



Land at Storthes Hall, Kirkburton For Ubrique Investments Limited

Report no: 4473/1A

Date: July 2023



SUMMARY OF GEOENVIRONMENTAL ISSUES

Job No.	4473	Site area/ha	13.8
Client:	Ubrique Investments Limited	NGR:	SE 180 127
Site:	Storthes Hall, Kirkburton	Nearest postcode:	HD8 0PT

The site is located off Storthes Hall Lane, approximately 5.3km southeast of Huddersfield town centre and can be split into 3 separate areas:

- **Area A** – (c. 2.1 ha in the east) open grassed field, with derelict building, allotment and woodland
- **Area B** – (c. 8.3 ha, centre) University of Huddersfield (DIGS) halls of residence buildings, Storthes Hall Park (The Venue), surrounding landscaped areas, tarmac access roads and car parks
- **Area C** – (c. 1.9 ha, west) derelict and heavily overgrown land

The site had been a mental hospital in the early 1900s before being redeveloped in the 1990s as a university hall of residence.

Lithos were commissioned by Ubrique to provide a geoenvironmental appraisal of the site, which it is understood is to be redeveloped with traditional 2 storey domestic dwellings, associated gardens, POS and adoptable roads and sewers. Lithos' investigation included a review of 3rd party reports, the site's history and environmental setting, and a ground investigation comprising 24 trial pits and 29 window sample boreholes.

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

Issue	Remarks
Made ground	Made Ground was encountered in Areas B & C generally comprising Made Ground Topsoil or tarmac and concrete hardstand overlying Granular & Cohesive Made Ground, with localised areas of Sub-Base, reworked natural ground and Ash & Clinker.
Natural ground	Topsoil was encountered in Area A. Natural ground comprised Granular Residual Soils, with thin beds (0.2m thick) of Cohesive Residual Soils. Bedrock comprising Grenoside Sandstone was encountered across the site from 1.5m depth.
Contamination	Topsoil in Area A contains trace amounts of asbestos fibres. This topsoil is not suitable for re-use in gardens on site. The Made Ground Topsoil and Made Ground in Areas B & C contain asbestos fibres, elevated concentrations of lead and Diesel Range Organics (DRO). Therefore, where residual made ground remains beneath garden and landscaped areas (i.e. not beneath hardstanding) a minimum of 600mm thick surface cover of "clean" soil comprising 450mm subsoil and 150mm topsoil is recommended. Hydrocarbon contamination has been encountered in Area C. This will require excavation and delineation during remediation earthworks with subsequent on-site treatment or off-site disposal. Testing of tarmac indicates that at least some is likely to be classified as hazardous waste.
Mining & quarrying	The site is located in a Coal Authority Low Risk Area and no mining is recorded beneath the site. A small (c. 200m ²) backfilled sandstone quarry is present on site adjacent to the southern boundary. Due to access constraints associated with ongoing uses, the quarry could not be investigated.
Hazardous gas	The site is in an area where <1% of homes are estimated to be above the radon action level. A backfilled sandstone quarry is present on site and further sandstone quarries are present within 250m of the site's boundaries. Therefore, monitoring wells have been installed to allow a period of gas monitoring to be undertaken. Gas monitoring has been completed and suggests that no special precautions against methane / carbon dioxide gas are required.
Preparatory & remediation works	The anticipated remediation works are summarised below: <ul style="list-style-type: none"> • Demolition of existing buildings and break-up of slabs and hardstand • Crushing of all suitable artificial hard material (i.e. concrete/brick etc) • Post demolition investigation of the ground beneath the former buildings and slabs, which were inaccessible during the earlier investigations • Turnover of the full thickness of made ground • Removal of fuel contamination: with subsequent treatment and/or off-site disposal in Area C • Removal of below ground obstructions • Preparation of the ground for highway construction • Provision of a minimum 600mm thick cover layer of 'clean' soils in all garden and landscaped areas within Areas B & C

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

SUMMARY OF GEOENVIRONMENTAL ISSUES

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Client:	Ubrique Investments Limited	NGR:	SE 180 127
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Issue	Remarks
Foundations	<p>Traditional strip and trench fill foundations from a minimum depth of 0.6m founded within Granular Residual Soils or Grenoside Sandstone bedrock will likely provide the most suitable foundation solution for the proposed development.</p> <p>If Cohesive Residual Soil are encountered at founding depth, the depth of foundations will require increasing to 0.75m depth.</p> <p>Foundations will require deepening through Made Ground into natural strata and where made ground is more than 2.5m thick, alternative foundation solutions such as piles may need to be considered.</p>
Groundwater & excavations	<p>Groundwater was not encountered during the investigation.</p> <p>Shallow excavations into natural ground are likely to encounter some overbreak of sidewalls in residual soils due to cobbles and the stability of excavations into made ground was very poor. An allowance should be made for shoring</p>
Flooding & drainage	<p>The site lies in Flood Zone 1, where the risk of flooding from rivers or the sea is classified as low.</p> <p>Based on observations made during the investigation and in-situ testing in Area A, soakaways constructed in natural granular soils or weathered bedrock might provide a suitable drainage solution for surface water run-off.</p>
Highways	<p>Based on visual inspection of the shallow natural materials and published guidance, the Granular Residual Soils should provide a CBR value of at least 3%.</p> <p>Where the made ground is re-engineered it is considered that a CBR value of at least 3% should be achievable</p>

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

- Demolition of existing buildings/foundations and grubbing up of hardstand.
- Ground improvement – turnover of the full thickness of made ground, in order to address the presence of contamination and remove buried obstructions.
- A minimum of 600mm 'clean' soil cover is required where made ground remains beneath gardens and areas of soft landscaping with Areas B & C.

Some further work is required, most notably:

- Given constraints (existing buildings across the majority of the site) a robust post-demolition trial pit investigation will be required in order to remove residual uncertainties with respect to ground and provide more definitive recommendations with respect to contamination and foundations. The post demolition investigation should allow for further sampling of both topsoil and tarmac.
- Production of a Remediation Strategy & Materials Management Plan.

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APPENDICES

Appendix A - General notes

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

Appendix B - Drawings

Drawing	Revision	Title
4473/1	-	Site location plan
4473/2	-	Proposed site layout
4473/3	A	Site features
4473/3A	A	Historical site features
4473/4	A	Site photographs
4473/5	-	Preliminary conceptual site model
4473/6	A	Exploratory hole locations
4473/6A	A	Exploratory hole locations (with historical site features)
4473/7	-	Revised conceptual site model
4473/9	A	Hydrocarbon contamination

Appendix C - Commission

Appendix D - Historical OS plans[#]

Appendix E - Search responses[#]

From	Date	Content
Landmark	5 th July 2022	Environmental search data
Coal Authority	5 th July 2022	Mining report

Appendix F & G - Exploratory records

Appendix F	TP01 to TP24
Appendix G	WS01 to WS29

Appendix H - Soakaway test results

Appendix I - Chemical test results

Appendix J - Geotechnical test results

Appendix K - Gas monitoring results

Appendix L – Walkover photographs

[#] Some of this data is not included within the paper or PDF copies of this report; by request, it can be provided on a CD.

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 on a CD.

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
STORTHES HALL, KIRKBURTON

1 INTRODUCTION

1.1 The commission and brief

1.1.1 Lithos Consulting Limited were commissioned by Ubrique Investments Limited to carry out a geoenvironmental appraisal of land at Storthes Hall, Kirkburton.

1.1.2 This document is a revision of the Geoenvironmental Appraisal (Report 4473/1) issued by Lithos in September 2022; Report 4473/1 is now superseded. This document includes updates associated with a revised site boundary and completion of the gas monitoring, with the only significant revisions to 4473/1 having been made in Sections 1.2, 2.2 & 13.

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

- A review of third party reports
- 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 24 trial pits and 29 window sample 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

1.1.4 Primary aims of this investigation were to identify salient geoenvironmental issues affecting the site to enable Ubrique and prospective developers to obtain budget costs for: foundations; gas protection measures; and site preparatory and remediation works.

1.2 The proposed development

1.2.1 It is understood that consideration is being given to demolition of buildings at Storthes Hall and construction of up to 261 residential dwellings and redevelopment of the Lodge cottage for a residential use and associated works on land south of Storthes Hall Lane.

1.2.2 A site layout has been provided by Parker Peel Architects (Drawing reference 1826-SI-03, dated July 2023) which is reproduced as Drawing 4473/2 in Appendix B to this report.

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 4473/1 presented in Appendix B to this report. Site details are summarised in the table below.

Detail	Remarks
Location	5.3km southeast of Huddersfield town centre
NGR	SE 180 127
Approximate area	12.3ha (30.4 acres)
Known services	Underground electric, telecom, gas, sewer and street lighting Overhead telecom Private service connections to each separate building off main

2.2 Site features

- 2.2.1 Lithos completed a walkover survey of the site on 12th July 2022.
- 2.2.2 Existing salient features, at the time of the walkover are presented on Drawing 4473/3 in Appendix B to this report and summarised in the table below.

Feature	Remarks
Current Access	Off Storthes Hall Road
Topography	Across the west and centre, land generally falls to the northeast. However, flat development terraces for accommodation buildings have been formed leading to localised steeper slopes. In the field in the east land falls gently to the west and more steeply to the south.
Approximate areas	3,500m ² concrete hardstand and paved surfacing 12,000m ² buildings 21,000m ² tarmac hardstand 48,500m ² grass & overgrown areas 48,500m ² woodland
Nature of boundaries	North – stone wall and Storthes Hall Road West – construction fencing boards East – hedgerows & garden fencing South – woodland
Surrounding land uses	North - Woodland South – Woodland and sports pitch West – derelict land (post demolition) East – Storthes Hall House & private gardens

- 2.2.3 The site comprises a university hall of residence complex and surrounding land and is accessed from Storthes Hall Lane in the northeast through an automatic gated barrier. A one-way system is in place for the main access road through the complex. Access is gained from the site's northern boundary, off Storthes Hall Lane, and egress back onto Storthes Hall Lane is in the far western corner.
- 2.2.4 Land falls from the southwest (186mAOD) to northeast (151mAOD) at an average gradient of 1 in 18. However, several flat development terraces have been formed across the site. This locally creates slopes of 1 in 3.5 which are typically vegetated.
- 2.2.5 The site can be split into 3 separate areas: as shown on Drawing 4473/2.
- Area A – (c. 2.1 ha in the east) open grassed field, allotment and woodland
 - Area B – (c. 8.3 ha, centre) University of Huddersfield (DIGS) halls of residence buildings, Storthes Hall Park (The Venue), surrounding landscaped areas, tarmac access roads and car parks
 - Area C – (c. 1.9 ha, west) derelict and heavily overgrown land
- 2.2.6 Area A comprises mature woodland in the north and open grassed field in the south. Access to the field is from the access road in the west. Topography across the field falls at 1 in 17 to the east and 1 in 10 to the south.
- 2.2.7 An allotment is present in the far west of Area A, with a small greenhouse and sheds. An off-site derelict building (Dale Bank) is present to the east of the mature woodland and de-vegetation of the building and surrounding area was ongoing (July 2022).
- 2.2.8 Area B comprises the main university accommodation buildings, reception building, Storthes Hall Park building, landscaped gardens and car parks. The main access road runs along the southern boundary of Area B and a bus stop is present opposite the reception building.
- 2.2.9 The majority of Area B is formed into level development platforms, with localised steep slopes between the platforms.
- 2.2.10 The 2-storey, stone reception building in the centre south is older than the surrounding accommodation buildings (converted from the former hospital; see Section 3) and has a separate tarmac approach road and car parking area.
- 2.2.11 The stone accommodation buildings, present across Area B, are typically 3 & 4 storeys high, with tarmac footpaths/roads and concrete stepped access. Sporadic areas of concrete block paving are also present around the accommodation buildings. Informal rough tracks are present around accommodation buildings in the southwest of this area. Residents and staff car parking is present in the northwest of the area accessed by a tarmac road on the boundary between Areas B & C. An electricity substation is present adjacent to the north of the car park.
- 2.2.12 The 2-storey gym/laundrette building is present in the far west and mature woodland is present along the southern, eastern and northern boundaries.
- 2.2.13 In the far southwest of Area B is Storthes Hall Park building (also known as The Venue) and surrounding landscaped gardens. The Venue is a 2-storey stone building with landscaped paving and gravel to the south, gardens to the west and delivery entrance to the north and east. The car park is present to the northwest of the building.
- 2.2.14 Area C comprises the overgrown and derelict land in the far southwest of the site. The access road runs along the southwestern boundary.
- 2.2.15 Area C also has flat development platforms with localised steep slopes.

- 2.2.16 In the southwest of Area C is a flat derelict area of tarmac hardstand. The northern portion of Area C comprises a tarmac/concrete hardstand road and heavily overgrown areas. The topographical survey indicates soil bunds but they were not clearly visible due to the density of vegetation. An electricity substation is also present adjacent to the complex access road.
- 2.2.17 A deep chamber was located adjacent to the concrete and tarmac hardstand in Area C, with a heras fencing panel placed across the opening to prevent falls into it. The depth could not be measured due to the rough and unstable nature of ground conditions surrounding the chamber.
- 2.2.18 A selection of site photographs is included in Appendix L, with the locations of the photos shown on Drawing 4473/4.

2.3 Site operations

- 2.3.1 The allotment in Area A is currently occupied by University of Huddersfield allotment society and some de-vegetation works were being undertaken around Dale Bank (off-site).
- 2.3.2 Within Area B, the accommodation and reception buildings are currently used by University of Huddersfield students. The Venue is operated as a Bar & Restaurant, used to host weddings and other functions.
- 2.3.3 No operations are undertaken in Area C.

3 SITE HISTORY

3.1 Historical Mapping

- 3.1.1 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.
- 3.1.2 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	Majority of site comprises open fields Pump located in centre-east Woodland in the southwest Track and woodland through centre of site	Storthes Hall immediately east Storthes Hall Lane immediately north with North Spring Wood beyond Sandstone quarry 60m to northwest Well 100m to southwest Woodland immediately south and Ravensknowle (farm) 200m to south Moor side (farm) 200m to west Farnley Mill (Woollen) 250m to north
1893	Quarry adjacent to track in centre of site Woodland labelled Little North Spring Wood	Pumps labelled at Storthes Hall Two springs labelled to the south Second quarry immediately beyond Storthes Hall Lane and both quarries labelled 'old quarry'
1906 to 1907	West Riding Lunatic Asylum (Storthes Hall) buildings & gardens/access roads constructed across the centre and southwest of the site Quarry no longer shown Lodge (house) constructed adjacent to Storthes Hall Lane	Farnley Mill labelled disused Miscellaneous buildings constructed within 100m to south

Date	Site	Surrounding land
1916 to 1932	Addition of glass/greenhouses (possible conservatories/orangeries) to buildings Bund adjacent to southwestern building	Lunatic asylum expanded to southwest of site Residential terraced housing immediately northwest Tank labelled 30m to southwest Pumping station (drainage) labelled 100m to south Quarry to northwest no longer shown Moor side (farm) expanded to west
1932 to 1933	Additional buildings constructed Structure labelled Knock Buie labelled in east field	Storthes Hall buildings reconfigured
1948	No significant changes	Dale bank house constructed 50m east Mortuary labelled 20m to southwest
1955	Site labelled Storthes Hall Hospital	Farnley Mill no longer shown
1958 to 1964	Chimney labelled in southwest of site Further glass/greenhouse constructed in north of site	Storthes Hall labelled 'The Mansion' Issues and Sinks labelled throughout woodland to the south
1968	No significant changes	
1979	No significant changes	Quarry to north no longer shown
1992	Tanks & electric substations labelled on site	Moor side buildings no longer shown
1996	Majority of hospital buildings & Knock Buie demolished and replaced with new student accommodation buildings	All weather playing field constructed to the south
1999 (aerial photo)	Student accommodation buildings expanded	Storthes Hall Hospital undergoing demolition Residential construction to west
2000	Student accommodation buildings expanded	No significant changes
2006	Arboretum labelled in southwest corner	Hospital fully demolished to the southwest
2021	Arboretum building in the southwest no longer shown	No significant changes

3.1.3 A number of greenhouse/glasshouse type structures were shown as part of the hospital site. These are anticipated to be either conservatories/orangeries for residents or more likely greenhouses associated with kitchen gardens for the hospital. Residents may have grown produce in these structures and they were typically well insulated to retain heat and kept warm using coal fires.

3.2 Storthes Hall Hospital

3.2.1 A psychiatric hospital (previously known as lunatic asylum) was previously present at Storthes Hall. These facilities were and were established for paupers ('very poor people').

3.2.2 The hospital operated from 1904 to 1992 and could be divided into three areas:

- Acute hospital (used for sick/infirm) – located in the centre of the red line boundary site
- Boiler & laundry house – located in the southwest
- Echelon complex (used for general cases) – located offsite to the southwest

3.2.3 Storthes Hall hospital operated a landfill, 350m to the south, which accepted commercial and inert waste, but no further details (dates of filling etc.) are available.

- 3.2.4 Lithos have visited the University of Huddersfield and West Yorkshire Archives to examine records and plans relating to the former Storthes Hall hospital. These plans cannot be reproduced due to copyright terms & conditions but they have been summarised in Drawing 4473/3A. They show the location of features such as the laundry building, boiler house & engine room, Work Department, coal stack and hospital ward numbers.
- 3.2.5 The plans also allude to the presence of a tunnel/subway running northwest from the Fire Station/laundry building (Area C) underneath the main Acute Hospital building wards. Another plan schematic drawing of a ward building indicates this tunnel was around 1.7m (5.5 feet) in height. The location of the tunnel corresponds with the deep chamber described in Section 2.2.17.

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 response's from the Coal Authority and the BGS 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 77 & 86) 1:10,000 BGS map (Sheet SE 11 SE)	Drift soils – None recorded. Solid (bedrock) – Grenoside Sandstone (micaceous sandstone and siltstone) part of Lower Coal Measures unit. Shallowest coal seam – 36 Yard at about 160m depth. Strata dip – 3° east. Faults – None recorded
Mining	Coal Authority	This site is located within a Coal Mining Development Low Risk Area (within the defined coalfield, but no known defined risks have been recorded by the Coal Authority; there may still be unrecorded issues). Past and present workings – None recorded beneath the site. Opencast – None within 500m of the site. Mine entries – None recorded within 100m of the site.
Quarrying	Historical OS plans	Sandstone Quarry (c. 300m ²) shown on site around 1893 and no longer shown by 1906. Further sandstone quarries shown within 250m of site to the north and west excavated around the same date (late 1890s) and no longer shown by 1980.
Landfills	Envirocheck Report	No known landfills within 250m. (Nearest is Storthes Hall Hospital landfill 350m).
Radon	Public Health England	The site lies in an area where < 1% of homes are estimated to be above the action level.
Hydrogeology	Environment Agency electronic open data via QGIS	Groundwater Source Protection Zone? None recorded on site, but there is an SPZ 2 25m to northeast. Secondary A Aquifer (Solid). Groundwater abstractions? Several potable abstractions within 1km of the site with the nearest being 275m to northeast for the university halls of residence (held by Ubrique Investments Limited) Soil leaching potential - High. Pollution incidents? None recorded
Hydrology	Environment Agency Envirocheck Report	Nearest watercourse – Range Dike, 200m to the north and other un-named field drains. Water quality – Site lies in the river catchment for Fenay Beck from Source to River Colne and was rated as ecologically moderate. Pollution incidents? Nearest is 45m to northeast and pollutant was crude sewage to land in 2007. Other sewage pollution incidences to Range Dike/Fenay Beck recorded in the 1990s. Abstractions? Nearest are 500m to the east from Shepley Dyke for general use (textiles & leather). Discharge consents? Nearest is 500m to the east to Fenay Beck for pumping station discharge,
Flood risk	Environment Agency electronic open data via QGIS	The site lies in Flood Zone 1, where the risk of flooding from rivers or the sea is classified as low. In accordance with Chapter 14 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.

4.2 Backfilled Quarries

4.2.1 A number of backfilled quarries are shown on and within 250m of the site boundary. These features are summarised below:

NGR (proximity to site)	Remarks	Source of data
418147, 412738 (on site, in the south between reception building and bus stop)	Label & approximate size: Quarry 300m ² Dates shown: 1893 to 1906 Current land use: woodland within student halls of residence.	OS plans Envirocheck QGIS* Google maps
417740, 412610 (60m to the west)	Label & approximate size: old quarry, 1500m ² Dates shown: 1854 to 1932 Current land use: open fields	
418118, 412947 (10m to the north)	Label & approximate size: old quarry, 2500m ² Dates shown: 1893 to 1968 Current land use: woodland	

* QGIS is an Open Source Geographic Information System.

4.2.2 The quarries were likely for the excavation of Coal Measures sandstone (for lintels, flagstones etc) and no details regarding backfilling have been provided.

4.2.3 The on-site backfilled sandstone quarry will require investigation although this not possible at this stage given it is situated within an area of woodland.

4.2.4 The possibility of further unrecorded quarries cannot be entirely discounted.

5 PREVIOUS INVESTIGATION FINDINGS

5.1 General

5.1.1 Ubrique have provided Lithos with a copy of the following reports:

- Phase 1 Geo-environmental Report (ref: SHF.1337.002.GE.R.001), issued by Enzygo in June 2018.
- Coal Mining Risk Assessment (ref: SHF.1337.002.GE.L.001), issued by Enzygo in April 2018

5.1.2 The phase 1 report includes a review of data from a Groundsure Geolinsight report and historical OS maps dating back to 1854. A site walkover was also undertaken. Sections 1 to 4 of this Lithos Report include similar content to the **Enzygo's** report, but with further detail.

5.1.3 Enzygo concluded there was low to moderate risk of contamination associated with the former use as a hospital with principal concerns being asbestos within soils and service ducts.

5.1.4 Enzygo considered that conventional foundations should be generally suitable for residential properties founding in residual soils/weathered bedrock although there may be areas of deeper made ground and old building foundations/basements. Soakaways were also considered possible depending on ground encountered (fines content of soils and fractures within sandstone).

5.1.5 Enzygo recommended a ground investigation to provide design information and assess the contamination risks identified.

5.1.6 Within the separate Coal Mining Risk Assessment letter, the site was considered low risk and no further investigation was recommended.

5.2 Lithos comments

- 5.2.1 The Enzygo report provides a sufficient desk study and broad recommendations for redevelopment of the site. The conclusions of the Coal Mining Risk Assessment correspond with Lithos' findings.
- 5.2.2 A ground investigation is required in phases (pre and post demolition) due to the current uses of the site.

6 PRELIMINARY CONCEPTUAL SITE MODEL

- 6.1.1 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, asbestos associated with existing made ground and service ducts)
 - Total Petroleum Hydrocarbons (TPH) & Polycyclic Aromatic Hydrocarbons (PAH) (fuels, oils associated with sources such as boiler houses, tanks, glasshouses)
 - Polychlorinated biphenyls (PCBs) (oils associated with substations)
 - Ash & Clinker (metals, organics including sVOC, dioxins/furans associated with any ash associated with the boiler house and open fires)
- 6.1.2 Historical plans show the presence of a backfilled quarry, buildings and greenhouses associated with the former Storthes Hall Hospital. Where reasonably possible these areas should be targeted during the investigation.
- 6.1.3 A preliminary conceptual site model, presented as Drawing 4473/5 in Appendix B, has been prepared after consideration of all the data presented in Sections 2 to 5.
- 6.1.4 Clearly, the conceptual model will be subject to modification in light of data arising from the proposed intrusive ground investigation.
- 6.1.5 Potential contaminant linkages are shown on the preliminary conceptual site model.
- 6.1.6 Given the proposed residential use the most significant receptors are likely to be the end users (human health) via ingestion, inhalation, dermal contact.

7 GROUND INVESTIGATION DESIGN

7.1 Anticipated ground conditions & potential issues

7.1.1 Based on the data reviewed in Section 4 (Environmental Setting) and 5 (Previous Investigation Findings), anticipated ground conditions are expected to comprise:

Anticipated condition	Remarks
Made ground	Likely to be a veneer (<1m thick) associated with former and current uses as hospital and student accommodation. Deep made ground in areas of former buildings where the surface has been re-profiled to create level development platforms. Possible ash associated with the boiler house and open fires. Below ground obstructions associated with former buildings may also be present.
Natural soils	Likely to be Granular Residual Soils (sandy Gravels)
Bedrock	Grenoside Formation (sandstones & siltstones) from c. 2m depth.
Mineworkings	Not anticipated
Groundwater	Likely to be a depth within sandstone bedrock. Possible perched water in made ground

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	<ol style="list-style-type: none"> Made Ground Topsoil Made Ground and/or Ash & Clinker Substations Former tanks 	<ol style="list-style-type: none"> Associated with former uses Associated with former hospital boiler house and open fires (organics & dioxins) Polychlorinated biphenyls (PCBs) Hydrocarbons (PAH/TPH)
Potential off-site contamination sources	<ol style="list-style-type: none"> None identified at desk study stage 	
Potential geotechnical hazards	<ol style="list-style-type: none"> Relict buried obstructions Deep made ground Steep slopes Backfilled quarry 	<ol style="list-style-type: none"> Foundations of former buildings Basements and/or land re-profiling Need for retaining structures Quarry highwall issues/easement
Other potential constraints	<ol style="list-style-type: none"> Underground and/or overhead utilities 	<ol style="list-style-type: none"> Decommissioning or diversion/easement

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
24 Trial Pits	To determine the general nature of soils underlying the site, including the: <ul style="list-style-type: none"> 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 soakaway tests	To determine whether natural ground is suitable and has the capacity to dispose of storm water drainage
29 window sample boreholes	To investigate the nature and distribution of shallow soils in areas of limited access (vicinity of student accommodation buildings) To install monitoring wells across the site in order to monitor for hazardous gas and determine groundwater levels and assess flow direction

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 40m 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 pits.

8 FIELDWORK

8.1 Objectives

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

8.2 Exploratory hole location constraints

8.2.1 Throughout Lithos' works much of the site remained in use as campus accommodation and a wedding/events venue. No access was available inside any of the existing buildings.

8.2.2 Consequently, trial pits were limited to Areas A & C and the peripheries of Area B. Window sampling was the only practical means of investigation within the majority of Area B (student accommodation blocks). 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). Furthermore, assessment of the strength of cohesive soils, via hand vane tests, is difficult due to disturbance caused by drilling.

8.2.3 It should be noted that trenching to locate highwalls associated with a former sandstone quarry in the south has not been possible due to woodland and current access roads.

8.2.4 No access was available to much of the woodland areas due to thickness of undergrowth etc.

8.3 Scope of works

8.3.1 Fieldwork was supervised by Lithos between 19th and 22nd July 2022 and comprised the exploratory holes listed below.

Technique	Exploratory holes	Final depth(s)	Remarks
Trial pitting (machine dug)	TPs 01 to 24	0.4m to 3.1m	Trial pits 08, 10, 19 & 23 terminated on obstructions in made ground. All other trial pits terminated within weathered bedrock.
Including soakaway tests	TPs 01 to 05, 9, 12 & 13	1.2m to 2.3m	Testing gave favourable infiltration rates in Area A but variable rates in Area C
Window sample boreholes	WSs 01 to 29	0.5m to 4.0m	Monitoring wells installed in 13 WS boreholes. All window sample boreholes refused in bedrock.

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 & G 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 4473/6 presented in Appendix B; hole positions are based on data from a hand-held GPS (typically +/- 3m accuracy) and have not been surveyed in.

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 & G.

9.1.2 The site has been divided into 3 areas; see Section 2. These areas are shown on Drawing 4473/2 and are summarised below:

Site area	General location	Exploratory holes	Area (m ²)
A	East	TPs 1 to 5 & WSs 1 to 3	21,000
B	Centre	TPs 6 to 8, 14, WSs 4 to 11 & 13 to 29	83,000
C	West	TPs 9 to 13, 15 to 24 & WS12	19,000

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 14 & 15.

9.2 Made ground

9.2.1 No significant made ground was encountered in **Area A**. Made Ground Topsoil (topsoil with clinker gravel) was only encountered in TP04 to 0.3m depth.

9.2.2 Made Ground was encountered in every hole within **Areas B & C**, average thickness of 0.8m; maximum of 2.1m (WS25) and comprised the following:

- **Tarmac Hardstand** – Encountered at surface in 10 exploratory holes (c. 200mm thick) locally completely weathered to a black Gravel of tarmac.
- **Concrete Hardstand** – Encountered in 5 exploratory at surface in TPs 15 & 22 (c. 200mm thick) and at depth in TPs 8, 10 & 23 (between 0.6m and 1.6m). The concrete at depth is likely to comprise relict foundations.
- **Made Ground Topsoil** – Encountered in 26 exploratory holes at surface (c. 250mm thick) in Areas B & C comprising dark brown, silty Sands with gravels of sandstone, brick, concrete, coal & tarmac.
- **Sub-Base** – Encountered in 5 exploratory holes (c. 200mm thick) beneath tarmac in car parks and access roads comprising light brown, subangular Gravels of limestone.
- **Granular Made Ground** – Encountered in 33 exploratory holes to an average depth of 0.8m comprising black, dark grey, brown, very gravelly Sands and sandy Gravels and Cobbles of brick, sandstone, concrete, tarmac, coal. Fragments of metal, wire, plastic, and glass were all encountered within Made Ground.
- **Cohesive Made Ground** – Encountered in 6 exploratory holes to an average depth of 1.0m comprising dark brown and orangish brown, slightly Sandy Clays with gravels of sandstone, coal, concrete and ceramic.
- **Reworked Natural Ground** – Encountered in 3 exploratory holes to an average depth of 0.8m comprising light brown, very sandy, subangular Gravel and Cobbles of sandstone.

9.2.3 Review of the trial pit logs suggest made ground thicknesses beneath the site vary between 0.2m and 2.1m; average 0.8m. The thickest made ground (WS25 & TP17) was encountered in the centre (around the accommodation buildings) and in the far west (underneath the landscaped lawn area).

- 9.2.4 Made ground more than 2m deep was only encountered in WS25. However, areas of deeper made ground not identified to date (such as basements, backfilled quarry, near the crest of steep slopes, etc.) may exist in inaccessible areas.
- 9.2.5 Whilst not encountered during this investigation, the possibility of 'burial pits', and/or asbestos sheeting (used as shuttering), and/or asbestos lagging (used in service ducts) and/or fragments of asbestos sheeting within the hardcore beneath concrete slab, cannot be entirely discounted.

9.3 Obstructions

- 9.3.1 It is apparent from the site visit that buildings are present on about 10% of the site area. Furthermore, a review of historical OS Plans (see Section 3) indicate that previous buildings relating to the former Storthes Hall Hospital (most now demolished) were previously present on about 12% of the site area. Furthermore, tarmac, and concrete hardstand, which is typically 100mm to 200mm thick, covers approximately 21,000m² (c. 17% of total area).
- 9.3.2 Drawings 4473/3 & 4473/3A show the footprint of the current structures, former structures, and areas of hardstand.
- 9.3.3 Constraints associated with existing buildings, ongoing operations and underground utilities have prevented trenching in Areas B & C to identify and assess the nature/extent of buried obstructions. However, the existing buildings will have foundations (likely columns on pads with walls on strips/trench fill), and other below ground structures should be anticipated.
- 9.3.4 Several trial pits excavated in Areas B & C encountered obstructions, summarised in the table below:

Hole	Area of site (location) – former feature	Depth (m)	Obstruction encountered
TP08	Area B (adjacent to substation – historical building)	0.6m	Concrete floor slab at 0.6m.
TP14	Area B (adjacent to accommodation building) – no historical feature	0.1m	Concrete slab beneath turf (excavated through with machine).
TP10	Area C (landscaped grass) – historical building/basement	1.3m	Concrete floor slab/basement at 1.3m.
TP23		1.6m	Concrete floor slab/basement at 1.6m. Brick wall from 0.3m to 1.6m
TP17	Area C (north) – historical building	0.75m	Metal rebar at 0.8m.
TP19	Area C (centre) – historical tank	1.3m	Significant metal rebar (200mm diameter) from 0.3m to 0.5m. Concrete base at 1.3m.
TP20	Area C (centre) – historical tank	0.6m to 0.8m	Concrete slab across pit (excavated through with machine).

- 9.3.5 Given the above, it is apparent that whilst former hospital buildings have been demolished, substantial foundations, bases etc remain below ground in Area C.
- 9.3.6 Across Area B, it is anticipated that the majority of relict foundations for former hospital buildings were removed to allow construction of the university accommodation buildings/ However, as indicated in TP08, hospital building obstructions should be anticipated where no subsequent university accommodation construction has taken place.
- 9.3.7 In addition to the obstructions described above, large oversize materials such as masonry boulders, bricks and stone lintels were encountered in Area C, most notably within TPs 10 & 23. These materials will require crushing and screening prior to being re-used as engineered fill.

- 9.3.8 Given the redevelopment proposals, removal of obstructions and oversize will be required from Areas B & C.
- 9.3.9 If available through historic archives, reference should be made to any demolition specification and/or Completion Report for the demolition of the former hospital. The University of Huddersfield may also hold construction records for the student accommodation and may be able to confirm whether obstructions conflicting with accommodation were removed at the time of construction.

9.4 Natural ground

- 9.4.1 Natural ground was encountered in the majority of the exploratory holes, and typically comprised:
- **Topsoil (Area A)** – (typically 300mm in thickness) comprising dark brown, silty, fine Sand, with gravel of sandstone.
 - **Relict Topsoil (Area B)** was encountered in 10 exploratory holes beneath Made Ground in Areas B to an average depth of 1.0m (average 0.2m thick). Comprising dark brown, slightly sandy Clays & Silts, with gravel of sandstone.
 - **Cohesive Residual Soil** – Encountered in 10 exploratory holes in Area B (generally as thin layers) within Granular Residual Soils to an average depth of 1.9m. Comprising orangish brown and light brown, sandy Silts & Clays, with gravel of sandstone.
 - **Granular Residual Soil** – Encountered in 34 exploratory holes beneath made ground and topsoil comprising light brown and orangish brown, gravelly Sands grading into sandy Gravels & Cobbles of sandstone to an average depth of 1.6m (maximum 3.5m).
 - **Grenoside Sandstone bedrock** – Encountered in 43 exploratory holes comprising weak to medium strong, light yellowish brown, fine and medium Sandstone, recovered as sandy gravelly cobbles & boulders from an average depth of 1.5m. Average penetration with an 8-ton wheeled excavator and window sample rig into bedrock was 0.5m.

9.5 Visual & olfactory evidence of organic contamination

- 9.5.1 Exploratory locations where evidence of significant organic contamination was noted are summarised below:

Site area	Hole	Material	Depth (m)	Observation
B	WS16	Granular Made Ground	0.3m to 0.8m	Hydrocarbon odour
C	TP17	Granular Made Ground	0.8m	Tar-like substance
	TP19		0.7m to 1.2m	Tar-like substance with free product sitting on surface of concrete base

- 9.5.2 Selected samples of potentially contaminated materials were scheduled for chemical testing to determine the nature and extent of the identified contamination.
- 9.5.3 Testing of topsoil (Area A) was scheduled to confirm the suitability of existing topsoil for re-use; see Section 11.

9.6 Groundwater

- 9.6.1 No seepages or inflows of groundwater were encountered during the investigation.
- 9.6.2 No groundwater was encountered in the monitoring wells on the first gas monitoring visit.

Summary of Ground Conditions

Area	Hole	Final depth (mbgl)	Depth to Base of Made Ground (mbgl)	Depth to Base of: (mbgl)										Depth to bedrock (mgl)	Penetration (m)	Remarks
				Made Ground						Natural Soils						
				Tarmac/Concrete Hardstand	Sub-Base	Made Ground Topsoil	Granular Made Ground	Cohesive Made Ground	Reworked Natural Ground	Topsoil	Relict Topsoil	Cohesive Residual Soil	Granular Residual Soil			
Area A	TP01	1.3	-	-	-	-	-	-	-	0.4	-	-	1.3	1.3	-	Refusal on bedrock at 1.3m
	TP02	1.9	-	-	-	-	-	-	-	0.3	-	-	1.7	1.7	0.2	Refusal on bedrock at 1.9m
	TP03	1.9	-	-	-	-	-	-	-	0.2	-	-	1.5	1.5	0.4	Refusal on bedrock at 1.9m
	TP04	1.5	-	-	-	-	-	-	-	0.3	-	-	1.0	1.0	0.5	Refusal on bedrock at 1.5m
	TP05	1.2	-	-	-	-	-	-	-	0.3	-	-	0.9	0.9	0.3	Refusal on bedrock at 1.2m
	WS01	1.7	-	-	-	-	-	-	-	0.3	-	-	1.6	1.6	0.1	Refusal on bedrock at 1.7m
	WS02	2.5	-	-	-	-	-	-	-	0.4	-	-	2.0	2.0	0.5	Refusal on bedrock at 2.0m
	WS03	1.4	-	-	-	-	-	-	-	0.3	-	-	0.8	1.4	0.6	Refusal on bedrock at 1.4m
Area B	TP06	1.7	0.5	-	-	-	0.5	-	-	-	-	-	1.4	1.4	0.3	Refusal on bedrock at 1.7m
	TP07	3.1	1.4	-	-	0.2	0.7	-	1.4	-	1.6	-	>3.1	-	-	Difficult to excavate from 2.8m
	TP08	0.6	>0.6	>0.6	-	-	0.6	-	-	-	-	-	-	-	-	Concrete obstruction - 0.6m
	TP14	1.7	0.6	-	-	0.2	0.6	-	-	-	0.8	-	>1.7	-	-	-
	WS04	3.0	0.5	-	-	0.5	-	-	-	-	0.7	-	2.9	2.9	0.1	Refusal on bedrock at 3.0m
	WS05	2.5	0.6	0.2	0.4	-	0.6	-	-	-	0.6	-	2.0	2.0	0.5	Refusal on bedrock at 2.5m
	WS06	1.8	0.8	0.2	0.4	-	0.8	-	-	-	-	-	-	0.8	1.0	Refusal on bedrock at 1.8m
	WS07	4.0	0.2	-	-	0.2	-	-	-	-	-	1.6 & 2.6	1.4, 2.4 & 3.2	3.2	0.8	Refusal on bedrock at 4.0m
	WS08	1.5	0.6	-	-	0.2	-	0.6	0.4	-	-	1.2	1.1	1.2	0.3	Refusal on bedrock at 1.5m
	WS09	3.7	1.0	-	-	0.6	-	1.0	0.8	-	-	2.7	1.7 & 3.5	3.5	0.2	Refusal on bedrock at 3.7m
	WS10	2.5	1.0	-	-	0.1	0.8	0.5 & 1.0	-	-	-	1.3	1.6	1.6	0.9	Refusal on bedrock at 2.5m
	WS11	4.0	1.9	0.2	-	-	0.4	1.9	-	-	2.0	2.8	-	2.8	1.2	Refusal on bedrock at 4.0m
	WS13	2.6	0.6	-	-	0.2	0.6	-	-	-	0.8	1.9	-	1.9	0.7	Refusal on bedrock at 2.6m
	WS14	1.7	0.3	0.2	0.3	-	-	-	-	-	0.4	0.6	0.9	0.9	0.8	Refusal on bedrock at 1.7m
	WS15	1.7	0.8	0.2	-	-	0.8	-	-	-	-	-	1.4	1.4	0.3	Refusal on bedrock at 1.7m
	WS16	2.5	0.8	0.1	0.3	-	0.8	-	-	-	-	1.2 & 2.4	1.7	2.4	0.1	Refusal on bedrock at 2.5m
	WS17	0.6	0.3	-	-	0.3	-	-	-	-	-	-	-	0.3	0.3	Refusal on bedrock at 0.6m
	WS18	0.7	0.4	0.2	0.3	-	0.4	-	-	-	-	-	0.5	0.5	0.2	Refusal on bedrock at 0.7m
	WS19	2.1	0.5	-	-	0.2	0.5	-	-	-	-	-	1.4	1.4	0.7	Refusal on bedrock at 2.1m

Area	Hole	Final depth (mbgl)	Depth to Base of Made Ground (mbgl)	Depth to Base of: (mbgl)										Depth to bedrock (mgl)	Penetration (m)	Remarks
				Made Ground						Natural Soils						
				Tarmac/Concrete Hardstand	Sub-Base	Made Ground Topsoil	Granular Made Ground	Cohesive Made Ground	Reworked Natural Ground	Topsoil	Relict Topsoil	Cohesive Residual Soil	Granular Residual Soil			
Area A	WS20	0.5	0.4	-	-	0.2	0.4	-	-	-	-	-	-	0.4	0.1	Refusal on bedrock at 0.5m
	WS21	1.0	0.8	-	-	0.4	0.8	-	-	-	-	-	-	0.8	0.2	Refusal on bedrock at 1.0m
Area B	WS22	1.8	1.2	-	-	0.1	1.2	0.3	-	-	-	-	-	0.8	1.0	Refusal on bedrock at 1.8m
	WS23	0.9	0.4	-	-	0.4	-	-	-	-	-	-	-	0.4	0.5	Refusal on bedrock at 0.9m
	WS24	0.8	0.6	-	-	0.3	0.6	-	-	-	-	-	-	0.6	0.2	Refusal on bedrock at 0.8m
	WS25	2.2	2.1	-	-	0.2	2.1	-	-	-	-	-	-	2.1	0.1	Refusal on bedrock at 2.2m
	WS26	1.2	0.6	-	-	0.3	0.6	-	-	-	-	-	-	0.6	0.6	Refusal on bedrock at 1.2m
	WS27	2.0	0.6	-	-	0.2	0.6	-	-	-	0.9	1.5	-	1.5	0.5	Refusal on bedrock at 2.0m
	WS28	1.7	0.7	-	-	0.3	0.7	-	-	-	0.8	-	1.6	1.6	0.1	Refusal on bedrock at 1.7m
	WS29	2.0	0.8	-	-	0.1	0.6	0.8	-	-	1.0	1.8	-	1.8	0.2	Refusal on bedrock at 2.0m
	Area C	TP09	1.8	0.3	-	-	-	0.3	-	-	-	-	-	1.3	1.3	0.5
TP10		1.3	>1.3	>1.3	-	-	1.2	-	-	-	-	-	-	-	-	Concrete obstruction across base of the pit.
TP11		1.2	0.8	-	-	-	0.8	-	-	-	-	-	0.8	0.8	0.4	Refusal on bedrock at 1.2m
TP12		2.1	0.2	-	-	0.2	-	-	-	-	-	-	1.5	1.5	0.6	Refusal on bedrock at 2.1m
TP13		2.3	0.6	0.2	-	0.1	0.6	-	-	-	-	-	2.2	2.2	0.1	Refusal on bedrock at 2.3m
TP15		1.3	0.3	0.3	-	-	0.1	-	-	-	-	-	1.0	1.0	1.3	Refusal on bedrock at 1.3m
TP16		2.0	1.3	-	-	0.2	1.3	-	-	-	-	-	>2.0	-	-	Difficult to excavate from 1.9m
TP17		2.0	1.1	-	-	0.3	1.1	-	-	-	-	-	1.8	1.8	0.2	Refusal on bedrock at 2.0m
TP18		2.0	2.0	0.3	-	0.1	-	-	-	-	-	-	>2.0	-	-	Sandstone 0.3m to 0.6m
TP19		1.3	>1.3	-	-	-	>1.3	-	-	-	-	-	-	-	-	Concrete obstruction across base of the pit at 1.3m
TP20		2.1	1.2	-	-	-	1.2	-	-	-	-	-	2.0	2.0	0.1	Refusal on bedrock at 2.1m
TP21		1.5	0.3	0.3	-	-	-	-	-	-	-	-	1.0	1.0	0.5	Sandstone 0.3m to 0.5m. Refusal on bedrock at 1.5m
TP22		0.4	>0.4	0.2	-	-	>0.4	-	-	-	-	-	-	-	-	300mm drain uncovered. Excavation abandoned.
TP23		1.7	>1.7	>1.7	-	-	1.6	-	-	-	-	-	-	-	-	Concrete obstruction across base of the pit at 1.7m
TP24		1.0	0.5	-	-	0.2	0.5	-	-	-	-	-	0.7	0.7	0.3	Refusal on bedrock at 1.0m
WS12	2.2	0.3	0.05 & 0.15	-	-	0.3	-	-	-	-	-	1.0	0.5	1.0	1.2	Refusal on bedrock at 2.2m

9.7 Stability

- 9.7.1 Shallow excavations into natural ground are likely to encounter some overbreak of sidewalls in residual soils due to cobbles.
- 9.7.2 The stability of excavations into made ground was very poor and an allowance should be made for shoring

9.8 Revised conceptual ground model (ground conditions)

- 9.8.1 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)
- 9.8.2 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 Given water table depth and topography it is considered highly unlikely that springs will appear down-gradient. However, this is likely dependent on final site gradients.
- 10.1.4 CIRIA C753¹ 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'.
- 10.1.5 BRE Digest 365² "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 Eight soakaway tests were carried out in general accordance with BRE Digest 365 "Soakaway Design". The locations of the soakaways are shown on Drawing 4473/6 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 Digest 365. 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.

¹ CIRIA C753. *The SUDS Manual (2015)*.

² BRE Digest 365. *Soakaway Design (1991)*.

- 10.2.3 Where the water level did not fall to 25% effective depth, the test was not considered suitable for calculation of an infiltration rate; this was the case for unsuccessful test in TP09 (second test) & TP13 (first test).
- 10.2.4 Relatively slow drainage meant that only one filling cycle was possible in TP13, with two filling cycles undertaken in TP09 and three filling cycles were undertaken in TPs 1 to 5 & 12.
- 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 H to this report.

Area	Soakaway	Stratum	Infiltration rate (m/s)	Remarks
A	TP01	Granular Residual Soil (0.7m to 1.2m) Grenoside Sandstone (1.2m to 1.3m)	Test 1 – 1.31×10^{-3} Test 2 – 2.77×10^{-3} Test 3 – 1.94×10^{-3}	3 fills completed
	TP02	Granular Residual Soil (0.8, to 1.7m) Grenoside Sandstone (1.7m to 1.9m)	Test 1 – 1.09×10^{-3} Test 2 – 1.39×10^{-3} Test 3 – 1.31×10^{-3}	
	TP03	Granular Residual Soil (0.7m to 1.5m) Grenoside Sandstone (1.5m to 1.9m)	Test 1 – 5.21×10^{-4} Test 2 – 4.30×10^{-4} Test 3 – 3.60×10^{-4}	
	TP04	Granular Residual Soil (0.4m to 1.0m) Grenoside Sandstone (1.0m to 1.5m)	Test 1 – 4.94×10^{-4} Test 2 – 3.86×10^{-4} Test 3 – 3.51×10^{-4}	
	TP05	Granular Residual Soil (0.6m to 0.9m) Grenoside Sandstone (0.9m to 1.2m)	Test 1 – 2.50×10^{-3} Test 2 – 1.55×10^{-3} Test 3 – 1.82×10^{-3}	
C	TP09	Granular Residual Soil (0.6m to 1.3m) Grenoside Sandstone (1.3m to 1.8m)	Test 1 – 2.20×10^{-5} Test 2 – n/a	Second test still c. 40% full after 3.5 hours
	TP12	Granular Residual Soil (0.8m to 1.5m) Grenoside Sandstone (1.5m to 2.1m)	Test 1 – 2.23×10^{-3} Test 2 – 1.30×10^{-3} Test 3 – 1.05×10^{-3}	3 fills completed
	TP13	Granular Residual Soil (0.7m to 2.2m) Grenoside Sandstone (2.2m to 2.3m)	Test 1 – n/a	First test still c. 50% full after 3.5 hrs

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. However, regard must be given to seasonal groundwater levels; UK guidance indicates that the seasonally high groundwater table must be at least 1m below the base the soakaway.
- 10.3.2 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, which is case for Area A. However, rates were more variable in Area C.

- 10.3.5 Consequently, soakaways might provide a suitable drainage solution. Drainage solutions are discussed further in Section 15.8.
- 10.3.6 Given that the soakaway tests have yielded satisfactory results, on completion of detailed drainage design, consideration should be given to the installation of groundwater wells to depths of around 6m in 6 boreholes, and subsequent groundwater level monitoring over about 12 months. Given the anticipated depth to bedrock, these boreholes will need to be advanced by rotary probing.

11 CONTAMINATION (ANALYSIS)

11.1 General

- 11.1.1 The site has been formerly used as a mental hospital which included a boiler house and greenhouses/glasshouses.
- 11.1.2 Raw materials used on the site are likely to include heating oils for the boiler house.
- 11.1.3 The site's former usage is likely to have given rise to some ground contamination. Furthermore, significant thicknesses of made ground were encountered in many of the exploratory locations during the ground investigation.
- 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 and olfactory evidence recorded during the ground investigation.

Area	Type of sample	No. of samples	Determinands
B & C	Made Ground (including Granular Made Ground, Cohesive Made Ground, Sub- base and Ash & Clinker)	23	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID Total Organic Carbon (TOC) Speciated Polycyclic Aromatic Hydrocarbons (PAH) Banded Total Petroleum Hydrocarbons (TPH)
		20	Water soluble sulphate, chloride, nitrate and magnesium
		5	Speciated Total Petroleum Hydrocarbons (TPH)
		6	Semi-Volatile Organic Compounds (sVOC), includes PAHs
		5	Speciated Total Petroleum Hydrocarbons (TPH)
		2	Calorific Value (CV)
	Tarmac Hardstand	9	Speciated PAH & Coronene
	Granular Residual Soils	2	Semi-Volatile Organic Compounds (sVOC), includes PAHs Poly-Chlorinated Biphenyls (PCB) Banded Total Petroleum Hydrocarbons (TPH) Speciated Total Petroleum Hydrocarbons (TPH)
	Made Ground Topsoil	10	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID Total Organic Carbon (TOC) Speciated Polycyclic Aromatic Hydrocarbons (PAH) Banded Total Petroleum Hydrocarbons (TPH)
		2	Clay/sand/silt content and visible contaminants, sharps (glass etc) to check compliance with BS3882:2015
A	Topsoil	5	pH, water soluble boron, and total metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) & Asbestos ID Total Organic Carbon (TOC) Speciated Polycyclic Aromatic Hydrocarbons (PAH)
		3	Clay/sand/silt content and visible contaminants, sharps (glass etc) to check compliance with BS3882:2015

11.2.2 Account was taken of previous uses in specific areas, with organics analysis concentrated on samples recovered from the vicinity of former tanks and exploratory holes that recorded visual evidence of organic contamination, and calorific value analysis concentrated on samples recovered of ash & clinker.

11.2.3 Area A could be considered as a Greenfield site whilst Area B & C should be considered as Brownfield.

11.3 Soil contamination results

11.3.1 The soil contamination test results are summarised in the tables on pages 20 to 25.

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

Summary of degree of soils contamination (inorganics)

Area	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	
A	TP01	0.1	Topsoil	6.2	18	0.4	0.5	36	39	87	0.4	18	0.5	33	110	-	N.D.
	TP02	0.1	Topsoil	6.3	8.4	< 0.2	0.2	30	15	32	0.1	13	< 0.5	33	71	-	N.D.
	TP03	0.1	Topsoil	5.6	15	0.3	0.4	33	31	76	0.2	17	< 0.5	32	95	-	N.D.
	TP04	0.1	Made Ground Topsoil	6.1	28	< 0.2	0.3	21	60	32	0.1	28	< 0.5	42	50	-	Chrysotile (0.001%)
	TP05	0.1	Topsoil	5.6	17	0.2	0.4	33	32	69	0.3	17	< 0.5	32	97	-	N.D.
B	TP07	0.1	Made Ground Topsoil	6.5	19	0.5	0.3	29	42	110	0.5	19	1.2	39	110	-	N.D.
	TP14	0.1	Made Ground Topsoil	7.5	23	0.4	0.5	35	62	120	0.2	22	0.6	40	120	-	Chrysotile (<0.001%)
	WS23	0 - 0.35	Made Ground Topsoil	7.2	22	0.5	1	37	96	150	0.3	22	< 0.5	36	150	-	N.D.
	WS09	0.2 - 0.5	Made Ground Topsoil	7.7	12	0.2	0.3	42	32	74	0.2	35	< 0.5	35	110	-	N.D.
	WS21	0.0 - 0.35	Made Ground Topsoil	6.3	36	0.6	0.4	31	70	97	0.6	24	1.1	51	110	-	N.D.
	WS24	0 - 0.3	Made Ground Topsoil	6.7	31	0.4	0.4	28	52	200	0.3	22	0.9	44	100	-	N.D.
C	WS26	0 - 0.25	Made Ground Topsoil	7.6	23	0.4	1	39	100	150	0.3	23	0.9	37	150	-	N.D.
	TP12	0.1	Made Ground Topsoil	7.2	6.7	1.9	0.7	14	23	54	0.1	9.9	< 0.5	17	72	-	N.D.
	TP17	0.2	Made Ground Topsoil	6.2	22	0.4	0.4	39	46	90	0.5	11	< 0.5	27	79	-	N.D.
	TP24	0.1	Made Ground Topsoil	6.3	20	0.3	0.4	15	37	84	8.7	11	0.5	33	48	-	N.D.
B	WS05	0.3	Sub-Base	8.5	2	< 0.2	0.1	14	15	10	0.1	5.3	0.5	7.9	21	-	N.D.
	WS13	0.5 - 0.6	Ash & Clinker	8.6	42	0.3	0.5	46	77	110	0.3	36	0.6	71	110	4.8	N.D.
C	TP17	1.0	Granular Made Ground	8.2	8.7	0.7	0.3	16	24	78	0.1	14	0.8	28	54	-	N.D.
	TP19	0.1	Granular Made Ground (ashy)	9.7	31	2.5	1.1	53	580	430	< 0.1	22	< 0.5	17	2,500	1.3	N.D.
	TP19	0.5	Granular Made Ground	10.3	5.3	0.9	0.2	14	23	36	0.2	10	< 0.5	21	130	-	Chrysotile (<0.001%)
	TP10	0.8	Granular Made Ground	8.4	6.7	0.3	0.3	13	39	180	0.2	9.3	< 0.5	22	92	-	Chrysotile (0.001%)
	TP11	0.4	Granular Made Ground	7.8	9.9	< 0.2	< 0.1	18	17	34	< 0.1	11	< 0.5	21	25	-	N.D.
	TP13	0.4	Granular Made Ground	7.5	18	0.3	0.3	14	49	53	0.7	15	0.6	31	76	-	Chrysotile (0.002%)
	TP17	0.5	Granular Made Ground	7.6	16	0.2	0.3	23	44	110	0.2	16	< 0.5	28	120	-	N.D.
	TP20	0.6	Granular Made Ground	10.4	3.7	0.3	0.2	4	14	17	0.7	4	< 0.5	6.6	50	-	N.D.
B	TP23	0.7	Granular Made Ground	8.6	3.4	0.2	0.1	13	13	77	880	8.1	< 0.5	16	44	-	N.D.
	TP06	0.3	Granular Made Ground	7.3	11	0.3	0.2	22	23	120	0.1	15	< 0.5	30	66	-	N.D.

Area	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	
B	TP07	0.5	Granular Made Ground	7.4	17	0.5	0.2	40	33	110	0.5	20	0.5	34	83	-	N.D.
	TP08	0.5	Granular Made Ground	8.0	8.3	0.5	0.3	40	37	93	0.1	24	< 0.5	29	88	-	Chrysotile (<0.001%)
	WS05	0.5	Granular Made Ground	8.1	14	1.6	0.2	19	27	570	0.1	14	< 0.5	29	210	-	N.D.
	WS15	0.4 - 0.6	Granular Made Ground	8.4	4.4	0.3	0.2	14	16	54	0.2	11	< 0.5	18	56	-	N.D.
	WS20	0.2 - 0.3	Granular Made Ground	7.9	11	0.3	0.3	27	25	130	0.2	18	< 0.5	28	130	-	N.D.
	WS22	0.5 - 0.8	Granular Made Ground	7.8	6	0.4	< 0.1	30	22	27	< 0.1	22	< 0.5	37	60	-	N.D.
	WS25	0.6 - 1.0	Granular Made Ground	8.0	17	0.8	0.2	20	82	490	0.1	17	< 0.5	27	170	-	N.D.
	WS08	0.4 - 0.6	Cohesive Made Ground	6.9	16	0.4	0.3	24	24	160	0.1	18	0.7	35	76	-	N.D.
	WS09	0.9	Cohesive Made Ground	7.2	9	0.9	0.2	28	23	65	0.1	21	< 0.5	36	70	-	N.D.
	WS10	0.8 - 1.0	Cohesive Made Ground	7.4	17	0.5	< 0.1	22	28	88	0.1	16	0.5	33	53	-	N.D.
	WS11	1.5	Cohesive Made Ground	7.7	1.8	3.7	0.1	25	12	29	< 0.1	19	0.6	30	48	-	N.D.

Key		Source of guidance trigger level	
36	Parameter tested for and found to be in excess of Tier 1 value.	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.	
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.	∞	Category 4 Screening Level – SP1010, December 2013 (CL:AIRE/Defra).
	Parameter not tested for.	\$	MAFF. Code of Practice for Agricultural Practice for the Protection of Soil, 1998.
♣	Tier 1 Value is pH dependent.	~	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.
x	Assumes Cr is CrIII. If demonstrated Cr is CrVI Tier 1 would be 21mg/kg.		
ND	No fibres detected (asbestos screen)	*	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 (organics)

Area	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	Benzene ∞	Toluene	Ethyl Benzene	Xylenes	Phenols	PCB	PAH		TPH - C6 to C40			
											B(a)P ∞	Naphthalene	GRO- C ₆ to C ₁₀	DRO ⁰ C ₁₀ to C ₂₁	LRO C ₂₁ to C ₄₀	
																1
A	TP01	0.1	Topsoil	3.2	-	-	-	-	-	-	-	0.7	< 0.1	-	-	-
	TP02	0.1	Topsoil	1.0	-	-	-	-	-	-	-	0.1	< 0.1	-	-	-
	TP03	0.1	Topsoil	2.9	-	-	-	-	-	-	-	0.4	< 0.1	-	-	-
	TP04	0.1	Made Ground Topsoil	9.0	-	-	-	-	-	-	-	1.1	< 0.1	-	-	-
	TP05	0.1	Topsoil	2.9	-	-	-	-	-	-	-	0.4	< 0.1	-	-	-
B	TP07	0.1	Made Ground Topsoil	3.2	-	-	-	-	-	-	-	0.4	< 0.1	< 0.1	< 30	< 20
	TP14	0.1	Made Ground Topsoil	4.3	-	-	-	-	-	-	-	0.6	0.2	< 0.1	< 30	56
	WS23	0 - 0.35	Made Ground Topsoil	4.4	-	-	-	-	-	-	-	1.3	0.1	< 0.1	< 30	62
	WS09	0.2 - 0.5	Made Ground Topsoil	2.4	-	-	-	-	-	-	-	0.7	< 0.1	< 0.1	< 30	46
	WS21	0.0 - 0.35	Made Ground Topsoil	6.1	-	-	-	-	-	-	-	1.3	1.1	< 0.1	44	61
	WS24	0 - 0.3	Made Ground Topsoil	5.2	-	-	-	-	-	-	-	1.1	0.2	< 0.1	37	56
	WS26	0 - 0.25	Made Ground Topsoil	3.7	-	-	-	-	-	-	-	0.6	1.4	< 0.1	45	73
C	TP12	0.1	Made Ground Topsoil	7.3	-	-	-	-	-	-	-	22	0.1	< 0.1	310	590
	TP17	0.2	Made Ground Topsoil	4.4	-	-	-	-	-	-	-	1	< 0.1	< 0.1	< 30	59
	TP24	0.1	Made Ground Topsoil	6.2	-	-	-	-	-	-	-	0.6	< 0.1	< 0.1	< 30	41
B	WS05	0.1	Tarmac Hardstand	-	-	-	-	-	-	-	-	< 0.1	< 0.1	-	-	-
	WS06	0.1	Tarmac Hardstand	-	-	-	-	-	-	-	-	< 0.1	< 0.1	-	-	-
	WS11	0.1	Tarmac Hardstand	-	-	-	-	-	-	-	-	160	1	-	-	-
	WS14	0.1	Tarmac Hardstand	-	-	-	-	-	-	-	-	< 0.1	< 0.1	-	-	-
	WS16	0.0-0.85	Tarmac Hardstand	-	-	-	-	-	-	-	-	0.5	< 0.1	-	-	-
C	TP13	0.2	Tarmac Hardstand	-	-	-	-	-	-	-	-	240	1.1	-	-	-
	TP18	0.2	Tarmac Hardstand	-	-	-	-	-	-	-	-	0.5	1.6	-	-	-
	TP21	0.2	Tarmac Hardstand	-	-	-	-	-	-	-	-	0.5	1.2	-	-	-
	WS12	0 - 0.04	Tarmac Hardstand	-	-	-	-	-	-	-	-	< 0.1	< 0.1	-	-	-
B	WS05	0.3	Sub-Base	7.2	-	-	-	-	-	-	-	< 0.1	< 0.1	< 0.1	< 30	< 20
	WS13	0.5 - 0.6	Ash & Clinker	17.0	-	-	-	-	-	-	-	70	0.5	< 0.1	754	2230

Area	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	Benzene ∞	Toluene	Ethyl Benzene	Xylenes	Phenols	PCB	PAH		TPH - C6 to C40			
											B(a)P ∞	Naphthalene	GRO~ C6 to C10	DRO C10 to C21	LRO C21 to C40	
																1
B	WS16	0.3 - 0.4	Granular Made Ground (Hydrocarbon odour)	4.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	See Speciated TPH Results		
	WS16	0.5 - 0.6	Granular Made Ground (Hydrocarbon odour)	5.0	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1	See Speciated TPH Results		
	WS16	1.2	Granular Residual Soil	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1	See Speciated TPH Results		
C	TP17	0.8	Granular Made Ground (Hydrocarbon odour)	6.7	< 0.1	< 0.1	< 0.1	45	< 0.1	-	< 0.1	< 0.1	See Speciated TPH Results			
	TP17	1.0	Granular Made Ground	4.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1	See Speciated TPH Results			
	TP17	1.3	Granular Residual Soil	< 0.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	< 0.1	< 0.1	See Speciated TPH Results			
	TP17	1.9	Grenoside Sandstone - Coal Measures	< 0.5	-	-	-	-	-	-	0.1	< 0.1	< 0.1	< 30	< 20	
	TP19	0.1	Granular Made Ground (ashy)	4.5	-	-	-	-	-	-	< 0.1	< 0.1	< 0.1	< 30	< 20	
	TP19	0.5	Granular Made Ground	15.0	-	-	-	-	< 0.1	-	< 0.1	< 0.1	< 0.1	< 30	58	
	TP19	0.8	Granular Made Ground (Hydrocarbon odour)	42.0	7.9	530	640	2,100	< 0.1	-	< 0.1	< 0.1	See Speciated TPH Results			
	TP10	0.8	Granular Made Ground	3.6	-	-	-	-	-	-	1.1	< 0.1	< 0.1	< 0.1	< 30	22
	TP11	0.4	Granular Made Ground	6.1	-	-	-	-	-	-	8	0.1	< 0.1	57	200	
	TP13	0.4	Granular Made Ground	7.4	-	-	-	-	-	-	38	0.2	< 0.1	628	1138	
	TP17	0.5	Granular Made Ground	2.7	-	-	-	-	-	-	2.3	< 0.1	< 0.1	34	64	
	TP20	0.6	Granular Made Ground	38.0	-	-	-	-	-	-	< 0.1	0.2	< 0.1	3,200	370	
	TP23	0.7	Granular Made Ground	0.9	-	-	-	-	-	-	2.4	< 0.1	< 0.1	33	108	
B	TP06	0.3	Granular Made Ground	2.2	-	-	-	-	-	-	0.8	< 0.1	< 0.1	< 30	38	
	TP07	0.5	Granular Made Ground	3.5	-	-	-	-	-	-	1.2	< 0.1	< 0.1	32	49	
	TP08	0.5	Granular Made Ground	1.4	-	-	-	-	-	< 0.1	0.8	< 0.1	< 0.1	41	68	
	WS05	0.5	Granular Made Ground	5.0	-	-	-	-	-	-	1.8	< 0.1	< 0.1	42	72	
	WS15	0.4 - 0.6	Granular Made Ground	2.8	-	-	-	-	-	-	0.2	< 0.1	< 0.1	< 30	77	
	WS20	0.2 - 0.3	Granular Made Ground	3.0	-	-	-	-	-	-	3.2	< 0.1	< 0.1	47	91	
	WS22	0.5 - 0.8	Granular Made Ground	1.1	-	-	-	-	-	-	< 0.1	< 0.1	< 0.1	< 30	< 20	

Area	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	Benzene ∞	Toluene	Ethyl Benzene	Xylenes	Phenols	PCB	PAH		TPH - C6 to C40		
											B(a)P ∞	Naphthalene	GRO~ C6 to C10	DRO C10 to C21	LRO C21 to C40
					1	2,048	592	590	3,360	8	25	6	23	218	5000
B	WS25	0.6 - 1.0	Granular Made Ground	7.8	-	-	-	-	-	-	9.1	0.6	< 0.1	216	191
	WS08	0.4 - 0.6	Cohesive Made Ground	2.9	-	-	-	-	-	-	0.4	< 0.1	< 0.1	< 30	< 20
	WS09	0.9	Cohesive Made Ground	2.0	-	-	-	-	-	-	0.4	< 0.1	< 0.1	< 30	< 20
	WS10	0.8 - 1.0	Cohesive Made Ground	2.3	-	-	-	-	-	-	16	14	-	-	-
C	WS11	1.5	Cohesive Made Ground	< 0.5	-	-	-	-	-	-	< 0.1	< 0.1	-	-	-
	TP18	0.8	Granular Residual Soil	1.5	-	-	-	-	-	< 0.1	-	-	-	-	-

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).

Summary of Speciated TPH results (organics)

Site Area	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.													
				Aliphatic						Aromatic							
				C5-C6	C6-C8	C8-C10	C10-C12	C12-C16	C16-C21	C21-C35	C5-C7	C7-C8	C8-C10	C10-C12	C12-C16	C16-C21	C21-C35
				58	175	44	218	1058	1x10 ⁶	1x10 ⁶	80	23	72	402	1,500	1x10 ⁶	1x10 ⁶
B	WS16	0.30-0.40	Granular Made Ground	<0.01	<0.01	< 0.01	< 1.5	2.6	5.3	45	<0.01	<0.01	< 0.01	< 0.9	2.6	28	110
	WS16	0.50-0.60	Granular Made Ground	<0.01	<0.01	< 0.01	< 1.5	< 1.2	< 1.5	25	<0.01	<0.01	< 0.01	< 0.9	3.8	35	98
	WS16	1.00-1.15	Granular Residual Soil	<0.01	<0.01	< 0.01	< 1.5	< 1.2	< 1.5	< 3.4	<0.01	<0.01	< 0.01	< 0.9	< 0.5	< 0.6	< 1.4
C	TP17	0.8	Granular Made Ground	<0.01	<0.01	66	520	3,200	3100	4100	<0.01	<0.01	< 0.01	30	640	1500	2500
	TP17	1.0	Granular Made Ground	<0.01	<0.01	< 0.01	< 1.5	17	36	100	<0.01	<0.01	< 0.01	1.4	21	63	120
	TP17	1.3	Granular Residual Soil	<0.01	<0.01	< 0.01	< 1.5	< 1.2	< 1.5	< 3.4	<0.01	<0.01	0.1	< 0.9	< 0.5	< 0.6	< 1.4
	TP19	0.8	Granular Made Ground	<0.01	<0.01	490	2,500	16,000	13000	16000	<0.01	0.5	< 0.01	28	890	2900	5900

Inorganic determinands

- 11.3.3 Of the 5 samples of topsoil and made ground topsoil from **Area A** analysed for inorganic parameters, all 5 can be classified as uncontaminated.
- 11.3.4 Of the 11 samples of Made Ground Topsoil from **Areas B & C** analysed for inorganic parameters, all 11 can be classified as uncontaminated.
- 11.3.5 For the purposes of inorganic determinands, 'Made Ground' from **Areas B & C** refers to Granular Made Ground (17 samples tested), Cohesive Made Ground (4 samples tested), Sub-Base (1 sample tested) and Ash & Clinker (1 sample tested).
- 11.3.6 Of the 23 samples of Made Ground from **Areas B & C** analysed for inorganic parameters, 18 can be classified as uncontaminated and 5 could be classified as contaminated.
- 11.3.7 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).
- 11.3.8 The contaminants are arsenic, copper, mercury (1 sample each), zinc (2 samples) and lead (3 samples).
- 11.3.9 The concentration of mercury (880mg/kg) recorded from TP23 is considered relatively high with respect to the Tier 1 screening value of 199mg/kg. Given the highest mercury concentration recorded from all other samples was 8.7mg/kg, the result of 880mg/kg is considered spurious.
- 11.3.10 Consequently, Lithos instructed the laboratory to undertake 3 sub-samples from the original sample provided and tested for mercury. The 3 further tests from the original sample returned concentrations of 7.1mg/kg, 11mg/kg & 13 mg/kg and therefore the original concentration of 880mg/kg is not considered representative of the original sample or widespread made ground soils across the wider site. It is likely to be associated with laboratory error or an isolated fragment of mercury containing material such as a dental filling.
- 11.3.11 Current UK guidance regarding the statistical analysis of soil contamination data obtained during a site investigation is provided by CL:AIRE³, 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.
- 11.3.12 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).
- 11.3.13 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.

³ CL:AIRE, 2020. *Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration.*

11.3.14 Lithos can confirm that statistical assessment of Topsoil (Area A) and Made Ground Topsoil and Made Ground (Areas B & C) from Areas B & C is **not** appropriate because:

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

Calorific value

11.3.15 The calorific value (CV) of a sample of ashy Granular Made Ground (TP19) & Ash & Clinker (WS13), have yielded a CV of 1.3MJ/kg and 4.8MJ/kg. Materials whose CVs exceed 10MJ/kg are almost certainly combustible, while those with values below 2MJ/kg are unlikely to burn.

11.3.16 Given, the absence of widespread Ash & Clinker across the site and the relatively low CVs recorded, the results are not considered significant.

11.3.17 However, if more widespread Ash & Clinker is encountered during the remediation earthworks, then further sampling and assessment (including consideration of Persistent Organic Pollutants – POPS) will be required.

Asbestos

11.3.18 Within Area A, asbestos fibres were identified in a single sample of Made Ground Topsoil in TP04.

11.3.19 Within Area B, asbestos fibres were encountered in Made Ground Topsoil in TP14 and in Granular Made Ground in WS05.

11.3.20 Within Area C, asbestos fibres were encountered in Granular Made Ground in TPs 10, 19 & 13.

11.3.21 On all occasions the asbestos identified was confirmed to be Chrysotile. Asbestos quantification testing suggests that total concentrations in soils are below 0.002%, with two samples below <0.001%.

Organic determinands

11.3.22 This site is brownfield and underlain by made ground which has yielded elevated concentrations of a number of inorganic determinands and asbestos. 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).

11.3.23 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.

11.3.24 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.

11.3.25 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)	3.8%	No
Made Ground Topsoil	4.7%	
Sub-base	>5%	
Ash & Clinker	>5%	
Granular Made Ground	>5%	
Cohesive Made Ground	2.5%	
Residual Soils	0.5%	Yes, but no significant organic contamination was recorded in this soil type. All determinands below limit of detection.

Hydrocarbons (TPH & PAH)

- 11.3.26 Petroleum sources were identified within the preliminary conceptual model (tanks) and olfactory evidence of hydrocarbon contamination was noted TP17 at 0.8m and TP19 between 0.7m and 1.2m. It is understood that TPs 17 & 19 were located in areas that were previously used by a Works Department (maintenance); and had a fuel tank for the boiler house that was used to heat the hospital respectively.
- 11.3.27 Additionally, a hydrocarbon odour was recorded in WS16 between 0.3m and 0.8m depth.
- 11.3.28 The hydrocarbon contamination encountered here is therefore likely to be due to leakage or spillage of fuel. Such contamination can be mobile and as such may pose a risk to the environment and human health.
- 11.3.29 Consequently, speciated analysis was scheduled on 7 samples (WS16 (0.3-0.4m bgl, 0.5 – 0.6m bgl, 1.0 – 1.15m bgl)), (TP17 (0.8m bgl, 1.0m bgl, 1.3m bgl)), (TP19 (0.8m bgl)), with a simple banded TPH initially scheduled on a further 31 samples from across the site.
- 11.3.30 Assessment of TPH has been undertaken in accordance with a 3-step approach, (outlined in Generic Note 04 in Appendix A). The first two steps involve review of speciated results. The third step assesses cumulative effects.
- 11.3.31 **Step 1 – Consideration of indicator compounds, (BTEX, naphthalene & B(a)P).** BTEX indicator compounds exceed their respective Tier 1 criteria in TP19 samples, therefore further site-specific assessment is required. As further action / assessment has been identified, no further assessment of fractions within TP19 is necessary.

11.3.32 Indicator Compounds did not exceed their respective Tier 1 criteria in TP17 & WS16, therefore the more toxic / prevalent compounds are below their representative screening value and the next step can be undertaken to consider mixtures within the fractions.

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 no cover or 300mm cover end use with 6% SOM.					
			GRO				DRO	LRO
			Benzene	Toluene	Ethyl Benzene	Xylenes	Naphthalene	Benzo(a)pyrene
			0.7	836	379	535	6	5
WS16	0.30-0.40	Granular Made Ground	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.1
WS16	0.50-0.60	Granular Made Ground	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.1
WS16	1.00-1.15	Granular Residual Soil	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.1
TP17	0.8	Granular Made Ground	< 0.01	< 0.01	< 0.01	45	< 0.1	< 0.1
TP17	1.0	Granular Made Ground	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.1
TP17	1.3	Granular Residual Soil	< 0.01	< 0.01	< 0.01	< 0.01	< 0.1	< 0.1
TP19	0.5	Granular Made Ground	-	-	-	-	< 0.1	< 0.1
TP19	0.8	Granular Made Ground	7.9	530	640	2100	< 0.1	< 0.1

11.3.33 **Step 2 – TPH fractions, does any individual fraction exceed Tier 1?** The table on page 25 outlines the concentrations recorded with respect to Tier 1 values. The C₁₀ to C₁₂ & C₁₂ to C₁₆ fractions exceeded their respective Tier 1 criteria in the sample from TP17, therefore further site-specific assessment will be required. As further action / assessment has been identified, no further assessment of the cumulative effects from fractions is necessary for TP17.

11.3.34 None of the fractions exceed their respective Tier 1 criteria in WS16, therefore the anticipated mixture of hydrocarbons within each fraction is not considered to pose a risk at the site.

11.3.35 **Step 3 – Assessing cumulative effects.** The third step of the assessment assesses the cumulative risk from all of the fractions identified. This is because each TPH fraction comprises a range of different substances, and a number of these can affect the same 'target organ' (i.e. cause skin irritation or affect the liver), resulting in cumulative effects.

11.3.36 The cumulative effect, associated with each source material, has been assessed via calculation of a Hazard Index (HI): HI < 1 indicates no cumulative effects; HI > 1, cumulative risk requires further consideration.

11.3.37 The HI for the samples from WS16 is < 1, therefore cumulative effects do not present a risk and hydrocarbon contamination at this location do not need to be considered further.

11.3.38 Using the 3-step approach the hydrocarbon contamination identified at TP17 and TP19 has been found to present an unacceptable risk and further consideration of contamination at these locations is required.

11.3.39 In this case it is considered unlikely that dQRA will negate the need for remediation of the hydrocarbon contamination identified at TP17 and TP19, or significantly reduce the volume of soil requiring treatment. Appropriate remediation is discussed in Section 12.6.

11.3.40 Across the rest of Areas B & C, given the previous uses of the site and absence of visual/olfactory evidence of hydrocarbon contamination in other exploratory holes, only a simple banded TPH (cf full speciation) was scheduled on 31 samples.

- 11.3.41 TPH can be associated with a variety of sources and elevated TPH concentrations do not automatically infer a petroleum product is present in the soils within that sample. TPH analysis will detect most hydrocarbons and is not restricted to those detailed within the TPHCWG reports.
- 11.3.42 Diesel Range Organics (DRO) above the Tier 1 screening value were recorded in TPs 12, 13 & 20 and WS13. These holes are in the broad vicinity of the hydrocarbon contamination discussed above and/or tanks identified in the preliminary CSM. However, no hydrocarbon contamination was identified in these exploratory holes and the made ground contained proportions of tarmac, coal, shale etc. which can all yield significant concentrations of DRO.
- 11.3.43 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).
- 11.3.44 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.
- 11.3.45 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.
- 11.3.46 The sample profiles here are sufficiently similar to the toxicity study adopted for the C4SL assessment, **but BaP concentrations exceed Lithos' Tier 1 Value.** Consequently, some remediation is required.
- 11.3.47 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.
- 11.3.48 A naphthalene exceedance of 14mg/kg (cf. Tier 1 screening value of 6 mg/kg) was recorded within Relict Topsoil in WS10, and this Relict Topsoil was overlain by made ground containing tarmac fragments. It is likely that the naphthalene concentration is associated with a fragment of this tarmac or another fragment of a material such as coal within the topsoil. All other samples tested for naphthalene at this site were below the Tier 1 value at this site.
- 11.3.49 Given the absence of any visual contamination within WS10, the concentration of naphthalene recorded is not considered significant.

Tarmac testing (B[a]P)

- 11.3.50 Nine samples of tarmac were obtained and tested for speciated PAH to determine concentrations of benzo[a]pyrene and establish whether the tarmac was coal tar derived or bitumen derived. Concentrations of B[a]P above 50mg/kg indicate that the tarmac is likely coal tar derived.
- 11.3.51 Two of the nine samples recorded concentrations of 160mg/kg and 240mg/kg which is significantly above 50mg/kg. Further assessment of the significance of these results is discussed in Section 12.8.

Semi-volatile Organic Compounds (sVOCs)

- 11.3.52 Eight samples from exploratory holes where visual evidence of hydrocarbon contamination was noted were tested for a suite of semi-volatile organic compounds to establish whether the hydrocarbon contamination was due to sources such as solvents, degreasers etc.
- 11.3.53 All compounds were below the limit of detection except carbazole (concentration of 1.8mg/kg, not considered significant) and 2-methylnaphthalene which recorded concentrations between 0.8mg/kg and 140mg/kg.
- 11.3.54 2-methylnaphthalene is a polycyclic aromatic hydrocarbon only slightly less volatile than naphthalene. When tentatively compared to the Tier 1 Screening Value for naphthalene (6mg/kg), concentrations of 2-methylnaphthalene are elevated at 2 locations TP17 (0.8m bgl) and TP19 (0.8m bgl). At both of these locations visual and olfactory evidence of hydrocarbon contamination was identified and based on the 3-step approach already undertaken it has been concluded remediation will be required. Therefore, no further consideration of 2-methylnaphthalene is necessary.

Polychlorinated biphenyls (PCBs)

- 11.3.55 TPs 8 & 18 were located adjacent to the existing substations, a single sample from each location was analysed for the presence of PCBs. Both samples returned concentrations of PCBs below the limit of detection and therefore PCBs are not considered a significant risk to this site.

11.4 Topsoil

- 11.4.1 Topsoil present all of Area A and Made Ground Topsoil is present across parts of Areas B & C; typically 300mm thick. Testing suggests this material is not suitable for re-use private gardens and landscaped areas due to concentrations of asbestos. At present only limited assessment of the topsoil from Area A has been undertaken, further assessment of the topsoil from this area may conclude it is appropriate for use in areas of private garden and landscaping.
- 11.4.2 Given the nature of the topsoil present on this site it would be expected to be suitable to support plant growth.

BS3882 Topsoil testing

- 11.4.3 The presence of visible contaminants, sharps (glass etc) was assessed by the Engineer in the field (inspection of initial trial pit arisings). BS3882 considers visual contaminants to comprise 'undesirable potentially injurious foreign object(s) visible to the naked eye'.
- 11.4.4 The clay/sand/silt content of 5 topsoil samples have been determined to check compliance with BS3882⁴ requirements.
- 11.4.5 It should be noted that this is a reduced suite of analysis, and no N-P-K etc. testing has been undertaken.

⁴ BS3882:2015. *Specification for topsoil*. Published by BSI Standards Limited.

11.4.6 The results are summarised below:

Parameter	BS3882 Specification	TP01, 0.2m	TP03, 0.2m	TP05, 0.2m	TP12, 0.1m	TP14, 0.1m
Retained on 2mm sieve	< 30%	27	31	28	33	24
Retained on 20mm sieve	< 10%	4	13	5	1	0
Retained on 50mm sieve	0%	0	0	0	0	0
Clay content	5 to 35%	14	15	15	12	16
Silt content	0 to 65%	27	26	29	21	32
Sand content	0 to 90%	59	59	56	67	53
Visible contaminants	No < 0.5%	No < 0.5%	No < 0.5%	No < 0.5%	Yes >0.5%	Yes > 0.5%

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

11.4.7 Visible contaminants (glass, metal, plastic etc.) were identified in TPs 12 & 14 (Areas B & C) and therefore the made ground topsoil is not physically suitable for re-use at this site.

11.4.8 The results indicate that the topsoil in Area A complies with the physical requirements for multipurpose topsoil, with the following exceptions:

- The gravel content of 1 of the 3 samples tested slightly exceeded the maximum permissible level (31% cf upper threshold of 30%) likely due to ploughing of the underlying residual soils and shallow bedrock into the topsoil.

12 CONTAMINATION (QUALITATIVE RISK ASSESSMENT & REMEDIATION)

12.1 Topsoil

12.1.1 Topsoil, typically 300mm thick is present in Area A. Testing suggests this material is not suitable for re-use in gardens due to the presence of asbestos and anthropogenic material (clinker gravel) in TP04. However, given this area of site is proposed as a drainage basin/pond and/or tank, then topsoil should be suitable for re-use below a clean capping layer as part of the drainage solution landscaping.

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 Made Ground Topsoil, typically 250mm thick is present in Areas B & C. Testing suggests this material is not suitable for re-use in gardens (asbestos and unsuitability of material). Given the compressible nature and gas-generating potential of this material if buried at depth, it is recommended that it is placed in garden areas and/or POS, immediately beneath the proposed 600mm cover, and that it is overlain by no more than 1m of soil.

12.2 Summary of significant contamination

12.2.1 A veneer of made ground (including Made Ground Topsoil) underlies Areas B & C, which is typically less than 1m thick and comprises concrete and tarmac Hardstand, Made Ground Topsoil at surface overlying Granular & Cohesive Made Ground with localised Ash & Clinker.

12.2.2 This made ground contains elevated concentrations of a number of inorganic determinands, asbestos and contains materials (e.g. brick), which would generally be considered undesirable as a near-surface material in garden areas.

12.2.3 An area of significant organic (hydrocarbon) contamination has been identified with Area C, summarised in the table below and shown on Drawing 4473/9.

Site area	Material	Depth (m bgl)	Observations & typical composition
Hotspot A (Area C)	Granular Made Ground	0.3 – 1.2	BTEX, Diesel 2500mg/kg to 16,000mg/kg (TP19) Diesel 3200mg/kg (TP17) B[a]P & DRO concentrations – WS13 & TPs 13 & 20

12.2.4 These areas are based on:

- Observations made during Lithos' ground investigation
- Lithos' laboratory test results

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 4473/7 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 the Range Dike, which flows in an easterly direction, approximately 200m 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 16.6.

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 (i.e. end users/aquifer etc). 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 Given the constraints discussed in Section 8.2 (existing buildings across the majority of the site), a robust post-demolition trial pit investigation will be required before any definitive recommendations are provided. At this stage only broad recommendations for remediation works based on the available data can be provided.

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

Asbestos

12.6.3 CL:AIRE has published a Joint Industry Working Group (JIWG) guidance⁵ 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.

12.6.4 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.

12.6.5 As discussed in Section 11.3, an asbestos ID (screen) was scheduled on 33 samples of made ground, with asbestos identified in 6 samples. Supplementary analysis (asbestos quantification) of the 5 samples yielded 3 results above the limit of measurement (<0.001%).

12.6.6 Nonetheless, 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).

12.6.7 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/cm³ airborne fibres averaged over a 4-hour period.

⁵ *Control of Asbestos Regulations 2012: Interpretation for Managing and Working with Asbestos in Soil and Construction & Demolition materials: Industry Guidance.* CL:AIRE, 2016.

- 12.6.8 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%).
- 12.6.9 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'.
- 12.6.10 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.
- 12.6.11 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.**
- 12.6.12 It should be noted that ACMs were commonly used as shuttering beneath concrete slabs, and to form ducts, and it is important that this is kept in mind when breaking through concrete slabs.
- 12.6.13 Made ground (and made ground topsoil) where asbestos has been positively identified and considered representative of near-surface soils, should ultimately be isolated beneath a minimum 600mm thick surface cover of "clean" soil (garden/landscaped areas), or hardstand (parking areas), or floor slabs (buildings) and therefore there will be no risk of release of asbestos fibres from the ground.
- 12.6.14 Consequently, in line with the principles of sustainable development, there should be no need to export any soil from site.
- 12.6.15 New utilities should be laid in trenches reinstated with 'clean' backfill in order to prevent exposure to maintenance workers in the future.
- 12.6.16 See also comments in the 'Waste Classification' Section below.

Inorganic contamination

- 12.6.17 The made ground has yielded elevated concentrations of a number of metals; most notably lead. Therefore, where residual made ground remains beneath garden and landscaped areas (i.e. not beneath hardstanding) a 600mm thick surface cover of "clean" soil comprising 450mm subsoil and 150mm topsoil is recommended. This cover will break potential contaminant linkages between the contaminated made ground and future end-users.
- 12.6.18 Alternatively, the Granular Made Ground is considered suitable for redistribution beneath concrete oversite or areas of hardstanding, where they would be satisfactorily isolated from end users.

Organic contamination

- 12.6.19 As discussed in Section 12.2 above, hydrocarbon contamination has been encountered. Such contaminants can be mobile and as such may pose a risk to the environment and human health.
- 12.6.20 Remediation options will be dependent on the post demolition site investigation however it is considered that there will be the need for excavation/removal of some grossly contaminated fill in the vicinity of hotspot identified in Area C, along with the placement of a 600mm clean cover layer in gardens.
- 12.6.21 Given the anticipated 600mm cover, Lithos Scenario B Screening Values (see Generic Note 4 in Appendix A) could be adopted as target concentrations for remediation.
- 12.6.22 Although these values are based on consideration of human health only, it is considered likely that clean-up to these values would further reduce pollution risks to controlled waters given that:
- The primary contaminant (fuel storage tanks) no longer exists.
 - The anticipated volume and lateral extent of hydrocarbon-contaminated soil are relatively small in comparison to the site.
 - No evidence (staining/free product etc) of visual or olfactory fuel contamination was encountered within the underlying natural Residual soils/bedrock
 - Groundwater monitoring data obtained to date suggests groundwater lies at depths exceeding 2.5m below ground levels.
- 12.6.23 It is considered likely that further hydrocarbon contamination could be encountered in post demolition investigation and remediation turnover earthworks.
- 12.6.24 Estimation of the volume of grossly contaminated soil requiring removal or treatment can only be approximate at this stage and is dependent on the target concentration(s) agreed with the Local Authority and/or Environment Agency. Contractors with experience of brownfield sites should be asked to review the site investigation data and make their own assessment once target concentrations have been agreed.
- 12.6.25 It will be necessary to agree clean-up criteria for hydrocarbon-contaminated soils with the Environment Agency and Kirklees Council in advance of the necessary remediation works. In the absence of a site-specific Quantitative Risk Assessment (QRA), generic soil screening values for a residential-with-gardens end use (Lithos Scenario B) could be adopted as remedial targets for hydrocarbon contamination in soils on this site. However, these remedial targets are based solely on a consideration of risks to human health.
- 12.6.26 Site-specific remedial targets for soils should be based on a consideration of risks to controlled waters, in accordance with the EA's 'Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination' (2006). If required, it is anticipated that the appointed Remediation Contractor will determine remedial targets for soils.

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 & DRO hydrocarbons in the made ground (Area B & C)	Treatment or removal of hydrocarbons. Isolation beneath at least 600mm clean soil cover in garden and landscaped areas within Areas B and C
	Ingestion		
	Dermal contact		
	Inhalation (dust)		
	Infiltration of water supply pipes	BTEX, and DRO hydrocarbons in the made ground	Treatment or removal of hydrocarbons Water company may still insist of "protectaline" pipework
Buildings	Migration & accumulation of explosive gas	Methane & carbon dioxide hydrocarbons in the made ground	To be assessed on completion of monitoring and gas risk assessment
Groundwater (Secondary A Aquifer)	Migration of dissolved and/or free phase organics	Hydrocarbons (leaking from former tanks, faults in the site drainage system, and spills)	Treatment or removal of hydrocarbons will remove

◇ 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 WM3⁶. 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.

⁶ 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 Areas B & C.
- 12.8.11 Speciated PAH analysis has been undertaken on 9 samples of tarmac and BaP concentrations ranged between < 0.1 mg/kg and 240mg/kg samples were > 50mg/kg. Consequently, tarmac is likely to fall within waste code 17 03 01 and as such would be considered **hazardous** waste:
- 17 – Construction and Demolition wastes,
 - 03 – bituminous mixtures, coal tar and tarred products
 - 01 – bituminous mixtures containing hazardous substances
- 12.8.12 Given the volume of tarmac at this site, disposal as hazardous waste has significant cost implications. It may be possible with PAK spray and further laboratory testing to zone areas of tarmac as hazardous and non-hazardous.
- 12.8.13 Material destined for landfill should be assessed for leaching potential in accordance with the appropriate WAC, prior to excavation.
- 12.8.14 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	Human health	Asphyxiation & explosion	Vertical migration, ingress & accumulation	Very Low: made ground essentially inert, with little degradable matter
	Buildings	Explosion		
On-site backfilled sandstone quarry	Human health	Asphyxiation & explosion	Lateral migration, ingress & accumulation	Very Low: unknown backfill (likely overburden) and quarry only c. 200m ²
	Buildings	Explosion		
Off-site backfilled sandstone quarries	Human health	Asphyxiation & explosion	Vertical migration, ingress & accumulation	Very Low: unknown backfill (likely overburden) however any gas generation is likely to vent to surface.
	Buildings	Explosion		

13.1.2 Given the above gas monitoring wells have been installed in 13 boreholes across the site. Details of the installations are given on the window sample borehole logs presented in Appendix H to this the report.

13.2 Scope of works

13.2.1 The generation potential of the gas source was initially considered to be Very Low and this has been confirmed by the monitoring results obtained. Consequently, in accordance with CIRIA Report C665⁷, given the proposed residential end use, 6 visits have been completed over a 3-month period, between August and December 2022; results are presented in Appendix K.

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)

⁷ CIRIA C665: Assessing risks posed by hazardous ground gases to buildings (2007)

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)
WS01	1.0 – 1.7m (Granular Residual & Grenoside Sandstone)	None detected	0.4 – 0.7	None detected
WS02	0.5 – 2.0m (Granular Residual & Grenoside Sandstone)		0.6 – 0.9	
WS03	0.5 – 1.4m (Granular Residual & Grenoside Sandstone)		0.3 – 0.7	
WS04	1.0 – 3.0m (Granular Residual & Grenoside Sandstone)		0.7 – 3.2	
WS08	1.0 – 1.5m (Cohesive Residual & Grenoside Sandstone)		N.D – 0.7	
WS10	1.0 – 2.5m (Residual Soil & Grenoside Sandstone)		0.2 – 0.7	
WS11	2.0 – 4.0m (Cohesive Residual & Grenoside Sandstone)		0.6 – 1.0	
WS12	1.0 – 2.2m (Grenoside Sandstone)		1.6 – 2.0	
WS14	0.5 – 1.7m (Residual Soil & Grenoside Sandstone)		1.5 – 3.3	
WS22	0.5 – 1.2m (Granular & Cohesive Made Ground?)		N.D – 0.6	
WS25	1.0 – 2.0m (Granular Made Ground)		0.1 – 0.7	
WS27	0.9 – 1.9m (Cohesive Residual & Grenoside Sandstone)		1.5 – 6.2	
WS29	1.0 – 2.0m (Cohesive Residual & Grenoside Sandstone)		1.9 – 3.6	

Note: Atmospheric pressures varied between 988mb and 1029mb. N.D – Not detected.
 Numbers in bold exceed the CS2 lower threshold.

13.4 Discussion (methane & carbon dioxide)

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

13.4.2 The proposed residential redevelopment comprises two and three storey domestic dwellings, associated gardens, POS, adoptable roads and sewers. Consequently, the gas regime has been characterised in accordance with the Situation A (Wilson & Card) methodology outlined in CIRIA Report C665 and BS8485:2015+A1:2019.

13.4.3 No methane was recorded during any of the 6 visits.

13.4.4 Based on worst-case (peak) gas concentration of carbon dioxide and the default value for flow, the Gas Screening Value (GSV) for carbon dioxide is 0.0062. This GSV equates to Characteristic Situation **CS1**.

13.4.5 A single elevated carbon dioxide concentration over 5% was recorded on one occasion (WS27 – Visit 3). The elevation is marginal and highly likely to be associated with microbial activity within the substrata. Based on the isolated occurrence of a marginally elevated concentration and the complete absence of flow, it is not considered necessary to raise the site's classification to **CS2**.

13.5 Scope of protection measures

13.5.1 Based on the site characterisation discussed above, the proposed foundation solution, and with reference to the gas protection “scoring” system outlined in BS8485:2015+A1:2019, Lithos consider that the following protective measures should be incorporated in all new buildings:

Characterisation situation (Wilson & Card, '99)	Gas “score” req'd by BS8485	Protective measures (Residential, low-rise housing)		
		Floor slab (BS8485 “score”)	Sub-floor ventilation (BS8485 “score”)	Membrane
				Type (BS8485 score)
1	0	well constructed ground-bearing or suspended	Not required for ground bearing slab, otherwise to comply with Building Regulations (Part C).	Waterproof DPM

Footnotes:

1. Building Type A is defined in Table 3 and Section 7 of BS8485:2015+A1:2019 as: private ownership with no building management controls on alterations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Examples include private housing and some retail premises.

13.5.2 BRE Environment Agency Report BR 414 (2001) – “Protective Measures for housing on gas-contaminated land” provides a practical guide to good practice for the detailing and construction of passive soil gas protection measures for new residential development. Of particular relevance are a list of ‘Watchpoints’, which offer practical information for installation and buildability.

13.6 Radon

13.6.1 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.

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

13.6.3 The Public Health England UK radon map and the Landmark report indicate that the site is in an area where < 1% of homes are estimated to be above the action level.

13.6.4 Consequently, basic radon protection measures are not required.

14 GEOTECHNICAL TESTING

14.1 General

14.1.1 A total of 27 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 J to this report.

14.2 Atterberg limits

14.2.1 The plasticity indices of 7 samples of cohesive soil have been determined; results are summarised below.

Soil type	No. samples tested	Moisture content range % (average)	Range of Plasticity Indices % * (average)	Shrinkability
Cohesive Residual Soil	7	11 to 22 (15.6)	6.2 to 19.6 (13.4)	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 Two samples returned a non-plastic result indicating the material tested was granular.

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

14.3 Soluble sulphate and pH

14.3.1 In accordance with BRE SD1⁸, this site has been classified as brownfield with a mobile groundwater regime.

14.3.2 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).

14.3.3 The concentrations of sulphate in the aqueous natural soil extracts of 26 samples were determined. In addition, 20 samples of made ground were tested as part of the contamination suite. The pH value of each sample has also been determined.

14.3.4 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)
Granular Made Ground	16	7.3	120
Cohesive Made Ground	4	6.9	110
Cohesive Residual Soil	7	5.6	100
Granular Residual Soil	11	6.5	69
Grenoside Sandstone (bedrock)	8	6.6	77

14.3.5 pH values were all above 5.5, therefore concentrations of chloride and nitrate are considered insignificant.

⁸ BRE Special Digest 1 (2005) – Concrete in aggressive ground.

- 14.3.6 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-1**.

15 GEOTECHNICAL ISSUES

15.1 Conceptual site model

- 15.1.1 Areas B & C are underlain by Granular Made Ground, with local areas of Cohesive Made Ground, Reworked Natural and Ash & Clinker to an average depth of 0.8m. Concrete and Tarmac hardstand are present across both areas with a veneer of Sub-Base underneath.
- 15.1.2 Significant relict obstructions (floor slabs/foundations etc.) were encountered across Areas B & C within the Made Ground.
- 15.1.3 Natural Ground beneath all areas comprises Granular Residual Soils (sandy gravels and cobbles), over Grenoside Sandstone bedrock (weak to strong fine and medium sandstone)

15.2 Mining & Quarrying

- 15.2.1 This site is underlain at depth by Grenoside Sandstone bedrock and the shallowest coal seam lies at least 100m below the surface. The CA report indicates that no mining has been undertaken beneath this site. 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.
- 15.2.2 A backfilled sandstone quarry (200m²) is located near to the southern boundary. However, site access constraints prevented investigation during this phase of site investigation.

15.3 Site regrade and/or ground improvement

- 15.3.1 Made ground currently underlies Areas B & C, to an average depth of about 0.8m; maximum of 2.1m. 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, asbestos and contains materials (e.g. brick, tarmac, 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 soil/fill grossly contaminated with hydrocarbons and relict foundations.
- 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 abnormalities 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 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.
- 15.3.8 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.
- 15.3.9 Much of the site has been subject to earthworks regrade to create flat development platforms. Careful consideration will need to be given to earthworks design, and implications for any slope stability, retaining walls, foundations, highway gradients and drainage
- 15.3.10 Any digital terrain modelling undertaken, or commissioned, by the Developer(s) should consider implications for the foundation recommendations outlined below.
- 15.3.11 Wherever possible, Lithos recommend that excavated soils are retained on site. However, if this is not possible the comments in Section 12.8 should apply.

15.4 Foundation recommendations

General

- 15.4.1 Foundation recommendations assume that development will be traditional 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.
- 15.4.2 The proposed layout suggests existing trees will be retained across the footprint of the former sandstone quarry, thereby avoiding issues associated with quarry highwalls etc.
- 15.4.3 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 the Developer(s) should consider implications for the foundation recommendations outlined below.
- 15.4.4 Foundation depths (and types) will depend on thicknesses of fill following the anticipated earthworks regrade.
- 15.4.5 Following the anticipated turnover earthworks, replaced fill materials will not contain obstructions and should be relatively stable with little overbreak. At this stage, it is assumed that fill will be placed with nominal compaction only, and reinforced footings on engineered fill are not currently anticipated.
- 15.4.6 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.
- 15.4.7 Sub-surface concrete in contact with the made ground and natural ground should be Design Sulphate Class DS-1, with the site allocated an ACEC Classification of AC-1.

Strip/trench fill footings

- 15.4.8 It is considered that shallow strip or deepened trench fill footings will be the most suitable foundation solution for the majority of two or three storey houses constructed at the site. Footings will be founded in residual soils or competent rock. This solution is viable where the made ground is less than about 2.5m thick, and residual soils or competent rock is the founding material.
- 15.4.9 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.
- 15.4.10 Where existing buildings are to be demolished, all concrete slabs and service ducts will require breaking out prior to re-development. However, relict foundations could probably be left in-situ and an allowance made for local breaking out, or (probably better) chased-out and removed during the necessary site preparatory works; see Section 15.3.
- 15.4.11 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.
- 15.4.12 Foundations will be required to be placed below a line drawn up at 45° from the base of any service or similar excavation.
- 15.4.13 Deepened foundations should be stepped in accordance with NHBC Standards, Chapter 4.3.
- 15.4.14 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).
- 15.4.15 The Developer(s) 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.

Granular Residual Soils (completely weathered bedrock)

- 15.4.16 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).
- 15.4.17 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 10m
 - A foundation breadth of 0.6m
 - A foundation thickness of 225mm
 - A foundation depth of 0.6m depth
 - An angle of shearing resistance of $\phi=33^\circ$ for the granular deposits
- 15.4.18 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.

- 15.4.19 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).
- 15.4.20 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.
- 15.4.21 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.
- 15.4.22 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).
- 15.4.23 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).

Cohesive Residual Soils (sandy Silts/Clays)

- 15.4.24 Clay was only encountered during drilling of WSs 7 to 14, 16 and 27 & 29 generally as thin layers of sandy Silts and Clays within Granular Residual Soils. No Cohesive material was encountered in the trial pits.
- 15.4.25 It is considered unlikely that the full footprint of a proposed plot will be underlain by Clay and therefore foundations should be placed entirely within Granular Residual Soils. However, the following paragraphs are provided for guidance.
- 15.4.26 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.
- 15.4.27 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.
- 15.4.28 Foundations should be deepened near trees in accordance with NHBC Standards Chapter 4.2.
- 15.4.29 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.
- 15.4.30 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.

Grenoside Sandstone Bedrock

- 15.4.31 The sandstone bedrock is generally considered to have a safe bearing capacity of at least 300kPa and minimal settlements would be anticipated.
- 15.4.32 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.

Summary of foundation recommendations

- 15.4.33 In summary, the following foundation solutions are likely to be most appropriate (subject to Developer preferences regarding site preparatory works, final levels & costs associated with each foundation option).

Foundation solution(s)	Remarks (influencing factors)
Strips from 0.6m	Granular Residual Soils/Grenoside Sandstone bedrock Deepened where necessary due to depth of Made Ground.
Strips from 0.75m	Low shrinkability Cohesive Residual Soils Deepened where necessary due to tree influence although this will likely take foundation into Granular Residual Soils/Grenoside Sandstone Bedrock
Piles	Would be required if any plots were proposed within the footprint of the former sandstone quarry (but current layout suggests existing trees will be retained). Will also be required area if made ground exceeds >2.5m depth following remediation turnover earthworks.

- 15.4.34 The foundation solutions outlined above will require review on completion of demolition and remediation earthworks (turnover of made ground).
- 15.4.35 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.

15.5 Floor slabs

- 15.5.1 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).
- 15.5.2 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.
- 15.5.3 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.
- 15.5.4 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.

- 15.5.5 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.
- 15.5.6 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.
- 15.5.7 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 2022.

15.6 Designated concrete mixes

- 15.6.1 Designated mixes are considered in BRE SD1⁹ and BS 8500¹⁰. 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.
- 15.6.2 Consequently, the Developer should seek advice from their appointed Structural Engineer.

15.7 Excavations

- 15.7.1 Based on the results of the investigation it is considered unlikely that major groundwater flows will be encountered in shallow excavations.
- 15.7.2 Any groundwater should be controlled in accordance with CIRIA Report R113¹¹.
- 15.7.3 Shallow excavations into natural ground are likely to encounter some overbreak of sidewalls in residual soils due to cobbles and the stability of excavations into made ground was very poor and an allowance should be made for shoring.
- 15.7.4 Bedrock was encountered in the majority of exploratory holes. Based on the exploratory hole logs, excavation greater than 2.5m is likely to prove difficult across the entire site. It would therefore be prudent to allow for excavation of hard rock in any deep excavations such as those that may be required for drainage etc.

⁹ BRE Special Digest 1 (2005) – Concrete in aggressive ground.

¹⁰ 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).

¹¹ CIRIA Report R113 (1986) - Control of Groundwater for Temporary Works.

15.8 Drainage

- 15.8.1 It is understood that Area A is to be utilised as SUDS area (ponds/basins etc) for the proposed development on Areas B & C.
- 15.8.2 Based on observations made during the investigation and in-situ testing, soakaways constructed in natural granular soils or weathered bedrock in Area A might provide a suitable drainage solution for surface water run-off at this site.
- 15.8.3 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*".
- 15.8.4 SUDS options (see CIRIA C753¹² 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.
- 15.8.5 Yorkshire Water have published a guide¹³ for developers and designers outlining their design requirements for surface water attenuation assets.
- 15.8.6 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.
- 15.8.7 Ground conditions must be suitable to allow free drainage from the detention basin all year round by having regard to groundwater levels, and impermeable liners are not to be used.
- 15.8.8 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 Yorkshire Water and/or the appointed drainage designer.
- 15.8.9 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.
- 15.8.10 The guide also discusses required access to flow control chambers, large diameter (i.e. >900mm) surface water storage pipes, and surface water storage tanks.

¹² CIRIA C753 (2015) – The SuDS Manual.

¹³ Design Requirements for Surface Water Attenuation Assets, February 2017.

15.8.11 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.

15.9 Highways

15.9.1 The natural soils present at shallow depth (anticipated formation) are predominantly granular. Based on visual inspection of the natural material, published guidance¹⁴ and tables¹⁵ indicate that the Granular Residual Soil would be expected to provide a CBR value of at least 3%. This value should be verified prior to or during construction.

15.9.2 Made ground is present across Areas B & C and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended.

15.9.3 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) and obstructions (old foundations etc), which represent potential 'hard-spots'.

15.9.4 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.

15.9.5 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.

15.9.6 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.

15.9.7 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.

15.9.8 Crushing of demolition/hardstand/foundation arisings will generate aggregate, which (subject to confirmatory testing) should be suitable for use as unbound pavement materials within the highways.

15.10 External works

15.10.1 Any digital terrain modelling undertaken, or commissioned, by the Developer(s) should be made available to their Engineering Designer prior to issue of an External Works Drawing.

15.10.2 When designing retaining walls, consideration should be given clause 10.2.3 of NHBC standards which states that flexible retaining walls such as gabion and timber structures should not be used to provide support to homes, garages, roads, drives, car parking areas or drainage systems.

¹⁴ CD225 Design for new pavement foundations Revision 1 (Design Manual for Roads and Bridges)

¹⁵ The Structural Design of Bituminous Road, TRRL Laboratory Report 1132 (Table C1, page 36)

16 REDEVELOPMENT ISSUES

16.1 General

16.1.1 This report has presented options, based on the existing site data, 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 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 Given the constraints discussed in Section 8.2 (existing buildings across the majority of the site), a robust post-demolition trial pit investigation will be required before a Remediation Strategy can be finalised.

16.2.5 However, in the meantime, anticipated remediation works are summarised below:

- General site clearance of surface materials and vegetation
- Demolition of existing buildings
- Break-up of slabs and hardstand
- Post demolition investigation of the ground beneath the former buildings and slabs, which were inaccessible during the earlier investigations
- Crushing of all suitable artificial hard material (i.e. concrete/brick etc)
- Turnover (excavation, screening and replacement in engineered layers, with nominal compaction) of the full thickness of made ground to enable:
 - Removal of fuel contamination; with subsequent treatment and/or off-site disposal in Area C.
 - Inspection of the made ground
 - Removal of below ground obstructions
 - Preparation of the ground for highway construction

- 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
- Provision of a minimum 600mm thick cover layer of 'clean' soils in all garden and landscaped areas within Areas B and C

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 It is strongly recommended that the demolition contractor should chase-out all significant buried structures, and survey-in the resultant excavations before making them safe by backfilling. At the very least, relevant features should be surveyed-in before "hiding" them beneath a veneer of rubble. Similarly, it would be prudent to complete a drainage survey prior to blading rubble across the site to leave it safe and secure.

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; i.e. there should be separate stockpiles of: topsoil; grubbed-up concrete hardstand; tarmac; Ash & Clinker; fuel-contaminated soil; excess clean, natural soil arisings; general construction waste etc.

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; only if suitable (i.e. not compressible, rich in deleterious matter etc)
- Isolated beneath the 600mm thick cover layer in garden or landscaped areas
- 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 Good practice guidance

16.4.1 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 C741¹⁶
- EA Pollution Prevention Guidelines¹⁷:
 - PPG6 - Working at construction and demolition sites
 - PPG2 - Above ground oil storage tank
 - PPG7 – The safe operation of refuelling facilities.
 - PPG21 – Incident Response Planning

16.4.2 Site preparatory works associated with this project are likely to involve the re-use of both natural and made ground soils on site and the import of natural soils from another development site. Therefore, the Contractor should prepare a Materials Management Plan (MMP) in accordance with the CL:AIRE Code of Practice (v2, March 2011)¹⁸.

16.4.3 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.

16.5 New utilities

16.5.1 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.

16.5.2 It is recommended that trenches for services 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.

16.5.3 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 Report¹⁹.

16.5.4 This site is 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.

16.5.5 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.

¹⁶ CIRIA C741 (2015) - *Environmental Good Practice on Site*

¹⁷ Whilst this has formally been withdrawn it can still be accessed via the EA archives and provides useful information on managing risks.

¹⁸ *The Definition of Waste: Development Industry Code of Practice. CL:AIRE, 2011.*

¹⁹ UKWIR Report 10/WM/03/21 – '*Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites*'.

16.5.6 However, given the proposed remediation works, the Verification Report should include the results of further testing within 15m of the proposed route(s) of water supply pipes. In the meantime, it is considered likely that will request the use of Protectaline mains, with plastic coated copper house connections, given that residual organic contaminants will still be present post-remediation, albeit at acceptable concentrations.

16.6 Health & safety issues - construction workers

16.6.1 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.

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

16.6.3 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.

16.6.4 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.

16.6.5 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.

16.7 Potential development constraints

- 16.7.1 Topography will require some regrade earthworks to form development platforms for the proposed housing.
- 16.7.2 The existing overheads present 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.
- 16.7.3 It is almost certain that Northern PowerGrid will have restrictions with respect to development in the vicinity of the substations; an easement will probably be required.
- 16.7.4 It is almost certain that Yorkshire Water will have restrictions with respect to development in the vicinity of the sewers along the northern boundary; an easement will probably be required.
- 16.7.5 Deep backfill (see Drawing 4473/3A) is anticipated in the vicinity of the former quarry. Foundation abnormalities associated with this area are likely to be significant. However, the proposed layout suggests existing trees will be retained in this area, with no new dwellings closer than 10m.

17 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

17.1 General

- 17.1.1 The site is located 5.3km southeast of Huddersfield town centre and currently comprises a grassed field (Area A), university halls of residence and wedding venue (Area B), and overgrown derelict land (Area C) all set within a mature woodland.
- 17.1.2 It is understood that consideration is being given to redevelopment of Areas B & C with 2 & 3 storey domestic dwellings, associated gardens, POS, adoptable roads, and sewers. It is understood that Area A is being considered for a SUDS feature (pond/basin etc.)
- 17.1.3 Made Ground was encountered in Areas B & C, generally comprising Made Ground Topsoil or tarmac and concrete hardstand overlying Granular & Cohesive Made Ground with localised areas of Sub-Base, reworked natural ground and Ash & Clinker.
- 17.1.4 Underlying natural ground comprised Granular Residual Soils (sandy Gravels), over Grenoside Sandstone bedrock (weak to strong fine and medium sandstone) from 1.5m depth.

17.2 Mining

- 17.2.1 This site is underlain by Grenoside Sandstone bedrock, and the shallowest coal seams lies at least 100m below the surface. 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 Hazardous gas

- 17.3.1 The site is in an area where < 1% of homes are estimated to be above the radon action level and protective measures are not required.
- 17.3.2 Gas monitoring has been completed and suggests that no special precautions against methane / carbon dioxide gas are required.

17.4 Contamination & remediation

- 17.4.1 Topsoil in Area A contains trace amounts of asbestos fibres. This topsoil is not suitable for reuse in gardens on site. However, it is likely acceptable that this topsoil could be used in the landscaping of the proposed SUDS feature in Area A. Further assessment of the topsoil in this area may conclude it is suitable for reuse in private gardens and landscaping.
- 17.4.2 The Made Ground Topsoil and Made Ground in Areas B & C contain asbestos fibres, lead and DRO. Therefore, where residual made ground remains beneath garden and landscaped areas (i.e. not beneath hardstanding) a 600mm thick surface cover of "clean" soil comprising 500mm subsoil and 100mm topsoil is recommended.
- 17.4.3 Hydrocarbon contamination has been encountered in Area C and this will require delineation and excavation during remediation earthworks, with subsequent on-site treatment or off-site disposal.
- 17.4.4 Testing of tarmac also indicates that at least some is likely to be classified as hazardous waste. Given the volume of tarmac at this site, disposal as hazardous waste has significant cost implications. It may be possible with PAK spray and further laboratory testing to zone areas of tarmac as hazardous and non-hazardous.

17.5 Foundations

- 17.5.1 On completion of Made Ground turnover earthworks, traditional strip and trench fill footings, from a minimum depth of 0.6m, founded within Granular Residual Soils or Grenoside Sandstone bedrock, will likely provide the most suitable foundation solution for proposed new houses.
- 17.5.2 If Cohesive Residual Soil are encountered at founding depth, the depth of foundations will require increasing to 0.75m depth.
- 17.5.3 Foundations will require deepening through Made Ground into natural strata and where made ground is in excess of 2.5m thick, alternative foundation solutions such as piles may need to be considered.
- 17.5.4 It would be prudent to consider creating an area of POS in development proposals over the former sandstone quarry to avoid any issues associated with quarry highwalls.

17.6 Flooding

- 17.6.1 The site lies in Flood Zone 1, where the risk of flooding from rivers or the sea is classified as low.

17.7 Drainage

- 17.7.1 Based on observations made during the investigation and in-situ testing in Area A, soakaways constructed in natural granular soils or weathered bedrock might provide a suitable drainage solution for surface water run-off at this site.
- 17.7.2 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.*"
- 17.7.3 Infiltration rates were more variable across Area C and no testing has been undertaken in Area B due to access constraints.

17.8 Highways

- 17.8.1 Based on visual inspection of the shallow natural materials and published guidance, the Granular Residual Soil should provide a CBR value of at least 3%. This value should be verified prior to or during construction.
- 17.8.2 However, made ground is present across the majority of the site, typically to depths of around 1m, and consultation with the adopting authority, regarding the specification of the highways, is strongly recommended.
- 17.8.3 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.

17.9 Further works

- 17.9.1 Given the constraints discussed in Section 8.2 (existing buildings across the majority of the site) a robust post-demolition trial pit investigation will be required in order to remove residual uncertainties with respect to ground, and provide more definitive recommendations with respect to contamination and foundations.
- 17.9.2 The post demolition investigation should allow for further sampling of both topsoil and tarmac.
- 17.9.3 As the initial soakaway tests yield satisfactory results in Area A, 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.
- 17.9.4 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.
- 17.9.5 Production of a Remediation Strategy & Materials Management Plan

Appendix A

General Notes

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 through 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 BR211¹, and the Public Health England 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 Health Protection Agency (HPA) in 2005; the HPA updated NRPB advice in July 2010². The HPA became part of Public Health England in 2013.

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 NRPB first indicated which parts of the country should be regarded as radon Affected Areas in 1990. A more detailed mapping method was developed by the HPA in conjunction with the British Geological Survey in 2007³. 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, Public Health England 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.

¹ BRE Report BR211, 2015: "Radon: guidance on protective measures for new buildings.

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

³ Miles JCH, Appleton JD, Rees DM, Green BMR, Adlam KAM and Myers AH (2007). Indicative Atlas of Radon in England and Wales. Chilton, HPA-RPD-033.

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.

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 stones¹ – 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 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 4°C, 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.

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:

$$I'p = Ip * (\% < 425\mu\text{m}/100)$$

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 SO₄ 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 ϕ') 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 ϕ') 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 (SO₄), 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 C₆ to C₁₀). Also referred to as PRO – Petroleum Range Organics
- DRO – Diesel Range Organics (typically C₁₀ to C₂₈)
- LRO - Lubricating Oil Range Organics (typically C₂₈ to C₄₀)
- MRO – Mineral Oil Range Organics (typically C₁₈ to C₄₄)

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 C₅-C₄₀, whereas others define TPH as C₁₀-C₃₀.

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 C₄ to C₅ 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 C₁₀ to C₄₀ (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 C₆ to C₈, aromatic C₁₀ to C₁₂ 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)	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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	
Cu			100		100	100	100	Based on phytotoxic risks as plants are the more sensitive receptor (Cu is pH dependant)
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	Scenario E based on professional judgement and lower than calculated value.
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
Diesel Range Organics			215	218	215	^5,000	1,429	^Based on professional judgement and lower than calculated value
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 study¹

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 C4SLs 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 physicochemical 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.

$$HI = \sum_{i=1}^n HQ F_i = \frac{\sum_{i=1}^n \text{Measured concentration } F_i \text{ (}\mu\text{g kg}^{-1}\text{)}}{\sum_{i=1}^n \text{SGV } F_i \text{ (}\mu\text{g kg}^{-1}\text{)}}$$

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

Statistical Assessment

Current UK guidance is provided by CL:AIRE², 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 heterogeneous 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 ICRCCL 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 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

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, 1999ⁱⁱⁱ

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.

Other relevant UK guidance includes:

- BS8485:2015+A1:2019 – Code of Practice for the characterisation & remediation from ground gas in affected developments.
- BS8576:2013 Guidance on investigations for ground gas – permanent gases and volatile organic compounds
- 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
- Wilson, Card & Haines (CIEH, 2008) The Local Authority Guide to Ground Gas
- CL:AIRE Research Bulletin RB17 (November 2012) A Pragmatic Approach to Ground Gas Risk Assessment
- CL:AIRE Research Bulletin RB13 (February 2011) The Utility of Continuous Monitoring in Detection & Prediction of 'Worst-Case' Ground Gas Concentration
- BRE\Environment Agency Report BR 414 (2001) – "Protective Measures for housing on gas-contaminated land".
- YALPAG (December 2016) - Verification Requirements for Gas Protection Systems - Technical Guidance for Developers, Landowners and Consultants.
- Environment Agency Report LFTGN 03 - Guidance on the management of landfill gas, June 2014

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 x 1.50m x 2.50m, with a total room volume of 5.63m³ 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.

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



Reproduced from OS Explorer map 1:25,000 scale by permission of Ordnance Survey on behalf of The Controller of Her Majesty's Stationery Office. Crown copyright. All rights reserved. Licence number 100049696.



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CLIENT

UBRIQUE
INVESTMENTS
LIMITED

JOB TITLE

STORTHES HALL,
KIRKBURTON

DRAWING TITLE

SITE LOCATION
PLAN

DRAWN

JBR

DATE

13/07/2022

CHECKED

GLM

DATE

13/07/2022

STATUS

FOR COMMENT

DRAFT

FOR APPROVAL

FINAL

SCALE

1:25,000

SHEET

A4

DRAWING NO.

4473/1

REVISION



NOTES
 REPRODUCED FROM PARKER PEEL
 ARCHITECTURAL'S DRAWING REF. 1826-SI-03
 DATED JULY 2023
 — APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE



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 Tel 01937 545330

CLIENT
 UBRIQUE
 INVESTMENTS
 LIMITED

JOB TITLE
 STORTHES HALL,
 KIRKBURTON

DRAWING TITLE
 PROPOSED SITE LAYOUT

DRAWN JBR	DATE 25/07/2023	STATUS FOR COMMENT <input type="checkbox"/> FOR APPROVAL <input type="checkbox"/> DRAFT <input type="checkbox"/> FINAL <input checked="" type="checkbox"/>
CHECKED GLM	DATE 25/07/2023	

SCALE 1:2000	SHEET A3	DRAWING NO. 4473/2	REVISION
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NOTES

- WOODLAND
- GRASS & OVERGROWN AREAS
- BUILDING
- TARMAC HARDSTAND
- BLOCK SURFACING & CONCRETE HARDSTAND
- APPROXIMATE SITE BOUNDARY
- APPROXIMATE AREA BOUNDARY

	A UPDATED SITE BOUNDARY	25/07/2023
REV.	DESCRIPTION	DATE



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CLIENT

UBRIQUE INVESTMENTS LIMITED

JOB TITLE

STORTHES HALL, KIRKBURTON

DRAWING TITLE

SITE AREAS

DRAWN	JBR	DATE	13/07/2022	STATUS	
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				DRAFT	<input type="checkbox"/>
				FINAL	<input checked="" type="checkbox"/>
SCALE	1:2,000	SHEET	A3	DRAWING NO.	4473/2
				REVISION	A



- NOTES
- WOODLAND
 - GRASS & OVERGROWN AREAS
 - BUILDING
 - TARMAC HARDSTAND
 - BLOCK SURFACING & CONCRETE HARDSTAND
 - APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE
A	UPDATED SITE BOUNDARY	25/07/2023



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CLIENT
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JOB TITLE
STORTHES HALL, KIRKBURTON

DRAWING TITLE
SITE FEATURES

DRAWN	JBR	DATE	13/07/2022	STATUS	FOR COMMENT <input type="checkbox"/>
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- NOTES
- CURRENT WOODLAND/TREES
 - CURRENT TARMAC HARDSTAND
 - CURRENT GRASS & OVERGROWN AREAS
- HISTORICAL FEATURES SUPERIMPOSED FROM 1891 OS PLAN (QUARRIES) 1977 OS PLANS (BUILDINGS/GLASSHOUSES) & 1985 OS PLAN (TANKS). HISTORICAL BUILDINGS SUPERIMPOSED FROM 1950s ARCHIVE PLAN
- GLASS/GREENHOUSES & CONSERVATORIES/ORANGERIES
 - HISTORIC BUILDING
 - QUARRY
 - HISTORIC TUNNEL/SUBWAY
 - HISTORICAL (FUEL) STORAGE TANKS
 - APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE
A	UPDATED SITE BOUNDARY	25/07/2023



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JOB TITLE
STORTHES HALL, KIRKBURTON

DRAWING TITLE
HISTORICAL SITE FEATURES

DRAWN	JBR	DATE	31/08/2022	STATUS	FOR COMMENT <input type="checkbox"/>
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SCALE	1:2,500	SHEET	A3	DRAWING NO.	4473/3A	REVISION	A
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NOTES

- WOODLAND
- GRASS & OVERGROWN AREAS
- BUILDING
- TARMAC HARDSTAND
- BLOCK SURFACING & CONCRETE HARDSTAND
- APPROXIMATE SITE BOUNDARY
- LOCATION & ORIENTATION OF PHOTOGRAPH
- 1 PHOTO REFERENCES

A	UPDATED SITE BOUNDARY	25/07/23
REV.	DESCRIPTION	DATE



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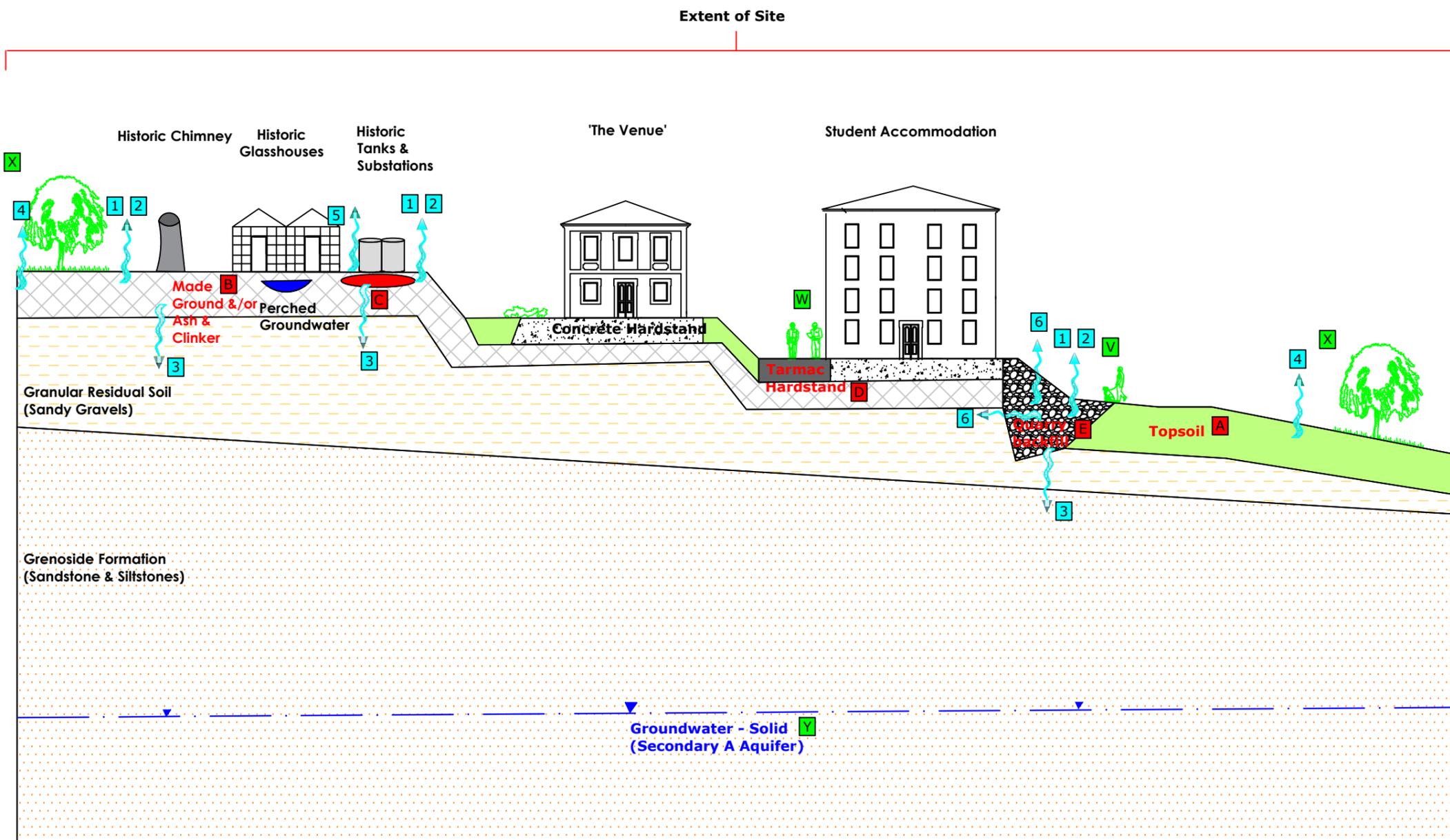
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STORTHES HALL, KIRKBURTON

DRAWING TITLE

SITE PHOTOGRAPHS

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SCALE	1:2,000	SHEET	A3	DRAWING NO.	4473/4
				REVISION	A



SOURCES	
A	TOPSOIL (INORGANICS)
B	MADE GROUND (INORGANICS)
C	LEAKAGE/SPILLAGE (ORGANICS & PCBs)
D	TARMAC (BaP)
E	QUARRY BACKFILL (HAZ. GAS)

PATHWAYS	
1	DERMAL CONTACT
2	INGESTION/INHALATION
3	LEACHING OF CONTAMINANTS
4	UPTAKE BY PLANTS
5	VOLATILISATION
6	MIGRATION OF GAS

RECEPTORS	
V	END USERS (RESIDENTS)
W	SITE WORKERS
X	VEGETATION
Y	GROUNDWATER

NOTES

REV.	DESCRIPTION	DATE



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STORTHES HALL, KIRKBURTON

PRELIMINARY CONCEPTUAL SITE MODEL

DRAWN	JBR	DATE	13/07/2022	STATUS	FOR COMMENT <input type="checkbox"/>
CHECKED	GLM	DATE	13/07/2022	FOR APPROVAL	<input type="checkbox"/>
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SCALE	Not to scale	SHEET	A3	DRAWING NO.	4473/5
				REVISION	



NOTES

- GRASS & OVERGROWN AREAS
- BUILDING
- TARMAC HARDSTAND
- BLOCK SURFACING & CONCRETE HARDSTAND
- HISTORICAL (FUEL) STORAGE TANKS
- TRIAL PIT LOCATION
- SOAKAWAY PIT LOCATION
- WINDOW SAMPLE LOCATION
- APPROXIMATE SITE BOUNDARY

EXPLORATORY HOLE LOCATIONS BASED ON DATA FROM A HAND-HELD GPS (+/- 3M ACCURACY)

REV.	DESCRIPTION	DATE
A	UPDATED SITE BOUNDARY	25/07/2023



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STORTHES HALL, KIRKBURTON

EXPLORATORY HOLE LOCATIONS

DRAWN	JBR	DATE	25/07/2022	STATUS	
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SCALE	1:2,000	SHEET	A3	DRAWING NO.	4473/6
				REVISION	A



- NOTES
- CURRENT WOODLAND/TREES
 - CURRENT TARMAC HARDSTAND
 - CURRENT GRASS & OVERGROWN AREAS
- HISTORICAL FEATURES SUPERIMPOSED FROM 1891 OS PLAN (QUARRIES) 1977 OS PLANS (BUILDINGS/GLASSHOUSES) & 1985 OS PLAN (TANKS). HISTORICAL BUILDINGS SUPERIMPOSED FROM 1950s ARCHIVE PLAN
- GLASS/GREENHOUSES & CONSERVATORIES/ORANGERIES
 - HISTORIC BUILDING
 - QUARRY
 - HISTORIC TUNNEL/SUBWAY
 - HISTORICAL (FUEL) STORAGE TANKS
 - APPROXIMATE SITE BOUNDARY

REV. A	UPDATED SITE BOUNDARY	25/07/2023
REV.	DESCRIPTION	DATE



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CLIENT
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JOB TITLE
STORTHES HALL, KIRKBURTON

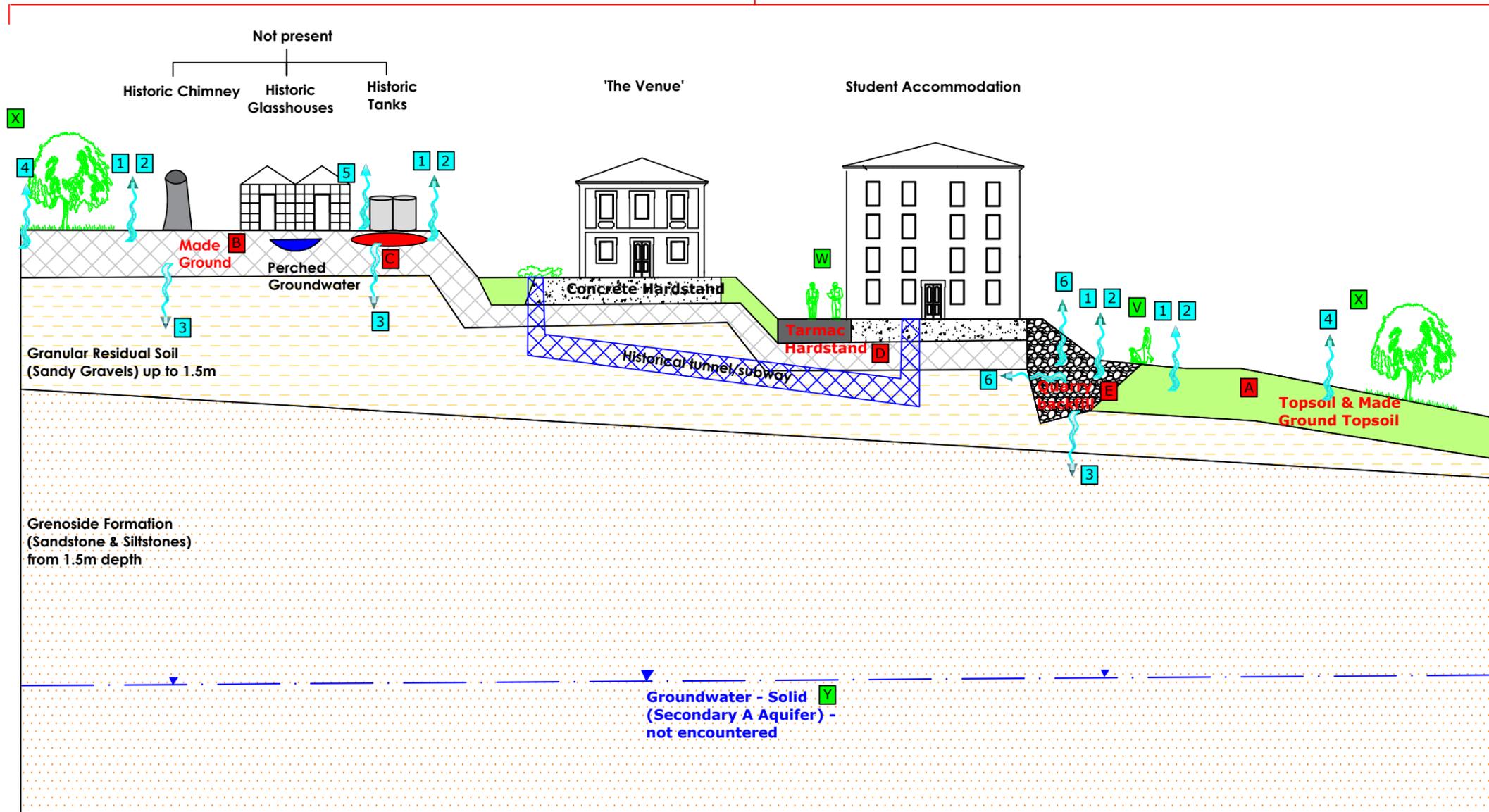
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SCALE	1:2,500	SHEET	A3	DRAWING NO.	4473/6A	REVISION	A
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Extent of Site



SOURCES	
A	TOPSOIL (INORGANICS)
B	MADE GROUND (INORGANICS)
C	LEAKAGE/SPILLAGE (ORGANICS & PCBs)
D	TARMAC (BaP)
E	QUARRY BACKFILL (HAZ. GAS)

PATHWAYS	
1	DERMAL CONTACT
2	INGESTION/INHALATION
3	LEACHING OF CONTAMINANTS
4	UPTAKE BY PLANTS
5	VOLATILISATION
6	MIGRATION OF GAS

RECEPTORS	
V	END USERS (RESIDENTS)
W	SITE WORKERS
X	VEGETATION
Y	SURFACE WATERS
Z	GROUNDWATER

NOTES

REV.	DESCRIPTION	DATE

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CLIENT

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JOB TITLE

STORTHES HALL, KIRKBURTON

DRAWING TITLE

REVISED CONCEPTUAL SITE MODEL

DRAWN	JBR	DATE	31/08/2022	STATUS	FOR COMMENT <input type="checkbox"/>
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SCALE	Not to scale	SHEET	A3	DRAWING NO.	4473/7	REVISION	
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NOTES

-  VISUAL AND OLFACTORY EVIDENCE OF HYDROCARBON CONTAMINATION
-  DRO CONCENTRATION ABOVE TIER 1 SCREENING VALUE
- 
-  HISTORICAL (FUEL) STORAGE TANKS

REV.	DESCRIPTION	DATE
A	UPDATED SITE BOUNDARY	25/07/2023



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JOB TITLE

STORTHES HALL,
KIRKBURTON

DRAWING TITLE

HYDROCARBON CONTAMINATION

DRAWN	JBR	DATE	25/08/2022	STATUS	
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SCALE	1:2,000	SHEET	A3	DRAWING NO.	4473/9
				REVISION	A

Appendix C
Commission

Subject: Storthes Hall, Kirkburton, Huddersfield

From: Reg
Sent: 21 June 2022 09:55
To: Guy Titchmarsh <guy@titchmarshandbagley.com>
Subject: Storthes Hall, Kirkburton, Huddersfield

Morning Guy

Thanks for your instruction, we'll make a start on the desk study next week, and George will advise shortly with regards to fieldwork dates.

We'll aim to have final Report with you late August (but preliminary findings likely end July).

We note your comment regarding Clauses 10.1 & 10.2 of our T&C and can confirm that we are able to provide £5M PI with a liability period of 12 years for our proposed works.

Any queries, please call.

Regards

Mark Perrin
Director
Lithos Consulting Ltd
M 07703 396 635
DD 01937 545 331
www.lithos.co.uk



From: Guy Titchmarsh <guy@titchmarshandbagley.com>
Sent: 21 June 2022 09:49
To: Reg <Reg@lithos.co.uk>
Subject: FW: Storthes Hall, Kirkburton, Huddersfield

Reg

Further to our below email, We wanted to address a couple of points within your T&Cs. The points we are referring to are 10.1 and 10.2. Please can you confirm that Lithos are willing to put their full £5M PI cover in place for this job (not 20x price of the work as per the T&Cs) and also that the cover is valid for 12 years and not the 6 referred to in the same at 10.2.

If you could please confirm you are happy to proceed on that basis.

Regards

Guy.

Guy Titchmarsh

Director



First Floor, Kenneth Hodgson House, 18 Park Row, Leeds LS1 5JA

Telephone: 0113 898 0745

Mobile: 07946 510 343

www.titchmarshandbagley.com

From: Guy Titchmarsh

Sent: 20 June 2022 12:22

To: Reg (Reg@lithos.co.uk) <Reg@lithos.co.uk>

Subject: Storthes Hall, Kirkburton, Huddersfield

Reg

Further to our conversation last week and your revised quote, attached above:

Please take this email as formal instruction for you to act on behalf on my clients Ubrique Investments to carry out the Geo-Technical site investigation, as per the terms of your attached quote.

The instructing Entity is as follows:

Ubrique Investments, c/o South Street Asset Management, Queen Anne Mansions, 86/87 Wimpole Street, London W1G 9RL. Company Number: 39364 Guernsey. The points of contact, aside from me, are cc'd into this email.

Prior to going on site, we would ask you to please liaise with our FM on the ground as the halls are still in use. This is particularly important in relation to the location of pits and holes and the making good of the same. You are still good to undertake the percolation tests in that field to the North of the buildings aren't you?

Steve's name and contact details are below:

Steven Moore

Facilities and Support Manager

[+44\(0\)7717733672](tel:+44(0)7717733672)

stevenmoore@southstreetam.co.uk

<http://www.southstreetam.co.uk>

Please do not hesitate to contact me if you have any questions.

Regards

Guy.

Guy Titchmarsh

Director



First Floor, Kenneth Hodgson House, 18 Park Row, Leeds LS1 5JA

Telephone: 0113 898 0745

Mobile: 07946 510 343

www.titchmarshandbagley.com

To: Reg; Guy Titchmarsh
Subject: RE: Storthes Hall, Kirkburton

From: Reg
Sent: 06 June 2022 12:42
To: 'Guy Titchmarsh' <guy@titchmarshandbagley.com>
Subject: Storthes Hall, Kirkburton

Guy

SI quote attached (£**). As always, this allows for a robust scope of works (including soakaway testing & gas monitoring) that should enable you to receive bids that are unconditional with respect to ground and discharge ground-related planning conditions.

However, constraints associated with existing buildings, operations and underground service runs, will mean a supplementary, post-demolition ground investigation is required.

We would expect to be on site within 3 weeks of instruction, with a summary of initial findings issued within 2 to 3 days of fieldwork completion. Our final SI Report should be available within 8 weeks of instruction (although a quicker turnaround might be possible).

Any queries, please call.

Regards

Mark Perrin
Director
Lithos Consulting Ltd
M 07703 396 635
DD 01937 545 331
www.lithos.co.uk



From: Guy Titchmarsh <guy@titchmarshandbagley.com>
Sent: 24 May 2022 11:35
To: Reg <Reg@lithos.co.uk>
Subject: Storthes Hall, Kirkburton

Reg

As discussed, please quote for a Intrusive Phase 2 SI on the above. We could also do with some soakaway suitability work doing as well especially on the field to the East of the main development area/ brownfield element of the site.

Best

Guy

Guy Titchmarsh

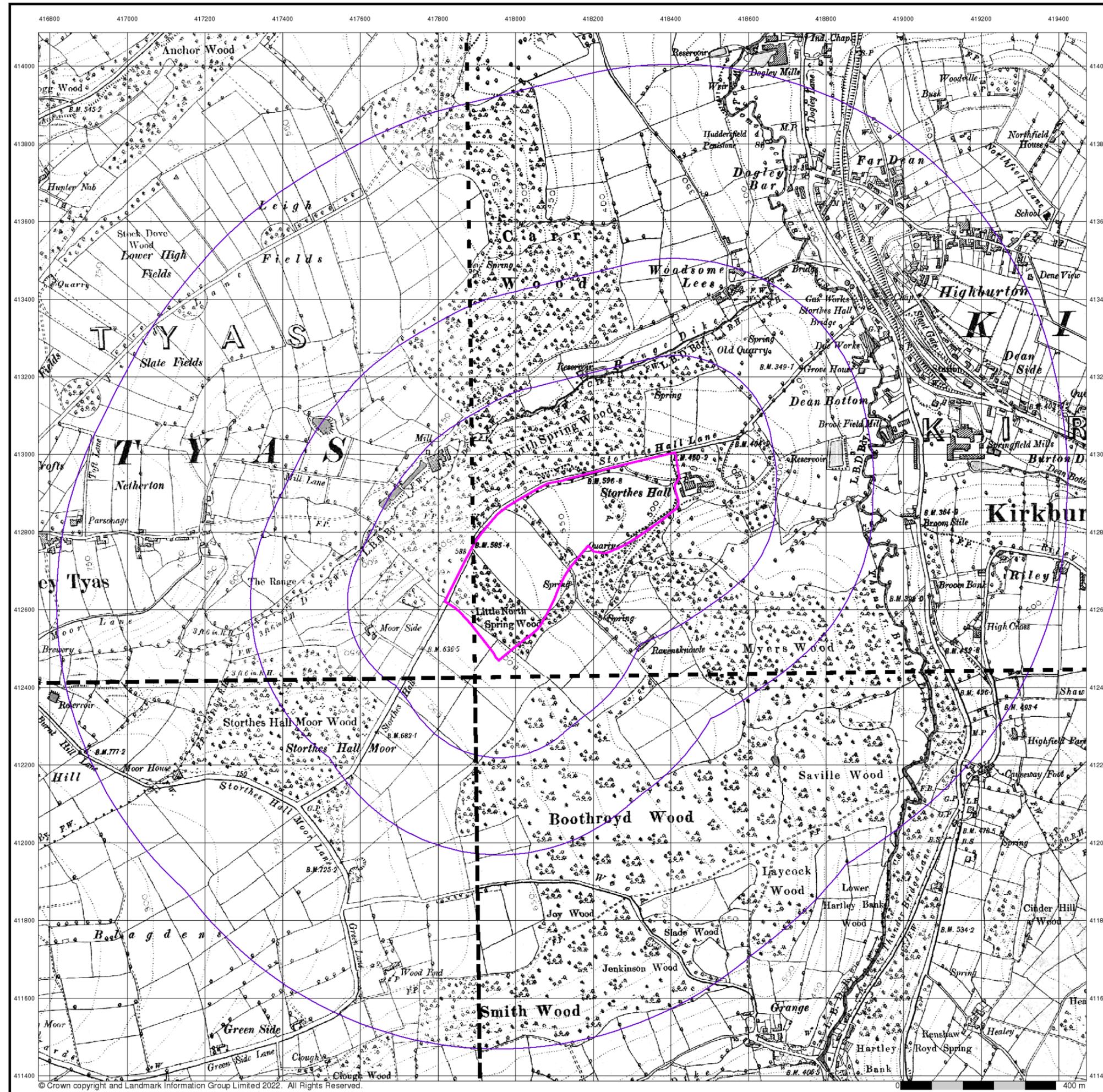
Director



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Mobile: 07946 510 343
www.titchmarshandbagley.com

Titchmarsh & Bagley is a trading name of Titchmarsh & Co Ltd.
Titchmarsh & Co Ltd is a limited company registered in England and Wales.
Registration number: 06725252.

Appendix D
Historical OS Plans



Yorkshire

Published 1894

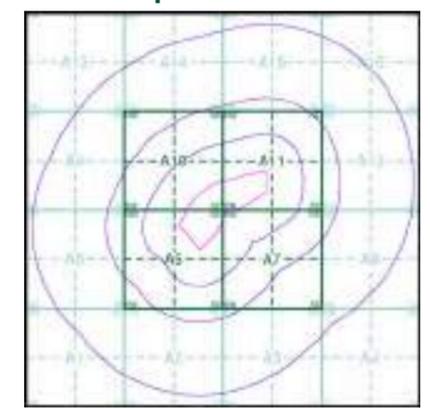
Source map scale - 1:10,560

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; these maps were used to update the 1:10,560 maps. The published date given therefore 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. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)

260NE 1894 1:10,560	261NW 1894 1:10,560
260SE 1894 1:10,560	261SW 1894 1:10,560

Historical Map - Slice A



Order Details

Order Number: 297903689_1_1
 Customer Ref: PO19359/JW/4473
 National Grid Reference: 418120, 412760
 Slice: A
 Site Area (Ha): 14.27
 Search Buffer (m): 1000

Site Details

Site at 418030, 412740



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Yorkshire

Published 1907 - 1908

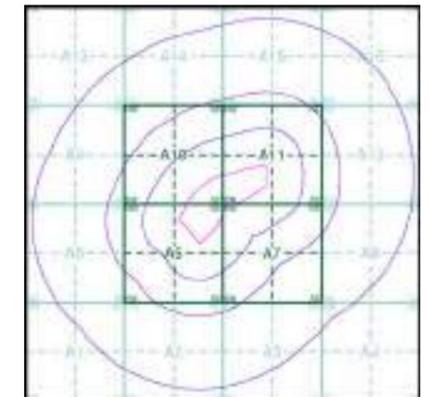
Source map scale - 1:10,560

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; these maps were used to update the 1:10,560 maps. The published date given therefore 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. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)

260NE 1908 1:10,560	261NW 1908 1:10,560
260SE 1907 1:10,560	261SW 1908 1:10,560

Historical Map - Slice A



Order Details

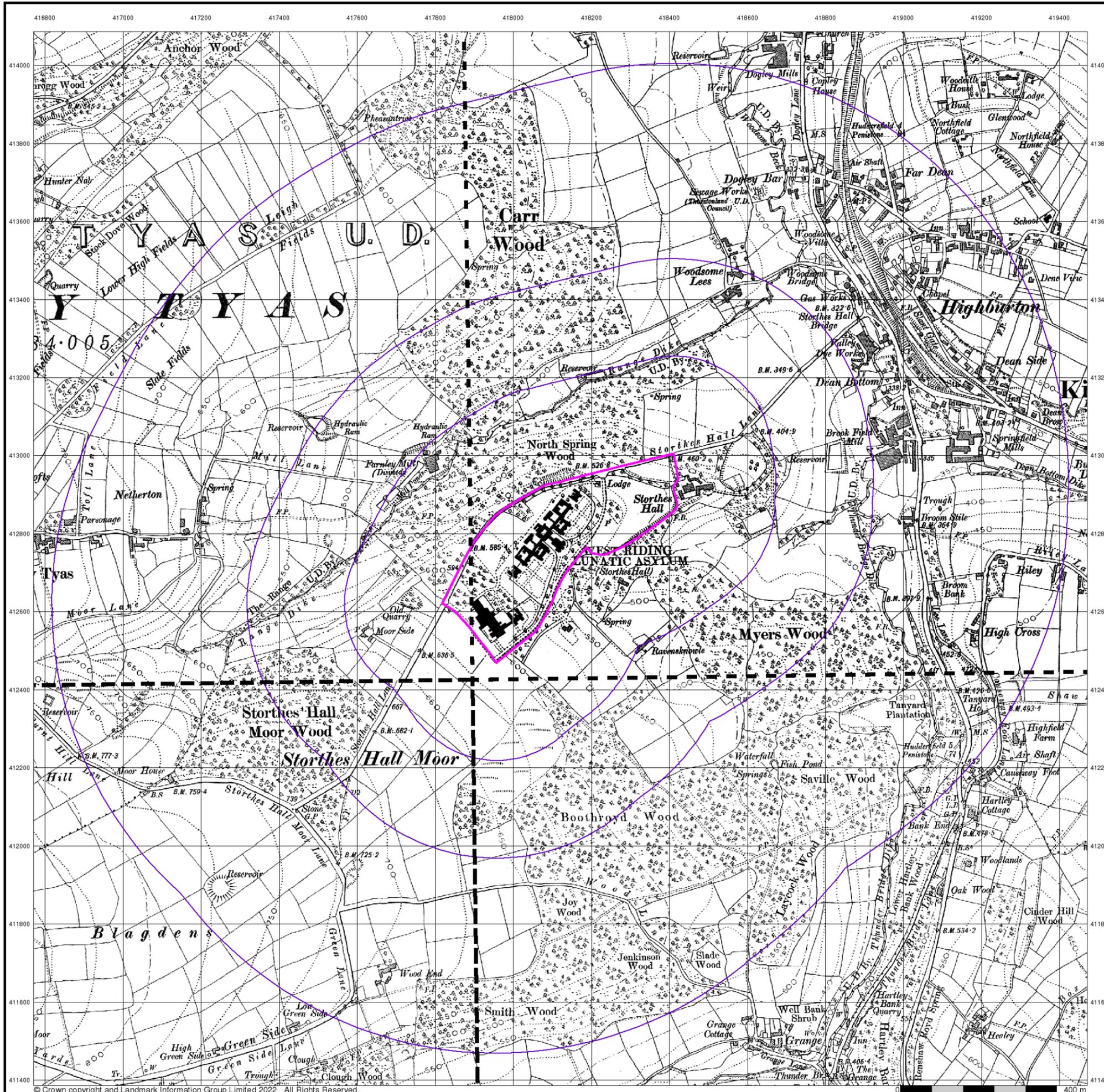
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 Slice: A
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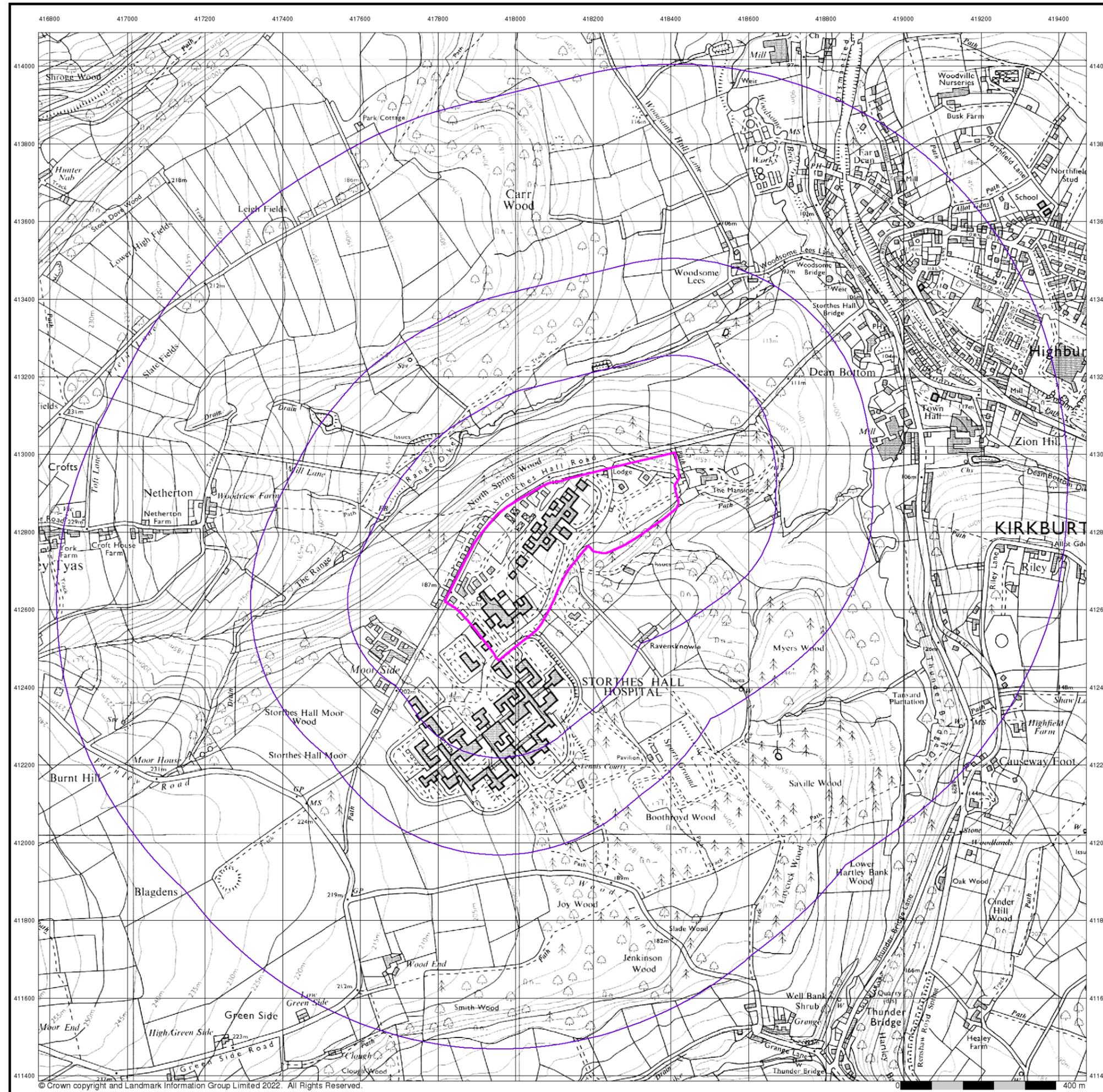
Site Details

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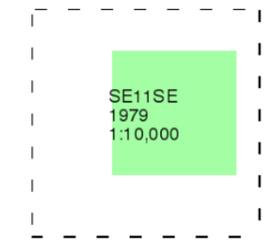




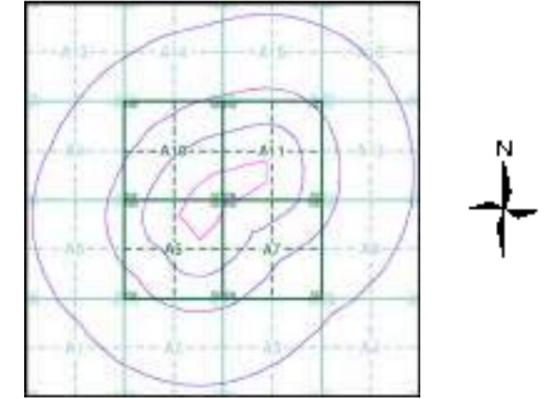
Ordnance Survey Plan
Published 1979
Source map scale - 1:10,000

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; these maps were used to update the 1:10,560 maps. The published date given therefore 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. In the late 1940's, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)



Historical Map - Slice A



Order Details

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