundation breadth of 0.6m
- A foundation thickness of 225mm
- A foundation depth of 0.75m depth
- An undrained shear strength of 55kPa for the firm clay (typical minimum recorded on site)

15.5.26 Assuming the foundation geometry detailed above, settlements of less than 25mm would be anticipated. This is considered likely to be acceptable. However, further advice should be sought from the Structural Engineer responsible for foundation design.

Granular Residual Soil

15.5.27 The weathered in-situ sandstone (sand, gravel and cobbles) is assumed to have a relative density of at least medium dense (in accordance with BS5930).

15.5.28 A safe bearing capacity of at least 150kPa, allowing a maximum foundation line load of 90kN/m run, can be assumed if the following are true:

- A foundation length of 8m
- A foundation breadth of 0.6m
- A foundation thickness of 225mm
- A foundation depth of 0.6m depth
- An angle of shearing resistance of ϕ=33° for the granular deposits

15.5.29 Assuming the foundation geometry detailed above, settlements of less than 25mm would be anticipated. This is considered likely to be acceptable. However, further advice should be sought from the Structural Engineer responsible for foundation design.

15.5.30 In accordance with NHBC Standards, a minimum founding depth of 450mm (due to potential frost susceptibility) is required in granular soils. This depth should be taken from finished ground level to the underside of the footing. If finished ground level is to be above existing ground level then the foundation excavation simply needs to ensure that there is sufficient depth of excavation to allow casting of the footing entirely within natural ground (not made ground or topsoil).

15.5.31 However, if the excavation is dug from original ground level in cold conditions when freezing is expected, then foundation depth should be taken from the existing, not finished, ground level.

15.5.32 Where ground level is being raised, it would be prudent to proof roll the exposed granular soils after stripping topsoil (to mitigate any near-surface disturbance), and ideally fill should be placed prior to construction (otherwise the Developer will need to consider the potential for movement associated with placement of the fill).

15.5.33 It should be noted that founding at shallow depth (450mm), whilst desirable from an excavation stability viewpoint, may not provide sufficient bearing capacity due to the lesser depth of (resisting) overburden. Consequently, a minimum founding depth of **600mm** is recommended.

15.5.34 It should also be noted that the footing may require deepening or stepping in order to allow plot drainage to exit the plot footprint (either over or under the footing).

Bedrock

15.5.35 The sandstone (and locally siltstone) bedrock is generally considered to have a safe bearing capacity of at least 300kPa and minimal settlements would be anticipated.

15.5.36 Where rock is encountered at shallow depth foundations should be placed **entirely** on rock and not partially on rock and partially on soil. This may, depending on surface gradient, necessitate significant deepening of foundations.

Geological fault

15.5.37 Drawing 4674/11 shows the approximate line of the fault superimposed on the proposed housing layout; the fault crosses the north-east corner site.

15.5.38 It should be noted that the line of a fault on a geological map is often very approximate, and it may be inaccurate by 10m or more. Furthermore, the presence of a fault is usually 'masked' by overlying drift or residual soils; they can only be seen where long trenches are excavated into bedrock.

15.5.39 At this site, no movement associated with past, present or future mining is anticipated, therefore building can take place over the fault, without the need to search for the fault, and without the need to adopt special precautions in the footings of those plots suspected to lie in the vicinity of the fault.

15.5.40 However, NHBC like to see reinforcement of footings with one layer of B385 mesh placed 75mm above the base of the footing. Given the uncertainty regarding the precise line of the fault, it would be prudent to reinforce the footings of all plots within 25m of its assumed line; i.e. Plots 64 to 67 (as shown on Drawing 4674/2).

15.5.41 Further advice should be sought if a significant weak zone is encountered (e.g. ground comprising loose, broken or soft 'gouge' material) during the excavation of footings. If associated with a fault, the weak zone is likely to form a fairly continuous "linear belt", rather than a localised "pocket", and be anything from a few centimetres to a few metres in width.

Reinforced strips or raft foundations (on engineered fill)

15.5.42 Raft foundations (or heavily reinforced strips) may provide a suitable foundation solution in Area C if the full thickness of made ground is subject to turnover (excavation, screening/sorting and replacement in engineered layers, with compaction). Fill would need to be compacted to an **End Product** Specification to achieve >95% of the maximum dry density (4.5kg rammer) and less than 5% air voids.

15.5.43 If it is intended to construct low-rise buildings which derive direct support from engineered fill, an Earthworks Specification document will be required and this would include definition of fill types and requirements for acceptability & testing, compaction trials, control testing and monitoring of fill performance.

15.5.44 In areas where raft foundations are proposed, the full thickness of made ground should be excavated, screened and placed in engineered layers (turned over). Excavations below proposed new-build should extend at least 3.0m beyond the footprint of structures. Excavation and screening will enable the removal of all relict foundations, oversize material and any grossly contaminated soil/fill.

15.5.45 Deep excavations to remove gross contamination, relict structures, and/or soft ground could result in "hollows" in the natural ground surface. The natural ground around these "hollows" should be overdug in order to ensure that the thickness of fill below each proposed plot does not vary by more than 15%. Where this requires benching of the natural ground, each bench should have a maximum vertical height not exceeding 500mm.

15.5.46 The suitability of made ground for placement as engineered fill should be confirmed by field trials and laboratory testing.

15.5.47 The field trials should be carried out in accordance with Lithos' Specification for Engineered Fill. The field trial will enable estimation of tolerable settlement characteristics and an achievable safe bearing capacity, with a view to establishing new dwellings on raft foundations. It will also yield the following information:

- Number of passes with the compaction plant (to be used during subsequent earthworks)
- Maximum and minimum layer thickness (plant dependent)
- Acceptance criteria; minimum dry density and moisture content range

15.5.48 The engineered fill should achieve at least 95% maximum dry density, with air voids comprising less than 5%; as determined by appropriate laboratory compaction tests.

15.5.49 Raft or beam-grillage design should be in accordance with NHBC Standards, Chapter 4.4. Granular sub-base product should be placed in accordance with Table 8/1 of the Highways Agency Specification for Highway Works (1998).

15.5.50 NHBC generally require any spread foundation on Engineered Fill to be capable of achieving a minimum spanning capability of 3m and a minimum cantilever capability of 1.5m. For reinforced strip foundations, NHBC also require continuity of reinforcement across orthogonal beams, ensuring a "grillage type" (not a true grillage) arrangement with cross wall / stiffening beams.

15.5.51 For reinforced strip foundations, NHBC typically require the aspect ratios (in plan) of all 'cells' of the 'grillage' to be no greater than 2:1, to ensure there is sufficient rigidity to the foundation. The maximum permissible angular distortion (tilt) is typically 1:400.

15.5.52 Should any long terraces/blocks be proposed they should incorporate structural movement joints to mitigate the risk of differential settlement across the block/terrace.

15.5.53 NHBC generally recommend that rafts be founded on a minimum 150mm thickness of DoT granular sub-base product. Granular sub-base should extend laterally for at least 0.5m beyond the raft. The base of the granular sub-base must be at least 600mm below original or finished level, whichever is the lower. At most reclaimed brownfield sites, original level is generally equivalent to the top of engineered fill.

15.5.54 Where rafts are within the influence of mature trees, the depth of crushed stone placed should be equal to 50% of the trench fill foundation depth determined in accordance with NHBC Chapter 4.2.

15.5.55 Placement of blankets of a granular sub-base, directly on top of engineered fill would normally be acceptable immediately after placement of the final layer of fill. However, if placement is delayed, climatic factors can lead to a deterioration of the near surface fill.

15.5.56 Where the engineered fill is cohesive, rainfall, (softening) or sunshine (desiccation) may cause deterioration. Cohesive fill should therefore be "blinded" with granular sub-base within 48 hours of placement of the final layer of fill. Wherever this is not possible, it is recommended that a minimum 300mm depth of fill is excavated from beneath the plot footprint, prior to placement of the granular sub-base. Furthermore, it may be necessary to remove any desiccated material if the engineered fill is left exposed during a prolonged spell of dry weather.

15.5.57 Where the engineered fill is granular, deterioration may be caused by frost (unless the fill contains less than 10% fines). Granular fill should therefore be "blinded" with granular sub-base prior to frosty weather.

Piled foundations

15.5.58 Piled foundations may be an option for dwellings constructed in Area C, as an alternative to ground bearing rafts/heavily reinforced strips, especially in the areas of deepest made ground (southwest).

15.5.59 The following general comments relating to piling are provided for guidance, and further advice should be sought from a specialist-piling contractor.

15.5.60 Should any impenetrable shallow obstructions be encountered, i.e. boulders etc, they should either be grubbed-up, or alternatively the piling layout could be re-designed (although this might also require design of foundations able to span and/or cantilever as necessary).

15.5.61 The made ground contains significant **boulders** (up to 2m diameter), and the depths to competent bedrock vary significantly over relatively short distances. Consequently, in order to ensure that piles are founded within natural bedrock (and not any overlying made ground), it may be prudent to advance piles to greater depth, so that they are embedded at least 3m into bedrock.

15.5.62 Warranty providers generally require pile lengths to be at least 3m (measured from pile cut off level to pile toe level). Short piles are likely to become dislodged during pile trimming operations, creating additional costs associated with remedial works. Where depths to bedrock vary significantly beneath a plot, pre-boring of piles may be necessary to reach required depths.

15.5.63 Piled foundations should extend into the underlying bedrock. The safe working load that may be supported on a pile is dependent on the pile diameter, its founding depth and the method of installation.

15.5.64 Boreholes indicate that competent sandstone bedrock lies at depths of between 1.6m and 5.2m, below current ground levels. As piles would be founded in bedrock, they will be essentially end bearing.

15.5.65 Consequently, preliminary estimates for pile lengths in the order of 4m to 8m.

15.5.66 Given the presence of cohesive made ground, it is essential that pile design allows for down-drag (negative skin friction).

15.5.67 In accordance with NHBC Standards, Chapter 4.2, heave precautions should be provided where a plot is within the zone of influence of trees. Table 3b in Chapter 4.2 defines the zone of influence as a function of tree height (between 0.5 and 1.25) dependant on the water demand. Figure 6 in Chapter 4.2 shows where heave precautions are required for pile foundations.

15.5.68 There is the potential for **settlement** of the ground in external areas around piled plots, and consideration should be given to mitigation, including:-

- Extending facing brickwork so that ground settlement does not result in exposing the underground portions of walls and foundations. Two additional courses should be more than adequate.
- Threshold issues
- Flexible connections (e.g. rocker pipes) in drainage and service pipes passing through the buildings.
- Ensuring drainage is laid with generous falls.

15.5.69 Driven piles may lessen the volume of potentially contaminated made ground requiring off-site disposal (cf arisings associated with say trench fill). However, driving can induce some ground vibration. Assessment of any vibration risk to adjacent structures and/or existing site features should be undertaken by pile designer.

15.5.70 New houses can be built off ring beams designed to span the piles. In order to bond them to the piles, the tops of the piles must be broken out to expose the reinforcement, which can then be tied to that of the beams.

15.5.71 Ground conditions at this site are considered likely to require provision of a piling mat (working platform) and further advice should be sought from the appointed specialist-piling contractor regarding the proposed plant loadings and resulting pressures. This data, together with a knowledge of the strength and variability of the near-surface ground conditions is required in order that design of a mat can be undertaken in accordance with guidance provided in the 2004 BRE document, "BR 470: Working platforms for tracked plant".

15.5.72 The design of working platforms for tracked plant is a geotechnical design process and should be carried out by a competent person. The following parties should have input into the design:

- Permanent works designer, to consider additional uses for platform material as part of the overall development
- Principal contractor, to define any other purposes for which the platform might be used
- Contractor or subcontractor, to specify requirements for the platform, including gradients, ramps and edges

15.5.73 The number of plots affected by piling will depend on layout proposals, however, it is considered unlikely to exceed 25% of the total number.

15.5.74 If piles are required for some plots in Area C, it may be more practical and economic to pile all the plots in Area C, since mobilisation charges are likely to be similar regardless of how many plots are piled. A piled solution would also result in less disturbance than strip footings and negate the need to dispose of contaminated arisings.

15.5.75 Piles can provide an enhanced pathway for the vertical migration of mobile contaminants. The Environment Agency may therefore object to the adoption of piles as a foundation solution. However, objection is considered unlikely given the nature of the contamination encountered, and the fact that quarry backfill is currently resting directly on the underlying mudstone bedrock.

15.5.76 Pile design should be undertaken in accordance with the Environment Agency's guidance booklet "Piling into Contaminated Sites".

Summary of foundation recommendations

15.5.77 In summary, the following foundation solutions are likely to be most appropriate based on the existing layout (subject to Fenwood Estates preferences regarding site preparatory works, final levels & costs associated with each foundation option).

Plot nos	Foundation solution(s)	Remarks (influencing factors)
1 to 51, 73, 76 to 79, 83 to 97, 112, 113 & 123 to 137	Strips	Deepened where necessary due to tree influence
60, 64 to 67, 70 to 72, 74, 75, 80, 98 to 100, 110, 111 & 122	Trench-fill	Made ground up to 2.5m depth and close proximity to backfilled quarry
52 to 59, 61 to 63, 68, 69, 81, 82, 101 to 109, 114 to 121 & 138	Rafts/grillage or piles	Deep made ground associated with backfilled quarry

15.5.78 A 'simple' foundation zoning plan is presented as Drawing 4674/11 in Appendix B.

15.5.79 Lithos could prepare a detailed Foundation Schedule if provided with: an External Works Drawing (with proposed FFLs & infrastructure details); a topographic survey; a tree survey; data from a 'tighter' grid of pits (due to the variable ground conditions encountered).

15.5.80 The foundation solutions outlined in the above table assume that ground levels will not change significantly from those existing at present. If this is not to be the case, further advice should be sought from Lithos.

15.6 Floor slabs

15.6.1 Floors for low rise housing (2-3 storeys) constructed on piled foundations typically utilise reinforced concrete ground beams which rest on pre-cast or in-situ pile caps. A suspended 'Beam and Block' ground floor is then usually constructed using concrete or polystyrene blocks placed between further concrete beams suspended across the ring beams.

15.6.2 Suspended floor slabs should be utilised where the depth of made ground or engineered stone exceeds 600mm in accordance with NHBC Standards Chapter 5.1 (to negate potential settlement problems).

15.6.3 It is estimated that the thickness of made ground is likely to exceed 600mm beneath at least 40% of the plots.

15.6.4 Where shallow foundations are within the influence of existing or proposed trees (and are underlain by shrinkable soils), NHBC require a suspended floor slab, with sub-floor void. The floor slab is most commonly a precast block and beam construction, but alternatively could comprise a suspended timber floor, or a slab cast on a suitable compressible void former. Ground-bearing and cast in-situ suspended slabs (other than those cast on a void former) are not acceptable where foundations are within the influence of trees.

15.6.5 In accordance with NHBC Standards Chapter 4.2, a minimum void height of 200mm should be adopted for a precast block and beam (or suspended timber) floor; this includes a 150mm ventilation allowance. If a suspended, cast in-situ slab (on a void former) is proposed, a minimum clear void height of 50mm should be adopted; of course, the actual thickness of the void former will be significantly greater.

15.6.6 Beyond the influence of existing or proposed trees, it is considered that the natural ground is generally suitable for the use of ground bearing floors. However, ground bearing slabs should not be cast on topsoil. Where plots are elevated for design reasons, the depth of engineered stone below a ground bearing slab should not exceed 600mm, in accordance with NHBC guidance.

15.6.7 The natural ground beneath this site includes cohesive soils and is therefore subject to seasonal variation in moisture content. If ground slabs were constructed on desiccated soil, heave of the slab would occur on re-hydration of the ground. If any significantly desiccated soil is present, a suspended floor slab, with sub-floor void will be required.

15.6.8 It should be noted that NHBC have suffered a significant number of claims resulting from the use of ground bearing floor slabs. Consequently, if ground bearing slabs are proposed, care should be taken to ensure correct and careful construction. For example, if fill to the internal face of the foundation excavation is not properly compacted, subsequent settlement can result in cracking of the slab.

15.6.9 Floor slab design should be finalised/take account of the results of the gas monitoring and protection measures required, which will be detailed in Lithos' gas risk assessment, to be issued on completion of monitoring in November 2024.

15.7 Designated concrete mixes

15.7.1 Designated mixes are considered in BRE SD1[20] and BS 8500[21]. However, in addition to soil chemistry (sulphate class), there are a number of other considerations relating to structural design that need to be taken into account when determining an appropriate concrete mix.

15.7.2 Consequently, Fenwood Estates should seek advice from their appointed Structural Engineer.

15.8 Excavations

15.8.1 Based on the results of the investigation it is considered unlikely that major groundwater flows will be encountered in shallow excavations beyond the former quarry. Groundwater control over and above normal site pumping practices may locally be required for any excavations within the former quarry (notably in the southeast).

15.8.2 Groundwater should be controlled in accordance with CIRIA Report R113[22].

15.8.3 Excavations in the centre and west should remain stable in the short term but if left open for any significant period of time may require shoring most notably in granular soils and localised made ground.

15.8.4 The stability of even shallow excavations in made ground is likely to be poor (within the former quarry), and therefore allowance should be made for shoring in this area.

[20] *BRE Special Digest 1 (2005) – Concrete in aggressive ground.*

[21] *BS 8500-1&2:2015+A2:2019. Concrete. Complementary British Standard to BS EN 206. Method of specifying and guidance for the specifier (1) & Specification for constituent materials and concrete (2).*

[22] *CIRIA Report R113 (1986) - Control of Groundwater for Temporary Works.*

15.8.5 Bedrock was encountered in the majority of the exploratory holes, especially beyond the backfilled quarry. Based on the exploratory hole logs, excavation greater than 2.5m is likely to prove difficult across about 65% of the site (beyond quarry). It would therefore be prudent to allow for excavation/ripping of hard rock in any deep excavations such as those that may be required for drainage etc.

15.9 Drainage

15.9.1 Given the significant thicknesses of made ground encountered in the east, on-site soakaway construction will be highly problematic. It should be noted that soakaways cannot be allowed to infiltrate into made ground due to the risk of settlement caused by wash out of fine soil particles.

15.9.2 However, in the centre and west of the site where sandstone bedrock is present, soakaways constructed in natural granular soils or weathered bedrock might provide a suitable drainage solution for surface water run-off at this site.

15.9.3 However, CIRIA C753:2015 states that: "*A minimum distance of 1m between the base of the infiltration system and the maximum likely groundwater level should always be adopted. This is to minimise the risk of groundwater rising into the infiltration component and reducing the available storage volume, to protect the functionality of the infiltration process by ensuring a sufficient depth of unsaturated material and to protect the groundwater from any contamination in the run-off*".

15.9.4 Consequently, consideration should be given to a 12 month period of groundwater monitoring to determine seasonal variation in the groundwater table.

15.9.5 Should the site not lend itself to the adoption of discrete soakaways, ground may have the capacity to absorb surface water run-off, and systems which spread infiltration over a wider area (e.g. an infiltration basin, swales and/or pervious paving) may provide the best solution.

15.9.6 Alternative SuDS options (see CIRIA C753[23] for further details) include:

- Pervious Pavements – provide a surface suitable for pedestrian and/or vehicular traffic, while allowing rainwater to infiltrate into subsurface storage, with subsequent infiltration or controlled discharge. Pavement could be porous (water able to infiltrate across entire surface material; e.g. reinforced grass), or permeable (water infiltrates via joints between concrete blocks).
- Swales – linear grassed features in which surface water can be stored or conveyed. Where suitable, swales can be designed to allow infiltration.
- Basins - a ground depression designed to store surface water that is normally dry, except during and immediately following a rainfall event. There are two types:
  - Infiltration – basin designed to store runoff and infiltrate it gradually into the ground.
  - Detention – an outlet restricts flows, so that the basin fills and provides attenuation.
- Ponds – designed to have permanent pool of water, but with capacity to provide temporary storage-controlled discharge.

15.9.7 Yorkshire Water have published a guide[24] for developers and designers outlining their design requirements for surface water attenuation assets. However, further to changes in drainage policy over recent years, independent water authorities (including IWNL, ICOSA, LEEF etc) now adopt more housing schemes than the traditional authorities such as Yorkshire Water. Consequently, the CIRIA C753 has become the more commonly used guidance for the design of SuDS features (including attenuation assets).

[23] *CIRIA C753 (2015) – The SuDS Manual.*
[24] *Design Requirements for Surface Water Attenuation Assets, February 2017.*

15.9.8 With respect to detention basins, which should normally be dry, water table levels should be taken from borehole monitoring wells over 4 consecutive seasons, for at least 3 points in the basin area. The detention basin should be designed to ensure that there is a minimum of 1m of unsaturated soil between the maximum groundwater level and the lowest part of the structure.

15.9.9 It is Lithos' understanding that ground does not have to be free-draining (i.e. sands/gravels), but where clay is present the basin needs to be designed to prevent waterlogging - because this renders maintenance (grass cutting) difficult. It would be prudent to seek confirmation of this from the adopting Water Authority and/or the appointed drainage designer.

15.9.10 Appropriate design usually comprises a fall across the short axis (to centre of basin), and then along the long axis (possibly inclusive of a pipe in gravel trench) to the outfall. However, some Independent Authorities allow a flat base but usually with a controlled flow channel.

15.9.11 The guide also discusses required access to flow control chambers, large diameter (i.e. >900mm) surface water storage pipes, and surface water storage tanks.

15.9.12 It is recommended that the developer contact Yorkshire Water Services with respect to capacity in existing foul and surface water sewers in the vicinity of the development area. However, surface water can go to watercourse and in terms of hierarchy should before sewer. If that is the case, consultation may include the Environment Agency (Main River), or Internal Drainage Board (only limited UK coverage), or Local Authority as Lead Local Flood Authority. Landowner Rights (riparian) are always required for watercourse discharge.

15.10 Highways

15.10.1 This centre and west of the site are greenfield and the routes, formation level and total length, of proposed estate roads are unknown. Additionally, the east is underlain by made ground which is likely to be subject to re-engineering prior to the construction of new estate roads. Consequently, there was no merit in obtaining CBR values at this stage.

15.10.2 The natural soils present at shallow depth (anticipated formation) are predominantly granular. Based on visual inspection of the natural materials, published guidance[25] and tables[26] indicate that the Granular Residual Soil deposits would be expected to provide a CBR value of at least 3%. This value should be verified prior to or during construction.

15.10.3 Whilst the CBRs estimated above should be achievable, some deterioration during/after periods of significant rainfall and/or site trafficking is likely. Consequently, it would be prudent to consider flexibility in the groundworks programme to enable highway construction during prolonged dry/warm weather (typically between May and September) when formation will be least vulnerable to deterioration. Alternatively, a minimum 200mm thickness of suitable granular fill (i.e. a "blanket" of 6F2) could be placed along the line of proposed highways to protect formation during the construction phase.

15.10.4 Made ground is present across the east of the site and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended.

15.10.5 The made ground present beneath this site is highly variable in terms of both composition, and strength/density. Furthermore, it often contains a significant amount of oversize (boulders etc), which represent potential 'hard-spots'.

[25] *CD225 Design for new pavement foundations Revision 1 (Design Manual for Roads and Bridges)*
[26] *The Structural Design of Bituminous Road, TRRL Laboratory Report 1132 (Table C1, page 36)*

15.10.6 Consequently, where made ground is present its full thickness (up to a maximum of 2m - from existing ground level or proposed highway formation, whichever is the lower) should be excavated and either:

- Replaced with suitable aggregate in accordance with Series 600 (Earthworks) of The Highways Agency (HA) "Specification for Highway Works" 1998; or
- screened, to allow selection of suitable material, before being replaced in engineered layers (in accordance with Series 600). Unsuitable materials include any soft or wet materials, biodegradables including topsoil, wood, scrap metal, frozen material and oversize.

15.10.7 Some refinement of the above advice might be possible after highways design (with consideration of the proposed formation level cf existing ground level), and via inspection (and usually CBR testing) of the proposed formation during site preparatory groundworks.

15.10.8 Any residual made ground materials in the base of the excavation should be inspected and (where necessary) any soft spots removed and replaced with suitable engineered fill.

15.10.9 Where the made ground is re-engineered it is considered that a CBR value of at least 3% should be achievable. However, this should be verified by field trials.

15.11 External works

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

15.11.2 Modelling should take account of the presence of highwalls and deep made ground (former quarry) as these may have an impact on proposed layout and earthworks design.

16 REDEVELOPMENT ISSUES

16.1 General

16.1.1 This report has presented options with respect to foundation solutions, treatment of contamination, re-use of topsoil 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 (Warranty Provider & Local Authority) for their comment/approval.

16.1.2 Even after an appropriate preliminary investigation and ground investigation, with exploratory holes on a closely spaced grid (say trial pits at 30m centres), a geoenvironmental appraisal is typically based on inspection of the ground underlying less than 0.5% of the total site area (and much less at depths in excess of about 3.5m). Consequently, there is always a possibility that unanticipated ground conditions will be encountered during the construction phase.

16.1.3 If unexpected ground is encountered during the construction phase, the Contractor should immediately seek further advice from the Engineer.

16.2 Remediation strategy

16.2.1 Redevelopment of this site will almost certainly be subject to planning conditions relating to remediation and validation. Once a specific, preferred development strategy has been decided, Lithos could liaise with local Planning Authority and Warranty Provider and prepare a detailed Remediation Strategy document for approval.

16.2.2 The 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

16.2.3 The Remediation Strategy will describe what is required, but not how it is achieved; the appointed Contractor would normally be expected to undertake an Options Appraisal, and then prepare a Method Statement.

16.2.4 The anticipated remediation works are summarised below:

- General site clearance of surface materials and vegetation
- Post vegetation clearance investigation of the ground in the north of Area which was inaccessible during the earlier investigation
- Stripping and stockpiling of "clean" Topsoil in Area A for re-use in gardens
- Separate stripping and stockpiling of Made Ground Topsoil in Area B for re-use in POS (or lowermost 150mm in gardens in Area C)
- Crushing of all suitable artificial hard material (i.e. concrete/brick etc)
- Turnover (excavation, screening and replacement in engineered layers, with compaction to an End Product Specification) of the full thickness of made ground in Area C to enable:
  - Inspection of the made ground
  - Removal of Landfill Material from the northeast of the area with subsequent off-site disposal
  - Removal of below ground obstructions
  - Redistribution of Ash & Clinker at greater than 1.0m depth
  - Preparation of the ground for highway construction and ground bearing foundations
- Excavation of natural soils from beneath made ground to source 'clean' subsoil for use in gardens and landscaped areas
- Backfill of all resultant excavations, with appropriate compaction
- Re-grade of site to levels specified by Fenwood Estates
- Provision of the required thickness of a cover layer of 'clean' soils in all garden and landscaped areas:
  - Minimum 150mm where natural ground is present
  - Minimum 450mm where residual made ground remains in Area B
  - 600mm plus a 150mm thick hard dig layer **or** 750mm plus marker barrier (**garden areas**), 300mm plus a 150mm thick hard dig layer **or** 450mm plus marker barrier (**landscaped areas**)in Area C

16.2.5 The stripping of Made Ground Topsoil in Area B and turnover of made ground in Area C should be carried out under the **full-time** supervision of a suitably qualified Engineer.

16.2.6 The remediation contractor should survey reduced levels during the proposed turnover, prior to the placement of any fill.

16.2.7 Subsoil excavated during the site preparatory works for subsequent use as cover in gardens and landscaped areas, would be best placed during the construction phase; i.e. it should be left in stockpile(s) on completion of the site preparatory works.

16.2.8 A minimum 200mm thickness of suitable granular fill (i.e. a "blanket" of 6F2) could be placed along the line of proposed haul roads to provide a firm and stable running layer for the subsequent construction works.

16.3 Control of excavation arisings

16.3.1 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.

16.3.2 The groundworker should appreciate the need for good materials management. Most notably the importance of not mixing different materials within a given stockpile.

16.3.3 Further characterisation of stockpiled materials is likely to be required if off-site disposal is proposed. See also comments in Section 12.8 regarding asbestos.

16.3.4 Made ground arisings could be:

- Placed in area deliberately left low on completion of the remediation works in order to accommodate construction arisings
- Redistributed beneath concrete oversite, or areas of hardstanding, where they would be satisfactorily isolated from end users;
- Isolated beneath the clean cover layer in garden or landscaped areas in Area C
- Exported from site to a suitably licensed landfill facility

16.3.5 Natural ground arisings should be suitable for use as subsoil in the proposed soil cover.

16.4 Placement of topsoil

16.4.1 NHBC Conditions require garden areas to be provided with topsoil to a thickness of not less than 100mm. Topsoil thicknesses in excess of 400mm should generally be avoided.

16.4.2 Prior to placement of topsoil, the underlying subsoil should be loosened by ripping or rotovating. Stones and other objects greater than 50mm should be removed from the prepared surface, and the loosened subsoil should be roughly levelled so that an even depth of topsoil can be achieved.

16.4.3 Subsequent trafficking over the loosened subsoil should be minimised.

16.4.4 Topsoil should not be placed during or immediately after heavy rain.

16.4.5 After spreading, any large compacted lumps should be broken down to produce a fine tilth suitable for planting, turfing and seeding (< 10mm maximum aggregate size).

16.5 Good practice guidance

16.5.1 The construction phase groundworker should follow good environmental practice to minimise the risks of spillage, leakage etc with reference, but not limited, to the following documents:

- CIRIA C741[27]
- EA Pollution Prevention Guidelines[28]:
  - PPG6 - Working at construction and demolition sites
  - PPG2 - Above ground oil storage tank

[27] *CIRIA C741 (2015) - Environmental Good Practice on Site*

[28] *Whilst this has formally been withdrawn it can still be accessed via the EA archives and provides useful information on managing risks.*

- PPG7 – The safe operation of refuelling facilities
- PPG21 – Incident Response Planning

16.5.2 Site preparatory works associated with this project are likely to involve the re-use of both natural and made ground soils on site. Therefore, the Contractor should prepare a Materials Management Plan (MMP) in accordance with the CL:AIRE Code of Practice (v2, March 2011) [29].

16.5.3 The MMP will document how all of the materials to be excavated during the proposed site preparatory and remediation earthworks are to be dealt with.

16.6 New utilities

16.6.1 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 enable them to assess at an early stage any potential abnormal costs.

16.6.2 It is recommended that trenches for services in the east, including site drainage and water supply, are cut over size in order to isolate pipe materials from potential contaminants and to enable maintenance to be conducted in "clean" material.

16.6.3 The west of the site (Area A) is greenfield, and no previous or current usage of the site or its immediate surroundings is likely to have resulted in ground contamination. Furthermore, no significant made ground was encountered in any of the exploratory holes in this area during the ground investigation.

16.6.4 Consequently, the use of 'standard' polyethylene water supply pipes in Area A should be acceptable, although Fenwood Estates should consult Yorkshire Water at the earliest opportunity to confirm this.

16.6.5 However, the centre and east of the site are brownfield, and therefore consideration of soil contaminant concentrations is required. Samples taken must be representative of the soil conditions in which the water pipes are proposed to be laid; normally water pipes are laid 0.7m to 1.3m below finished ground level.

16.6.6 Water Companies have a statutory duty to supply wholesome water, which could be compromised by the selection of an inappropriate pipe material. For example, compounds such as petroleum hydrocarbons and solvents can permeate commonly used plastics pipes, and/or corrosive chemicals can reduce the service life of metallic pipes. Guidance has been developed for the selection of pipes in brownfield sites and is contained in a UKWIR Report[30].

16.6.7 At the time of writing, the proposed route(s), and total length, of water supply pipes were unknown. Consequently, to date laboratory testing of soil samples in line with UKWIR guidance has not been undertaken.

16.6.8 At the time of writing, significant remediation earthworks are anticipated, and ground currently present along proposed supply pipe routes will almost certainly be redistributed. Consequently, to date laboratory testing of soil samples in line with UKWIR guidance has not been undertaken.

[29] *The Definition of Waste: Development Industry Code of Practice. CL:AIRE, 2011.*

[30] *UKWIR Report 10/WM/03/21 – 'Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites'.*

16.6.9 However, given the site's size, history, and ground conditions encountered, Yorkshire Water may require sampling within 15m of proposed water supply pipes, once infrastructure design has been completed. In the meantime, it is considered likely that Yorkshire Water will request the use of barrier pipe mains, with plastic coated copper house connections, in Areas B & C given that residual organic contaminants will still be present post-remediation, albeit at acceptable concentrations.

16.7 Health & safety issues - construction workers

16.7.1 Access into excavations etc. must be controlled and undertaken in accordance with the CDM Regulations 2015, most notably Regulation 22, to mitigate risk of collapse or asphyxiation.

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

16.7.3 The bulk of the made ground will be retained on site. 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.

16.7.4 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 personal protective equipment. See also comments in Section 12.8 regarding asbestos.

16.7.5 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.
- Care should be taken to minimise the potential for off-site migration of contamination by the provision of dust suppression control and wheel cleaning equipment during the construction works.
- 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.

16.8 Potential development constraints

16.8.1 Some deterioration of the surface is likely to be caused by trafficking, especially after topsoil has been stripped and during/after periods of significant rainfall. Consequently, it would be prudent to consider placement of a minimum 200mm thickness of suitable granular fill (i.e. a "blanket" of 6F2) along the line of proposed highways and any temporary haul roads to protect formation during the construction phase.

16.8.2 A steep slope (c. 1 in 3) is present immediately beyond the northwest boundary with land falling to the A628 (Cudworth Parkway). Depending on the proposed layout, a slope stability assessment may be required.

16.8.3 The existing utilities present on site (water, telecom, gas, electric and fibre optic) a potential development constraint unless they can be relocated. Additional enquiries are required to ascertain the feasibility of such diversionary works and the particular easement required by each service undertaker if they remain in-situ.

16.8.4 Deep quarry backfill (see Drawing 4674/9) is present across the east of the site and foundation abnormals associated with this area are likely to be significant. It would be prudent to consider revision of the layout with some public open space over the backfilled quarry.

17 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

17.1 General

17.1.1 The site is located off the A628 (Cudworth Parkway), approximately 6km northeast of Barnsley town centre, and currently comprises currently comprises agricultural grassland in the west with dense trees/vegetation in the centre and east. The centre has previously been occupied by houses and allotments, with a former sandstone quarry in the east which was used as a landfill between 1947 and 1984. The west of the site has remained undeveloped throughout history.

17.1.2 It is understood that consideration is being given to redevelopment of the site with two storey domestic dwellings, associated gardens, POS, adoptable roads and sewers. A layout has been provided by Fenwood Estates although it is understood the layout is to be revised in light of the findings of this investigation.

17.1.3 The site can be divided into 3 broad areas based on site history and ground conditions (see Drawing 4674/10):

- Area A (west) – greenfield and no significant made ground
- Area B (centre & northeast) – former allotments with localised made ground
- Area C (east) – former quarry and subsequent landfill with deep made ground

17.1.4 Ground in **Area A** typically comprises Topsoil over Cohesive Residual Soil (firm/stiff clay) and Granular Residual Soil (sand/gravel). Sandstone bedrock is present across the area at shallow depth (<2.5m).

17.1.5 Ground conditions in **Area B** are similar although the Made Ground Topsoil is not considered suitable for re-use at shallow depth in proposed gardens. Additionally, localised areas of made ground are present likely associated with past use (allotments, former terraced housing, adjacent quarry, etc).

17.1.6 Made ground is present across the majority of **Area C** predominantly comprising Cohesive and Granular Made Ground (clay/gravel of mixed lithologies with cobbles and boulders) with lesser amounts of Ash & Clinker, Quarry Waste and Landfill Material. The base of the quarry has been identified at between 1.6m and 5.2m depth (average 3.1m).

17.1.7 The majority of "highwalls" encountered have been within the residual soil with only localised highwalls observed within bedrock which are generally of a shallow gradient (<25°). The depth to bedrock is typically similar (within c. 1m) both inside and outside the quarry.

17.2 Mining

17.2.1 The far northeast of the site is located within a Coal Mining Development High Risk Area although it is understood no development is proposed in this area.

17.2.2 The majority of the site is underlain at depth by sandstone bedrock and the shallowest coal seam is anticipated to lie at c. 20m depth in the far west (although no mining has been recorded in this seam). Whilst the site lies within a Coal Authority Low Risk area, no significant risks have been identified, and an intrusive mining investigation will not be required.

17.3 Quarrying

17.3.1 A former sandstone quarry is recorded in the east of the site which was shown to be disused in 1962. The quarry was subsequently used as a landfill accepting waste until 1984.

17.3.2 Lithos' quarrying investigation found the extent of the quarry to be similar to that recorded on the 1962 OS map (see Drawing 4674/8). The base of the quarry has been found to be between 1.6m and 5.2m deep (average 3.1m).

17.3.3 The majority of "highwalls" encountered have been within the residual soil with only localised highwalls observed within bedrock which are generally of a shallow gradient (<25°). The depth to bedrock is typically similar (within c. 1m) both inside and outside the quarry.

17.3.4 It appears the quarry mainly extracted the residual soil (sand/gravel) with only the uppermost c. 1m of sandstone removed.

17.4 Hazardous gas

17.4.1 The site is in an area where less between 1% and 3% of homes are estimated to be above the radon action level. Therefore, **no** radon specific protection measures are required in new dwellings.

17.4.2 Given the east of the site is underlain by a significant thickness of made ground, gas monitoring is currently underway to determine the need for special precautions against methane / carbon dioxide gas in new plots.

17.5 Contamination & remediation

17.5.1 Testing suggests the Topsoil in Area A is suitable for re-use.

17.5.2 Made Ground Topsoil in Area B is not suitable for reuse in gardens and therefore should be stripped, stockpiled separately from the "clean" Topsoil in Area A, and redistributed in areas of POS or as the lowermost 150mm of cover in proposed garden areas in Area C. Where any residual made ground remains in Area B beneath garden and landscaped areas (i.e. not beneath hardstanding), a **450mm** thick surface cover of "clean" soil is recommended.

17.5.3 Within Area C in **garden areas** a minimum 600mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 750mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base in (**750mm** in total) is recommended. In **landscaped areas** a minimum 300mm thick surface cover of "clean" soil with 150mm thick "hard dig" layer at the base or a minimum 450mm thick surface cover of "clean" soil with a high-visibility contaminated marker at the base (**450mm** in total) is recommended.

17.5.4 The Landfill Material encountered in the northeast of Area C has yielded significantly elevated concentrations of a number of inorganic determinands and is therefore not considered suitable for retention on site. Consequently, this material should be delineated by excavation, stockpiled separately from other material types and disposed of off-site.

17.6 Preparatory works

17.6.1 Significant preparatory works will be required to render the east of the site suitable for redevelopment given the presence of a backfilled quarry.

17.6.2 Turnover of the full thickness of made ground beneath plots is required to remove relict obstructions and boulders and prepare the ground for highway construction, with an **End Product** specification for compaction prepared if a ground bearing foundation solution is required.

17.7 Foundations

17.7.1 New plots constructed in the centre and west of the site will be founded on traditional strip/trench-fill foundations in residual soils or bedrock, deepened where necessary due to tree influence.

17.7.2 Plots constructed in the east over the backfilled quarry will be founded on either rafts/stiffened strips on engineered fill or piles embedded in sandstone bedrock.

17.8 Flooding

17.8.1 The majority of the site lies in Flood Zone 1, where the risk of flooding from rivers or the sea is classified as low. However, the east of the site lies in Flood Zone 2, where the risk of flooding is classified as moderate.

17.9 Drainage

17.9.1 Given the significant thicknesses of made ground encountered in the east, on-site soakaway construction in this area will be highly problematic. It should be noted that soakaways cannot be allowed to infiltrate into made ground due to the risk of settlement caused by wash out of fine soil particles.

17.9.2 However, in the centre and west of the site where sandstone bedrock is present, soakaways constructed in natural granular soils or weathered bedrock might provide a suitable drainage solution for surface water run-off at this site.

17.9.3 However, CIRIA C753 states that: "*A minimum distance of 1m between the base of the infiltration system and the maximum likely groundwater level should always be adopted.*

17.10 Highways

17.10.1 Based on visual inspection of the shallow natural materials in the centre and west, and published guidance, the Residual Soils should provide a CBR value of at least 3%. This value should be verified prior to or during construction.

17.10.2 However, made ground is present across the east of the site, typically to depths of around 3m, and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended.

17.10.3 Where made ground is present it should be excavated and either replaced with suitable aggregate, or screened, to allow selection of suitable material, before being replaced in engineered layers. Where the made ground is re-engineered it is considered that a CBR value of at least 3% should be achievable. However, this should be verified by field trials.

17.11 Further works

17.11.1 Given the constraints discussed in Section 8.2 (dense vegetation/trees in the north of the quarry), additional trial pitting/trenching might be considered prudent to further delineate the extent of made ground in this area in order to remove residual uncertainties with respect to ground, and provide more definitive recommendations with respect to contamination and foundations.

17.11.2 If the drainage designer considers the initial soakaway tests yielded satisfactory results, it may be necessary to:

- Undertake further testing in order to obtain approvals from the LLFA etc: (a) within 25m of proposed chamber locations; and (b) to include 3 fills.

- Install groundwater monitoring wells to depths of around 5m in at least 3 boreholes. Given the anticipated depth to bedrock, these boreholes might need to be advanced by rotary probing.
- The wells should then be monitored on at least 7 occasions; monthly for 3 months, and then bi-monthly for a further 8 months.

17.11.3 If a detention basin is proposed, water table levels should be taken from borehole monitoring wells over 4 consecutive seasons, for at least 3 points in the basin area.

17.11.4 Preparation of a Remediation Strategy and Earthworks Specification.

Appendix A

General Notes

01 - Environmental setting
Generic notes – geoenvironmental investigations

General

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

Geology, mining & quarrying

In order to establish the geological setting of a site, Lithos refer to BGS maps for the area, and the relevant geological memoir. Further information is sourced by reference to current and historical OS plans.

In July 2011, the Coal Authority (CA) formalised their requirements in relation to planning applications and introduced some new terminology. The CA, using its extensive records has prepared plans for all coalfield Local Planning Authorities, which effectively refines the defined coalfield areas into High Risk and Low Risk areas. **High Risk** areas are likely to be affected by a range of legacy issues that pose a risk to surface stability, including: mine entries; shallow coal workings; workable coal seam outcrops; mines gas; and previous surface mining sites. **Low Risk** areas comprise the remainder of the defined coalfield, and are areas where no known defined risks have been recorded; although there may still be unrecorded issues. Where a site lies within either a High or Low Risk area, a mining report is obtained from the CA.

Landfills

Reference is made to publicly available Government held digital data via **QGIS** (an Open Source Geographic Information System), data from Landmark or Groundsure, and sometimes the Environment Agency and the Local Authority with respect to known areas of landfilling within 250m of the proposed development site.

Historical OS plans are also 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, Lithos refer to BRE Report BR211[1], and the UK Health Protection Agency (HPA) website. In December 2022, the British Geological Survey (BGS), deployed a revised dataset which increased accuracy and also the number of properties falling within radon affected areas. This revised dataset is now referenced by maps on the HSA website.

Advice on the limitation of exposure of the population to radon in buildings was originally published in 1990 by the National Radiological Protection Board (NRPB), which joined the HPA in 2005; the HPA updated NRPB advice in July 2010[2].

The HPA recommended that the NRPB radon Action Level for homes be retained, and a new Target Level for radon in homes be introduced. The values of the Action Level and Target Level, expressed as the annual average radon concentration in the home, are 200 Bqm^{-3} and 100 Bqm^{-3} respectively. The Target Level was to provide an objective for remedial action in existing homes and preventive action in new homes.

The term 'radon Affected Area' is defined as those parts of the country with >1% of homes estimated to be above the Action Levels. The level of protection needed is site-specific and can be determined by reference to this mapping on the Public Health England website, which indicates the highest radon potential within each 1km grid square. Each 1km grid square is classified on the basis of the percentage of existing homes within that grid square estimated to have radon concentrations above the Action Level. There are 6 'bands': <1%; 1 to 3%; 3 to 5%; 5 to 10%; 10 to 30%; and >30%.

The NRPB advised that action should be taken to reduce radon concentrations in existing homes if the radon concentration exceeded the Action Level of 200 Bqm^{-3} in room air averaged over a year; ten times the average UK domestic radon concentration. NRPB advice informed changes in the requirements for radon protection in new buildings.

- **Basic** preventive measures are required in new buildings, extensions, conversions and refurbishments if the probability of exceeding the Action Level is **>3%** in England and Wales, and >1% in Scotland and Northern Ireland.
- Provision for further preventive (**Full**) measures is required in new buildings if the probability of exceeding the Action Level is **>10%**.

At present Building Regulations Approved Document C advocates basic measures for the probability banding 3% to 10%, and full measures if >10%. However, HPA would like to see all new build include basic measures.

Action & Target Levels should also be applied to non-domestic buildings with public occupancy exceeding 2,000 hrs/yr and to all schools.

Hydrogeology

Reference is made to publicly available Government held digital data via QGIS, and Landmark or Groundsure with respect to:

- Groundwater quality
- Recorded pollution incidents
- Licensed groundwater abstractions

From April 2010 the EA's Groundwater Protection Policy uses aquifer designations that are consistent with the Water Framework Directive. These 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. The maps are split into two different types of aquifer designation:

- Superficial (Drift) - permeable unconsolidated (loose) deposits. For example, sands and gravels
- Bedrock - solid permeable formations e.g. sandstone, chalk and limestone

The maps display the following aquifer designations:

Principal aquifers: These are layers of rock or superficial deposits that have high intergranular and/or fracture permeability - meaning they 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 major aquifer.

Secondary aquifers: These include a wide range of rock layers or superficial deposits with an equally wide range of water permeability and storage. Secondary aquifers are subdivided into three 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 the former non-aquifers
- Secondary undifferentiated - In most cases, this is because the rock type in question has previously been designated as both a minor and non-aquifer in different locations due to the variable characteristics.

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1 BRE Report BR211, 2023: "Radon: guidance on protective measures for new buildings (including supplementary advice for extensions, conversions and refurbishment projects".

2 Limitation of Human Exposure to Radon, Documents of the Health Protection Agency - Radiation, Chemical and Environmental Hazards, RCE-15. July 2010.

Unproductive strata: These are rock layers or superficial deposits with low permeability that have negligible significance for water supply or river base flow.

The EA maps only display the principal and secondary aquifers as coloured areas. All uncoloured areas on the map will be unproductive strata. However, for uncoloured areas on the superficial (drift) designation map it is not possible to distinguish between areas of unproductive strata and areas where no superficial deposits are present; to do this, it is necessary to consult the published geological survey maps.

For the purposes of the EA's Groundwater Protection Policy the following default position applies, unless there is site specific information to the contrary:

- If no superficial (drift) aquifers are shown, the bedrock designation is adopted
- In areas where the bedrock designation shows unproductive strata (the uncoloured areas) the superficial designation is adopted
- In all other areas, the more sensitive of the two designations is used (e.g. If secondary superficial overlies principal bedrock, an overall designation of principal is assumed)

The EA have also designated groundwater 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 and the effective rainfall, and may vary from tens to several thousand hectares.

Hydrology

Reference is made to publicly available Government held digital data via QGIS, and Landmark or Groundsure 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 6 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 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 (Flood Zone 3) 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 (Flood Zone 2) 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. Where there is no blue shading (Flood Zone 1), there is less than a 0.1% (1 in 1000) chance of flooding occurring each year.

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, 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 who can advise on appropriate mitigating measures; i.e. raising slab levels, provision of storage etc. In accordance with Chapter 10 of the National Planning Policy Framework, a site-specific flood risk assessment is required for: proposals of 1 hectare or greater in Flood Zone 1, or in an area within Flood Zone 1 which has critical drainage problems (as notified to the local planning authority by the Environment Agency); and any new development in Flood Zones 2 and 3.

COMAH & explosive sites

Lithos obtain information from Landmark or Groundsure with respect to Control of Major Accident Hazards (COMAH) or explosive sites within 1km of the proposed development site. Lithos' 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 its 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 site model

The site's environmental setting (and proposed end use) is used by Lithos 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 receptors.

Potential pollutant linkages are shown on a preliminary conceptual site model (pCSM). A CSM is essentially a cross-section through a site that reflects both the surface topography and underlying geology, and shows surface features of interest. The most significant sources of contamination are then superimposed onto this cross-section together with potential receptors (human health & controlled waters), and plausible pathways between the two. In addition to environmental issues, the CSM should also highlight geotechnical issues.

A pCSM is prepared after consideration of all available "desk study" data, and before design of the ground investigation. Data reviewed should include historical plans (with superimposition on a current-day plan), previous SI reports, geological maps etc. The pCSM, in conjunction with knowledge of site constraints (buildings, services, slopes etc) is used to design the ground investigation.

The revised CSM takes account of data obtained during the ground investigation, including the distribution of made ground, the nature and distribution of contamination etc.

02 - Ground investigation fieldwork
Generic notes – geoenvironmental investigations

General

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

- BS5930:2015 "Code of practice for site investigation"
- Eurocode 7: BS EN 1997-1:2004. Geotechnical design - Part 1: General rules
- Eurocode 7: BS EN 1997-2:2007. Geotechnical design - Part 2: Ground investigation and testing
- 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"

Exploratory hole locations

Exploratory hole locations are selected by Lithos, 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 Lithos include:

- Machine excavated **trial pits**, usually equipped with a backactor and a 0.6m wide bucket. Allows a thorough inspection of the ground; especially the uppermost 1m or so (but able to reach depths of up to c. 4m), with the recovery of representative, disturbed samples. Also used to conduct soakaway testing.
- **Window or windowless** sampling boreholes (**dynamic sampling**). 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).
- **Cable percussive** (Shell & Auger) boreholes, typically using 150mm diameter tools and casing. Enables the recovery of soil samples and data from greater depth than is possible via trial pitting or a mini-percussive drill rig. Also enables the installation of better/deeper monitoring wells (cf use of a mini-percussive drill rig) due to the utilisation of temporary steel casing during drilling.
- **Rotary percussive** open-hole probeholes are typically drilled using a tri-cone rock roller or polycrystalline diamond compact (PDC) bit with air as the flushing medium. Probeholes are generally lined through made ground with temporary steel casing to prevent hole collapse. Often used to penetrate bedrock to investigate abandoned shallow mineworkings
- **Rotary cored** boreholes. A rock core is cut by a bit, passes up into the inner barrel and, at the end of the coring run, the core barrel assembly is lifted to the surface. Core drilling is relatively expensive, but essential if quality data is required to assess issues associated with deep excavation, rock slope stability etc.

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

Relative densities of granular materials given on the trial pit logs are based on visual inspection only, they do not relate to any specific bearing capacities.

The relative densities of granular materials encountered in cable percussive boreholes are based on Standard Penetration Test (SPT) results. SPTs are carried out 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 (hand vane readings) 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

Typically Lithos collect at least three soil samples from each exploratory hole, although in practice a greater number are often taken. The collection of a sufficient number of samples provides a sound basis upon which to schedule laboratory analysis, ensuring:

- A sufficient number of samples from each (common) site material are tested
- Horizontal and vertical coverage of the site is adequate, thereby providing a robust data set for use in the conceptual ground model
- Any localised, significant, but non-pervasive conditions are considered

Made ground and natural soils encountered in the field during a ground investigation often contain a significant proportion of coarse grained material (e.g. brick etc). Soil samples obtained during most investigations are often only truly representative of the in-situ soil mass where there is an absence of particles coarser than medium gravel; i.e the entire soil mass would pass a 20mm sieve.

Representative bulk samples of the **soil mass** are retrieved from coarse soils for specific geotechnical tests (most notably grading and compaction); this typically requires the collection of at least 10kg of soil, and occasionally >50kg. However, in the context of assessing land contamination, it is generally accepted that samples should be representative of the **soil matrix** of the stratum from which they are taken. Consequently, truly representative samples of coarse soils for subsequent contaminant analysis are not obtained - only the finer fraction is placed in sample containers. Coarse constituents not sampled would typically comprise any 'particles' with an average diameter greater than about 20mm (i.e. coarse gravel, cobble and boulder).

At present, neither ISO/IEC 17025 nor MCERTS specify sample pre-treatment with respect to stone removal. Unsurprisingly therefore UKAS accredited testing laboratories do not adopt the same approach to stones[1] – some crush and test the "as received" soil, whilst others sieve out stones and analyse only the residual soil (the sieve size used varies depending on the laboratory).

In essence, samples taken from coarser soils for contaminant analysis are "screened" by the geoenvironmental engineer in the field, and often sieved again by the laboratory during sample preparation. Geoenvironmental engineers do not typically re-calculate soil mass contaminant concentrations by taking account of the unsampled coarse fraction. Likewise, laboratories that remove stones typically report contaminant concentrations based on the dry weight of soil passing the sieve. In the context of land contamination and human health risk assessment, this is considered reasonable, because it is the soil matrix which is of greatest concern. Stones are unlikely to:

- Provide a significant source for plant uptake (consumption of vegetables)
- Remain on vegetables after washing (consumption of vegetables)
- Be eaten (accidentally by an adult, or deliberately by a child)
- Be whipped-up by the wind for dust generation (inhalation)
- Stick to the skin for any length of time (dermal contact)
- Yield toxic vapour (inhalation)

Consequently, Lithos instruct labs to remove all stones >10mm, and to report the results as dry-weight based on the mass of matrix tested. However, the laboratory are given site-specific instruction where coarse stones are coated in say oil, or impregnated with mobile contaminants such as diesel. Where the stones are predominantly natural, or inert (e.g. brick, concrete etc), removal will clearly result in higher reported concentrations, than if the stones were crushed and added to the matrix.

Where the stones include a significant proportion of contaminant-rich material (e.g. slag, fragments of galvanised metal etc) an argument could be made for crushing and analysing. However, provided the stones are stable (i.e. unlikely to disintegrate or degrade) they should not pose a significant risk to human health for the reasons stated above.

Sometimes it is necessary to obtain samples that are not representative of the wider soil matrix, for example when investigating localised, significant, but non-pervasive conditions. Any such unrepresentative samples are annotated with the suffix '*' (eg 2D*, or 4G*). Lithos' site engineer describes both the unrepresentative sample, and the soil mass from which it was been taken.

Sample Containers (for contaminant analysis). Samples of soil for contaminant testing are placed into appropriate containers (see below). Soil samples for organic analysis are stored in cool boxes, at a temperature of approximately 4ºC, until delivery to the selected laboratory.

Anticipated testing	Container(s)
Asbestos identification	1000ml plastic tub
pH & metals	1000ml plastic tub or 250ml glass jars
non-volatile organics	250ml glass jars
Speciated TPH	250ml & 50ml glass jars
VOCs (incl. naphthalene and\or GRO)	50ml glass jar

Sample Containers (for geotechnical analysis). The majority of samples are only scheduled for PI and sulphate testing, for which 500g of sample is required (a full 0.5-litre plastic tub). However, bulk bags are taken where scheduling of compaction or grading tests is proposed.

Groundwater

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

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.

Description of strata

Soils encountered during a Lithos investigation are described (logged) in general accordance with BS 5930:2015. 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 the 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.

[1] *Mark Perrin. Stoned – Sample Preparation for Soils Analysis. Ground Engineering, April 2007.*

03 – Geotechnical laboratory testing
Generic notes – geoenvironmental investigations

General

Soil samples are delivered to the laboratory for testing along with a schedule of testing drawn up by Lithos. All tests are carried out in accordance with BS 1377:1990. The following laboratory testing is routinely carried out on a selection of samples:

- Atterberg limits & moisture contents
- Soluble sulphate & pH

Where soft, cohesive soils are encountered, one-dimensional consolidation tests are scheduled in order to assess settlement characteristics, and unconsolidated undrained triaxial compression tests to assess shear strength.

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

- Grading
- Compaction tests
- Particle density

Test results are presented as received in an Appendix to the Geoenvironmental Report.

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. Lithos 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. Lithos 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 (ie differentiate between residual soil and alluvium)
- The number of results in each class and
- The actual values

Unless the judgment strongly indicates otherwise, Lithos typically adopts a conservative approach and recommends 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.

Lithos refer to BRE Special Digest 1 (SD1) "Concrete in aggressive ground. Part 1: Assessing the aggressive chemical environment" (2005). 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 (DS class) and
- The aggressive chemical environment for concrete (ACEC class)

Lithos 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.

Oedometer (Consolidation) tests

Oedometer tests measure a soil's consolidation properties, and are performed by applying different loads to a soil sample and measuring the deformation response. Typically the sample is subject to 5 incremental pressures (4 loading & 1 unloading), and the convention is for each subsequent pressure to be double the previous pressure. BS1377 suggests the **initial** pressure should be:

a) For stiff soils the effective overburden pressure*
b) For firm soils "somewhat less" than the effective overburden pressure
c) For soft soils "appreciably less" than the effective overburden pressure, usually 25 kPa or less
d) For very soft soils very low, typically 5 kPa or 10 kPa

* Effective **overburden pressure** (kNm^{-2}) = depth (m) x soil bulk unit weight (kNm^{-3})

Results from these tests are used to predict how a soil in the field will deform in response to a change in effective stress.

Triaxial tests

This test measures the mechanical properties of a soil by placing the sample between two parallel platens which apply stress in one (usually vertical) direction, with fluid used to apply a confining pressure in the perpendicular directions. During the test, the surrounding fluid is pressurized, and then stress on the platens is increased until the material in the cylinder fails.

From triaxial test data, it is possible to extract fundamental material parameters, including its angle of shearing resistance, apparent cohesion, and dilatancy angle. These parameters are then used in computer models to predict how the material will behave in a larger-scale engineering application.

Quick (single stage, Unconsolidated, Undrained tests) are most appropriate for foundation design. This is because load is applied relatively quickly, and shear strength of the clay will be lowest initially; after the applied load causes some consolidation of the ground (after drainage results in dissipation of short-term excess pore water pressure), the in-situ clays will become progressively stronger and hence the factor of safety will increase. Confining pressure is specified as equivalent to overburden pressure (kNm^{-2}).

Foundations on granular soils would use effective shear strength parameters (c' and phi') to assess safe bearing capacity, as the soil would fully drain quickly. These effective shear strength parameters could be determined from Consolidated Undrained (or sometimes the more expensive Consolidated Drained) triaxial tests, but often correlations to the SPT are used.

Unconsolidated Undrained triaxial tests are most appropriate for assessment of the stability of fill slopes on clays. Similar to foundations, the application of load gradually increases the strength of the clays and hence the critical case is the short term undrained condition.

Consolidated Undrained (or sometimes **Consolidated Drained**) triaxial tests are most appropriate for assessment of the stability of cut slopes in clays. This is because unloading of the ground leads to short term reduction in pore pressures that approximately balance the unloading, hence the soil strength is largely unchanged. Over time the reduced pore pressures suck water in, which leads in to the progressive increase in pore pressure and loss of strength. The fully drained state is critical, which must be modelled using effective strength parameters and a reasonable estimate of the long term water table conditions.

Slopes formed in granular soils would use effective shear strength parameters (c' and phi') to assess safe bearing capacity, as the soil would fully drain quickly. These effective shear strength parameters could be determined from Consolidated Undrained (or sometimes the more expensive Consolidated Drained) triaxial tests, but often correlations to the SPT are used.

Determination of analytical suite

An assessment of potential contaminants associated with the former usages of the site is undertaken with reference to CLR 8 "Potential contaminants for the assessment of land" and the relevant DETR Industry Profile(s).

Common contaminants

Common **Inorganic** Contaminants 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 include hydrocarbons, phenols, and polychlorinated biphenyls.

Petroleum is a mixture of hydrocarbons produced from the distillation of crude oil, and includes aliphatics (alkanes, alkenes and cycloalkanes), aromatics (benzene and derivatives) 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 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" and "DRO" 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_{40}, whereas others define TPH as C_{10}-C_{30}.

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_4 to C_5 range) that are volatile. The aromatic hydrocarbons in gasoline are primarily benzene, toluene, ethylbenzene and xylenes, referred to as BTEX. Small amounts of polycyclic aromatic hydrocarbons (PAHs) such as benzo(a)pyrene 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% is composed of aromatic hydrocarbons. BTEX concentrations are generally low.

Heavy Fuel Oils are typically dark in colour and considerably more viscous than water. 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 insoluble in groundwater. They may contain 10 to 30% aromatics, including the heavier PAHs. NSO compounds are also common.

Polycyclic Aromatic Hydrocarbons (PAHs) have two or more 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. Certain PAH compounds are carcinogenic (benzo(a)pyrene) and\or mobile in the environment (naphthalene).

Volatile Organic Compounds (VOCs) are organic chemicals, and most are liquids that readily evaporate on exposure to air. Examples include benzene, toluene, xylene, chloroform etc. Semi-Volatile Organic Compounds (sVOCs) include phenol and benzo(a)pyrene, and have relatively low boiling points. 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 (-OH) attached to an aromatic ring (ie 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 are of increasing toxicity relative to the degree of chlorination. 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 backyard burn-barrels. 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 broad, 'banded' breakdown of the TPH results into gasoline range organics (GRO), diesel range organics (DRO) and heavier lubricating oil range organics (LRO), or fully speciated results with the reporting of hydrocarbon concentrations in 14 specific carbon bandings based upon behavioural characteristics, e.g. aliphatic C_6 to C_8, aromatic C_{10} to C_{12} etc.

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 16 USA-EPA priority PAHs, phenols, 7 USA EPA priority PCB congeners, herbicides & pesticides.

Note: PAHs are hydrocarbons and consequently (where present) will be picked-up when scheduling TPH by GC-FID.

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 Land Contamination Risk Management (2020). 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 (eg controlled water or people); and (3) a pathway linking (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.

Lithos adopt 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, Lithos risk-derived screening values, or remedial targets. It should be noted that exceedance of Tier 1 does not necessarily mean that remedial action will be required.

Soil screening values used by Lithos

In March 2002 DEFRA and the Environment Agency published a series of technical papers (R&D Publications CLR 7, 8, 9 & 10) outlining the UK approach to the assessment of risk to human health from land contamination. In 2008 CLR 7, 9 & 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
- Evaluation of models for predicting plant uptake of chemicals from soil - Science Report – SC050021/SR
- Human health toxicological assessment of contaminants in soil - Science Report: SC050021/SR2
- Updated technical background to the CLEA model - Science Report: SC050021/SR3
- CLEA Software Handbook, Science report: SC050021/SR4
- Compilation of data for priority organic pollutants for derivation of Soil Guideline Values - Science Report: SC050021/SR7

In December 2013 Defra published the results of research project SP1010 – Development of Category 4 Screening Levels (C4SLs) for Assessment of Land Affected by Contamination. The objective of this project was to provide technical guidance in support of Defra's revised Statutory Guidance for Part 2A of the Environmental Protection Act 1990 (Part 2A). The revised Statutory Guidance, published in April 2012, introduced a new four-category system for classifying land under Part 2A, where Category 1 includes land where the level of risk is clearly unacceptable, and Category 4 includes land where the level of risk posed is acceptably low. Project SP1010 aimed to deliver:

- A methodology for deriving C4SLs for four generic land-uses comprising residential, commercial, allotments and public open space; and
- Demonstration of the methodology, via derivation of C4SLs for 6 substances – arsenic, cadmium, chromium IV, lead, benzene & benzo(a)pyrene.

The methodology for deriving both the previous Soil Guideline Values and the Category 4 Screening Levels is based on the Environment Agency's Contaminated Land Exposure Assessment (CLEA) methodology. Development of C4SLs has been achieved by modifying the toxicological and\or exposure parameters used within CLEA (while maintaining current exposure parameters).

Part 2A Statutory Guidance was developed on the basis that C4SLs could be used under the planning regime. Defra anticipate that, where they exist, C4SLs will be used as generic screening criteria, and Lithos consider C4SLs to be suitable for use as Tier 1 Screening Values. Lithos have discussed this matter with both NHBC and YALPAG (collection of Yorkshire & Lincolnshire local authorities) and received confirmation that they are satisfied with this approach.

The CLEA conceptual site model assumes a source located in a sandy loam, with 6% soil organic matter (SOM) - equivalent to 3.5% total organic carbon (TOC). However, many organic contaminants are more mobile when the SOM is lower, and consequently comparison of soil results with revised, lower screening values may be required. Other CLEA default characteristics adopted by Lithos are:

Sandy Loam characteristics (source)	Default values adopted
Total porosity (fraction)	0.53
Water filled porosity (fraction)	0.33
Air filled porosity (fraction)	0.2

Lithos have derived Screening Values for five different CSMs (scenarios); these are:

A - Residential with gardens, but no cover (or only up to 300mm)

B - Residential with gardens and 600mm 'clean' cover

C - Residential apartments with landscaping (i.e. no home grown produce)

D - Commercial/industrial with landscaping

E – Importation of soil cover

The **exposure** pathways considered for each scenario are detailed in the table below.

Scenario	Land use	Pathways	Justification
A	Residential with garden, but no cover (or only up to 300mm)	• Direct ingestion of soil • Dermal contact • Consumption of vegetables & soil attached to vegetables • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	Minimal cover – insufficient to break any pathways therefore all exposure pathways are relevant.
B	Residential with garden minimum 600mm cover	• Inhalation of indoor vapours • Inhalation of outdoor vapours	The 600mm cover removes the risk from all pathways other than inhalation.
C	Residential apartments with landscaped areas and minimum 300mm cover	• Direct ingestion of soil • Dermal contact • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	All pathways applicable due to possible exposure from landscaped areas. However consumption of home grown produce not included as unlikely to be grown in landscaped areas. Where vegetables are to be grown site specific QRA may be required.

Scenario	Land use	Pathways	Justification
D	Commercial/ industrial with landscaped areas no cover	• Direct ingestion of soil • Dermal contact • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	All pathways applicable due to possible exposure from landscaped areas. Assumed the commercial development consists of offices to provide a conservative assessment.
E	Importation of soil for cover in garden and landscaped areas	• Direct ingestion of soil • Dermal contact • Consumption of vegetables & soil attached to vegetables • Inhalation of outdoor vapours and dust	Material used as cover to break existing pathways therefore all direct and indirect pathways relevant; however cover is **not** placed below plots therefore indoor inhalation is not relevant.

Lithos have assumed the source of contamination is directly below the building foundation; i.e. a depth to source of 0.15m as opposed to the CLEA default of 0.65m. This assumption provides for a more conservative approach than the UK default.

Lithos have derived Tier 1 values for a number of inorganic and organic determinands in the context of the five Scenarios A to E. The Tier 1 values are **not** intended to be used when considering potential risks associated with:

- Existing land uses in the context of Part 2A of the Environment Protection Act 1990;
- End uses such as allotments, sports fields, children's playgrounds, care homes, hospitals etc; or
- Groundwater and surface water

Inorganic Tier 1 values for scenarios A to E

Inorganic contaminant	Tier 1 assessment criteria (mg/kg) for Scenarios A to E							Comments/notes
	SGV*	C4SL*	A	B	C	D	E	
As	32	37	37	Use (A) in SI Report for initial "screen" If >5 x A, then consider increase of cover to 1,000mm	40	640	37	C4SL adopted
Cd	10	26	26		149	410	26	C4SL adopted
Cr			4,000		4,000	28,767	4,000	Assumes Cr is CrIII
Pb	450	200	200		314	2,330	200	C4SL adopted
Ni	130		109		123	892	109	Assessment of health risk only
Se	350		434		596	13,018	434	
Hg	170		199		244	3,603	199	Assumes in an inorganic compound
Vn			584		586	4,994	584	
B			5		5	5	5	Based on phytotoxic risks as plants are the more sensitive receptor (Cu is pH dependant)
Cu			100		100	100	100	
Zn			200		200	200	200	

Organic Tier 1 values for scenarios A to E

Organic contaminant (all sourced via CLEA)	Tier 1 assessment criteria (mg/kg) for Scenarios A to E							Comments/notes
	SGV*	C4SL*	A	B	C	D	E	
Benzene	0.33	0.87	0.7	<1^	<1^	63	<1	<1 based on professional judgement and lower than calculated value.
Toluene	610		836	2,048	1,912	5,000	<1	Scenario D based on professional judgement and lower than calculated value.
Ethyl Benzene	350		379	592	566	5,000	<10	
Xylenes	240		535	590	585	5,000	<10	Scenario E based on professional judgement and lower than calculated value.
Phenol	420		1,434	3,360	2,264	5,000	<10	
PCBs			2	8	2	38	N/A	Based on toxicity of EC7
Benzo(a)pyrene		5	5	25	5	76	5	C4SL adopted. Scenario B 5 times scenario A
Naphthalene			6	6	6	619	<10	Scenario E based on professional judgement and lower than calculated value
Gasoline Range Organics			22	23	23	2178	626	See 3-step assessment of TPH below ^Based on professional judgement and lower than calculated value
Diesel Range Organics			215	218	215	^5,000	1,429	
Lubricating Range Org			3,299	5,000	3,829	^5,000	3,299	

* *For a residential end use*

The significance of PAHs can be determined by considering indicator compounds. In most cases benzo(a)pyrene (BaP) is adopted as an indicator due to the amount of toxicological data available and has been used by various authoritative bodies to assess the carcinogenic risk of PAHs in food. A surrogate marker approach can be used to estimate the toxicity of a mixture of PAHs in soil using toxicity data for individual indicator compounds within that mixture. Exposure to the surrogate marker is assumed to represent exposure to all PAHs in that matrix. The surrogate marker approach relies on a number of assumptions:

- Surrogate marker (BaP) must be present in all soil samples
- Profile of the different PAH relative to BaP should be similar in all samples
- PAH profile in the soil samples should be similar to that used in the pivotal toxicity study[1]

To assess the PAH profile in a soil sample, the ratio of the seven genotoxic PAHs (benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[g,h,i]perylene, chrysene, dibenz[a,h]anthracene and indeno[1,2,3-c,d]pyrene), relative to BaP, should be calculated. The ratio relative to BaP should lie within an order of magnitude above and below the mean ratio to BaP.

[1] SP1010 Appendix E, Provisional C4SIs for benzo(a)pyrene as a surrogate marker for PAHs, CL:AIRE 2013

Naphthalene should also be considered separately against its generic screen. Whilst classed as a PAH, naphthalene is more volatile and mobile in the environment than most other PAHs. As such the significance of naphthalene cannot be considered within the surrogate marker approach.

Similarly, **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). The TPHCWG have broken down "TPH" into representative constituent fractions or "EC Bandings". The TPHCWG have derived a series of physiochemical and toxicological parameters for each of the bandings.

The significance of speciated TPH results can be assessed by following the 3 steps outlined in the tables below.

Step	Result	Action
1. Consider indicator compounds: Are BTEX, naphthalene, benzo(a)pyrene above their respective Tier 1 values?	Yes	Remediation or dQRA required
	No	Proceed to Step 2
2. Consider individual TPH fractions: are they above respective screening values?	Yes	Remediation or dQRA required
	No	Proceed to Step 3
3. Assess Cumulative effects: Is the calculated Hazard Index for each source >1	Yes	Remediation or dQRA required
	No	TPH compounds pose no significant risk

The equation used to assess cumulative effects in step 3 is shown below.

$$HI = \sum_{F_i=1}^{16} HQ\ F_i = \frac{Measured\ concentration\ F_i\ (mg\,kg^{-1})}{SGV\ F_i\ (mg\,kg^{-1})}$$

where HI = Hazard Index
HQ = Hazard Quotient
F_i = Fraction $_i$
SGV = Soil Guideline Value

Statistical Assessment

Current UK guidance is provided by CL:AIRE[2], and uses two-way confidence intervals and graphical summaries, to assist assessors when determining whether or not a dataset is adequate to answer the question posed; e.g. "is existing site topsoil suitable for retention & re-use?". To answer such a question, it is necessary to recover and test a large number of samples (a minimum of 10; ideally 20+) in order to undertake meaningful statistical analysis.

However, in the context of site investigation to assess the significance of contamination on brownfield sites which are typically underlain by **heterogenous made ground**, some remediation is almost always required (placement of soil cover, excavation of gross contamination etc). Consequently, in such circumstances, it is not necessary to demonstrate that made ground soils are "clean" and therefore there is no need to test large numbers of samples and undertake statistical analysis. Sample results can simply be compared directly with appropriate screening values (e.g. Lithos Tier 1 values).

The CL:AIRE (2020) guidance replaces the withdrawn "Guidance on Comparing Soil Contamination Data with a Critical Concentration" (2008).

The old approach to statistical analysis was based on a definitive yes/no answer which required limited consideration of the dataset and Conceptual Site Model. It was widely accepted that this did not allow sites or risk to be adequately assessed. The updated approach requires a comprehensive understanding of the datasets within the context of the Conceptual Site Model.

Current guidance requires that:

- A robust CSM is in place which identifies source areas, averaging areas and averaging zones
- Sampling locations are relatively evenly spread across the site and were selected using simple or stratified random sampling with no targeting being undertaken
- The field data and CSM do not suggest the presence of a hotspot of contamination which should be treated as a separate zone
- The samples are all taken from a similar same depth and within the same material type across the zone being assessed
- A minimum of 10 samples have been taken. It should be appreciated that confidence in a dataset increases as the number of samples obtained and tested from a zone increases.

The statistical analysis assumes a homogenous distribution of strata and contamination and therefore the dataset will be normally distributed (symmetric, log symmetric or fat tailed).

A normally distributed dataset is assessed using a number of statistical tools to generate a Dot and Box Plot which includes summary statistics and confidence intervals. The review of statistical data enables the assessor to make a decision, with an associated level of confidence, where the true mean of the sample population lies in relation to the critical concentration.

It is essential when using statistics to assess sample data that all decisions relate back to the conceptual site model. Statistics cannot indicate if contamination on a site is likely to present a risk to the end user, this is the role of the 'competent person' i.e. Lithos.

However, broadly speaking the following applies:

- Mean and UCL below the critical concentration – no further assessment required.
- Mean below the critical concentration, but UCL above – consider the CSM and likely sources.
- Mean and UCL above the critical concentration – further assessment required, remediation likely depending on the CSM.
- LCL, Mean & UCL above the critical concentration – further assessment required, remediation likely.

[2] *CL:AIRE, 2020.Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration.*

Other screening values used by Lithos

Tier 1 risk assessment of **hazardous gas** is undertaken through reference to the following documents (and further information is presented in Generic Note No. 5 – Hazardous Gas):

- Approved Document C, Building Regulations 2000
- Boyle & Witherington (2007) – 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 characterisation & remediation from ground gas in affected developments

With respect to the assessment of potential **phytotoxic effects** of contaminants, Lithos refer to The Sewage Sludge in Agriculture: Code of Practice 2018 for copper and zinc (at pH 5.5 to 6.0). The CLEA derived Tier 1 value is adopted for nickel due to its human health effects.

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*".

Tier 1 **groundwater risk assessments** are always site specific and compare leachate or groundwater concentrations with the appropriate water quality standard based on the CSM and consideration of relevant water quality impacts and assessments.

Waste classification & 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.

Landfill operators require Waste Acceptance Criteria (WAC) laboratory data, if soil waste is classified as **hazardous**. 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.

Lithos 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 during redevelopment is anticipated, then WAC analysis should be scheduled at an early stage in the remediation programme. However, organic compounds (BTEX, TPH, PAH etc) are the most common contaminants that result in soils being classed as hazardous, and 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 (e.g. WAC) is required.

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 landfill gas).

1. Undertake further statistical analysis following the approach set out in Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration, 2020 (see above) in order to determine whether contaminant concentrations of inorganic contaminants within soil\fill actually present a risk (only applicable to assessing the risk to human health).
2. Carry out a more detailed quantitative risk assessment in order to determine whether contamination risks actually exist.
3. 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 the issue of the **averaging area** requires further consideration. Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration, 2020 provides some guidance on averaging areas noting that they are the area within which a receptor may be exposed to contamination but leaving the site assessor to determine the appropriate averaging area for their site.

Lithos consider the entire site needs to be characterised by reference to the Conceptual Site Model. Consequently, Lithos gather and analyse sample results by fill type, and\or by former use in a given sub-area of the site, before undertaking statistical analysis; i.e. the averaging area 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. As such the entire site is considered in terms of the proposed end use, be this residential with, or without gardens.

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

05 – Hazardous gas
Generic notes – geoenvironmental investigations

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 Notes 01 – Environmental Setting.

Assessment of potential risks associated with hazardous gas are based on a review of data obtained from the Landmark Information Group, the Environment Agency and the Local Authority and the British Geological Survey. Reference is also made to historical OS plans, which are inspected for evidence of backfilled quarries, railway cuttings, colliery spoil tips etc.

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

Sources

Potential sources of hazardous gas include:

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

Generation

Wherever biodegradable material is deposited, landfill gas (principally a mixture of methane and carbon dioxide) is likely to be generated by microbial activity. Carbon dioxide is an asphyxiant and toxic; methane is flammable and a mixture containing between 5% and 15% methane by volume in air is explosive. Landfill gas in the ground is unlikely in itself to pose a significant risk, though it may damage vegetation. However, infiltration of landfill gas into confined spaces (e.g. cellars, services, etc) may give rise to considerable risk.

There is no typical figure for the length of time that landfill gas will be evolved, but at many sites significant gas generation continues for at least 15 years after the last deposit of waste.

Migration

Gas migration from a landfill site 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 is 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

Lithos adopt a standard gas monitoring procedure, in accordance with CIRIA guidance. This procedure involves the measurement, in the following order of:

- Atmospheric temperature, pressure and ambient oxygen concentration
- Gas emission rate
- Methane, oxygen and carbon dioxide concentrations using an infra-red gas analyser
- Standing water level using a 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 multi-layer Tedlar / ALTEF sampling bags are used. Gas concentrations in the well are typically recorded immediately before and after retrieval of a sample.

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:

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

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

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

A – All developments except low rise housing

(Wilson & Card, 1999)[v] revised Table 28 of CIRIA 149[v] in terms of borehole gas volume flow rate (now GSV) 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.

Characteristic Situation	Gas Screening Value, CH_4 or CO_2 (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 low organic content
2	<0.7	Borehole air flow rate not to exceed 70 litre/hr otherwise increase to Characteristic Situation 3	Natural soil, high peat/organic content
3	<3.5		Old landfill, inert waste, mineworkings flooded.
4	<15	Quantitative Risk Assessment required to evaluate scope of protection measures.	Mineworkings – susceptible to flooding, completed landfill, inert waste
5	<70		Mineworkings unflooded, inactive
6	>70		Recent landfill site

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.

B – Low rise housing.

NHBC have developed a characterisation system similar to that of Wilson & Card above, but specific to low-rise housing development (Boyle and Witherington) (Table 8.7). This approach compares measured gas emission rates with generic "Traffic Lights". The Traffic Lights include "Typical Maximum Concentrations" 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 worst case adopted in order to establish the appropriate protection measures.

Table 8.7 NHBC Traffic light system for 150 mm void

Traffic Light Classification	Methane [1]		Carbon Dioxide [1]	
	Typical Maximum Concentration [5] (%v/v)	Gas Screening Value [2,4,6] (l/hr)	Typical Maximum Concentration [5] (%v/v)	Gas Screening Value [2,3,4,6] (l/hr)
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. A leak of gas from the sub-floor void into a small room (e.g. downstairs toilet with soil pipe potentially passing into sub-floor void) of dimensions 1.50m × 1.50m × 2.50m, with a total room volume of 5.63m^3 has been considered.
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.

---

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

ii *CIRIA (2007) – Assessing risks posed by hazardous ground gases to buildings.*

iii *Wilson SA and Card GB (February 1999). Reliability and Risk in Gas Protection Design. Ground Engineering.*

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 *Wilson SA and Card GB (February 1999). Reliability and Risk in Gas Protection Design. Ground Engineering.*

06 - Soakaways
Generic notes – geoenvironmental investigations

Background

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

Soakaways are increasingly seen as a more widely applicable option alongside other means of stormwater control and disposal. Soakaways must store the immediate stormwater run-off and allow for its efficient infiltration into the adjacent 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, DG365: 1991 describes design and construction procedures, explains how to calculate rainfall design values and soil infiltration rates, and gives design examples. Further advice is provided in **NHBC** Standards Chapter 5.3 (Section 9 & Appendix F), **Building Regulations** Section 3 of Approved Document H (Drainage & Waste Disposal), and Chapter 13 of **CIRIA's** SUDS Manual (C753:2015).

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.

BRE365 states that '**Groundwater should not rise to the level of the base of the soakaway** during annual variations in the water table' this is further reinforced in Chapter 13 of CIRIA C753:2015 which states that: "*A minimum distance of 1m between the base of the infiltration system and the maximum likely groundwater level should always be adopted. This is to minimise the risk of groundwater rising into the infiltration component and reducing the available storage volume, to protect the functionality of the infiltration process by ensuring a sufficient depth of unsaturated material and to protect the groundwater from any contamination in the run-off*". There may be a requirement to install groundwater monitoring wells at a site in order to monitor seasonal variations in groundwater level at least over a wet winter period.

Soakaways should **not be sited on sloping sites**, an assessment should also be made to ensure that infiltrating water will not cause a rise in groundwater levels, waterlogging of downhill areas or springs, and that slopes are not made unstable.

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

Chalk: CIRIA C574:2002 notes that concentrated ingress of water into the chalk can initiate dissolution, particularly in low-density chalk. For this reason, soakaways should be sited well away from foundations for structures, roads or railways:-

- in areas where dissolution features are known to be prevalent, soakaways should be avoided but, if unavoidable, should be sited at least 20m away from foundations etc
- where the chalk is of low density (weak), or where density is not known, soakaways should be sited at least 10m away from foundations
- where the chalk is of medium density, or higher (moderately weak), soakaways should be sited at least 5m away from foundations

Test methodology

Lithos undertake 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 consecutive days. However, each test can take over 2 hours to complete. Consequently, at site investigation / feasibility stage, testing is usually undertaken in a 'broad sweep', relatively widely spaced; often only 1 or 2 fills. The drainage designer reviews SI data and if soakaways look feasible, commences design with the incorporation of soakaways. Prior to finalising design, the Drainage Engineer will usually recommend further soakaway testing: (a) within 25m of proposed chamber locations; and (b) to include 3 fills.

Whilst in theory 3 fills is fine, in practice it is often not straightforward. Where drainage rates are quick (draining < 1 hour), allowing 3 fills per pit within a day, even larger water bowsers (say 2,300 gallon/10,000 litre) will run out of water after testing in two pits. Re-filling can take 2 to 3 hours depending on available water supplies etc. So, it is typically only possible to do fully compliant BRE 365 testing in 4 pits a day.

Where infiltration is moderate (a fill drains in say 2 to 4 hours), soakaways may be considered feasible, but it will not usually be possible to complete 3 fills in a day. Therefore, it becomes necessary to leave pits open overnight (usually with a consequent need for herras fencing, site security etc, or the use of stone backfill).

Infiltration rates

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

Soakaway design

Soakaway design should be carried out by a suitably qualified and experienced Drainage Engineer, in accordance with BRE Digest 365 using the infiltration rates calculated from soakaway testing during a ground investigation.

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

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

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

- Standing groundwater level
- Depth to base of permeable strata
- Cost of excavation

Soakaway percolation in some rock types is predominately 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. However, it is likely that the larger surface area of a completed soakaway within the development will intercept such joints.

The drainage designer submits designs for approval to:

- The Lead Local Flood Authority (LLFA), usually part of the Local Authority (e.g. NYCC). The LLFA are a consultee to the planning authority. They review the full technical design to ensure that proposals (both plots & highways) are satisfactory. The LLFA may also set standards for soakaway design (NYCC have, and these now require 3 fills and soakaway testing within 25m of proposed chamber locations).
- Local Authority Highways Dept. The Highways Authority adopt highways drainage, so review drainage design (via approval of a Section 38 submission). They also visit site to inspect construction.
- Building warranty provider (e.g. NHBC, Premier etc), if soakaways are proposed for roof & driveway waters.

Appendix B

Drawings

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CLIENT	FENWOOD ESTATES LIMITED
JOB TITLE	CUDWORTH PARKWAY, BARNSLEY
DRAWING TITLE	SITE LOCATION PLAN
DRAWN	LEW
DATE	03 01 23
CHECKED	AG
DATE	03 01 23
STATUS	FOR COMMENT ☐ DRAFT ☐ FOR APPROVAL ☐ FINAL ☑
SCALE	1:25,000
SHEET	A4
DRAWING NO.	4674/1
REVISION	

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JOB TITLE

CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE

PROPOSED LAYOUT

NOTES

APPROXIMATE SITE BOUNDARY

REPRODUCED FROM FENWOOD ESTATES' DRAWING REFERENCE 22-04-001-01-02, DATED 14TH FEBRUARY 2023

REV.	DESCRIPTION	DATE

STATUS

FOR COMMENT ☐ FOR APPROVAL ☐ DRAFT ☐ FINAL ☑

DRAWN	DATE
LEW	05 01 23
APPROVED	DATE
AG	05 01 23

SCALE	SHEET
1:1500	A3

DRAWING NO.	REVISION
4674/2	

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JOB TITLE
CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE
SITE FEATURES

NOTES
- DENSE VEGETATION
- GRASS & OVERGROWN AREAS
- BUILDING
- TARMAC HARDSTAND
- APPROXIMATE FOOTPRINT OF FORMER QUARRY (1962 OS MAP)
- APPROXIMATE FOOTPRINT OF FORMER BUILDING
- APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE

STATUS: FOR COMMENT ☐ FOR APPROVAL ☐ DRAFT ☐ FINAL ☑

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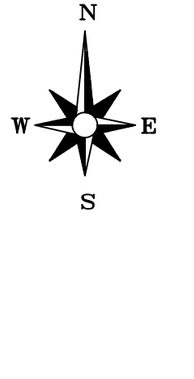

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JOB TITLE

CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE

SITE PHOTOGRAPHS

NOTES

- DENSE VEGETATION
- GRASS & OVERGROWN AREAS
- BUILDING
- TARMAC HARDSTAND
- APPROXIMATE SITE BOUNDARY
- LOCATION & ORIENTATION OF PHOTOGRAPH

REV.	DESCRIPTION	DATE

STATUS

FOR COMMENT ☐ FOR APPROVAL ☐ DRAFT ☐ FINAL ☑

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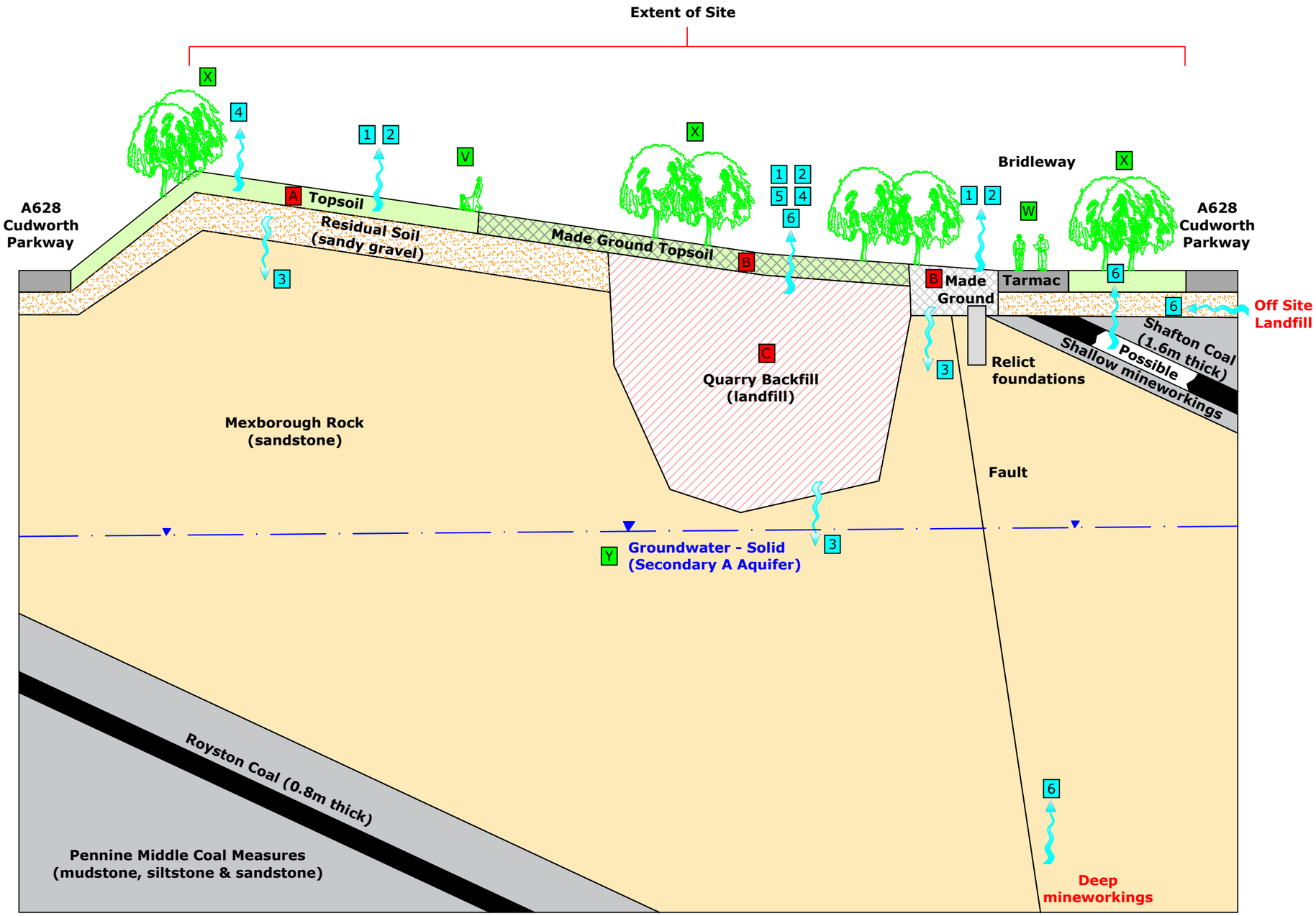

SOURCES	PATHWAYS	RECEPTORS
A TOPSOIL (INORGANICS & ORGANICS)	1 DERMAL CONTACT	V END USERS (RESIDENTS)
B MADE GROUND (INORGANICS & ORGANICS)	2 INGESTION/INHALATION	W SITE WORKERS
C QUARRY BACKFILL (INORGANICS, ORGANICS & GAS)	3 LEACHING OF CONTAMINANTS	X VEGETATION
	4 UPTAKE BY PLANTS	Y GROUNDWATER
	5 VOLATILISATION	
	6 MIGRATION OF GAS	

NOTES

REV.	DESCRIPTION	DATE

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PRELIMINARY CONCEPTUAL SITE MODEL

DRAWN	DATE	STATUS
LEW	05 01 23	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
AG	05 01 23	DRAFT ☐
		FINAL ☑

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Not to scale	A3	4674/5	

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JOB TITLE

CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE

EXPLORATORY HOLE LOCATIONS

NOTES

- TRIAL PIT LOCATION
- SOAKAWAY TEST LOCATION
- TRIAL TRENCH LOCATION
- ROTARY PROBEHOLE LOCATION
- ROTARY CORED BOREHOLE LOCATION
- WINDOW SAMPLE LOCATION
- APPROXIMATE SITE BOUNDARY

EXPLORATORY HOLE LOCATIONS HAVE BEEN SURVEYED IN (COORDINATES & GROUND LEVEL) ON COMPLETION

REV.	DESCRIPTION	DATE

STATUS: FOR COMMENT ☐ FOR APPROVAL ☐ DRAFT ☐ FINAL ☑

DRAWN	DATE
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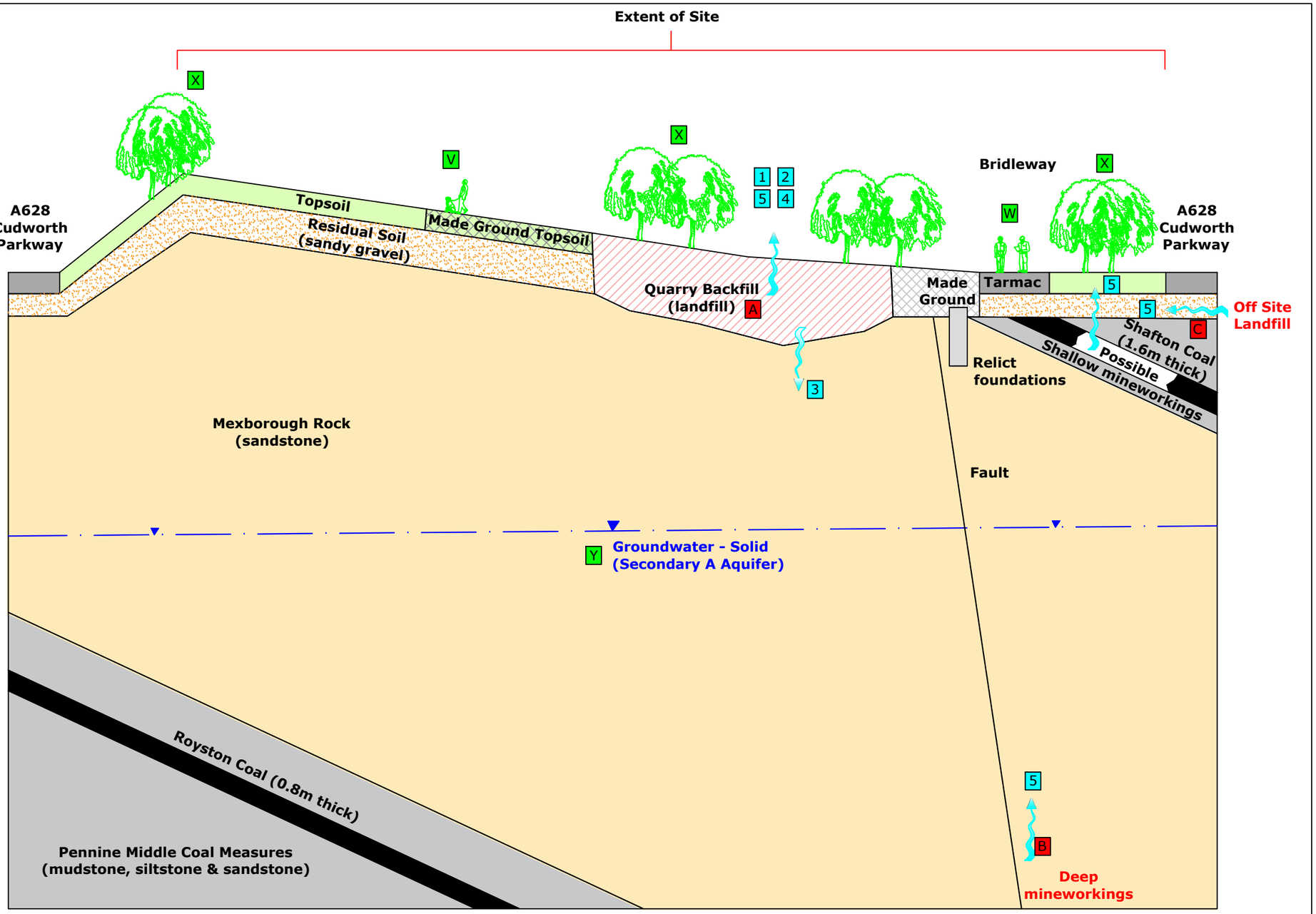

SOURCES	PATHWAYS	RECEPTORS
A QUARRY BACKFILL (INORGANICS, ORGANICS & GAS)	1 DERMAL CONTACT	V END USERS (RESIDENTS)
B DEEP MINE WORKINGS (GAS)	2 INGESTION/INHALATION	W SITE WORKERS
C OFF SITE LANDFILL (GAS)	3 LEACHING OF CONTAMINANTS	X VEGETATION
	4 UPTAKE BY PLANTS	Y GROUNDWATER
	5 MIGRATION OF GAS	

NOTES

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JOB TITLE

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PARKWAY,
BARNSLEY

DRAWING TITLE

REVISED CONCEPTUAL SITE MODEL

DRAWN	DATE	STATUS
LEW	23 05 24	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
AG	23 05 24	DRAFT ☐
		FINAL ☑

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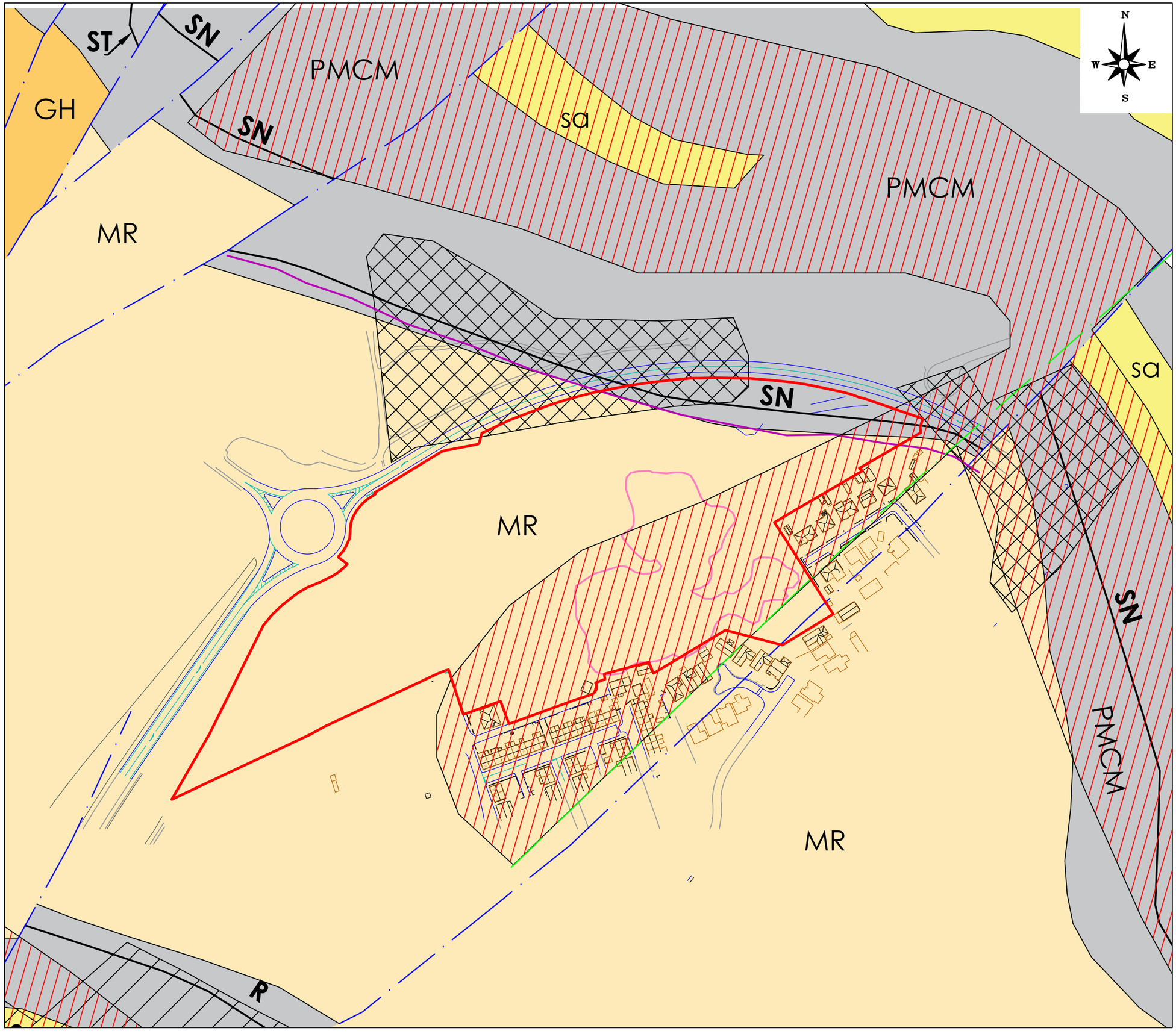

NOTES

- APPROXIMATE FOOTPRINT OF FORMER QUARRY (1962 OS MAP)
- COAL MINING DEVELOPMENT HIGH RISK AREA
- BGS RECORDED MADE GROUND
- CA RECORDED OPENCAST
- PENNINE MIDDLE COAL MEASURES
- MR MEXBOROUGH ROCK
- GH GLASS HOUGHTON ROCK
- sa UNNAMED SANDSTONE UNIT
- SN SHAFTON COAL
- R ROYSTON COAL
- ST SHARLSTON TOP COAL
- APPROXIMATE COAL OUTCROP (BGS)
- APPROXIMATE COAL OUTCROP (CA)
- APPROXIMATE FAULT LINE (BGS)
- APPROXIMATE FAULT LINE (CA)
- APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE

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CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE

SITE GEOLOGY & MINING

DRAWN	DATE	STATUS
LEW	05 01 23	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
AG	05 01 23	DRAFT ☐
		FINAL ☑

SCALE	SHEET	DRAWING NO.	REVISION
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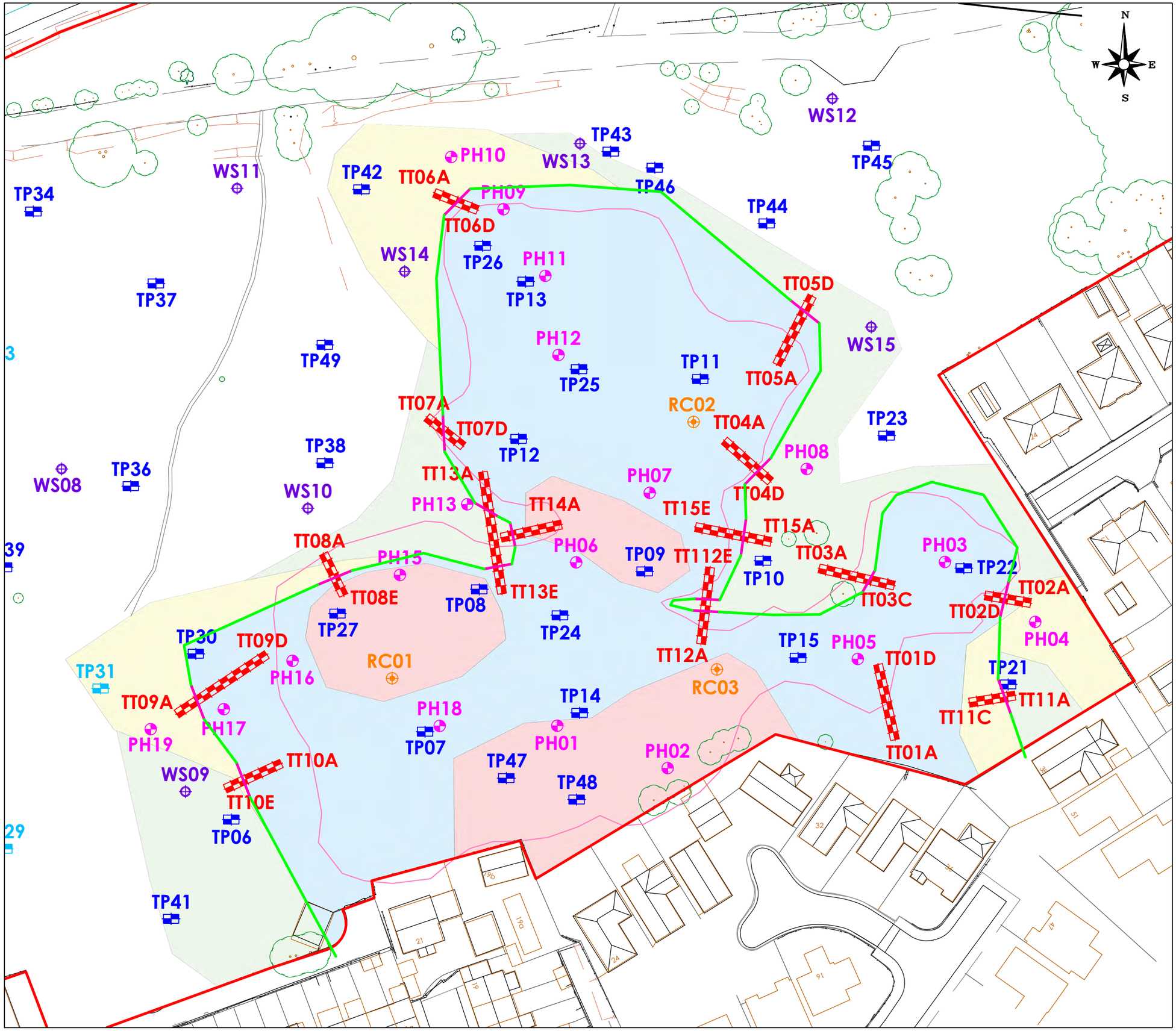


NOTES

- TRIAL PIT LOCATION
- SOAKAWAY TEST LOCATION
- TRIAL TRENCH LOCATION
- ROTARY PROBEHOLE LOCATION
- ROTARY CORED BOREHOLE LOCATION
- WINDOW SAMPLE LOCATION
- QUARRY HIGHWALL (1962 OS MAP)
- QUARRY HIGHWALL (OBSERVED)
- QUARRY HIGHWALL (INFERRED)
- APPROXIMATE SITE BOUNDARY

THICKNESS OF MADE GROUND

- <1m
- 1.0m - 2.0m
- 2.1m - 3.0m
- 3.0m - 4.0m

NOTES:

- This drawing may require revision in light of any additional investigation undertaken in previously inaccessible areas (dense vegetation)
- Line of highwall and thickness of made ground is extrapolated between exploratory holes and may vary locally
- PH02 encountered made ground to 5.2m depth - there is some doubt over this due significant inconsistency with adjacent holes and may be associated with the method of drilling.

REV.	DESCRIPTION	DATE

LITHOS CONSULTING

info@lithos.co.uk
www.lithos.co.uk

Tel 01937 545330

CLIENT

FENWOOD ESTATES LIMITED

JOB TITLE

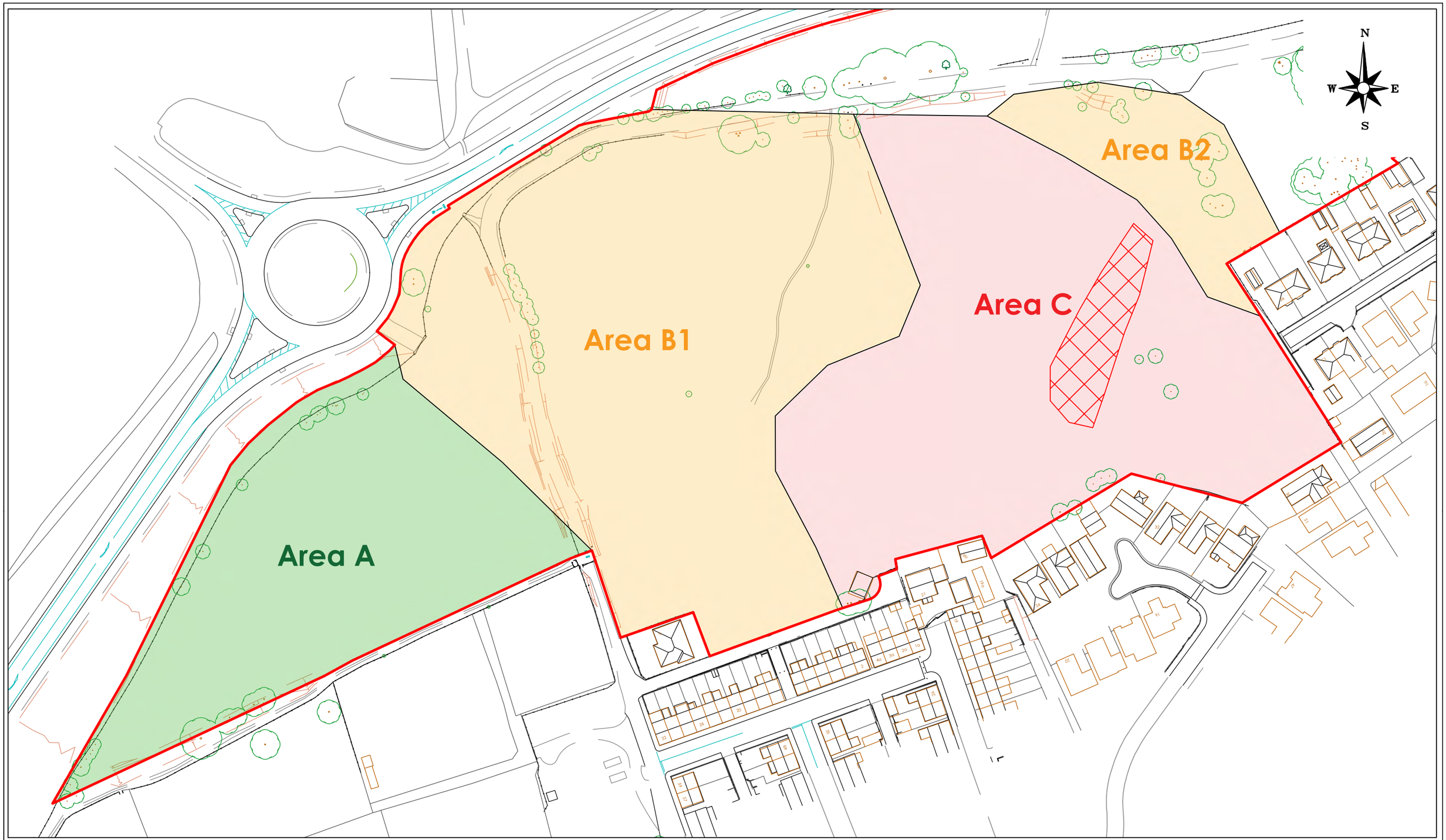
CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE

SANDSTONE QUARRY INVESTIGATION FINDINGS

DRAWN	DATE	STATUS
LEW	19 04 24	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
AG	19 04 24	DRAFT ☐
		FINAL ☑

SCALE	SHEET	DRAWING NO.	REVISION
1:750	A3	4674/ 9	



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FENWOOD ESTATES LIMITED

JOB TITLE

CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE

INDICATIVE REMEDIATION REQUIREMENTS

NOTES

AREA A - Provision of 150mm clean topsoil

AREA B - Excavation of Made Ground Topsoil for use in POS and provision of 150mm clean topsoil (increased to 450mm where residual made ground remains)

AREA C - GARDENS - Provision of either:
- 600mm clean cover with 150mm hard dig layer, or
- 750mm clean cover with marker barrier

- POS - Provision of either
- 300mm clean cover with 150mm hard dig layer, or
- 450mm clean cover with marker barrier

Approximate area containing LANDFILL MATERIAL - material has significant inorganic contamination and requires off-site disposal

APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE

STATUS

FOR COMMENT ☐ FOR APPROVAL ☐ DRAFT ☐ FINAL ☑

DRAWN	DATE
LEW	14 05 24
APPROVED	DATE
AG	14 05 24

SCALE	SHEET
1:1250	A3

DRAWING NO.	REVISION
4674/10	

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CLIENT

FENWOOD ESTATES LIMITED

JOB TITLE

CUDWORTH PARKWAY, BARNSLEY

DRAWING TITLE

INDICATIVE FOUNDATION ZONING PLAN

NOTES

REPRODUCED FROM FENWOOD ESTATES' DRAWING REFERENCE 22-04-001-01-02, DATED 14TH FEBRUARY 2023

- QUARRY HIGHWALL (OBSERVED)
- QUARRY HIGHWALL (INFERRED)
- STRIP FOUNDATION - MAX. 1.2m
- TRENCH-FILL FOUNDATION - Max 2.5m
- GRILLAGE/RAFT OR PILES
- APPROXIMATE FAULT LINE (BGS)
- 25m OFFSET FROM FAULT
- APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE

STATUS

FOR COMMENT ☐ FOR APPROVAL ☐ DRAFT ☐ FINAL ☑

DRAWN	DATE
LEW	23 05 24
APPROVED	DATE
AG	23 05 24

SCALE	SHEET
1:1250	A3

DRAWING NO.	REVISION
4674/11	

Appendix C

Commission

011/4674/AG

25th September 2023

Registered in England 07068066

Parkhill
Wetherby
West Yorkshire
LS22 5DZ

T 01937 545 330

www.lithos.co.uk

Ms M Kroger
Fenwood Estates Limited
Sanctum House
Unit 9 Hayfield Business Park
Field Lane
Auckley
Doncaster
DN9 3FL

Dear Melissa,

Cudworth Parkway, Barnsley

Further to your recent invitation and meeting on 12th September 2023, and email on 22nd September, please find attached our updated proposal (updates following meeting in blue and following email in purple) for undertaking a site investigation on the above land. We understand that proposed development will include 260 traditional 2 storey domestic dwellings with associated gardens, POS and adoptable roads and sewers; a sketch layout has been provided.

Review of the information supplied suggests that the site consists of a single parcel of land divided by Three Nooks Lane. A recent site inspection noted two grassed fields in the west, with well trodden paths. The centre and east of site was heavily overgrown with areas of fly tipping, fires and general waste. In addition, wooded areas are present in the far north and east of site.

Brief review of internet data suggests the site:

- Historically comprised allotment gardens in the west and north. A historical quarry and crane were present in the centre south.
- Contains a historical landfill ("Quarry off Weetshaw Lane") that was backfilled with inert and commercial waste between 1947 and 1984 (approx. 10,000m^2 in area).
- A second historical landfill is also recorded directly north of site (recorded as "Weetshaw Lane Landfill"), however no further information is known.
- The on-site landfill appears to have been permitted, with the license surrendered in 1984.
- Is not within a groundwater source protection zone;
- Is in an area where the risk of encountering UXO is considered low; and
- Is located within a Coal Mining Development High Risk Area (approx. 24,000m^2 in the southeast). The west of site lies within a Coal Mining Development Low Risk Area.

Additional research suggests that there is an error with the Coal Authority data, meaning we think it is unlikely that the site will be underlain by unrecorded shallow mine workings. Following instruction, we will contact the Coal Authority to explain, which will hopefully negate the need for a mining rotary investigation, therefore making a saving.

The presence of a recorded **historic landfill** may have implications for preparatory earthworks. If the landfilled material was placed under a Waste Management License (or similar) it cannot be retained and re-used in accordance with the CL:AIRE Code of Practice because the Environment Agency have indicated they would consider such material waste, irrespective of its suitability for reuse. It is likely the EA would require a recovery of waste permit (or similar) to control reuse; application for such a permit would have both financial and time implications and approval is by no means certain.

Brief examination of the relevant geological map suggests the site is underlain by the Mexborough Rock (sandstone) which likely completely weathered near surface to a sandy, gravelly Clay.

The scope of works outlined in this letter should enable us to assess abnormal development issues, associated with ground. However, the nature of site investigation is such that it is not always possible to foresee all the potential issues. Consequently, it is sometimes necessary to recommend additional work, but where this occurs we will inform you immediately, provide costs, and seek your further instruction. We have visited site and reviewed available internet data and our geological maps in order to minimise the likelihood of further work.

Redevelopment of this site will almost certainly be subject to planning conditions relating to ground investigation, remediation and validation. Recent experience suggests that a single phase of ground investigation may not be sufficient to obtain regulatory approval and enable discharge of all relevant planning conditions. Nonetheless, useful data can be obtained at this time and we will certainly aim to resolve as much uncertainty relating to ground as possible.

In order to avoid potentially abortive consultancy costs, a phased approach (review of desk study, exploratory ground investigation, main ground investigation etc) may be the most appropriate way forward.

Our site investigation will be undertaken in accordance with UK good practice (as outlined in BS5930, BS10175, LCRM etc). Our Report may not be fully compliant with Eurocode 7 (EC7) and will not purport to be a Ground Investigation Report, nor a Geotechnical Design Report as defined by EC7. Our ground appraisal is intended to assist others as they proceed with design of the proposed development.

This proposal allows for the following works:

Desk study: Environmental search data and historical maps (obtained from Landmark or Groundsure), will be reviewed in order to determine whether past land uses have had any effect on the proposed development. In addition, published geological plans of the area will be examined.

Given the on-site landfill, we will also make enquiries with the Local Authority and Environment Agency to obtain any relevant records.

Given the site's location and discrepancy regarding the Coal Mining Risk Areas, a Consultant's mining report will be obtained.

Fieldwork: We have allowed for the following:

- 4 days trial pitting across the site using a tracked excavator (Item C)
- 2 days soakaway testing (western part of the site only) (Item E)
- 3 days trial trenching to confirm the location of the buried highwall (Item D)
- 3 cable percussive boreholes (Item F)
- 3 rotary cored boreholes to determine the rock strength beneath the former quarry (Item H)
- Installation of c. 20 gas & groundwater monitoring wells (Item G)
- Gas monitoring (12 visits over 6 months) (Item M)

All trial pits, trenches, and boreholes will be supervised and logged by an experienced geoenvironmental engineer.

Trial pitting / trenching will enable us to determine the:

- Nature of any made ground, including:
  - visual/olfactory evidence of potential contamination and the proportion of undesirable elements e.g. biodegradable matter, relict foundations etc
  - the proportion of "oversize", boulder-sized material

  - the location and extent of the quarry, with some trenching to locate the quarry high wall
- Nature, distribution and thickness of shallow soils beyond the former quarry
- Suitability of the ground for soakaways
- Suitability of the ground for founding structures and highways

Due to vegetation and topography and anticipated ground conditions, we have allowed for all pits to be dug using a tracked 360° excavator.

Representative soil samples of natural and man-made ground, including any contaminated samples, will be taken during the works. In-situ shear strengths of any cohesive soils encountered will be determined by the use of a hand-held shear vane.

We will make every effort to compact arisings and 'sweep' them over each trial pit. However, you should be aware that on completion of the investigation, "graves" of spoil (each about 3m long by 1m wide) unsuitable for trafficking, will be left up to 400mm proud at each trial pit location. At this stage, no allowance has been made for any further reinstatement such as removal of excess arisings, replacement of turf etc.

Based on anticipated ground and topography, **soakaways** may provide a satisfactory solution for surface water drainage in the western part of the site.

Soakaway testing will also be carried out in at least 6 pits in order to assess suitability of the ground for plot and highway surface water drainage. This will provide an 'initial sweep' at relatively wide spacings and often with only 1 or 2 fills.

It should be noted that if the initial soakaway tests yield satisfactory results, in order to obtain approvals from the LLFA, Highways etc, the drainage designer is likely to require further testing: (a) within 25m of proposed chamber locations; and (b) to include 3 fills.

Mini-boreholes are proposed here in order to allow the installation of shallow gas & groundwater monitoring wells.

The **cable percussion boreholes** will be advanced to depths of c. 20m or refusal in bedrock, whichever is the shallower, and are primarily intended to confirm ground conditions, recover samples for environmental testing, and enable the retrieval of geotechnical data from depth to inform pile design.

Borehole locations will be determined on completion of the pitting in order to target specific areas of the quarry.

Given the anticipated presence of deep made ground, SPTs will be undertaken at approximate 1m to 1.5m intervals as the boreholes are advanced. SPTs allow assessment of the in-situ density of granular soils, enabling determination of allowable bearing capacity and thereby definitive foundation advice.

The boreholes will be cased-off during drilling to at least rock head, in order to reduce the possibility of blowing sands, groundwater ingress, mis-sampling etc.

Boreholes will also allow the installation of gas & groundwater wells (50mm ID, HDPE pipework with bentonite seals and a gravel filter pack). Well headworks will comprise a 100mm diameter steel security helmet which will extend about 150mm above ground level (if required, the position of each helmet could be "marked" with a 1.5m high fence post to reduce the likelihood of damage by farm machinery).

At this stage, we have assumed that overnight security will not be required, but this will be reviewed following a site visit. If required, security would be an E\O of £*** per night.

We have allowed for all exploratory holes to be picked-up by a **surveyor** (co-ordinates/ground levels will be included on the logs).

Given the backfilled quarries and adjacent area of landfill within 250m of the site, we have allowed for the installation of wells in c. 20 holes and monitoring for hazardous **gas** (and any shallow groundwater).

The generation potential of this gas source is considered likely to be moderate. Therefore, in accordance with CIRIA Report C665, we have initially allowed for 12 visits over a 6-month period. A hazardous gas risk assessment will be issued on completion of monitoring.

We strongly recommend that groundwater / gas wells be decommissioned after monitoring has been completed. Decommissioning involves removal of the metal covers, unscrewing the upper 1m to 2 m of pipework and filling the void / remaining well with bentonite.

Decommissioning of monitoring wells removes the potential for groundwater pollution caused by accidental spillages during the construction phase and prevents gas migration into sub-floor voids and. Subject to your instruction, we will decommission accessible wells after the last monitoring visit for an E\O price of £***+VAT. We will contact you to seek instruction following issue of our gas risk assessment / groundwater dip results.

Testing: This will comprise routine **geotechnical** soils analysis, including 20 moisture content & Atterberg limits, and 20 pH & water-soluble sulphate and 10 gradings by wet sieve & 10 by pipette. We will also schedule 8 compaction tests (4.5kg rammer) on samples of made ground to assess suitability for use in earthworks ground improvement.

This site is brownfield and therefore likely to be underlain by made ground which in turn is likely to be subject to re-engineering prior to the construction of new estate roads. Consequently, there is no merit in obtaining CBR values at this stage.

Appropriate **chemical analyses**, based on our review of the site's history, have been allowed for; this will comprise 40 samples for a suite including heavy metals, speciated PAH, and banded TPH (with supplementary speciation as/where appropriate). In the event that ground contamination is more significant or different to that anticipated, it might be necessary to carry out additional chemical testing.

Within in our proposal we have allowed for the screening (ID) of 40 samples for asbestos. In the event that positive IDs are reported, it is likely that we will need to schedule further analysis (asbestos quantification), in order to determine the significance of the results. Asbestos quantification is currently a relatively expensive test and consequently we have not allowed for it at this stage. We will inform you immediately after receipt of results if we consider asbestos quantification is required.

Visible contaminants, sharps and the clay/sand/silt content of 6 topsoil samples will be determined to check compliance with BS3882 requirements.

Reporting & timescales: In order to provide you with sufficient information to enable assessment of abnormal costs at the earliest opportunity we will issue a concise overview report within 3 days of fieldwork completion.

On completion of the desk study, fieldwork and laboratory testing a comprehensive, factual and interpretative report will be issued. This will contain exploratory hole logs, laboratory test results, copies of all relevant correspondence and drawings of the site. The report will include qualitative risk assessment with respect to both controlled waters and human health. The report will also include consideration of foundation types.

At the time of writing, fieldwork could be commenced within 4 weeks of receipt of your written instruction to proceed. Our comprehensive geoenvironmental appraisal report will be issued within 4-6 weeks of fieldwork completion. This report will comment on issues associated with hazardous gas, but the gas risk assessment will not be issued until monitoring is completed.

This report will include a **mining risk assessment** in accordance with Coal Authority guidance.

A completed copy of the **YW** Contaminated Land Assessment Form will be included in an Appendix to our Report. However, the proposed route(s), and total length, of water supply pipes are not currently known and no allowance has been made for laboratory testing of soil samples in line with UKWIR guidance.

Given previous usage of this land, it is considered highly likely that a **Remediation Strategy** report will be required by the Local Authority. However, at this stage, due to the large number of unknowns, it is not possible to provide a quote for a remediation strategy.

It should be noted that a Remediation Strategy outlines the remediation objectives necessary to protect environmental receptors and render a site suitable for the proposed end use. A Remediation Strategy is not the same as a Method Statement; the latter should be prepared subsequently, usually by a Contractor, in order to detail how the objectives will be achieved.

A copy of the final report will be issued to the relevant regulatory authorities on receipt of written instruction from yourselves.

Invoicing: The attached proposal provides a breakdown of the costs associated with this project. This breakdown is for information only and the proposal can be regarded as a lump sum price of **£***** plus VAT. Variation will only occur in the event that a given item is not undertaken or that substantial additional works are recommended, in which case we will inform you immediately, provide costs for the required works, and seek your prior consent. Revision of the costings provided may be required if works are not instructed within 6 months of the date this proposal was issued.

Our proposal allows for submission of the report to the Local Authority and NHBC, and for submission of a single piece of subsequent correspondence with each regulator to address any queries they may have. Any further meetings, correspondence etc, would be chargeable.

We will submit invoices for this project on completion of each Item(s) instructed.

Please note if following instruction of the works outlined in this proposal, it is necessary to subsequently **postpone or cancel**, this should be done at least 3 working days before Lithos are due to commence intrusive investigation on site. We reserve the right to charge a cancellation fee in the event of later notification to cover plant / drill rig costs and abortive consultancy time. The cancellation fee will not exceed £*** plus VAT.

Health, safety & welfare: The works outlined above will be carried out in accordance with Lithos' task- and site- specific Risk Assessments and Method Statements.

Details of welfare will be included within the Method Statements. However, this investigation is expected to last for at least 5 working days and therefore this proposal includes for provision of a Welfare Unit, with the benefit of full canteen facilities, hot water with full size sink, toilet and drying room.

Immediately prior to commencement of fieldwork, a site compound will be established in a location to be agreed, comprising a welfare cabin for site staff, secured with Heras fencing; equipment and plant will be stored here overnight.

Utility plans are required in order to protect operatives from the hazards associated with striking buried services and avoid potentially substantial disruption\repair costs. We will make every effort not to damage any services (including review of utility plans and use of a CAT detector). However, Lithos cannot accept liability for damage to any underground services that are not accurately marked on plans made available to us prior to commencement of our field investigation, or have not been accurately marked on the ground by a responsible third party (e.g. utility company, site owner).

Most developers have copies of the necessary utility plans (including electricity, gas, water, drainage & telecom), and it would be appreciated if you could forward these prior to the proposed fieldworks.

However, if you do not have the necessary plans, Lithos will obtain them direct from each of the utility companies.

Under the **CDM** Regulations 2015, Lithos must be provided with pre-construction information already in your possession, or information that can reasonably be obtained through sensible enquiry. This information must be relevant to the project, have an appropriate level of detail, and be proportionate to the nature of the risks.

If no other designers or contractors have been appointed, Lithos could perform the role of Principal Contractor but only for the duration of the site investigation outlined in this proposal. If you require us to perform the role of Principal Contractor, please make this clear in your instruction. It should be noted that we are not suitably qualified to perform this role where other designers or contractors are also appointed.

It is anticipated that the site investigation outlined in this proposal will be undertaken several months before any construction is commenced on site. Consequently, our works can be considered in isolation and, given the anticipated number of person days on site, this site investigation is not notifiable to the HSE.

Further work: In addition to the investigation outlined above, the following further works may ultimately be required:

- If the initial **soakaway** tests yield satisfactory results, it may be necessary to:
  - Undertake further testing in order to obtain approvals from the LLFA etc: (a) within 25m of proposed chamber locations; and (b) to include 3 fills.
  - Install groundwater monitoring wells to depths of around 5m in at least 3 boreholes. Given the anticipated depth to bedrock, these boreholes might need to be advanced by rotary probing.
  - The wells should then be monitored on at least 7 occasions; monthly for 3 months, and then bi-monthly for a further 8 months.
- **Rotary Stitch probeholes** to confirm the geometry of the buried quarry highwalls.
- Detailed Quantitative Risk Assessment (**dQRA**)
- Preparation of a **Remediation Strategy**
- Preparation of an **Earthworks Specification**
- Large scale **load tests**, to assess the settlement performance of the quarry backfill

Terms & conditions: This work will be undertaken in accordance with our Standard Terms and Conditions, a copy of which are enclosed. Given the potential need for a subsequent letter(s) of reliance in favour of a Developer(s), your attention is drawn to your attention is drawn to Clauses **10.1 & 10.2** which relate to capped liability. If these Clauses are of concern you should inform us prior to instruction; revision may be possible.

It is hoped the above is sufficient for your present needs. However, should you require any further information, please contact the undersigned.

Yours sincerely

Adam Gombocz
Director
for and on behalf of
LITHOS CONSULTING LIMITED

1 DEFINITIONS AND INTERPRETATION

1.1 In this Agreement, unless the context otherwise requires, the following words and expressions have the following meanings:

"Agreement" means these Terms (entitled "Terms and Conditions for the Appointment of Lithos Consulting"), the Proposal, any document recording your unequivocal acceptance of the Proposal and any other documents or parts of other documents expressly referred to in any of the foregoing;

"Documents" means all documents of any kind and includes plans, drawings, reports, programmes, specifications, Bills of Quantities, calculations, letters, e-mails, faxes, memoranda, films and photographs (including negatives), or any other form of record prepared or provided or received by, or on behalf of us, and whether in paper form or stored electronically or on disk, or otherwise;

"Intellectual Property" includes all rights to, and any interests in, any patents, designs, trade marks, copyright, know-how, trade secrets and any other proprietary rights or forms of intellectual property (protectable by registration or not) in respect of any technology, concept, idea, data, programme or other software (including source and object codes), specification, plan, drawing, schedule, minutes, correspondence, scheme, programme, design, system, process logo, mark, style, or other matter or thing, existing or conceived, used, developed or produced by any person;

"Project" means the project described in the Proposal and any enquiry from you on which we have based our Proposal;

"Proposal" means the offer document prepared by us in response to an enquiry or otherwise, in connection with the proposed provision of the Services;

"Services" means the work and services relating to the Project to be provided by us pursuant to the Agreement and as set out in the Proposal and includes any additions or amendments thereto made in accordance with these Terms;

"Terms" means these terms entitled "Lithos Consulting Terms of Appointment" as amended from time to time.

1.2 Words importing the singular only shall also include the plural and vice versa, where the context requires.

1.3 Words importing persons or parties shall include firms, corporations and any organisation having legal capacity and vice versa, where the context requires; and words importing a particular gender include all genders.

1.4 The sub-headings to the clauses of these Terms are for convenience only and shall not affect the construction of the Agreement.

1.5 A reference to legislation includes that legislation as from time to time amended, re-enacted or substituted and any Orders in Council, orders, rules, regulations, schemes, warrants, by-laws, directives or codes of practice issued under any such legislation.

1.6 In the event of conflict between the documents forming part of the Agreement, the Proposal shall prevail, followed by the Terms.

2 APPOINTMENT

2.1 You agree to engage us and we agree to provide the Services in accordance with the provisions of this Agreement.

3 OUR OBLIGATIONS

3.1 We shall perform the Services using the reasonable standard of skill and care normally exercised by qualified members of our profession, performing similar services under similar conditions.

3.2 We shall use all reasonable endeavours to perform the Services in accordance with relevant environmental and safety legislation.

4 YOUR OBLIGATIONS

4.1 Throughout the period of this Agreement you shall afford to us, or procure for our benefit, access to any site where access is required for the performance of the Services.

4.2 You accept responsibility for ensuring that we are notified in writing of all special site and/or plant conditions, including without prejudice to the generality of the foregoing, the existence and precise location of all underground services, cables, pipes, drains or underground buildings, constructions or any hazards, which you shall clearly mark on the ground or identify on accurate location plans supplied to us prior to the commencement of the Services. You shall also inform us in writing of any relevant operating procedures including any site safe operating procedures and any other regulations relevant to the carrying out of the Services. You shall indemnify us against all costs, losses, claims, demands and expenses arising as a result of any non-disclosure in this respect, including but not limited to indemnification against any action brought by the owner of the land or otherwise.

4.3 If you discover any conflict, defect or other fault in the information or designs provided by us pursuant to the Agreement, you will advise us in writing of such defect, conflict or other fault and we shall have the right to rectify the same or where necessary, to design the solution for rectification of any works carried out by others pursuant the conflicting, defective or in any other way faulty information or designs.

5 COPYRIGHT

5.1 The copyright in all Intellectual Property prepared by or on behalf of us in connection with the Project for delivery to you shall remain vested in us.

5.2 You shall have a non-exclusive licence to copy and use such Intellectual Property for purposes directly related to the Project. Such licence shall enable you to copy and use the Intellectual Property but solely for your own purposes in connection with the Project and such use shall not include any licence to reproduce any conceptual designs or professional opinions contained therein nor shall it include any license to amend any drawing, design or other Intellectual Property produced by us.

5.3 Should you wish to use such Intellectual Property in connection with any other works or for any other purpose not directly related to the Project or wish to pass any Intellectual Property to any third party, you must obtain our prior written consent. The giving of such consent shall be at our absolute discretion and shall be upon such terms as we may require. We shall not be liable to you for the use by any person of such Intellectual Property for any purpose other than that for which the same were prepared by or on our behalf.

5.4 Ownership of any proposals submitted to you that are not subsequently confirmed as part of the Services to be provided for you remain with us and such proposals must not be used as the basis for any future work undertaken by you or a third party and no liability can be accepted howsoever arising from such proposals.

5.5 In the event of you being in default of payment of any fees or other amounts due, we may suspend further use of the licence on giving no less than 2 calendar days' notice of the intention to do so. Use of the licence may be resumed on receipt of the outstanding amounts.

6 CONFIDENTIALITY

6.1 Neither you nor we shall at any time disclose to any person any confidential information concerning the business, affairs, customers, clients or suppliers of the other party or of any member of the group of companies to which the other party belongs, except as permitted by clauses 6.2 and 6.4.

6.2 Each party may disclose the other party's confidential information:

(a) to its employees, officers, representatives, contractors, sub-contractors or advisers who need to know such information for the purposes of exercising the party's rights or carrying out its obligations under or in connection with this Agreement. Each party shall ensure that its employees, officers, representatives, contractors, sub-contractors or advisers to whom it discloses the other party's confidential information comply with this paragraph 6; and

(b) as may be required by law, to a court of competent jurisdiction or any governmental or regulatory authority.

6.3 Neither you nor we shall use any other party's confidential information for any purpose other than to exercise our rights or perform our respective obligations under or in connection with this Agreement.

6.4 Subject to the above and our privacy policy which can be found on www.lithos.co.uk, we shall be permitted to use information related to the Services we provide in connection with the Project for the purposes of marketing its services and in proposals for work of a similar type.

7 ASSIGNMENT

7.1 You may assign the benefit of this Agreement on two occasions with our prior written consent (not to be unreasonably withheld) and any additional assignments shall be with our prior consent.

7.2 We may at any time assign, mortgage, charge, subcontract, delegate, declare a trust over or deal in any other manner with any or all of our rights and obligations under this Agreement.

8 INSURANCE

8.1 We shall maintain a professional indemnity insurance policy covering our liabilities for negligence under this Agreement, with a limit of indemnity of £5,000,000 (FIVE MILLION POUNDS) any one claim, save for pollution and contamination claims and asbestos claims both of which carry £2,000,000 (TWO MILLION POUNDS) in the aggregate cover. This policy is annually renewable and whilst renewal is not automatic, We shall maintain such insurance at all times until six years from the date of the completion (or termination) of the Services under this Agreement, provided such insurance is available at commercially reasonable rates and terms.

8.2 If for any period such insurance is not available at commercially reasonable rates and terms, we shall inform you and shall obtain in respect of such period such reduced level of professional indemnity insurance as is available and as would be fair and reasonable in the circumstances for us to obtain.

9 PAYMENT

9.1 Invoices for services rendered will be submitted for payment in accordance with the Proposal.

9.2 You shall pay you any VAT properly chargeable on the Services and any amount expressed as payable to us under this Agreement is exclusive of VAT unless stated otherwise.

9.3 The due date for payment is the date of the invoice and the final date for payment is 28 days from the date of the invoice.

9.4 If you dispute the amount included for payment in an invoice then you must serve a written notice on us no later than 14 calendar days before the final date for payment. If no notice is given within the required timeframe the amount due shall be the amount stated in the invoice.

9.5 If you fail to pay any monies in accordance with the foregoing payment provisions, we shall be entitled to charge interest on any monies owed to us, such interest to be at a rate of 4% above the base rate of a clearing bank from time to time calculated from the final date for payment to the date of actual payment on a compound basis. The parties acknowledge that our liability under this clause 10.5 is a substantial remedy for the purposes of section 9(1) of the Late Payment of Commercial Debts (Interest) Act 1998.

10 LIMITATIONS ON LIABILITY

10.1 Unless otherwise agreed in writing, our total liability under or in connection with this Agreement whether in contract, tort, negligence, breach of statutory duty or otherwise (other than in respect of personal injury or death) shall be limited to and shall not exceed the lesser of either the level of insurance cover referred to within clause 8.1 above, or 20 times the total value of invoices issued to you for the Services.

10.2 No action or proceedings under or in respect of the Agreement whether in contract, tort, negligence, under statute or otherwise shall be commenced against us after the expiry of a period of six years from the date of the completion (or termination) of the Services under this Agreement.

10.3 Whilst we usually scan for potential exploratory locations with a Cable Avoidance Tool, we shall not be liable for any damage to underground services, cables, pipes, drains or underground buildings, constructions and the like which were either not marked on site or for which accurate plans were not provided.

10.4 We shall not be liable for the cost of rectifying any defect, conflict or other fault in the information or designs provided by us or for the cost of designing a solution for and rectifying any subsequent works carried out by others pursuant to the conflicting, defective or in any other way faulty information or designs, unless we have been advised in writing of the same by you and have been given the opportunity to rectify the same or where necessary, to design the solution for rectification of any subsequent works carried out by others pursuant to the same.

11 DELAY

We shall comply with any timescale agreed for completion of the Services unless delayed or prevented by circumstances beyond our reasonable control and in the event of any such circumstances arising we undertake to complete the Services within a reasonable period, but will not be liable to you for any delay as a result.

12 TERMINATION

12.1 The Agreement may be terminated by either of us in the event of the other making a composition or arrangement with its creditors, becoming bankrupt, or being a company, making a proposal for a voluntary arrangement for a composition of debts, or has a provisional liquidator appointed, or has a winding-up order made, or passes a resolution for voluntary winding-up (except for the purposes of a bona fide scheme of amalgamation or reconstruction), or has an administrator or an administrative receiver appointed to the whole or any part of its assets. Notice of termination must be given to the party which is insolvent by the other party.

12.2 If for any reason our Services are suspended for a period in excess of three calendar months then we shall be entitled to terminate our appointment under this Agreement in respect of the Services by no less than seven days written notice to you.

12.3 If you fail to pay in full any sum due under the terms of this Agreement by the final date for payment for that sum and no effective pay less notice is issued, we may serve written notice to you demanding payment within 14 days of such notice. If you fail to comply with such notice, we shall be entitled to terminate our employment under this Agreement forthwith.

12.4 Any termination of our appointment howsoever caused shall be without prejudice to our rights to require payment for all Services performed up to the date of such termination including but not limited to payment of a fair and reasonable proportion of any figure identified in the Proposal or otherwise for fees in respect of a particular service which Lithos has started, but not completed.

13 THIRD PARTY RIGHTS

The Agreement shall not confer and shall not purport to confer on any third party any benefit or any right to enforce any term of this Agreement for the purposes of the Contracts (Rights of Third Parties) Act 1999 or otherwise.

14 COLLATERAL WARRANTIES & LETTERS OF RELIANCE

We shall consider and may consent to a request from you for us to enter into a collateral warranty or letter of reliance with a third party with regard to the Services provided under this Agreement. The giving of such consent shall be at our absolute discretion and providing we agree to our standard form of collateral warranty or letter of reliance (subject to any reasonable changes to be approved by us at our absolute discretion) and in return for payment of a fee (to be notified at the time of the request).

15 NOTICES

15.1 Any notice provided for in the Agreement shall be in writing and shall be deemed to be properly given if delivered by hand or sent by pre-paid first class post to the address of the relevant party as may have been notified by each party to the other or, in the absence of notification, to our respective registered office addresses.

15.2 Such notice shall be deemed to have been received on the day of delivery if delivered by hand or on the second working day after the day of posting if sent by pre-paid first class post.

16 ENTIRE AGREEMENT

16.1 The Agreement constitutes the complete and entire agreement between us with respect to the Services and supersedes any prior oral and/or written warranties, terms, conditions, communications and representations, whether express or implied and any claim against us in respect of the Services can only be made in contract under the provisions of this Agreement and not otherwise under the law or tort or otherwise.

16.2 No amendments, modifications or variation of this Agreement shall be valid unless made in writing and agreed to by us; such agreement must be recorded in writing by at least one of us.

16.3 We shall not be bound by any standard or printed terms or conditions furnished by you in any of your documents unless we specifically state in writing separately from such documents that we intend such terms and conditions to apply.

17 DISPUTES, JURISDICTION AND GOVERNING LAW

17.1 This Agreement shall be governed by and construed in accordance with English law and we irrevocably and unconditionally submit to the jurisdiction of the English Courts.

17.2 Where the Housing Grants, Construction and Regeneration Act 1996 applies, any dispute between us may be referred to adjudication in accordance with The Scheme for Construction Contracts Regulations 1998 or any amendment or modification thereof being in force at the time of the dispute, as applicable to England, Wales, Scotland and Northern Ireland.

DEVELOPER: **FENWOOD ESTATES LIMITED**
SANCTUM HOUSE,
UNIT 9, HAYFIELD BUSINESS PARK
DONCASTER, DN9 3FL

ORDER REF. **5338 001**

DATE 18th March 2024

OVERARCHING SUB-CONTRACT ORDER

SUB-CONTRACTOR:

LITHOS Consulting

Parkhill

Wetherby

West Yorkshire

LS22 5DZ

Company Number: 07068066

PROJECT:
Cudworth Parkway
Barnsley
South Yorkshire

The Main Contract Works:
Proposed new build housing development

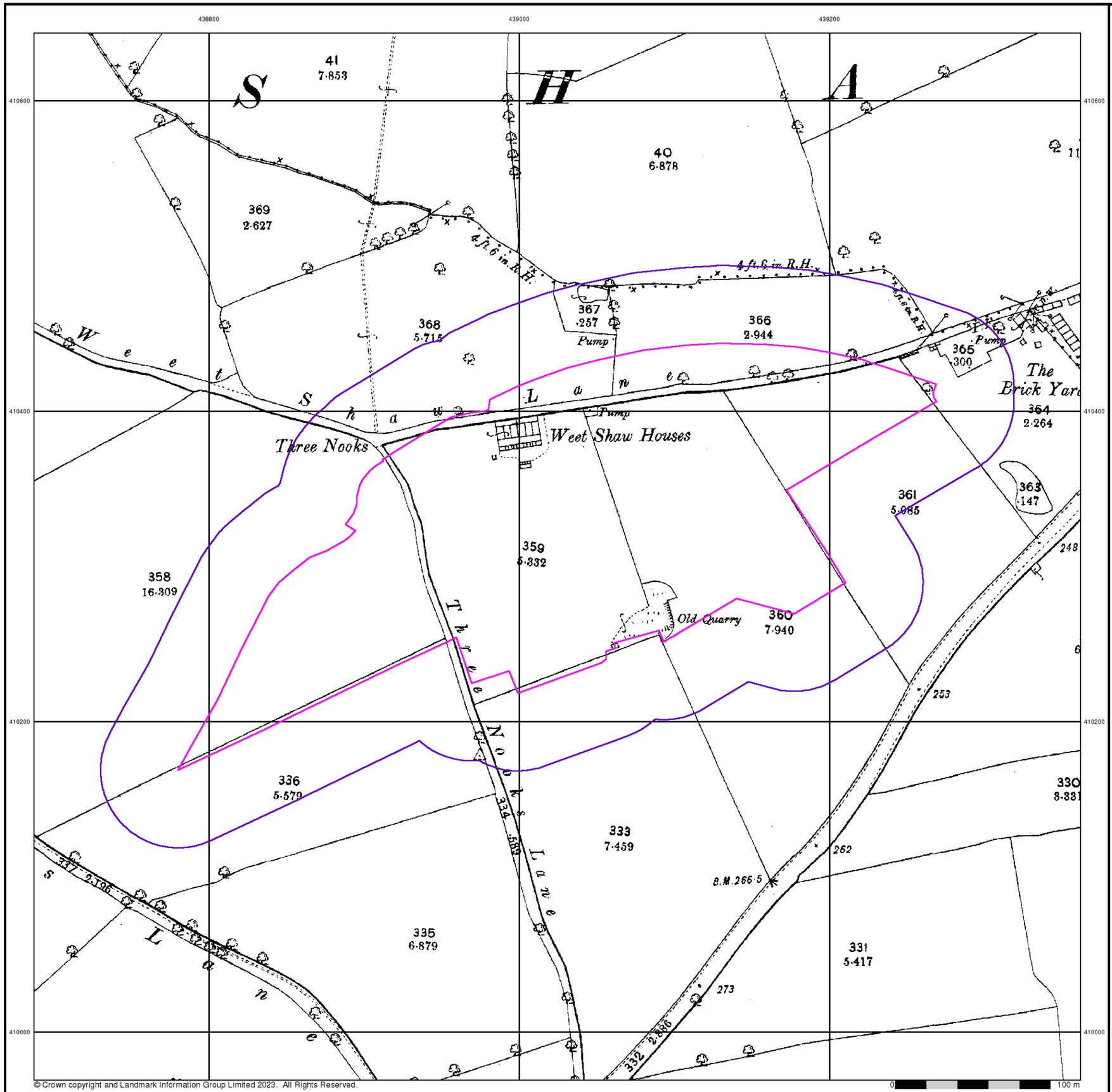
PLEASE PROVIDE ALL PLANT AND/OR LABOUR AND/OR MATERIALS NECESSARY TO EXECUTE THE SUB-CONTRACT WORKS DETAILED BELOW IN ACCORDANCE WITH THE OVERARCHING SUB-CONTRACT ORDER, THESE SUB-CONTRACT PARTICULARS AND ALL OTHER SUB-CONTRACT DOCUMENTS LISTED BELOW

Item	
1	**APPLICABLE SUB-CONTRACT PARTICULARS** Sub-Contract Particulars (Longer Generic Sub-Contract) as Contained within this sub-contract order. **APPLICABLE SUB-CONTRACT SUM** The Sub-Contract Sum is a lump sum of **£***** Payment will be determined by the accumulation of works undertaken utilising the agreed Schedule of Rates as contained within this sub-contract order.
2	**SUB-CONTRACT WORKS** Site Investigation works (desk study, fieldwork, trial pitting, soakaway testing, trail trenching, cable percussive boreholes, gas & groundwater monitoring) at Cudworth Parkway, Barnsley (copy enclosed in subcontract).
3	**VARIATIONS** All/Any variations to the works are to be agreed with and signed off by Paul Kaszewski **paulk@fenwood.com** before they are carried out. Failure to do so will lead to non-payment of variation works.
4	**ACCEPTANCE OF TERMS** The sub-contractor shall indicate its acceptance of the terms and conditions of this sub-contract by signing and returning the enclosed duplicate of this Over-Arching Sub-Contract Order. Notwithstanding the foregoing, the sub-contractor acknowledges and agrees that any commencement and/or continuation of the Sub-Contract Works by the Sub-Contractor shall be deemed to be the Sub-Contractor's unequivocal and unconditional acceptance of the terms of this subcontract. Acceptance of this Sub-Contract indicates that the Sub-Contractor accepts that in some cases, where a main contract is not present, the terms of the sub-contract shall still apply in line with the amendments made in the sub-contract conditions. **THIS OVERARCHING SUB-CONTRACT ORDER, INCORPORATING THE SUB-CONTRACT PARTICULARS DETAILED ABOVE AND ALL OTHER DOCUMENTATION DETAILED THEREIN, IS EXECUTED AS A DEED ON THE DATE SET OUT ABOVE.**

Fenwood Estates Ltd Signed By: Paul Kaszewski Quantity Surveyor	LITHOS Consulting. Signed By:……..*(Signature)* ……..*(Print Name)* ……..*(Position/Role)*

Appendix D

Historical OS Plans



LITHOS CONSULTING

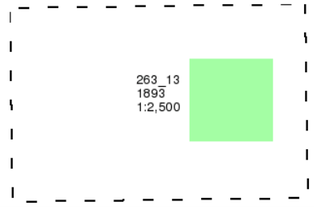
Yorkshire

Published 1893

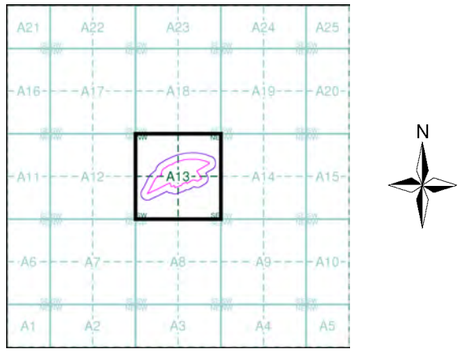
Source map scale - 1:2,500

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840`s. In 1854 the 1:2,500 scale was adopted for mapping urban areas and by 1896 it covered the whole of what were considered to be the cultivated parts of Great Britain. The published date given below is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas.

Map Name(s) and Date(s)



Historical Map - Segment A13



Order Details

Order Number:	328862346_1_1
Customer Ref:	4674
National Grid Reference:	439030, 410320
Slice:	A
Site Area (Ha):	6.23
Search Buffer (m):	50

Site Details

Cudworth Parkway, Cudworth, BARNSLEY, S72 8FG

Landmark INFORMATION GROUP
Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk

LITHOS CONSULTING

Ordnance Survey Plan

Published 1962

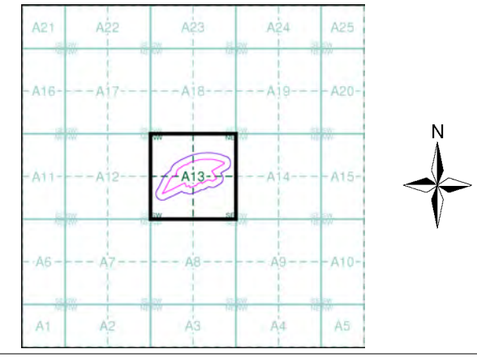
Source map scale - 1:2,500

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840`s. In 1854 the 1:2,500 scale was adopted for mapping urban areas and by 1896 it covered the whole of what were considered to be the cultivated parts of Great Britain. The published date given below is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas.

Map Name(s) and Date(s)

SE3810 1962 1:2,500	SE3910 1962 1:2,500
SE3809 1962 1:2,500	SE3909 1962 1:2,500

Historical Map - Segment A13



Order Details

Order Number:	328862346_1_1
Customer Ref:	4674
National Grid Reference:	439030, 410320
Slice:	A
Site Area (Ha):	6.23
Search Buffer (m):	50

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LITHOS CONSULTING

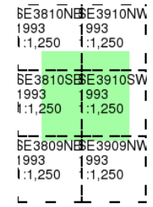
Large-Scale National Grid Data

Published 1993

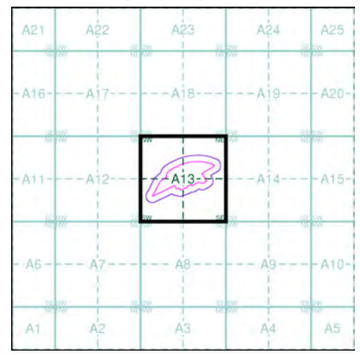
Source map scale - 1:1,250

'Large Scale National Grid Data' superseded SIM cards (Ordnance Survey's 'Survey of Information on Microfilm') in 1992, and continued to be produced until 1999. These maps were the fore-runners of digital mapping and so provide detailed information on houses and roads, but tend to show less topographic features such as vegetation. These maps were produced at both 1:2,500 and 1:1,250 scales.

Map Name(s) and Date(s)



Historical Map - Segment A13



Order Details

Order Number:	328862346_1_1
Customer Ref:	4674
National Grid Reference:	439030, 410320
Slice:	A
Site Area (Ha):	6.23
Search Buffer (m):	50

Site Details

Cudworth Parkway, Cudworth, BARNSLEY, S72 8FG

Appendix E

Search Responses & other Correspondence

Envirocheck® Report:

Datasheet

Order Details:

Order Number:
328843319_1_1

Customer Reference:
4674

National Grid Reference:
439020, 410300

Slice:
A

Site Area (Ha):
6.23

Search Buffer (m):
1000

Site Details:

Cudworth Parkway
Cudworth
BARNSLEY
S72 8FG

Client Details:

Mr M Perrin
Lithos Consulting Ltd
Parkhill
Walton Road
Wetherby
LS22 5DZ

Contents

Introduction

The Environment Act 1995 has made site sensitivity a key issue, as the legislation pays as much attention to the pathways by which contamination could spread, and to the vulnerable targets of contamination, as it does the potential sources of contamination.
For this reason, Landmark's Site Sensitivity maps and Datasheet(s) place great emphasis on statutory data provided by the Environment Agency/Natural Resources Wales and the Scottish Environment Protection Agency; it also incorporates data from Natural England (and the Scottish and Welsh equivalents) and Local Authorities; and highlights hydrogeological features required by environmental and geotechnical consultants. It does not include any information concerning past uses of land. The datasheet is produced by querying the Landmark database to a distance defined by the client from a site boundary provided by the client.
In this datasheet the National Grid References (NGRs) are rounded to the nearest 10m in accordance with Landmark's agreements with a number of Data Suppliers.

Report Version v53.0

Summary

Data Type	Page Number	On Site	0 to 250m	251 to 500m	501 to 1000m (*up to 2000m)
Agency & Hydrological					
BGS Groundwater Flooding Susceptibility	pg 1	Yes	Yes	Yes	n/a
Contaminated Land Register Entries and Notices					
Discharge Consents	pg 3	2			4
Prosecutions Relating to Controlled Waters			n/a	n/a	n/a
Enforcement and Prohibition Notices					
Integrated Pollution Controls	pg 4				1
Integrated Pollution Prevention And Control	pg 4				2
Local Authority Integrated Pollution Prevention And Control					
Local Authority Pollution Prevention and Controls	pg 5				2
Local Authority Pollution Prevention and Control Enforcements					
Nearest Surface Water Feature	pg 5		Yes		
Pollution Incidents to Controlled Waters	pg 5		1	2	30
Prosecutions Relating to Authorised Processes					
Registered Radioactive Substances					
River Quality	pg 10				5
River Quality Biology Sampling Points					
River Quality Chemistry Sampling Points					
Substantiated Pollution Incident Register	pg 11				7
Water Abstractions	pg 12				(*4)
Water Industry Act Referrals					
Groundwater Vulnerability Map	pg 13	Yes	n/a	n/a	n/a
Groundwater Vulnerability - Soluble Rock Risk			n/a	n/a	n/a
Groundwater Vulnerability - Local Information			n/a	n/a	n/a
Bedrock Aquifer Designations	pg 13	Yes	n/a	n/a	n/a
Superficial Aquifer Designations			n/a	n/a	n/a
Source Protection Zones					
Extreme Flooding from Rivers or Sea without Defences	pg 13	Yes	Yes	n/a	n/a
Flooding from Rivers or Sea without Defences				n/a	n/a
Areas Benefiting from Flood Defences				n/a	n/a
Flood Water Storage Areas				n/a	n/a
Flood Defences				n/a	n/a
OS Water Network Lines	pg 14		5	7	25

Summary

Data Type	Page Number	On Site	0 to 250m	251 to 500m	501 to 1000m (*up to 2000m)
Waste					
BGS Recorded Landfill Sites	pg 19	1			
Historical Landfill Sites	pg 19	2			1
Integrated Pollution Control Registered Waste Sites					
Licensed Waste Management Facilities (Landfill Boundaries)					
Licensed Waste Management Facilities (Locations)	pg 19				4
Local Authority Landfill Coverage	pg 20	1	n/a	n/a	n/a
Local Authority Recorded Landfill Sites	pg 20	1			2
Potentially Infilled Land (Non-Water)	pg 21	3	3		5
Potentially Infilled Land (Water)	pg 21		2	1	18
Registered Landfill Sites	pg 23	1			1
Registered Waste Transfer Sites	pg 23				2
Registered Waste Treatment or Disposal Sites	pg 24				5
Hazardous Substances					
Control of Major Accident Hazards Sites (COMAH)					
Explosive Sites					
Notification of Installations Handling Hazardous Substances (NIHHS)					
Planning Hazardous Substance Consents					
Planning Hazardous Substance Enforcements					

LITHOS CONSULTING

Summary

Data Type	Page Number	On Site	0 to 250m	251 to 500m	501 to 1000m (*up to 2000m)
Geological					
BGS 1:625,000 Solid Geology	pg 26	Yes	n/a	n/a	n/a
BGS Estimated Soil Chemistry	pg 26	Yes	Yes		Yes
BGS Recorded Mineral Sites	pg 27	2	3	2	6
BGS Urban Soil Chemistry					
BGS Urban Soil Chemistry Averages					
CBSCB Compensation District			n/a	n/a	n/a
Coal Mining Affected Areas	pg 29	Yes	n/a	n/a	n/a
Mining Instability	pg 30	Yes	n/a	n/a	n/a
Man-Made Mining Cavities					
Natural Cavities					
Non Coal Mining Areas of Great Britain	pg 30	Yes	Yes	n/a	n/a
Potential for Collapsible Ground Stability Hazards	pg 30	Yes	Yes	n/a	n/a
Potential for Compressible Ground Stability Hazards	pg 30	Yes	Yes	n/a	n/a
Potential for Ground Dissolution Stability Hazards				n/a	n/a
Potential for Landslide Ground Stability Hazards	pg 30	Yes	Yes	n/a	n/a
Potential for Running Sand Ground Stability Hazards	pg 31	Yes	Yes	n/a	n/a
Potential for Shrinking or Swelling Clay Ground Stability Hazards	pg 31	Yes	Yes	n/a	n/a
Radon Potential - Radon Affected Areas	pg 31	Yes	n/a	n/a	n/a
Radon Potential - Radon Protection Measures			n/a	n/a	n/a
Industrial Land Use					
Contemporary Trade Directory Entries	pg 32		8	12	23
Fuel Station Entries	pg 35		1		1
Points of Interest - Commercial Services	pg 35		4	4	15
Points of Interest - Education and Health					
Points of Interest - Manufacturing and Production	pg 37	2			11
Points of Interest - Public Infrastructure	pg 38			2	
Points of Interest - Recreational and Environmental	pg 39		1	3	1
Gas Pipelines					
Underground Electrical Cables					

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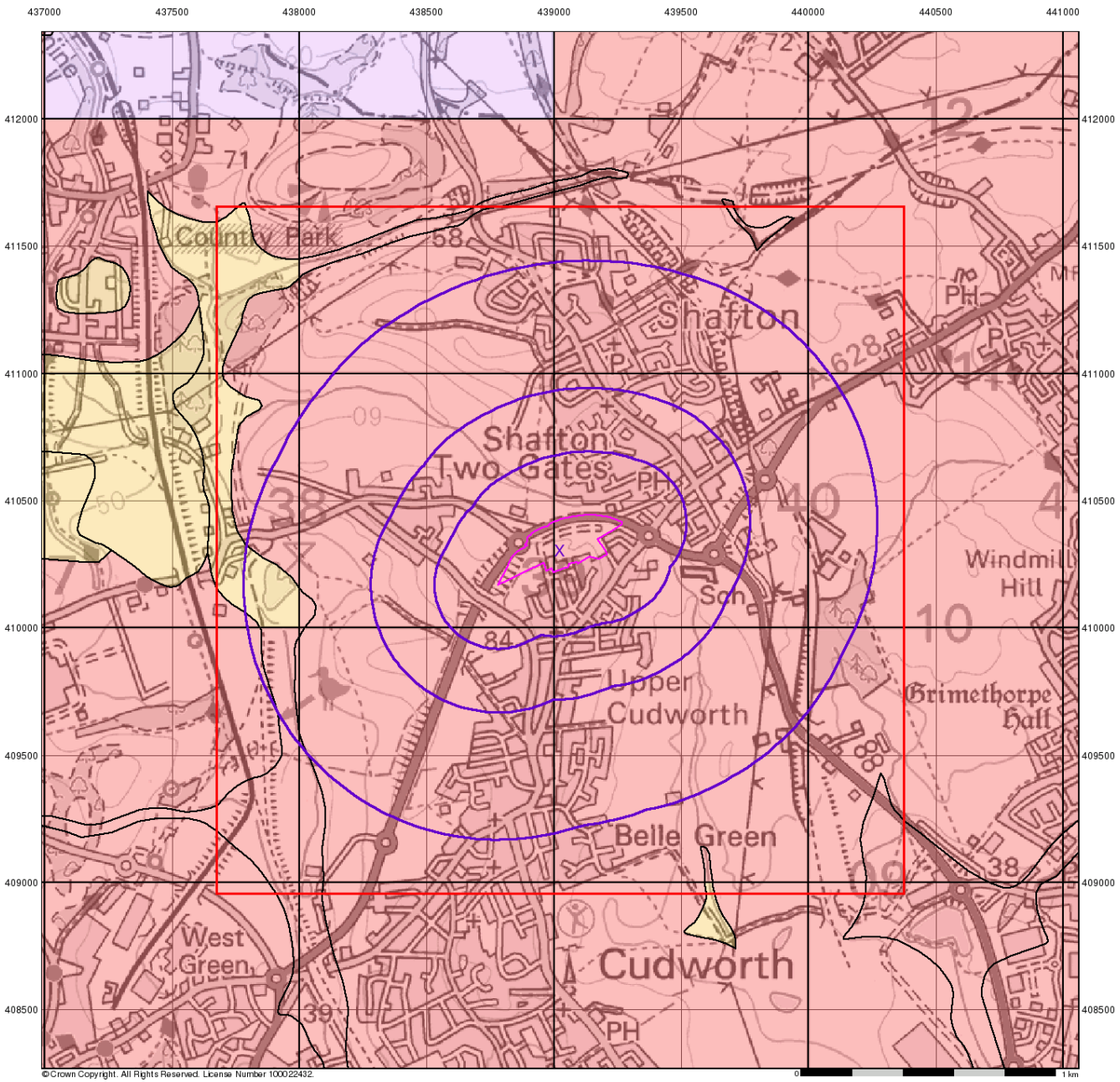
Summary

Data Type	Page Number	On Site	0 to 250m	251 to 500m	501 to 1000m (*up to 2000m)
Sensitive Land Use					
Ancient Woodland					
Areas of Adopted Green Belt	pg 40	1			
Areas of Unadopted Green Belt					
Areas of Outstanding Natural Beauty					
Environmentally Sensitive Areas					
Forest Parks					
Local Nature Reserves	pg 40				1
Marine Nature Reserves					
National Nature Reserves					
National Parks					
Nitrate Sensitive Areas					
Nitrate Vulnerable Zones	pg 40	1			
Ramsar Sites					
Sites of Special Scientific Interest	pg 40				1
Special Areas of Conservation					
Special Protection Areas					
World Heritage Sites					



LITHOS CONSULTING

Groundwater Vulnerability

General

Specified Site | Specified Buffer(s) | Bearing Reference Point | Slice | Map ID

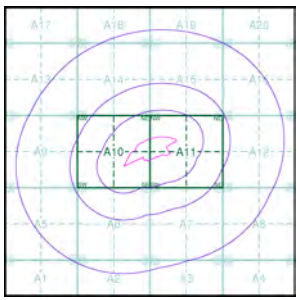
Agency and Hydrological

Bedrock Aquifers	Superficial Aquifers
High Vulnerability, Principal Aquifer	High Vulnerability, Principal Aquifer
High Vulnerability, Secondary Aquifer	High Vulnerability, Secondary Aquifer
Medium Vulnerability, Principal Aquifer	Medium Vulnerability, Principal Aquifer
Medium Vulnerability, Secondary Aquifer	Medium Vulnerability, Secondary Aquifer
Low Vulnerability, Principal Aquifer	Low Vulnerability, Principal Aquifer
Low Vulnerability, Secondary Aquifer	Low Vulnerability, Secondary Aquifer

Unproductive Aquifer

Soluble Rock

Site Sensitivity Context Map - Slice A



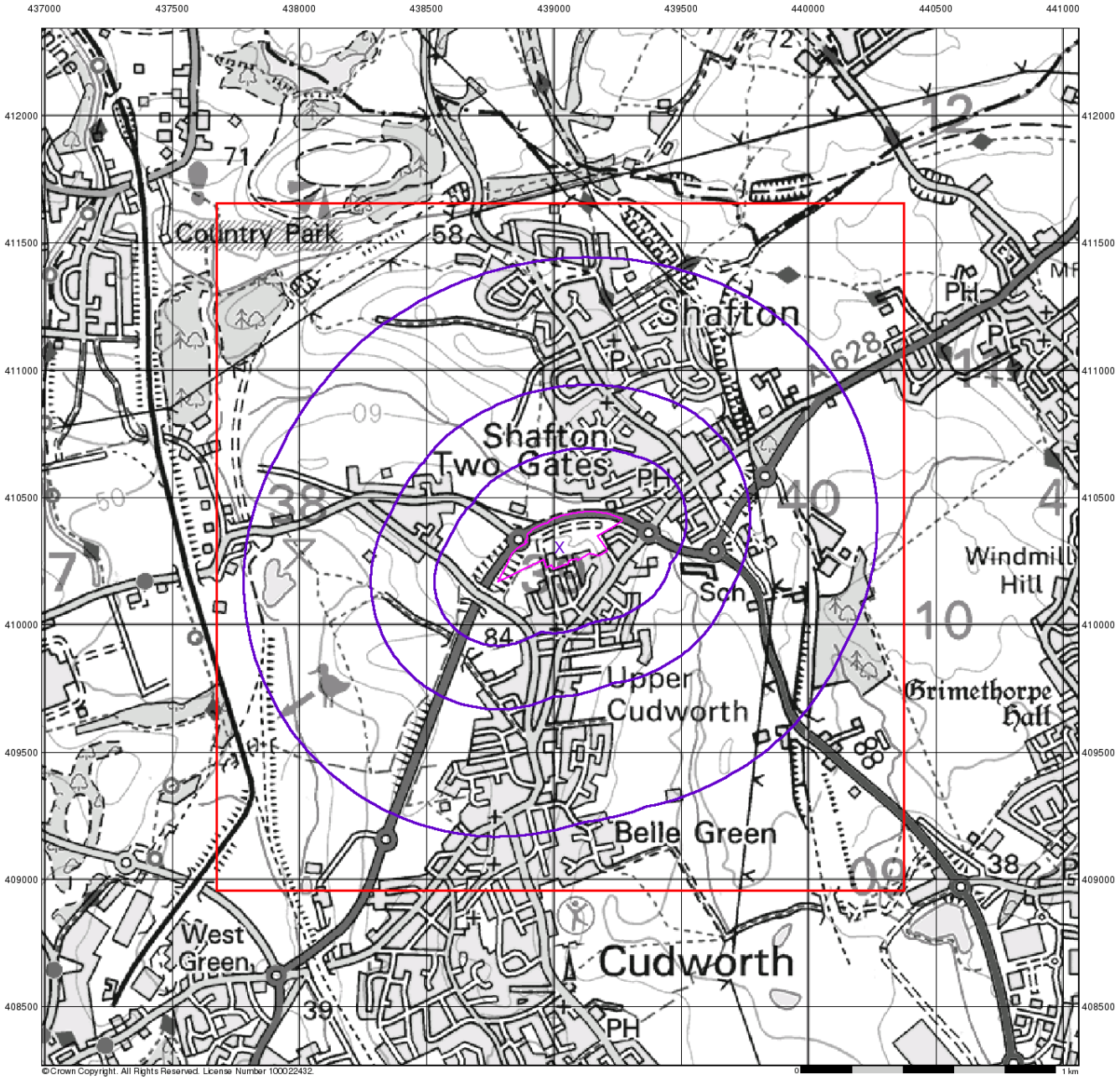
Order Details

Order Number:	328843319_1_1
Customer Ref:	4674
National Grid Reference:	439020, 410300
Slice:	A
Site Area (Ha):	6.23
Search Buffer (m):	1000

Site Details

Cudworth Parkway, Cudworth, BARNSLEY, S72 8FG

Landmark INFORMATION GROUP
Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk



LITHOS CONSULTING

Source Protection Zones

General

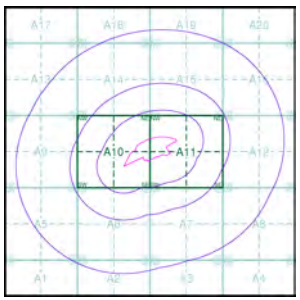
Specified Site | Specified Buffer(s) | Bearing Reference Point

Slice | Map ID

Agency and Hydrological

- Inner zone (Zone 1)
- Inner zone - subsurface activity only (Zone 1c)
- Outer zone (Zone 2)
- Outer zone - subsurface activity only (Zone 2c)
- Total catchment (Zone 3)
- Total catchment - subsurface activity only (Zone 3c)
- Special interest (Zone 4)

Site Sensitivity Context Map - Slice A



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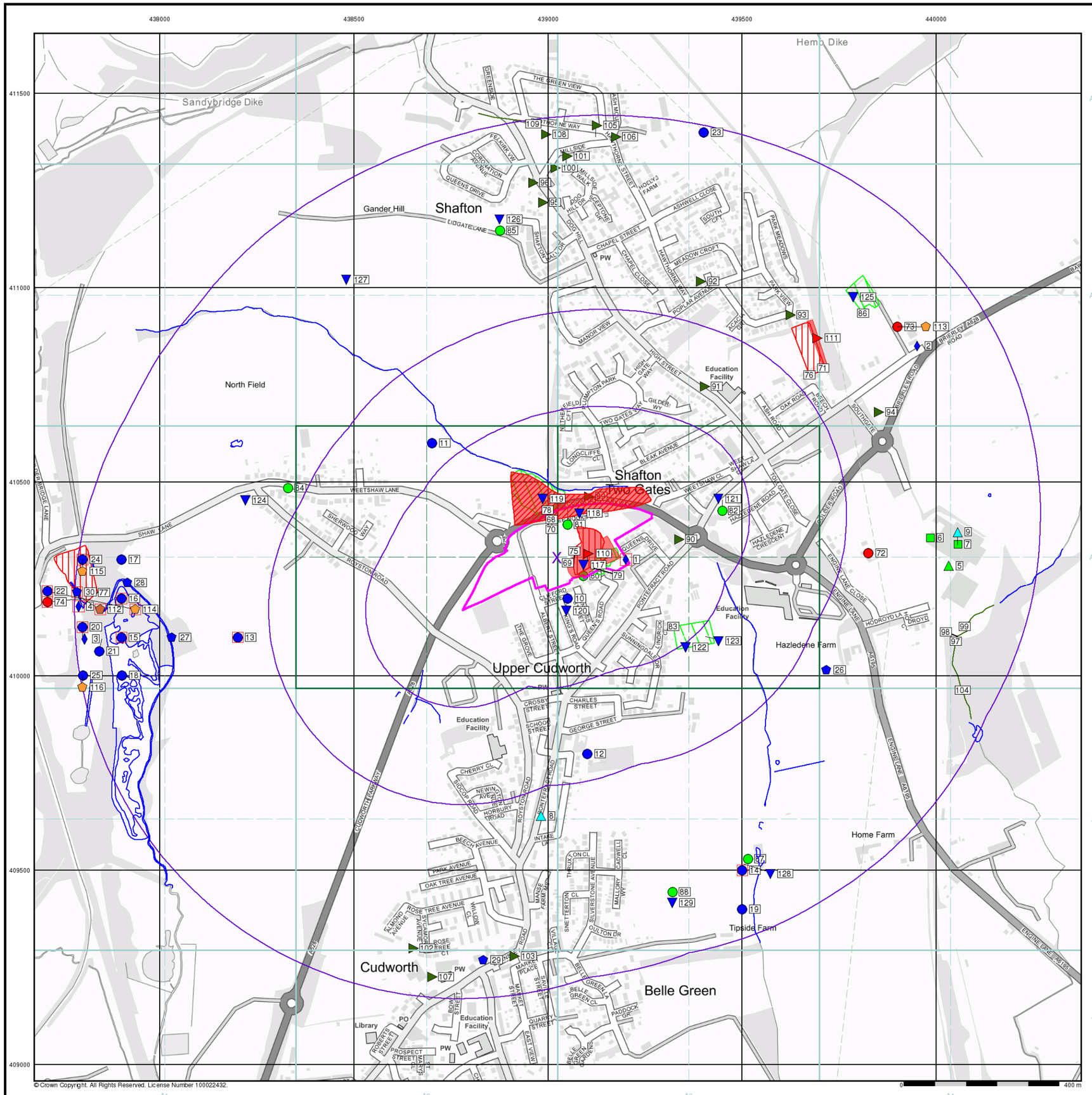


LITHOS CONSULTING

General

- Specified Site
- Specified Buffer(s)
- Bearing Reference Point
- Map ID
- Several of Type at Location

Agency and Hydrological

- Contaminated Land Register Entry or Notice (Location)
- Contaminated Land Register Entry or Notice
- Discharge Consent
- Enforcement or Prohibition Notice
- Integrated Pollution Control
- Integrated Pollution Prevention Control
- Local Authority Integrated Pollution Prevention and Control
- Local Authority Pollution Prevention and Control
- Local Authority Pollution Prevention and Control Enforcement
- Pollution Incident to Controlled Waters
- Prosecution Relating to Authorised Processes
- Prosecution Relating to Controlled Waters
- Registered Radioactive Substance
- River Network or Water Feature
- River Quality Sampling Point
- Substantiated Pollution Incident Register
- Water Abstraction
- Water Industry Act Referral

Hazardous Substances

- COMAH Site
- Explosive Site
- NIHHS Site
- Planning Hazardous Substance Consent
- Planning Hazardous Substance Enforcement

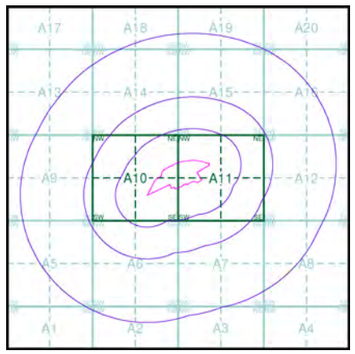
Geological

- BGS Recorded Mineral Site

Waste

- BGS Recorded Landfill Site (Location)
- BGS Recorded Landfill Site
- EA Historic Landfill (Buffered Point)
- EA Historic Landfill (Polygon)
- Integrated Pollution Control Registered Waste Site
- Licensed Waste Management Facility (Landfill Boundary)
- Licensed Waste Management Facility (Location)
- Local Authority Recorded Landfill Site (Location)
- Local Authority Recorded Landfill Site
- Potentially Infilled Land (Non-water)
- Potentially Infilled Land (Non-water)
- Potentially Infilled Land (Non-water)
- Potentially Infilled Land (Water)
- Potentially Infilled Land (Water)
- Potentially Infilled Land (Water)
- Registered Landfill Site
- Registered Landfill Site (Location)
- Registered Landfill Site (Point Buffered to 100m)
- Registered Landfill Site (Point Buffered to 250m)
- Registered Waste Transfer Site (Location)
- Registered Waste Transfer Site
- Registered Waste Treatment or Disposal Site (Location)
- Registered Waste Treatment or Disposal Site

Site Sensitivity Map - Slice A



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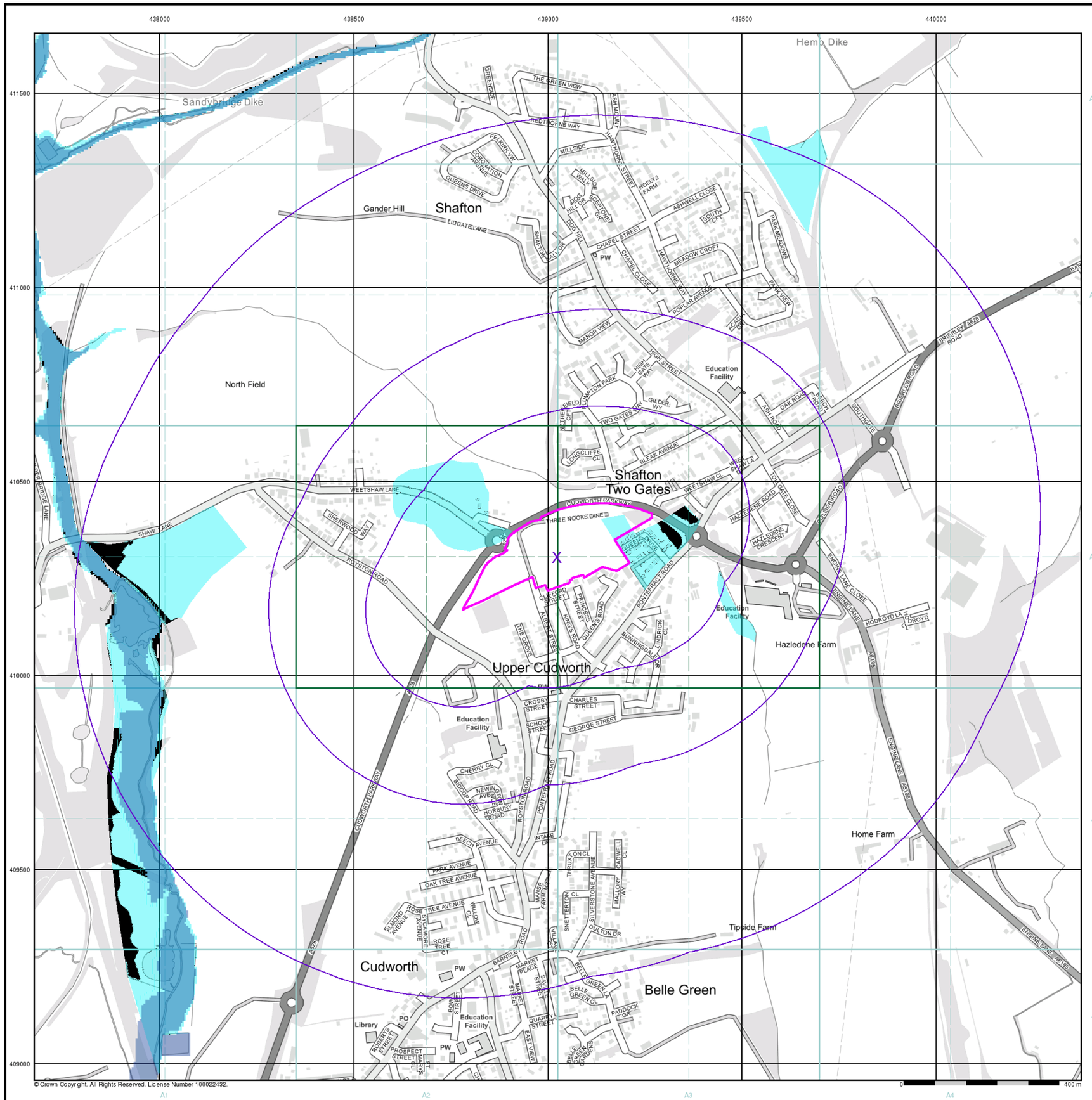


LITHOS CONSULTING

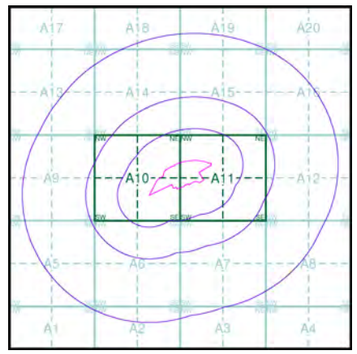
General

- Specified Site
- Specified Buffer(s)
- X Bearing Reference Point

Agency and Hydrological (Flood)

- Extreme Flooding from Rivers or Sea without Defences (Zone 2)
- Flooding from Rivers or Sea without Defences (Zone 3)
- Area Benefiting from Flood Defence
- Flood Water Storage Areas
- Flood Defence

Flood Map - Slice A



Order Details

Order Number:	328843319_1_1
Customer Ref:	4674
National Grid Reference:	439020, 410300
Slice:	A
Site Area (Ha):	6.23
Search Buffer (m):	1000

Site Details

Cudworth Parkway, Cudworth, BARNSLEY, S72 8FG

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