LITHOS

Remediation Strategy

Land at Black Cats, Blackmoorfoot Road, Huddersfield

For Vistry Homes and Countryside Partnerships, Miller Homes (the Developers) & Empire Knight Group (the Vendor)

Report no: 4486/3C

Date: October 2024

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REMEDIATION STRATEGY
for land at
BLACK CATS, BLACKMOORFOOT ROAD, HUDDERSFIELD

1 INTRODUCTION

1.1 The commission and brief

1.1.1 Lithos Consulting Limited has been commissioned by Vistry Homes, Countryside Partnerships, Miller Homes (the Developers) & Empire Knight Group (the Vendor) to prepare a Remediation Strategy for land at Black Cats, Blackmoorfoot Road, Huddersfield.

1.1.2 Lithos has already issued the following reports:

- Preliminary Geoenvironmental Appraisal: Land and Black Cats, Blackmoorfoot Road, Huddersfield. Report No. 4486/1, dated April 2023
- Geoenvironmental Appraisal: Land at Black Cats, Blackmoorfoot Road, Huddersfield. Report No. 4486/2B, dated December 2023

1.1.3 The appointed Remediation Contractor will need to familiarise themselves with the above Reports, and comply with all relevant recommendations contained therein.

1.1.4 This document is a revision of the Remediation Strategy (Report 4486/3B) issued by Lithos in June 2024; Report 4486/3B is now superseded. Document 4486/3B took into account discussions with a Senior Technical Officer at Kirklees Council and comments made by the Developers. Revisions to this document have been made to Drawings 4486/2A and to Sections: 1.2, 6.9 and 6.19..

1.1.5 This document outlines the remediation objectives necessary to protect environmental receptors, and render the site suitable for the proposed development. A Method Statement should be prepared in order to detail how the objectives will be achieved.

1.1.6 The Method Statement should be accompanied by a Designer's Risk Assessment in accordance with the CDM Regulations, 2015. The Method Statement and Risk Assessment should be submitted to, and approved by the Engineer.

1.2 The proposed development

1.2.1 The proposed development comprises 700 domestic dwellings, a 70-bed care home, associated gardens, POS, adoptable roads and sewers within the red line area shown on Drawing Ref. 4486/3 in Appendix A. A local centre and extra care facility are proposed in the south of site.

1.2.2 A site layout has been provided by the Developers (Drawing reference n2114 007 Rev H, dated 24th April 2024 which is reproduced as Drawing 4486/2 in Appendix A.

1.2.3 The site can be divided into two areas:

- **Area A:** Fireworks Factory – located in the centre of site and comprising a range of buildings, roadways and storage yards. Three residential buildings are located in the centre south, off Standard Drive. Total area of 17.8ha (60% of the total red line area).
- **Area B:** Agricultural land – located in the east, west and south. Total area of 11.5ha (c.40% of the total red line area)

1.2.4 Given the absence of any significant contamination in Area B, a remediation strategy covering this area of site is not considered necessary. Consequently, this Remediation Strategy **only refers to Area A**.

1.2.5 Site areas are shown on Drawing 4486/2A included in Appendix A. Individual plot numbers where remediation is required and where it is not required are presented in the tables below.

Vistry plots where remediation is required	Vistry plots where remediation is not required
48 – 68	1 - 47
74 – 80	69 - 73
86 – 238	81 - 85
244 – 250	239 - 243
267 – 274	251 - 266
277 – 381	275 - 276
403 – 469	382 - 402

Miller plots where remediation is required	Miller plots where remediation is not required
60 – 91	1 – 59
187 - 215	92 - 186
-	216 - 231

1.2.6 Ground conditions beneath Area A are complex, and multiple foundation solutions have been recommended, as summarised in the table below.

Foundation solution(s)	Remarks
Strips from a minimum 0.6m depth	Beyond former sandstone quarries and where made ground is <2.5m thick following turnover earthworks.
Raft or heavily reinforced strip foundations on engineered fill	Within the footprint of former quarries and beyond influencing distance of quarry highwalls following turnover earthworks and ground improvement techniques.
Piles	Plots over/or adjacent to the quarry highwalls where significant differential settlement and thickness of fill anticipated (i.e., highwalls). Due to significant obstructions (boulders) throughout the quarry backfill, piles will require pre-boring, casing and socketing into competent sandstone bedrock.

1.2.7 Access to the development will be from Blackmoorfoot Road in the south.

2 BACKGROUND

2.1 Site description

2.1.1 Site details are summarised below.

Detail	Remarks
Location	3.5 km southwest of Huddersfield town centre
NGR	SE 113 147
Area	29.3 ha (72 acres)
Known live services	Underground electric, sewer, drainage It is understood all electric services were disconnected during the soft strip of buildings

2.1.2 The site location and current salient features are shown on Drawings 4486/1 and 4486/3 in Appendix A.

2.2 Ground investigation

2.2.1 Following completion of a desk study which culminated in a preliminary conceptual site model, ground investigation fieldwork within Area A was supervised by Lithos between the 24th August and 19th September 2023. It comprised 136 trial pits, 20 trial trenches, 11 foundation pits, 16 window sample boreholes, 50 probeholes & stitch lines and 33 gas/groundwater monitoring wells.

2.2.2 The following suites of chemical testing were undertaken on made ground:

- 95 x samples of made ground (pH, water soluble boron, total metals, calorific value, water soluble sulphate, chloride, nitrate and magnesium, TOC, speciated PAH and banded TPH
- 102 x samples of made ground for Asbestos ID (fibres within made ground)
- 6 x ACM spot samples for Asbestos ID (ACM fragments)
- 37 x samples of made ground for sulphur and sulphide
- 10 x samples of made ground for phenol, antimony and potassium
- 6 x samples of made ground for a site-specific Fireworks and Explosive Suite
  - 2,4,6-trinitrophenyl-N-methylnitramine (tetryl)
  - 2,4,6-trinitrotoluene (2,4,6-TNT), 2,4-dinitrotoluene (2,4-DNT)
  - 2,6-dinitrotoluene (2,6-DNT)
  - Cyclotetramethylenetetranitramine (HMX)
  - Pentaerythritol tetranitrate (PETN)
  - 2,4,6-trinitrophenol (picric acid)
  - Picrite (nitroguanidine)
  - Ethylene glycol dinitrate (EGDN)
  - Nitroglycerine (NG)
  - Nitrocellulose (NC)
  - Chlorate
  - Perchlorate

2.2.3 The following geotechnical testing was also undertaken:

- 5 x moisture content and atterberg tests
- 75 x pH and water soluble sulphate
- 18 x particle size distribution
- 18 x compaction tests

2.2.4 Gas monitoring wells have been installed at 33 locations and will be monitored on 9 visits over a 6-month period. To date, two visits have been undertaken.

Made Ground

2.2.5 Made ground was encountered in all but 13 trial pits across Area A, varying in thickness from 0.5m to 24.3m (maximum depth of recorded quarries). Beyond the areas of quarrying, made ground thicknesses ranged from 0.1m to 3.7m (average depth to base of 1.0m). Ground conditions are variable and can be divided into two distinct sub-areas; **within quarries** and **beyond quarries**.

2.2.6 Review of the exploratory hole logs presented in the Geoenvironmental Appraisal (ref. 4486/2B, dated December 2023) indicates that the bulk of the made ground can be classified as one of the following types, as summarised below.

- **Made Ground Topsoil**: encountered from surface in 14 trial pits within quarries and 10 trial pits beyond quarries. The maximum depth to base of 1.4m was excavated within a soil mound, average depth to base of 0.3m.
- **Macadam Hardstand**: encountered from surface in 38 trial pits within quarries and 33 trial pits beyond quarries. Maximum depth to base of 0.2m, average depth to base of 0.1m.
- **Concrete Hardstand**: encountered from surface in 7 trial pits within quarries and 9 trial pits beyond quarries. Thickness ranging from 0.05m to 0.2m, the majority of which was reinforced.
- **Sub-base**: encountered in 12 trial pits within quarries and 26 trial pits beyond quarries beneath macadam hardstand to between 0.2m and 0.7m depth. Comprised a gravel of sandstone or limestone.
- **Brickfill**: encountered in TP322 (beyond quarries) between 0.2m and 0.3m depth.
- **Reworked Natural**: within the quarries reworked natural ground was only encountered in TP428 beneath Made Ground Topsoil between 0.3m and 0.9m depth and comprised an orangish brown gravelly fine to coarse Sand. Beyond quarries, Reworked Natural Ground was encountered in 15 trial pits to depths of between 0.8m and 2.0m.
- **Granular Made Ground**: encountered in 35 trial pits within quarries and 44 trial pits beyond quarries to a maximum depth of 3.0m, average depth to base of 0.8m. Typically comprised a sandy Gravel of mixed lithologies including sandstone, brick, concrete, clinker, red shale, coal, limestone, mudstone and tarmac.
- **Cohesive Made Ground**: encountered in 4 trial pits within quarries and 4 trial pits beyond quarries to a maximum depth of 3.7m, average depth to base of 1.8m. Typically comprised a sandy Clay with gravel of mixed lithologies including brick, sandstone, concrete, metal, glass and wood.
- **Ash & Clinker**: encountered in 29 trial pits within quarries and 13 trial pits beyond quarries to a maximum depth of 4.9m, average depth to base of 1.8m. Typically comprised a fine to coarse Sand with gravel of clinker, tarmac, burnt shale and coal.
- **Quarry Backfill**: Sand and/or Gravel with a high cobble content. Encountered in 75 trial pits/trenches to a maximum depth of 5.0m in machine excavated pits and to a maximum depth of 24.3m in probeholes.

Obstructions

2.2.7 Historical plans and previous reports show that buildings have been present on about 6% of the total site area (10% of Area A). Furthermore, concrete and tarmac hardstand, which is typically 100mm thick, covers approximately 112,000m^2.

2.2.8 Drawing 4486/3 shows the footprints of the buildings, and areas of hardstand.

2.2.9 Frequent **boulders** (usually sandstone) up to 2.5m in diameter were encountered during trial pitting. The presence of boulders was also noted throughout the quarry backfill during rotary probehole drilling.

2.2.10 A total of 11 trial pits were excavated adjacent to buildings to determine their **foundation depths**. Concrete foundations were encountered to depths of between 0.1m and 0.4m depth. In addition, 16 window sample boreholes were drilled within a selection of buildings to assess **floor slab thickness**. Concrete floor slabs were between 0.14m and 0.19m thick. **Voids** (potential basements) were encountered beneath building 166F and 166D (WS308 & WS309).

Natural ground

2.2.11 Natural ground was encountered in the majority of the exploratory holes outside quarry footprints, and typically comprised:

- **Topsoil**: encountered in 13 trial pits beyond quarries to depths of between 0.1m and 0.6m (average depth to base of 0.3m). Typically comprised a sand with gravel of sandstone.
- **Relict Topsoil**: within the footprint of the quarries. Typically comprised a dark brown silty Sand/silty Clay with occasional rootlets.
- **Granular Residual Soil**: encountered beneath quarry backfill in 10 trial pits to depths of between 1.3m and 3.8m (average depth to base of 2.3m). Beyond areas of quarrying Granular Residual Soils were encountered in 150 trial pits/trenches to depths of between 0.9m and 3.4m (average depth to base of 1.9m).
- **Cohesive Residual Soil**: encountered within areas of quarrying to depths of between 2.3m and 3.7m, average depth to base of 3.0m. Encountered beyond areas of quarrying to depths of between 0.9m and 2.6m, average depth to base of 1.6m.

2.2.12 **Rough Rock Sandstone (bedrock)** was encountered and excavated to depths of between 0.2m and 3.0m. Where encountered, trial pits typically refused.

Groundwater

2.2.13 No significant inflows of groundwater were encountered within Area A during the investigation.

2.2.14 Dip data to date (2 of 9 monitoring visits) suggests there is some isolated **perched water** within Granular Residual Soils and Quarry Backfill material.

2.2.15 Based on the findings of the intrusive investigation and monitoring undertaken to date. The groundwater table is anticipated to lie at depth within bedrock.

Mining

2.2.16 The site is located beyond the Coal Authority's defined coalfields.

Quarrying

2.2.17 Multiple quarries are located within and within the vicinity of the site, most of which are now disused and have been backfilled.

2.2.18 A total of 76 deep probeholes, 18 stitch lines and 20 trial trenches have been undertaken within Area A to investigate the quarry depths and highwalls.

2.2.19 The depth to base of the sandstone quarries varied between 6.0m and 24.3m across 65 probeholes.

2.2.20 The quarry highwall was successfully identified in 18 of 20 trenches excavated. Highwalls were typically located where deeper made ground (c.>2.5m depth) was identified. The majority of highwalls appear to be vertical/near vertical, with evidence of benching being encountered in 2 stitch lines. Additionally, unworked sandstone 'land bridges/pillars/roads' with two highwalls in immediate proximity laterally were recorded in 5 stitch lines.

2.2.21 The extent of quarrying proven by drilling and trial trenching to date appears to contradict the historical OS mapping.

2.2.22 The approximate outline of the quarry and approximate depths of fill are shown on isopachyte drawing 4486/11. Cross sections through the quarries are also presented on Drawings 4486/12, 13 & 14, included in Appendix A.

2.2.23 Highwall lines appear to be highly irregular with 'bays' and 'spurs' along the crest and at depth. Due to the highly irregular nature of the highwall alignment, some variation from that shown on Drawing 4486/11 is likely.

2.2.24 In total, deep quarry backfill appears to be present beneath about 20% (c. 6.1ha) of the total site area. Considering the Fireworks Factory only (Area A), deep quarry backfill is present beneath c. 35%.

Landfills

2.2.25 The site was occupied by sandstone quarries (Matlock House, Crosland Hill & Waterhouse Quarries) from pre-1850 to 1995.

2.2.26 Quarries in the north (Crosland Hill) and centre (Waterhouse) of Area A were probably backfilled prior to the Control of Pollution Act 1974; these areas are not recorded as areas of historic landfill. However, the quarry in the south (Matlock House) was infilled more recently and is a recorded historic landfill.

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

Hazardous gas

2.2.28 The site might be affected by sources of hazardous gas generation as it is:

- Located within 250m of known former & current landfill sites
- Underlain by significant areas of deep quarry backfill

2.2.29 Consequently, 33 gas monitoring wells have been installed and have been monitored on 9 occasions over 6 months.

2.2.30 No methane was recorded during any of the 9 monitoring visits, and carbon dioxide concentrations were all below 5%.

2.2.31 Whilst the site was classified as a Characteristic Situation 1, given the numerous plausible gas sources, the relatively short monitoring period, the absence of continuous monitoring data and the need for basic radon protection measures, it is considered prudent to increase the classification to **CS2**.

2.2.32 The HSA website radon map indicates that the site is in an area where **5% to 10%** of homes are estimated to be above the action level, and **basic** radon protection measures are required in new dwellings.

2.2.33 Findings of the gas monitoring have been reported in a Hazardous Gas Risk Assessment issued by Lithos in April 2024.

Contamination

2.2.34 Of the 95 samples of made ground analysed for inorganic parameters, the majority can be classified as uncontaminated. A third of the samples recorded elevated concentrations of heavy metals, classifying them as potentially contaminated. The most common contaminants are arsenic, copper, lead, nickel and zinc.

2.2.35 Six samples of suspected ACMs were sent for analysis, with the presence of asbestos (Chrysotile) confirmed in all 6 of the samples. A total of 102 samples of soil were screened for the presence of asbestos, fibres were positively identified in 11 samples. Further analysis (asbestos quantification) was instructed on all soil samples where asbestos was positively identified. Quantification revealed concentrations ranging between <0.001% to 0.288%.

2.2.36 No areas of significant gross organic contamination were encountered during the site works. However, two localised areas (TP306, TP322) of organic contamination were identified. More onerous contamination than that identified to date may be present.

2.2.37 Lithos understands a previous investigation undertaken by a third party (Gaia) noted the loss of 3,000 litres of diesel from an above ground fuel tank in 2006. A copy of this report has been requested, but has never been provided, as such the location of the spillage is unknown.

2.2.38 Assessment of the site investigation data enabled formulation of a conceptual model, which is presented as Drawing 4486/7 in Appendix A.

2.2.39 In terms of the proposed redevelopment plausible contaminant linkages, and feasible remediation options, are summarised below:

Receptors	Pathways	Contaminant source	Remediation options
Human health (Future residents) ◊	Consumption of contaminated vegetables	Metals, Hydrocarbons in the made ground	Yes. Isolation beneath a minimum 600mm clean soil cover underlain by 150mm hard to dig layer in gardens (750mm in total). Isolation beneath 300m clean soil cover underlain by a 150mm hard to dig layer in landscaped areas (450mm in total).
	Ingestion		
	Inhalation (dust and/or vapours)		
	Dermal contact		
	Infiltration of water supply pipes	BTEX, Halogenated aliphatic & aromatics, Phenol, CN, Sulphate, Sulphide & Chloride in the made ground	To be assessed on completion of remediation. Treatment or removal of hydrocarbons. Water company may still insist on barrier pipes.
Buildings	Migration & accumulation of explosive gas	Methane, Hydrocarbons in the made ground	CS2 gas protection measures required (including radon resistant membrane).
	Migration & accumulation of gas	Radon	

◊ 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.

3 RISK ASSESSMENT & TARGET CONCENTRATIONS

3.1 Clean-up criteria relevant to the contamination encountered at this site are not driven by risks to controlled waters, therefore in the absence of a site-specific Quantitative Risk Assessment, it is conservatively proposed that Lithos' generic soil screening values for a residential-with-gardens end use (assuming gardens with 600mm clean soil cover) be adopted as remedial targets for hydrocarbon contamination in soils on this site.

3.2 These screening values are based on an inhalation pathway. However, some contaminants reach residual saturation before a vapour risk is predicted to occur by the QRA model. Lithos recognise that it is unacceptable to leave free product in the ground where redevelopment of a site is proposed. Consequently, this Remediation Strategy advocates the removal/ treatment of soils that contain significant free product at all depths.

3.3 In this context, significant free product is readily identifiable by the naked eye, and pervasive throughout the soil mass, probably with noticeable seepages. Traces of free product in fissures or localised, cobble-sized pockets would not normally be considered significant.

3.4 Information on the derivation and use of these screening values is presented in Appendix B.

4 EARTHWORKS LEVELS, REGRADE & ANTICIPATED FOUNDATIONS

4.1 The Geoenvironmental Appraisal Report (No. 4486/2B, dated December 2023), indicates that the following foundation solutions are likely to be most appropriate.

Foundation solution(s)	Remarks
Strips from a minimum 0.6m depth	Beyond former sandstone quarries and where made ground is <2.5m thick following turnover earthworks.
Raft or heavily reinforced strip foundations on engineered fill	Within the footprint of former quarries and beyond influencing distance of quarry highwalls following turnover earthworks and ground improvement techniques.
Piles	Plots over/or adjacent to the quarry highwalls where significant differential settlement and thickness of fill anticipated (i.e., highwalls). Due to significant obstructions (boulders) throughout the quarry backfill, piles will require pre-boring, casing and socketing into competent sandstone bedrock.

4.2 The foundation solutions outlined above assume that ground levels will not change significantly from existing. However, final site levels will be determined by the Developers, in conjunction with their Earthworks Contractor and Engineering Designer.

4.3 Some revision of the foundation solutions outlined above is likely to be necessary on completion of the site preparatory and remediation earthworks, especially where deeper excavation is necessary to remove relict obstructions.

4.1.2 Any digital terrain modelling undertaken by the Earthworks Contractor should be designed with a view to enabling a "materials balance" (i.e. volume of cut to broadly equals the volume of fill), and be made available to the Developers' Engineering Designer. The digital terrain modeller should consider:

- Volume reduction caused by turnover (compaction of loose made ground; removal of obstructions/tanks etc)
- Whether or not processed arisings/treated soils are retained on site
- The thickness of the soil cover required in garden areas
- Implications for foundations (i.e. those indicated in the geoenvironmental appraisal report may no longer be the most appropriate)

4.1 Final site levels should then be issued by the Engineering Designer, via an External Works Drawing, which should show:

- Proposed finished floor levels
- Proposed finished road levels
- Garden & driveway levels and gradients

5 REMEDIATION STRATEGY (GENERAL)

5.1 Aims

5.1.1 Remediation aims are to:

- Resolve contamination issues in order to protect environmental receptors, and render the site suitable for the proposed development
- Provide a stable development platform (to agreed levels and gradients) for subsequent construction of the proposed development and associated infrastructure
- Satisfy requirements of the Local Planning Authority and warranty provider

5.2 Overview

5.2.1 The following remediation works within Area A are required:

- Treatment of Japanese Knotweed and other invasive weeds
- General site clearance of surface materials and vegetation
- Demolition of buildings (after asbestos removal)
- 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
- Removal of fuel tanks with a post-removal trial pitting investigation beneath each tank
- Crushing of all suitable artificial hard material (i.e. concrete/brick etc)
- Turnover (excavation, screening and replacement in engineered layers (End Product compaction)) of the uppermost 4m of made ground within the footprint of former quarries and uppermost 2m of made ground outside the areas of quarrying from existing or proposed ground level, whichever is lower, to enable:
  - Inspection of the made ground
  - Surveying of highwalls and areas of deeper made ground associated with former quarries.
  - Picking of fragments of asbestos cement sheeting and placement in double sealed bags prior to off-site disposal
  - Removal of below ground obstructions
  - Removal of any localised fuel/oil contamination; with subsequent treatment and/or off-site disposal
  - Preparation of the ground for highway construction
- Where sewer inverts are lower than 4m inside the quarries or 2m outside the quarries, then the turnover needs to continue to 1m below the lowest sewer invert, unless natural ground is encountered before this.
- Advance rotary probeholes on a tight grid pattern across the quarries during the preparatory earthworks to remove residual below ground uncertainty
- Ground improvement of areas of deeper made ground (former quarries) at reduced dig level during turnover earthworks
- Backfill of all resultant excavations, with appropriate compaction
- Re-grade of site to levels
- Excavation of up to a maximum depth of 2m (beyond former quarries) beneath proposed adoptable road footprints and controlled re-engineering of selected materials in layers to approximately 770mm below final road levels
- Provision of a minimum **600mm** thick cover layer of 'clean' soils in all garden areas underlain by a **150mm** thick 'hard dig layer of crushed demolition arisings (**750mm** in total)
- Provision of a minimum **300mm** thick cover layer of 'clean' soils in all landscaped areas underlain by a **150mm** thick 'hard dig layer of crushed demolition arisings (**450mm** in total)

5.3 Site set-up, organisation and safety

5.3.1 Site cabins and welfare facilities are to be established at a location to be agreed with the Developers' Site Manager. All welfare facilities must be established in accordance with the relevant health & safety statutory requirements. Provision should be provided on site for car parking for all site employees.

5.3.2 All site personnel should undergo a site-specific health and safety induction prior to commencement of work on site.

5.3.3 The Developers' Site Manager should be informed prior to any proposed entry of a confined space or deep excavation. Entry must be restricted to suitably qualified and equipped personnel.

5.3.4 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.

5.3.5 During the remediation works, all personnel on site will comply with guidance provided 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 should be provided:

- A designated "clean" area should be fenced off and suitable warning signs posted. The only access to or from the "dirty" area should be via a hygiene facility (personnel) or wheel wash (vehicles).
- Protective clothing, footwear and gloves. (Personnel should be instructed in why and how they are to be used).
- Hand-washing and boot-washing facilities.
- Designated smoking areas.

5.3.6 If at any time during the works personnel begin to feel unwell, they are to inform the Developers' Site Manager, who will determine appropriate action.

5.3.7 All visitors to site must enter and register at the main Site Office.

5.4 Contractor's responsibilities

5.4.1 Prior to the commencement of any works the Contractor, in agreement with the Developers' Site Manager, should:

- Comply with any requirements of the Developers' contract documentation
- Establish the boundaries of the site and the working areas
- Undertake a dilapidation survey of site boundaries, adjacent properties and highways, via dated photographs or video footage
- Liaise with the Local Authority regarding working hours, noise/dust/odour control, and protected trees
- Liaise with the Local Water Company regarding any proposed discharge to sewer
- Complete a full services search and liaise with all relevant utility companies regarding work in close proximity to their apparatus
- Obtain a pre-demolition (formerly Type 3) asbestos survey report for all buildings to be demolished
- Prepare a detailed Method Statement outlining how the objectives of this Remediation Strategy will be achieved (and obtain approvals)
- Inform the Developers' Site Manager of any risk, identified and assessed, which could impact upon the Developers' Site Manager activities
- Prepare the necessary COSHH statements and Health & Safety Plan in accordance with CDM regulations
- Provide and erect secure Heras-type fence to protect monitoring wells

5.4.2 The Contractor should satisfy the Health & Safety Executive with regard to all matters concerning the health, safety and welfare of persons on the site.

5.4.3 The Contractor should ensure that:

- Personnel, plant, materials and other equipment related to the contract are confined within the boundaries of the site.
- Any live services lying within the site boundary are marked and protected, or appropriate arrangements made to truncate them.
- Good practices relating to personal hygiene are adopted.
- Suitable precautions are implemented at all times to prevent off-site migration of contaminants via airborne dust and vapours.
- Suitable precautions are taken to prevent the spread of mud and debris on public highways.
- Refuelling of mobile plant is undertaken in a designated area. Above ground oil storage tanks should comply with the requirements of Pollution Prevention Guideline PPG2. A spill kit should be kept on site, adjacent to the designated refuelling area. (Lithos are aware that some of the EA PPG documents have been withdrawn from the gov.uk website. However, whilst some references to UK legislation and guidance are now outdated; the PPGs still set out key principles and provide a useful, concise overview).

5.5 Materials Management Plan

5.5.1 This project will involve the re-use of both natural and made ground soils on site. Therefore, the Contractor will need to prepare a Materials Management Plan (MMP) in accordance with the CL:AIRE Code of Practice (v2, March 2011).

5.5.2 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. In summary the MMP should provide:

- Details of the parties that will be involved with the implementation of the MMP
- A description of the materials in terms of potential use and relative quantities of each category
- The specification for use of materials against which proposed materials will be assessed, underpinned by an appropriate risk assessment related to the place where they are to be used
- Details of where and, if appropriate, how these materials will be stored
- Details of the intended final destination and use of these materials
- Details of how these materials are to be tracked
- Contingency arrangements that must be put in place prior to movement of these materials
- Verification Plan

5.5.3 The MMP should include consideration of the following factors:

- Any risks posed by the excavated materials to both human health and the environment
- Suitability for use
- Certainty of use
- Anticipated quantities of materials

5.5.4 The MMP should also detail how materials will be tracked throughout the earthworks in order that the subsequent Verification Report can provide an auditable trail. The tracking system must include:

- Annotated plans of the site(s) identifying different excavation areas, stockpile locations, treatment areas (if applicable) and placement locations

- Inspection procedures
- Registered waste carrier and non-waste haulier
- Tracking form / control sheets
- Treatment results (if applicable)
- Delivery tickets for non-waste materials (if moving from one site to another)
- Acceptance procedures for non-waste materials

5.5.5 Finally, the MMP will have to set out a Verification Plan that identifies how the placement of materials is to be recorded and the quantities of material to be used. It will contain a statement on how the use of the materials relate to the remediation or design objectives.

5.5.6 Once completed, the MMP will need to be reviewed by a Qualified Person (QP), who will submit an online Declaration to CL:AIRE and send a copy to the Developers. It should be noted that in accordance with the Code of Practice, Lithos cannot act as the Qualified Person because we have undertaken the site investigation and prepared this Remediation Strategy.

5.6 Engineering supervision and verification

5.6.1 Site works should be supervised throughout by a suitably qualified Engineer, who will report to the Developers' Site Manager, supported as/where necessary by a suitably qualified geoenvironmental engineer. Supervision may be part-time for certain activities, but must be full-time during the removal of any grossly contaminated soil/fill and any placement of fill to an engineering specification.

5.6.2 Details of site regrade and ground improvement works are given in section 15.4 of the Lithos Geoenvironmental Appraisal Report (Ref. 4486/2A, dated December 2023). An Earthworks and Ground Improvement Specification Report should be commissioned to provide more detail on the Earthworks required.

5.6.3 The Developers' Site Manager will ensure that the requirements of this Remediation Strategy are complied with in a safe and orderly manner.

5.6.4 The responsibilities of the Developers' Site Manager should include, but not be limited to, the following:

- Ensuring that all site personnel are suitably qualified and given an appropriate induction at the beginning of their first day
- Supervision of the remediation and ground preparatory works
- Provision of advice on the correct handling of materials and conditions encountered
- Provision of guidance on the appropriate protective clothing and safety equipment that is to be made available and used
- Ensuring that personal hygiene arrangements are adequate
- Retrieval of soil and water samples and the subsequent scheduling of appropriate laboratory analysis to enable verification of various aspects of the works, and to advise the Project Manager of progress
- Liaison with statutory authorities as required

5.6.5 The Developers' Site Manager will maintain records of the works to include the following:

- Daily record sheets to include a summary of the day's activities
- Date and weather conditions
- Plant, personnel and visitors present
- Aspects relating to Health and Safety, Environmental Control, or non-compliance with either this Remediation Strategy or the Contractor's Method Statement

- Site surveys as necessary to record the locations of demolition, excavation and filling activity
- Test results

5.6.6 On satisfactory completion of all the works the Developers' Site Manager, with input from the geoenvironmental engineer as necessary, will prepare a Verification Report, in accordance with the Environment Agency's online guidance "Land Contamination Risk Management" which replaced CLR11 in October 2020. Copies of the Verification Report will be issued to the Developers, the Local Authority and NHBC.

5.6.7 The Verification Report will stand as certification that the remediation and ground preparatory works have been carried out in accordance with this Remediation Strategy.

5.6.8 The Verification Report will include:

- A summary of the preparatory & remediation works undertaken, including any works associated with unforeseen ground conditions
- Verification test results associated with "hot-spot" treatment, including plans showing sample locations & levels, and the extent of any "hot-spot" excavations
- Details of the fate of any arisings excavated from "hot-spot"
- Verification test results associated with proposed source materials for clean cover
- Earthworks compliance testing (in accordance with the Earthworks Specification) associated with ground improvement beneath proposed highways and dwellings
- Copies of any correspondence with Regulators relating to specific aspects of the remediation works
- Reference to the MMP and associated tracking system, including alterations made and why
- Treatment records
- Reference to waste transfer documentation, including return loads (if applicable)
- Signed delivery tickets (if applicable)
- Record of quantity of materials used
- A receipted copy of the Qualified Person's Declaration

5.6.9 The Verification Report will also provide recommendations with respect to:

- Foundation Solution(s)
- Gas Measures
- Placement of Soil Cover
- Handling of Contaminated Soils

5.6.10 The above recommendations will take account of the actual remediation works undertaken, and may differ significantly from recommendations originally presented in the site investigation report.

6 REMEDIATION STRATEGY (SPECIFIC OBJECTIVES)

6.1 Contingency for unknowns

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

6.1.2 If unanticipated ground is encountered during the remediation works, the Contractor should immediately seek further advice from the Engineer.

6.1.3 In order to assess the nature of any unanticipated grossly contaminated soil/fill, and (if necessary) allow revision of this Strategy document, it should be placed in temporary stockpiles on hardstand or an impermeable membrane, suitably covered and bunded.

6.1.4 Analysis of at least 6 samples, for an appropriate range of determinands should be undertaken. On receipt of the results, the Engineer will liaise with the Contractor regarding the most appropriate remediation option.

6.1.5 A minimum of a 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.

6.2 Well decommissioning

6.2.1 Monitoring wells should be decommissioned in order to prevent the possibility of gas migration into sub-floor voids. Decommissioning could be achieved by filling the well with gravel and then bentonite pellets (uppermost 3m; to be wetted after placement). The headworks (raised helmet or stop-cock type cover) should then be removed, and the surface made good.

6.2.2 Ideally the upper length of HDPE well pipe should be back-screwed and removed from the borehole, with the resultant 'hole' to be filled with bentonite pellets (to be wetted after placement).

6.3 Ecology

Invasive weeds

6.3.1 An invasive weeds survey has been undertaken, and reported by Ebsford. The survey identified a number of distinct areas of Japanese Knotweed and Himalayan Balsam. Areas of invasive weeds are shown on Drawing 4486/8 included in Appendix A.

6.3.2 Knotweed and Himalayan Balsam treatment/removal will be required prior to redevelopment, and should be undertaken in accordance with Environment Agency guidance, most notably '*Managing Japanese knotweed on development sites – the knotweed code of practice*' (Environment Agency).

6.3.3 Treatment/removal should be undertaken by a suitably qualified sub-contractor, and options include:

- Herbicide treatment
- Excavation & off-site disposal
- Excavation & on-site burial
- Burning (only in combination with one of the above)

If treatment is proposed, consideration should be given to programme and seasonal implications.

Badgers

6.3.4 Evidence of multiple badger setts and habitats have been identified during a survey by Ecus Ltd, locations of which are shown on Drawing 4486/8.

6.3.5 The relocation of badgers will be required prior to redevelopment which should be undertaken in accordance with a licence issued by Natural England.

6.3.6 Further advice regarding the relocation should be sought from a suitably qualified ecologist.

6.4 Site clearance

6.4.1 Any trees currently under a preservation order should be identified and agreed with relevant authorities prior to the commencement of the works. All trees subject to a TPO should be clearly identified and protected by fencing in accordance with BS5837: 2012.

6.4.2 The site should then be cleared of all residual debris, any vegetation, shrubs, bushes and unprotected trees as instructed by the Developers.

6.4.3 Topsoil and Made Ground Topsoil was encountered in Area A which is not considered suitable for reuse. However, topsoil typically 300mm thick is present across most of Area B which is considered suitable for reuse.

6.4.4 Topsoil should be stripped and placed in a temporary stockpile. The Engineer may instruct analysis (pH, metals, asbestos ID and speciated PAH) of further samples from the topsoil stockpile in order to confirm its suitability for re-use.

6.5 Topsoil stockpiles

6.5.1 Topsoil stockpiles should be located in areas of the site where the material can be left undisturbed and it won't interfere with site operations. Unnecessary double-handling of the soils should be avoided where possible.

6.5.2 Stockpiles should not be positioned within the root or crown spread of retained trees, or adjacent future excavations.

6.5.3 Stockpile locations should first be cleared of any vegetation, made ground and development waste.

6.5.4 The soil should be tipped in a line of heaps to form a windrow, starting at the furthest point in the storage area and working back towards the access point.

6.5.5 Adjacent windrows should be placed sufficiently apart to allow tracked plant to gain access between them, so that the soil can be heaped up to the maximum height.

6.5.6 Topsoil stockpiles should not be greater than 2.5m in height. In large stockpiles adequate oxygen supply is unlikely to penetrate more than 1m from the surface; stockpiles should therefore be as low and narrow as possible so that the core material is within 1m of the surface.

6.5.7 Stockpile surfaces should be firmed and re-graded to form a smooth gradient, using tracked plant, to prevent rainwater ponding and infiltration.

6.5.8 A maximum side slope of approximately 1 (vertical) in 2 (horizontal) is recommended.

6.5.9 Stockpiles should be fenced off to prevent any disturbance or contamination by other construction activities.

6.5.10 If the soil is to be stockpiled for more than 6 months, the surface of the stockpiles could be seeded with a grass/clover mix to minimise soil erosion and to help reduce infestation by nuisance weeds that might spread seed onto adjacent land.

6.5.11 Management of weeds that do appear should be undertaken during the summer months, either by spraying to kill them or by mowing or strimming to prevent their seeds being shed.

6.5.12 The site should be managed so as to keep soil storage periods as short as possible.

6.6 Asbestos

6.6.1 Current legislation (as outlined in HSG 264) requires a pre-demolition (formerly Type 3) asbestos survey to be undertaken, immediately prior to demolition of any building. The Contractor should request a copy of the survey report from the Developers. If no survey report is available, the Contractor will instruct an asbestos survey.

6.6.2 The licensed contractor should submit a Method Statement detailing how the works will be carried out in accordance with the Control of Asbestos Regulations 2012.

6.6.3 Localised fragments of asbestos cement sheeting may be encountered during the 'turnover' works; see Section 6.8. All suspected asbestos-containing material should be recovered by hand and placed in double sealed bags, within a sealed skip for off-site disposal at a suitably licensed landfill site. Personnel involved in this activity should be equipped with appropriate personal protective equipment, including dust masks (minimum FFP3).

6.6.4 An asbestos ID (screen) was scheduled on 102 samples of made ground, with asbestos identified in 11 samples. Supplementary analysis (asbestos quantification) of the 11 samples yielded concentrations of between <0.001% to 0.288%.

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

6.6.6 Made ground where asbestos has been positively identified and considered representative of near-surface soils, should ultimately be isolated beneath a cover of "clean" soil underlain by a **hard dig** layer (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.

6.6.7 Within areas of **private garden,** the clean cover layer should comprise a minimum **600mm** thick surface cover of "clean" soil underlain by a minimum **150mm hard dig** layer resulting in a minimum total cover thickness of **750mm**.

6.6.8 Within areas of **landscaping,** the clean cover layer should comprise a minimum **300mm** thick surface cover of "clean" soil underlain by a minimum **150mm hard dig** layer resulting in a minimum total cover thickness of **450mm**.

6.6.9 The proposed thickness of soils creates an appropriate **growing medium**, whilst the presence of the hard dig layer creates an appropriately **robust physical barrier** which, in the circumstances of normal site usage, would be extremely difficult to penetrate. It is considered that an increase in the overall thickness of the proposed cover system (i.e. >750mm in gardens and >450mm in landscaping) would not provide significant additional benefit and is therefore not necessary.

6.7 Demolition

6.7.1 Demolition works should commence on completion of asbestos removal and a "soft-strip" of the existing buildings.

6.7.2 Existing buildings should be demolished in a safe and controlled manner.

6.7.3 All demolition operations should conform to BS 6187:2011 Code of Practice for Demolition. All personnel working on these operations should be fully qualified to do so.

6.7.4 A detailed Method Statement specific to the project must be prepared by the Contractor and submitted to the Developers . The Method Statement should also be submitted to, and approved by, the Developers' Site Manager and the Local Authority.

6.7.5 Once buildings have been demolished, all surface hardstand and floor slabs should be grubbed-up and stored in a location on site, to be agreed with the Developers' Site Manager, prior to crushing (see Section 6.15). Any unsuitable materials should be removed to a suitably licensed landfill site (see Section 6.26).

6.8 Supplementary ground investigation

6.8.1 On completion of the demolition, hardstand grubbing-up and tank/fuel line removal, the Engineer will supervise the excavation of trial pits in areas of particular interest, most notably within the footprint of former fuel tanks and buildings inaccessible to the initial ground investigation.

6.8.2 Representative soil/fill samples should be taken by the Engineer. The number of samples taken should be reflective of the fill/geological complexity actually encountered. However, in general about 3 samples should be taken from most pits.

6.8.3 Selected samples should be sent to a suitably accredited laboratory and scheduled for appropriate chemical analysis (likely to comprise speciated PAH, BTEX, TOC and speciated TPH). Analysis for other determinands may be appropriate and should be requested by the Engineer as necessary.

6.8.4 The investigation should be undertaken in general accordance with current UK guidance (most notably BS10175:2011+A2:2017). The soils encountered during this investigation will be logged in general accordance with BS5930:2015.

6.9 Turnover of made ground

6.9.1 The extent of turnover (excavation, screening and replacement in engineered layers) required will depend on the likely long-term settlement predictions and therefore the ground improvement technique used. However, at this stage, it is likely that turnover of at least the uppermost 4m of made ground within the footprint of the quarries and uppermost 2m of made ground outside of the quarries (in both circumstances from existing or proposed ground levels, whichever is lower) will be required in order to:

- To remove relict foundations and obstructions (including USTs, boulders and other obstructions within quarry backfill)
- To remove shallow 'islands' of rock within the quarry footprints
- To prepare the ground beneath proposed new estate roads

6.9.2 The depth of turnover in landscaped areas shall be the same as that beneath plot footprints, unless directed by the Engineer. Some relaxation of the depth of turnover may be permitted, see Section 6.19.

6.9.3 Further details of specific operations associated with turnover are described in the following sections.

6.10 General excavation

6.10.1 Excavation of made ground will be undertaken in a controlled manner, working from a line agreed with the Developers' Site Manager in linear panels.

6.10.2 Excavated material should be removed from each panel and screened to remove oversize (> 200mm) and other unsuitable (e.g. anthropogenic or biodegradable materials), prior to replacement.

6.10.3 Any stockpile of made ground should be assumed to contain elevated concentrations of inorganic contaminants, and it should be ensured that such materials are not allowed to cross-contaminate any clean soils.

6.10.4 Each panel should be inspected by the Developers' Site Manager, and have its depth and extent recorded by survey, prior to backfilling (see Section 6.24).

6.10.5 Any material that needs to be stockpiled temporarily should be placed in areas designated by the Developers' Site Manager. Any stockpile of made ground should be assumed to contain elevated concentrations of inorganic contaminants, and it should be ensured that such materials are **carefully segregated** and not allowed to cross-contaminate any clean soils or controlled waters.

6.10.6 In the event that cross contamination occurs an excessive volume of unsuitable material could be generated which may then require off site disposal.

6.11 Site regrade

6.11.1 Regrade of site is anticipated to facilitate the proposed housing layout. It is understood that the Developers will require the appointed earthworks contractor to undertake digital terrain modelling, with a view to:

- Achieving a materials balance (thereby avoiding the need for any significant import or export of soils)
- Confirming final levels, including Plot FFLs
- Achieving acceptable highway and drive gradients
- Minimising foundation abnormals

6.11.2 The earthworks modelling should consider the possibility of using site-won subsoil from Area B as cover material (subject to the Engineer's approval), and how excess foundation and drainage arisings will be accommodated.

6.12 Tank removal

6.12.1 Drawing 4486/3 shows the location of all known fuel storage tanks.

6.12.2 Each tank should be carefully emptied of any residual product, purged of potentially explosive vapour, and safely disposed of from the site by an appropriately qualified and licensed contractor.

6.12.3 Any underground distribution pipe work should be purged of any residual product and explosive vapours and then carefully removed.

6.12.4 The Contractor should inform the local Petroleum Licensing Officer (PLO) prior to undertaking any works in the immediate vicinity of petrol storage tanks. The PLO should be able to provide a list of approved tank removal contractors.

6.12.5 The Engineer will inspect the resultant excavations, and supervise the chasing-out of any grossly contaminated soil/fill encountered (see Section 6.13).

6.13 Excavation of contaminated soil/fill

Fuel-contaminated soils

6.13.1 Organic contamination has been identified at two isolated locations. The possibility that localised 'hot-spots' will be encountered during either the supplementary (post-demolition) investigation, or during the site preparatory works cannot be discounted.

6.13.2 Consequently, the made ground should be carefully inspected during turnover and ground improvement works (including preparation of the ground beneath highways, foundation and drainage excavations etc).

6.13.3 Any fuel contaminated material encountered during turnover should be excavated under the full-time supervision of the Engineer, who will be equipped with a portable PID instrument to assist with delineation.

6.13.4 Each excavated 'hot-spot' of potentially significant fuel/oil contaminated soil should be placed in a separate stockpile on hardstand or an impermeable membrane, suitably covered and bunded.

6.13.5 Following excavation of the grossly contaminated ground, the Engineer will inspect and sample the resultant excavations.

6.13.6 A minimum of 5 verification samples should be taken from the excavation sidewalls and base. These samples should be tested for TOC, BTEX compounds, speciated PAH & speciated TPH. Analysis for other determinands may be appropriate and will be requested by the Engineer as necessary.

6.13.7 In larger excavations, additional verification samples should be taken from the exposed excavation surfaces on a 10m grid.

6.13.8 The Engineer will instruct continued removal of soil/fill if verification samples yield concentrations in excess of the clean-up criteria outlined in Section 3.

6.13.9 Excavations should not be left open for longer than is necessary, and should be securely cordoned-off using 2m high Heras-type fencing, with appropriate warning signs whenever excavation works are suspended.

6.13.10 Excavated contaminated soils should either be treated or disposed of off-site; see Sections 6.25 and 6.26 respectively.

6.13.11 On completion of tank/soil removal, excavations are to be backfilled.

Ash & Clinker

6.13.12 The calorific value of 12 samples of Ash & Clinker yielded an average CV of 3.1 MJ/kg (maximum of 8.3MJ/kg with 4 samples recorded as <1MJ/kg). Materials whose CVs exceed 10MJ/kg are almost certainly combustible, while those with values below 2MJ/kg are unlikely to burn.

6.13.13 Due to its combustibility near-surface Ash & Clinker is to be removed from proposed garden areas and placed beneath plots or areas of hardstand.

6.13.14 Redistribution beneath plots or hardstanding (see Section 6.17) will satisfactorily isolate the ash & clinker from both end users and potential heat sources.

6.14 Control of water

6.14.1 Groundwater should be controlled in accordance with CIRIA report 113 "Control of Groundwater for Temporary Works".

6.14.2 Arrangements should be made to prevent ponding in any excavation "hollows"; the Contractor should ensure that ground levels are of sufficient gradient to enable the collection of surface water run-off in sumps or grips.

6.14.3 Pumping from over-excavated sumps may be required to maintain satisfactory working conditions.

6.14.4 The Contractor should make all necessary arrangements to prevent off-site migration of contaminated sediment via surface water run-off. This will necessitate the installation of surface water grips, and removal, sealing-off, or diversion of all redundant former site drains (and any land drains).

6.14.5 A Surface Water Management Plan should be prepared by the Contractor, describing the mitigation measures that will be put in place to intercept direct run-off from any disturbed areas, stockpiles etc, thereby preventing any potential impact of adjacent land and nearby watercourses. Surface water run-off will probably require treatment (as a minimum to allow settlement of fines) prior to consented discharge.

6.14.6 It is quite likely that perched waters will be encountered during the remediation earthworks; most commonly associated with redundant drains and buried structures. Some perched water may be contaminated with hydrocarbons and/or VOCs.

6.14.7 It should be noted that significantly elevated concentrations of hydrocarbons and heavy metals are often associated with sediment within the former drainage network below brownfield sites such as this, and that these, if released, pose potential risk to waters.

6.14.8 Any potentially contaminated water should not be allowed to escape to other areas until the results of the analysis are available and, if required, a suitable means of water treatment has been agreed.

6.14.9 Water collected in sumps should be passed through a series of oil/water separators to remove any oily contamination. Oils trapped in the absorbent medium should be disposed of to a suitably licensed landfill site.

6.14.10 Treated water should then be tankered off-site, or be discharged to sewer, subject to analytical results and local water treatment company consent.

6.15 Removal of below ground obstructions

6.15.1 All foundations and redundant existing drainage utilities associated with existing buildings and other relict structures should be chased out and grubbed-up, in order to remove potential obstructions to new foundations and infrastructure.

6.15.2 Where relict structures are found to retain fluid contaminants, they should be drained first. The drained fluids should be stored in appropriate, sealed tanks/containers and analysed for a range of determinands to be agreed with the Engineer. Fluids may then be tankered off-site, or be discharged to sewer, subject to analytical results and local water treatment company consent.

6.15.3 Deep excavations for the removal of structures etc will be unstable in the short term and continuous side support will be necessary.

6.15.4 Where significantly deep foundations (e.g. piles) cannot be removed by conventional means, they are to be cut at a depth to be agreed with the Developers' Site Manager and the position of the remaining lower section is to be accurately recorded by survey.

6.15.5 Suitable materials derived from grubbing-up should be stored in a location on site, to be agreed with the Developers' Site Manager, prior to crushing (see Section 6.16). Any unsuitable materials should be removed to a suitably licensed landfill site (see Section 6.26).

6.16 Crushing

6.16.1 Production of selected granular fill should be possible if suitable materials (generated by demolition operations and grubbing-up of floor slabs, foundations and other relict structures) are crushed.

6.16.2 The crushed product should be screened to remove any unsuitable elements and stockpiled for re-use during the subsequent construction works. Generation of a Class 6 material as defined in the Highways Agency Specification (Series 600) should be possible.

6.16.3 Tarmac could be recycled and crushed to yield a 6F3 selected granular material, provided the recovered bitumen content is less than 10% (determined in accordance with BS598-1:2011). Alternatively, crushed tarmac could also be blended with crushed concrete etc to generate 6F2 graded material. 6F2 can contain up to 50% recycled tarmac/asphalt (provided it does not pose a contamination risk to controlled waters and, if the proportion of asphalt is greater than 20%, the recovered bitumen content is less than 2%).

6.16.4 The Engineer should check the suitability of crushed product for re-use, instruct the removal of any unsuitable material and schedule appropriate confirmatory geotechnical or chemical testing.

6.16.5 It should be possible to generate other secondary aggregates from crushed concrete provided it is subject to good sorting prior to crushing and thereby contains little 'impurity' (e.g. brick, breeze block, wood, re-bar etc). The Contractor should liaise with the Local Authority to obtain their views with respect to the use of Type 1 etc generated from recycled concrete.

6.16.6 A minimum of 3 samples (or 1 sample per 500m^3, whichever is the greater) should be taken from any stockpile of specific crushed product and sent to a UKAS accredited laboratory for asbestos analysis.

6.17 Placement of Ash & Clinker

6.17.1 The Ash & Clinker at this site yielded an average CV of 3.1 MJ/kg. This is at the lower end of the range where the potential for combustion exists, and it is not considered a significant hazard. As a precautionary measure Ash & Clinker will not be placed within the top **250mm** of the development platform beneath plots, resulting in it being isolated beneath a total minimum cover of **1,000mm**.

6.17.2 Excavated Ash & Clinker is to be placed beneath plots or areas of hardstand in locations to be agreed with the Engineer and the Developers.

6.17.3 Alternatively, Ash & Clinker arisings could be exported from site to a suitably licensed landfill facility; see Section 6.26.

6.18 "Clean" corridors

6.18.1 Along the line of proposed new sewers and any proposed attenuation tanks, made ground should be excavated to its full thickness, or at least 1.0m below deepest sewer invert whichever is the lesser, to a width agreed with the Developers.

6.18.2 The resultant excavation will only be backfilled with "clean" material which might comprise any of:

- site-won natural soils;
- crushed concrete; and/or
- suitable imported natural soils or quarry aggregate.

6.19 Engineering of fill materials for raft or heavily reinforced strip foundations

6.19.1 In areas where raft/heavily reinforced strip foundations are proposed, the uppermost 4.0m of made ground should be excavated, screened and placed in engineered layers (turned over) to an End Product Earthworks Specification. Excavation and screening/sorting will enable the removal of all relict foundations, oversize material and any grossly contaminated soil/fill.

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

6.19.3 Clearly, such works will be undertaken in accordance with the Developers' layout, and it is essential that the Engineer is provided with the most recent (and proposed final) scheme. Any subsequent revisions to the plot layout could result in rafts/reinforced strips straddling a 'high wall', and the Engineer should be consulted if any layout revisions are proposed.

6.19.4 Where it is not possible to provide an even thickness of fill beneath proposed plots, raft/reinforced strip foundations are unlikely to be acceptable, and consideration should be given to an alternative foundation solution.

6.19.5 Two basements/voids have been identified beneath two buildings, and further basements/voids associated with other existing buildings should not be discounted. Basement excavations will need to be enlarged to ensure that engineered fill, of even thickness, underlies and extends at least 3.0m beyond house footprints.

6.19.6 In addition, any "cellar fill", or other unsuitable material, must be removed to its full depth. Any retained cellar floor slabs should be punched through to limit the risk of perched groundwater and confirm that loose ground does not exist below the slab.

6.19.7 Any excavated and screened material that needs to be stockpiled temporarily should be placed in areas designated by the Engineer. Any stockpile of made ground should be assumed to contain elevated concentrations of inorganic contaminants, and it should be ensured that such materials are not allowed to cross-contaminate any clean soils or controlled waters.

6.19.8 Prior to placement of engineered fill, the excavation base should be inspected by the Engineer, and then surveyed.

6.19.9 Where landscaped areas contain no structures or infrastructure the underlying fill shall be selected, placed and compacted in the same was as the Engineered Fill, unless directed otherwise by the Engineer.

6.19.10 Where some relaxation of the specification is permitted beneath landscaped areas, there shall be a transition zone between the fill beneath the landscaped areas and the fill beneath structures. As a **minimum** the transition zone should 5m or half the thickness of the engineered fill, whichever is greater (in accordance with NHBC Ch. 4.6).

6.19.11 The exact dimensions of the transition zone will depend on degree to which the compaction and thickness of engineered fill is relaxed. The location, extent and depth of fill placed to a relaxed specification should be recorded.

6.20 Placement of stone blankets for rafts/reinforced strips

6.20.1 Any engineered fill containing more than 10% fines will require protection to ensure that climatic factors do not cause deterioration of the near surface. Protection should be provided by the placement of a 450mm thick blanket of non-frost susceptible granular sub-base, within 48 hours of placement of the final layer of fill. The granular sub-base should extend at least 800mm beyond the footprint of all dwellings to be founded on rafts as per the appointed Structural Engineers requirements.

6.20.2 If this is not possible, the Engineer may instruct the excavation of up to 450mm of fill from beneath the plot footprint (and if suitable re-engineered), prior to placement of the granular sub-base.

6.20.3 Granular sub-base should be placed in accordance with Table 8/4 of the Specification for Highway Works.

6.20.4 Crushed brick may be considered a suitable granular sub-base, provided it is:

- Not frost susceptible
- Does not contain significant amounts of plaster

6.21 Placement of a granular running layer piling mat

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

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

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

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

6.22 Highways

6.22.1 The Contractor should consult the adopting authority regarding preparation of the ground beneath new highways (as outlined below, or in any proposed alternative specification) in advance of the works. The Contractor should also agree acceptable performance criteria, with the Engineer and the adopting authority.

6.22.2 However, it is considered that the following options would be suitable to enable the construction of the highways.

6.22.3 Beyond areas of deep made ground, the natural soils present at shallow depth (anticipated formation) are predominantly granular. Based on visual inspection of the natural materials, published tables[1] indicate that the shallow deposits would be expected to provide a CBR value of at least 3%. This value should be verified prior to or during construction.

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

6.22.5 Made ground should be excavated from beneath new highway footprints to a maximum of depth of 2.0m outside the areas of quarrying and 4.0m inside areas of quarrying - from existing ground level or proposed finished highway level, whichever is the lower. Highways should then be raised to formation level, either with:

- Suitable aggregate placed & compacted in accordance with The Highways Agency Specification for Highway Works (SHW) Series 600, or
- Suitable screened & selected site-won material, placed & compacted in accordance with SHW Series 600. Unsuitable materials include any soft or wet materials, biodegradables including topsoil, wood, scrap metal, frozen & oversize material.

6.22.6 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.

6.22.7 Any residual made ground materials in the base of the excavation (i.e. in areas where the thickness of made ground exceeds 2m outside quarries and 4m inside quarries) should be inspected and (where necessary) any soft spots removed and replaced with suitable engineered fill.

6.22.8 In the footprint of proposed highways, the contractor, under supervision, must ensure that relict obstructions are removed to a minimum of 1.0m below deepest sewer invert. The resultant sub-formation should then be proof rolled, in accordance with the Specification for Highway Works.

6.22.9 Where quarry highwalls, sandstone 'pillars/roads' or backfilled cellars/basements conflict with new highways, further advice should be sought from the Engineer responsible for detailed infrastructure design. However, where highways span the 'high-wall', the following precautions are recommended to protect infrastructure from damage due to differential settlement (also see drawings 4486/17 & 17A).

- The made ground should be excavated over the full width of the adoptable highway to at least 1.0m below deepest sewer invert
- The base of the excavation (1.0m below sewer invert) should be reinforced with two layers of Tensar Triax TX160 (or equivalent) geogrid sandwiched within at least 300mm of suitable aggregate (i.e. nominally 75mm aggregate, geogrid, 150mm aggregate, geogrid and then another 75mm aggregate).

6.22.10 Where highways cross perpendicular to the highwall, geogrids should be placed the full width of the adoptable carriageway and extend at least 5m either side of the highwall, although the final specification should be agreed with the adopting authority.

[1] *Interim Advice Note 73/06 Revision 1 (2009), Chapter 5. Characterisation of Materials Design Guidance for Road Pavement Foundations - Draft HD25*

6.22.11 Where highways cross parallel to the highwall, geogrids should extend across the highwall and at least 2.5m into competent natural strata.

6.22.12 Geogrids should be lapped a minimum 0.5m with adjacent grids.

6.22.13 Where excavation associated with ground improvement (e.g. turnover of made ground) beneath a highway results in sub-formation slopes greater than 1:5 (v:h), the sub-formation should be stepped (max. 0.5m high) and benched (min. 1m wide). Where the excavation works exceed 1m in depth, the footprint of earthworks should be extended beyond the highway footprint a minimum of 1m, plus the depth of excavation. The Engineer will keep records of any such work undertaken.

6.22.14 The benching detail when excavating bedrock beneath highways can be relaxed to 0.5m wide, 0.5m high (i.e. 1:1) to avoid unnecessary hard rock excavations (see Drawing 4485/17A).

6.22.15 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.

6.22.16 The suitability of site-won material for placement as engineered fill should be confirmed by field trials and geotechnical laboratory testing, which will yield the following information:

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

6.22.17 The engineered fill should be placed in accordance with the agreed specification.

6.22.18 The Contractor should ensure that only suitable granular fill is placed within 450mm of estate road formation in order to protect cohesive sub-grade materials (including natural cohesive soils). Such fill should be placed in accordance with the Specification for Highway Works.

6.22.19 The Contractor will arrange for the necessary compliance testing to be undertaken at formation level on road alignments, as required by the adopting authority and Engineer. As a minimum this should comprise plate load tests, carried out to determine the CBR at formation level, at approximate 25m intervals. Test locations should be staggered across the width of the highway to ensure the whole highway area is assessed.

6.23 Boundary issues

6.23.1 the Developers' Designer should ensure that proposed levels tie in with the surrounding infrastructure, and ground levels of adjacent properties (after allowance for the placement of any required soil cover).

6.23.2 Advice should be sought from the Engineer if mobile contamination or redundant drains/utilities are encountered close to the site's boundaries.

6.24 Surveying

6.24.1 The Contractor should arrange for the following survey work as directed by the Developers' Site Manager:

- All setting out necessary to allow the works to proceed
- Recording of the depth and lateral extent of excavations to remove obstructions, contaminated soils etc
- Recording of the positions of any relict obstructions (i.e. piles) left in-situ

- Recording the depth & extent of each excavation panel during turnover of made ground, prior to backfilling
- Recording of natural ground levels, where natural ground encountered during the earthworks
- Recording the final location of potentially combustible or treated hydrocarbon-contaminated soils
- Recording the locations and volumes of all stockpiles of suitable materials left on site for the Developers 's use during the development works
- Recording the depth and lateral extent of new benched highwalls created by earthworks
- Location and depth of invasive weeds if buried
- As-built survey of the finished surface on completion of the remediation contract

6.24.2 The Contractor should supply the results of this survey work to the Developers' Site Manager for inclusion in the Verification Report.

6.25 On-site treatment of contamination

6.25.1 Given the limited anticipated volume of hydrocarbon-contaminated soils anticipated, export to landfill (see Section 6.26) may prove to be the most efficient and economical option. However, treatment on site of hydrocarbon contaminated material might be considered by the Contractor.

6.26 Export to landfill

6.26.1 Excavation arisings that are unsuitable for retention and re-use on site should be placed in temporary stockpiles on hardstand or polythene sheeting and be suitably covered to minimise the potential for dust/odour nuisance, and prevent surface water run-off.

6.26.2 Given the proximity of existing housing, and in order to avoid any potential odour nuisance, stockpiles of material should be exported from site as soon as practically possible.

6.26.3 Any material exported from site to landfill should be hauled by a registered waste carrier in accordance with the requirements of the Waste Regulations 2011 and the Landfill (England & Wales) Regulations 2002.

6.26.4 A transfer note should be completed, signed and retained by the parties involved. The transfer note should include the volume of waste, the nature of the material and a statement of its chemical composition, details of the source and destination sites, and details of the haulier.

6.26.5 In order to protect the general public from dust and vapour emissions, wagons that are to be used for the haulage of the contaminated material from the site must be sheeted. In addition, the Contractor must ensure that no fluids seep from the wagons.

6.26.6 In order to provide the landfill facility with information regarding chemical composition of the waste, further analysis of any material that requires removal from site may be required.

Waste classification

6.26.7 Sampling and characterisation of stockpiled materials generated during the site preparatory works is likely to be required if off-site disposal is proposed.

6.26.8 It should be noted that the classification and assessment of waste soils under the Environment Agency's Technical Guidance WM3[2], is a complex process.

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

6.26.9 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 site), to ensure that the waste is handled and disposed of appropriately.

6.26.10 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%).

6.26.11 Tarmac hardstand is present within Area A. This **tarmac** could be recycled and crushed to yield a 6F3 selected granular material, provided the recovered bitumen content is less than 10% (determined in accordance with BS598-1:2011). Crushed tarmac could also be blended with crushed concrete etc to generate 6F2 graded material. 6F2 can contain up to 50% recycled tarmac/asphalt (provided it does not pose a contamination risk to controlled waters and, if the proportion of asphalt is greater than 20%, the recovered bitumen content is less than 2%).

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

6.26.13 Tarmac is likely to fall within waste code 17 03 02:

- 17 - Construction and Demolition wastes,
- 03 – bituminous mixtures, coal tar and tarred products
- 02 – bituminous mixtures other than those mentioned in 17 03 01

6.26.14 17 03 02 is a mirror non-hazardous entry (17 03 01 is the corresponding mirror hazardous entry). This code along with this supporting report, in particular the laboratory results, should be used to complete a paper trail documenting disposal routes for tarmac.

6.26.15 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.

6.27 Placement of soil cover

6.27.1 Clean inert soil will be placed over the made ground in proposed garden and landscaped areas (but not beneath hardstanding).

6.1 Within areas of **private garden,** the clean cover layer will comprise a minimum **600mm** thick surface cover of "clean" soil underlain by a minimum **150mm** hard dig layer resulting in a minimum total cover thickness of **750mm**.

6.27.2 Within areas of landscaping, the clean cover layer will comprise a minimum **300mm** thick surface cover of "clean" soil underlain by a minimum **150mm** hard dig layer resulting in a minimum total cover thickness of **450mm**.

6.27.3 Following the proposed earthworks regrade, some gardens may be underlain by natural soils only, and where this is the case placement of a minimum 100mm of topsoil will suffice (in accordance with NHBC Standards, Chapter 10.2).

6.27.4 If any garden is directly underlain by sandstone bedrock, placement of a minimum of 450mm of subsoil/topsoil will be required (in accordance with NHBC Standards, Chapter 10.2).

6.27.5 Subsoil suitable for use as cover material may be sourced on site (from Area A), subject to the Engineer's approval. The Engineer will assess accessibility, suitability, the conceptual site model (most notably the creation of new pathways by which mobile contaminants could impact controlled waters), and engineering implications (for example, increased foundation depth) before allowing any excavation of in-situ natural soils for re-use as clean cover. However, there may also be a need for soil import.

6.27.6 Topsoil and subsoil quality should be assessed in accordance with Lithos' Protocol for Importation & Use of Soil Cover (Capping), copied in Appendix D.

6.27.7 This Protocol includes chemical assessment criteria which should not be exceeded.

6.27.8 Any material imported for use as cover should be validated in accordance with Lithos' Protocol for Importation & Use of Soil Cover (Capping), copied in Appendix D. This Protocol includes chemical assessment criteria which should not be exceeded.

6.27.9 This work may be undertaken as part of the contract for the preparatory & remediation works, in which case imported soils should be stockpiled in a location agreed with the Engineer. Alternatively, the developer may choose to import soil at a later stage in the development.

6.28 Topsoil placement

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

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

6.28.3 For the loosening to be most effective, it should be undertaken when the subsoil is dry to the full depth of working.

6.28.4 Subsequent trafficking over the loosened subsoil should be minimised.

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

6.28.6 An excavator with a toothed bucket should be used to load the topsoil from stockpile into dumpers, to prevent excessive smearing.

6.28.7 The dumper should tip the topsoil onto the receiving surface, and topsoil should then be spread to the required depth by an excavator. Both the dumper and excavator should avoid tracking over the placed topsoil.

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

6.29 Hazardous gas protection

6.29.1 Gas monitoring wells were installed at 33 locations and monitored carried on 9 occasions over a 6-month period. A detailed ground gas risk assessment was subsequently produced by Lithos dated 24th April 2024 (ref. 092/4486/AG/jhr).

6.29.2 A maximum concentration of carbon dioxide of 4.6% was recorded, along with a maximum steady flow of 0.7l/hr. Methane was absent during the monitoring period.

6.29.3 Based on the site data a classification of **CS1** was identified, but given the numerous plausible pathways, relatively short monitoring period, the absence of continuous monitoring data and the need for basic radon protection measures the classification has been raised to **CS2**.

6.30 Scope of protection measures

6.30.1 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:

Charac. situation (Wilson & Card, '99)	Gas "score" req'd by BS8485	Protective measures (Residential)		
		Floor slab (BS8485 "score")	Sub-floor ventilation (BS8485 "score")	Membrane Type (BS8485 score")
2	3.5	*Select one from:* Block & Beam – (0). Reinforced ground bearing slab – (0.5). Reinforced, cast in-situ suspended slab (with minimal and suitably sealed service penetrations & joints) – (1.5). Reinforced ground bearing raft (with limited service penetrations cast into slab). Note: the venting area through any downstand beam should be 3 times greater than that provided by the side ventilation (air bricks) – (1.5).	*Select one from:* Passive sub-floor ventilation; venting layer could be: A min. 150mm clear void (2.5), or A proprietary void former providing an equivalent clear void depth of 60mm; see Section B7 in BS8485 (2.5), or Min. 300mm thick blanket of min. 20mm single size rounded or sub-angular gravel (1.0). Min. ventilation = 1,500 mm²/m run of external wall (via air bricks on each of 2 opposite sides), with 100mm pipes at 1.75m centres or honeycombing of any sub-floor sleeper walls.	Gas resistant membrane meeting all of the following criteria: • sufficiently impervious to gases with a methane gas transmission rate <40.0 ml/day/m²/atm (average) for sheet and joints (tested in accordance with BS ISO 15105-1 manometric method); • sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • sufficiently strong to withstand in-service stresses (e.g. settlement if placed below a floor slab); • sufficiently strong to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc); • capable, after installation, of providing a complete barrier to the entry of the relevant gas; • a minimum 0.4 mm thickness (1600g polyethylene) reinforced membrane (virgin polymer); and • verified in accordance with CIRIA C735∞ (2.0)

Footnotes:

∞ In accordance with CIRIA C735, a Verification Plan should be prepared which outlines the activities (inspection and testing), the relevant personnel, and the type of records to be collected.

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
2. A combination of two or more of the three types of protection measures (slab, ventilation & membrane) should be used to achieve the BS8485 score.
3. The membrane should always be lapped and sealed in accordance with BRE\Environment Agency Report BR 414 (2001) – "Protective Measures for housing on gas-contaminated land". The membrane should be continuous across internal walls & the cavity, and there should be a cavity tray in external walls.
4. In all cases there should be minimum penetration of floor slab by services; any penetrations should be suitably sealed.

6.30.2 In general accordance with NHBC guidance[3] and YALPAG guidance[4], a Design Report and Construction Drawings detailing the site specific requirements for the gas protection system with respect to the development should be prepared. The design report should include a verification plan which specifies the required verification for all elements of the gas protection system. The report should be issued to NHBC and Kirklees Council in advance of the construction phase.

6.30.3 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.

[3] Hazardous ground gas – as essential guide for housebuilders. NHBC Foundation, April 2023
[4] Verification Requirements for Gas Protection Systems - Technical Guidance for Developers, Landowners and Consultants. Yorkshire and Lincolnshire Pollution Advisory Group, December 2016

6.30.4 Designers/Architects should be made aware of the importance of gas protection measures, and their house designs should take account of potential constraints associated with Building Regulations (most notably those relating to access thresholds, noise and insulation), flood mitigation measures, and utility providers (external meter boxes may have to be located away from air bricks) etc.

6.31 Radon

6.31.1 The HSA website radon map indicates that the site is in an area where **3% to 5%** of homes are estimated to be above the action level, and basic radon protection measures are required in new dwellings.

6.31.2 **Basic radon** measures comprise a radon resistant barrier* (membrane) laid within the floor construction and across the wall cavity in accordance with BR211:2023[5]. The joints between the sheets that form the membrane and cross the cavity must be sealed, along with all service penetrations, to make the construction as airtight as possible. A separate cavity tray should be installed in the cavity one brick course above the radon membrane. In order to withstand the installation and follow on construction process, membranes should be no less than 400 microns thick.[6] With the selection of an appropriate product, a single membrane can provide both the function of ground gas protection and radon protection.

6.31.3 BRE211:2023 highlights the importance of good practice and a high standard of workmanship to ensure radon membranes are installed to a high standard.

6.31.4 A building site is a harsh environment and barriers can easily become damaged during construction by operatives or equipment moving across or working over a completed section of barrier. As a consequence, where there is a risk of puncturing the membrane, it should be ensured that the membrane is well protected with sand or lean mix concrete before advancing construction.

6.31.5 The radon protection system should be subject to inspection and verification by a third party inspector that has a full understanding of all elements of the radon protection system.

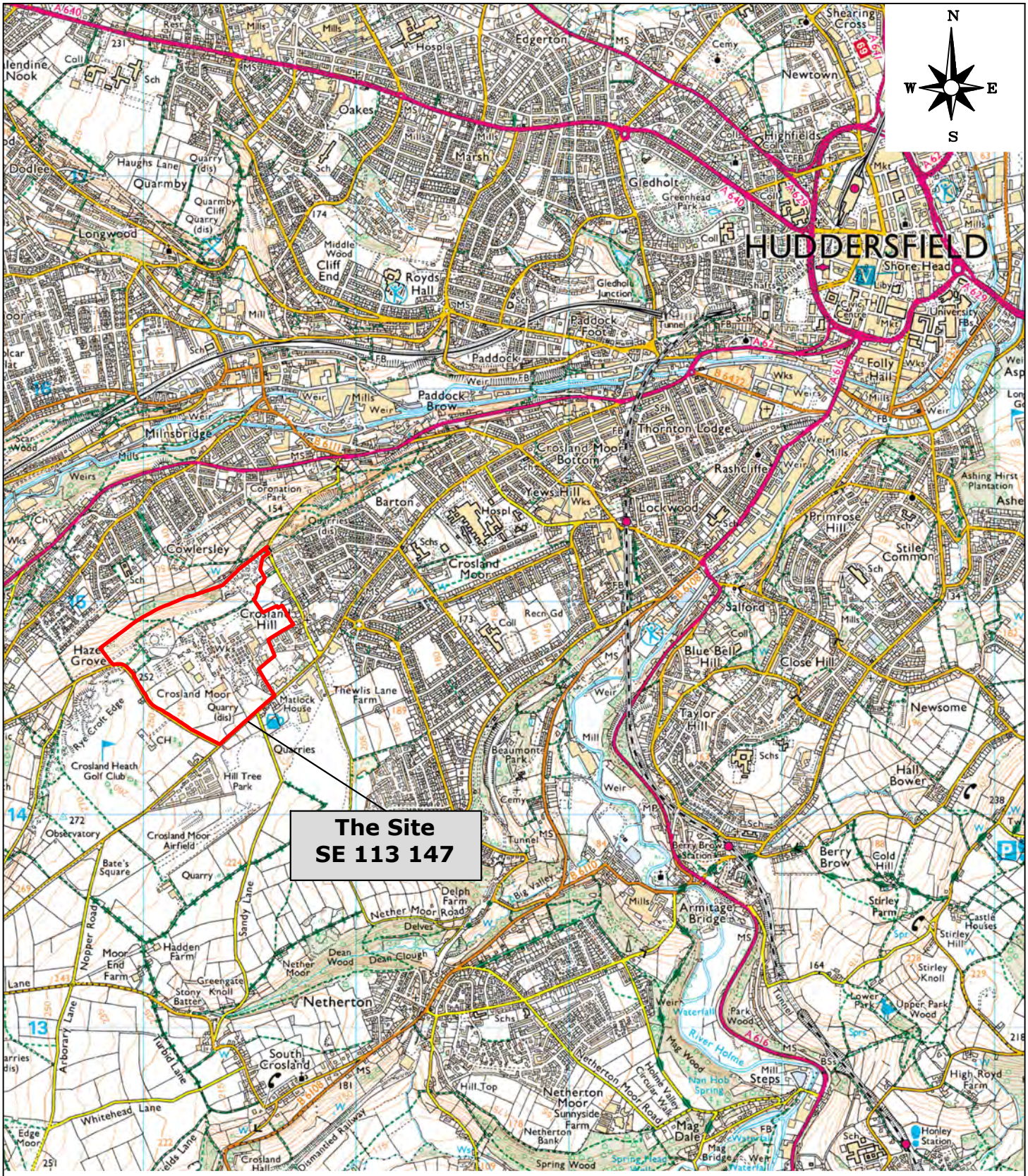
6.31.6 Verification should be carried out at a minimum frequency of 1 in 10 plots where groundworkers carry out installation, and 1 in 20 plots where accredited installers are used. Plots selected for inspection should be located across the development and not clustered.

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

* *Confirmation of resistance to radon must be obtained from the manufacturer.*

[6] *BS8485:2015+A1:2019. Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings. January 2019.*

APPENDIX A
DRAWINGS



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CLIENT	CLIENT
JOB TITLE	LAND OFF BLACKMOORFOOT RD, HUDDERSFIELD (BLACK CATS)
DRAWING TITLE	SITE LOCATION PLAN
DRAWN	ENGINEER
DATE	GLM
CHECKED	PROJ MNGR
DATE	REG
STATUS	FOR COMMENT ☐ DRAFT ☐ FOR APPROVAL ☐ FINAL ☑
SCALE	1:25,000
SHEET	A4
DRAWING NO.	4486/1
REVISION	

NOTES

APPROXIMATE SITE BOUNDARY

REPRODUCED FROM NINETWEEN47'S DRAWING REFERENCE n2114 007 REV H, DATED 24.04.2024

REV.	DESCRIPTION	DATE
A	UPDATED PROPOSED CLIENT LAYOUT	22/05/2024

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CLIENT

VISTRY HOMES, COUNTRYSIDE PARTNERSHIP, MILLER HOMES & EMPIRE KNIGHT GROUP

JOB TITLE

BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE

PROPOSED SITE LAYOUT WITH SITE AREAS

DRAWN	DATE	STATUS
CC	02 05 2024	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	02 05 2024	DRAFT ☐
		FINAL ☑

SCALE	SHEET	DRAWING NO.	REVISION
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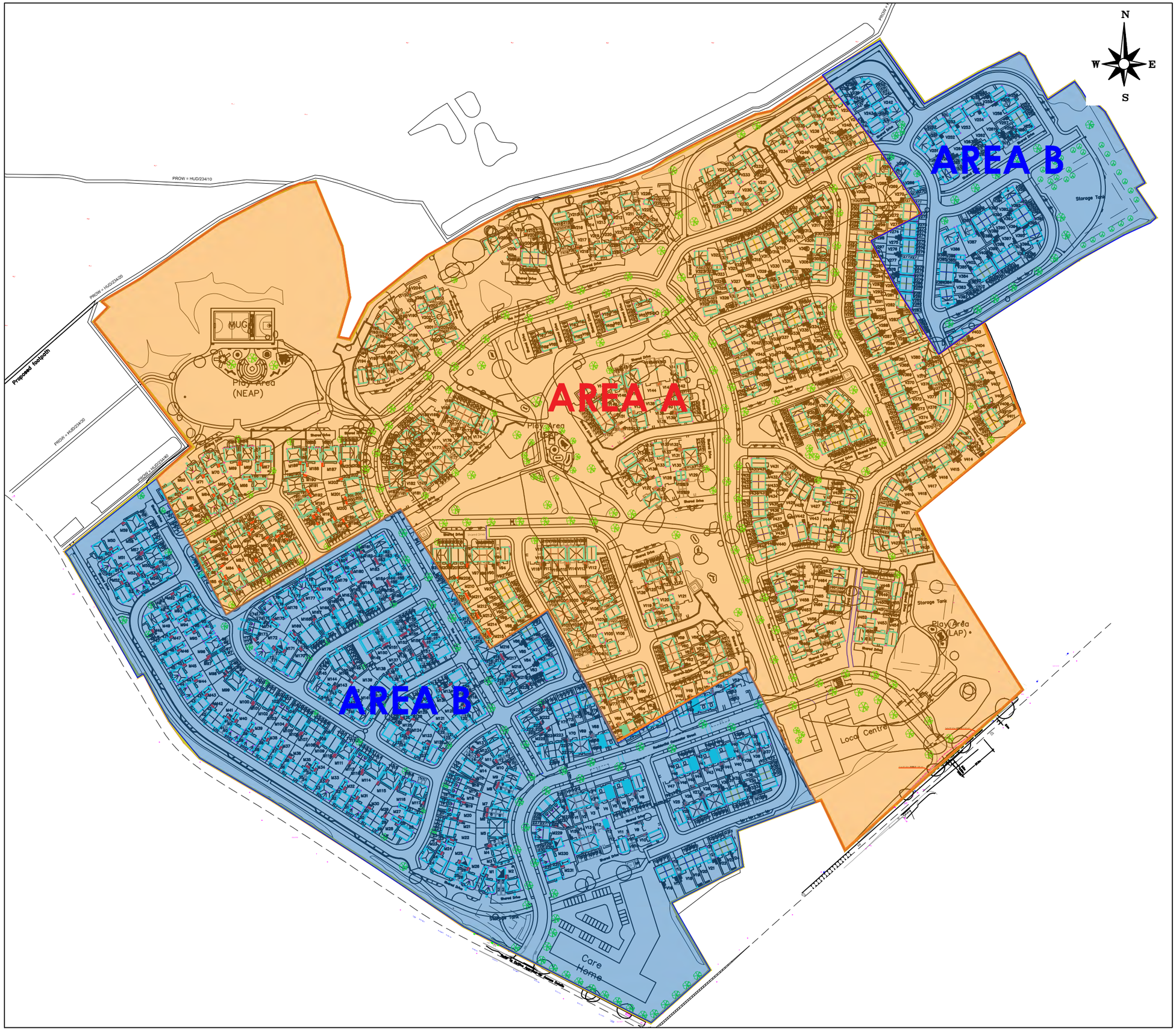

NOTES

APPROXIMATE SITE BOUNDARY

REPRODUCED FROM NINETWEEN47'S DRAWING REFERENCE n2114 008

AREA A - FIREWORK FACTORY

AREA B - FIELDS

REV.	DESCRIPTION	DATE
A	UPDATED CLIENT LAYOUT	04/10/2024

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JOB TITLE

BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE

PROPOSED SITE LAYOUT WITH SITE AREAS

DRAWN	DATE	STATUS
CC	02 05 2024	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	02 05 2024	DRAFT ☐
		FINAL ☑

SCALE	SHEET	DRAWING NO.	REVISION
1:2500	A3	4486/2A	A

NOTES

- GRASS AREAS
- TREES & OVERGROWN AREAS
- BUILDING
- GRAVEL OR HARDCORE SURFACING
- TARMAC HARDSTAND
- CONCRETE HARDSTAND
- HISTORICAL RESERVOIR
- FUEL STORAGE TANKS
- APPROXIMATE SITE BOUNDARY

REV.	DESCRIPTION	DATE

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JOB TITLE

BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE

SITE FEATURES

DRAWN	DATE	STATUS
CC	31 03 2023	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	04 04 2023	DRAFT ☐
		FINAL ☑

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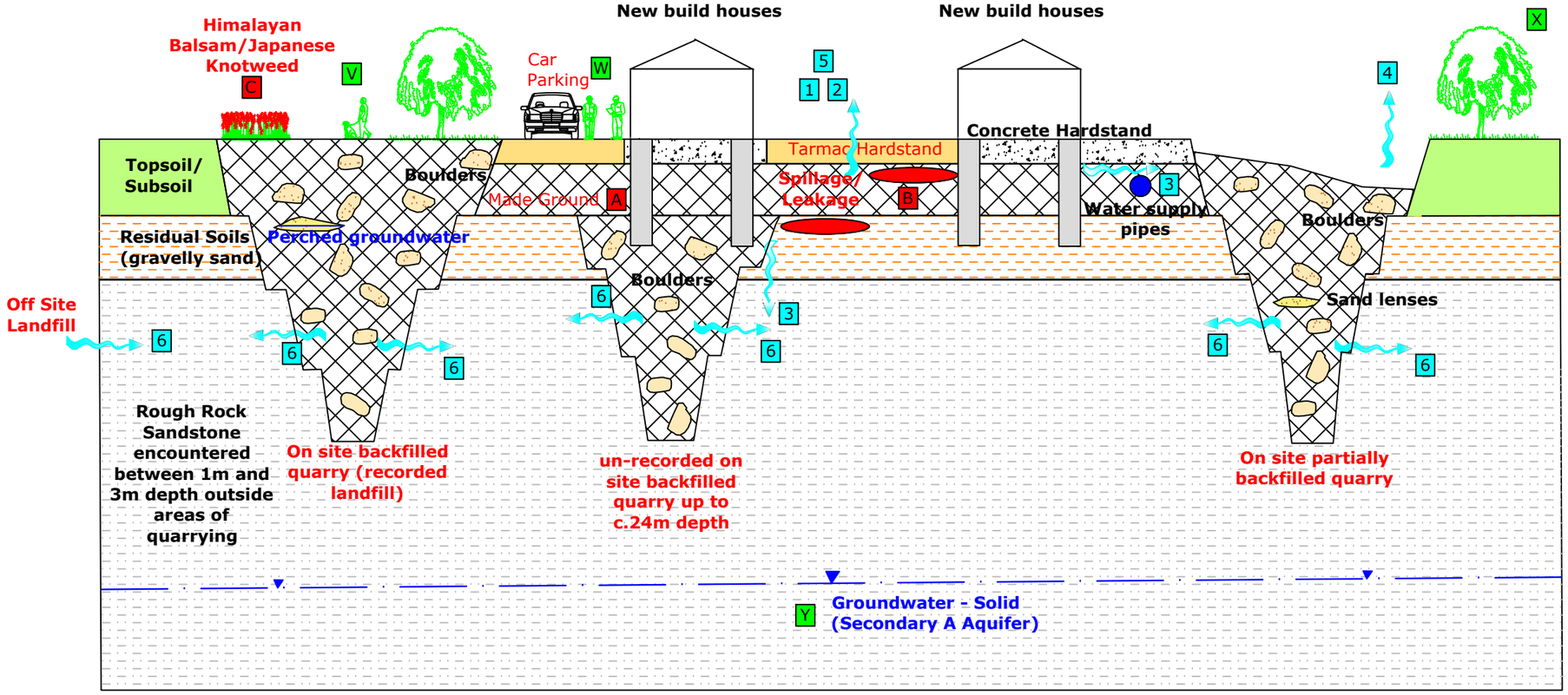

SOURCES	PATHWAYS	RECEPTORS
A MADE GROUND (INORGANICS)	1 DERMAL CONTACT	V END USERS (RESIDENTS)
B LEAKAGE/SPILLAGE (ORGANICS)	2 INGESTION/INHALATION	W SITE WORKERS
C INVASIVE PLANTS	3 LEACHING OF CONTAMINANTS	X VEGETATION
	4 UPTAKE BY PLANTS	Y GROUNDWATER
	5 VOLATILISATION	
	6 MIGRATION OF GAS	

NOTES

REV.	DESCRIPTION	DATE

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JOB TITLE

BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE

REVISED CONCEPTUAL SITE MODEL

DRAWN	DATE	STATUS
CC	14 11 2023	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	14 11 2023	DRAFT ☐
		FINAL ☑

SCALE	SHEET	DRAWING NO.	REVISION
Not to scale	A3	4486/7	

Current surveys:
Reptiles - Whole site has suitability
Bat activity - Whole site has suitability
Breeding birds - Whole site has suitability
Invertebrates - Mosaic of habitats in Black Cat area has suitability

Surveys to be undertaken:
Bat roost assessment of all trees on Site

HIMALAYAN BALSAM
JAPANESE KNOTWEED
RISK AREA

REPRODUCED FROM EBSFORD ENVIRONMENTAL DRAWING REFERENCE JK/HB-A4L-001

NOTES

Site Boundary
Badger sett
Badger sett 30m buffer

Invasive Plant Species
Wall cotoneaster
Himalayan balsam
Japanese knotweed
Hollyberry cotoneaster
Rhododendron

Building Bat Roost Suitability
High
Moderate
Low
Negligible

REV.	DESCRIPTION	DATE
A	UPDATEDECOLOGICAL CONSTRAINTS PLAN	13/07/2023
B	UPDATEDECOLOGICAL CONSTRAINTS PLAN	22/05/2024

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JOB TITLE
BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE
ECOLOGY & INVASIVE PLANTS

DRAWN	DATE	STATUS
CC	31 03 2023	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	31 03 2023	DRAFT ☐
		FINAL ☑

SCALE	SHEET	DRAWING NO.	REVISION
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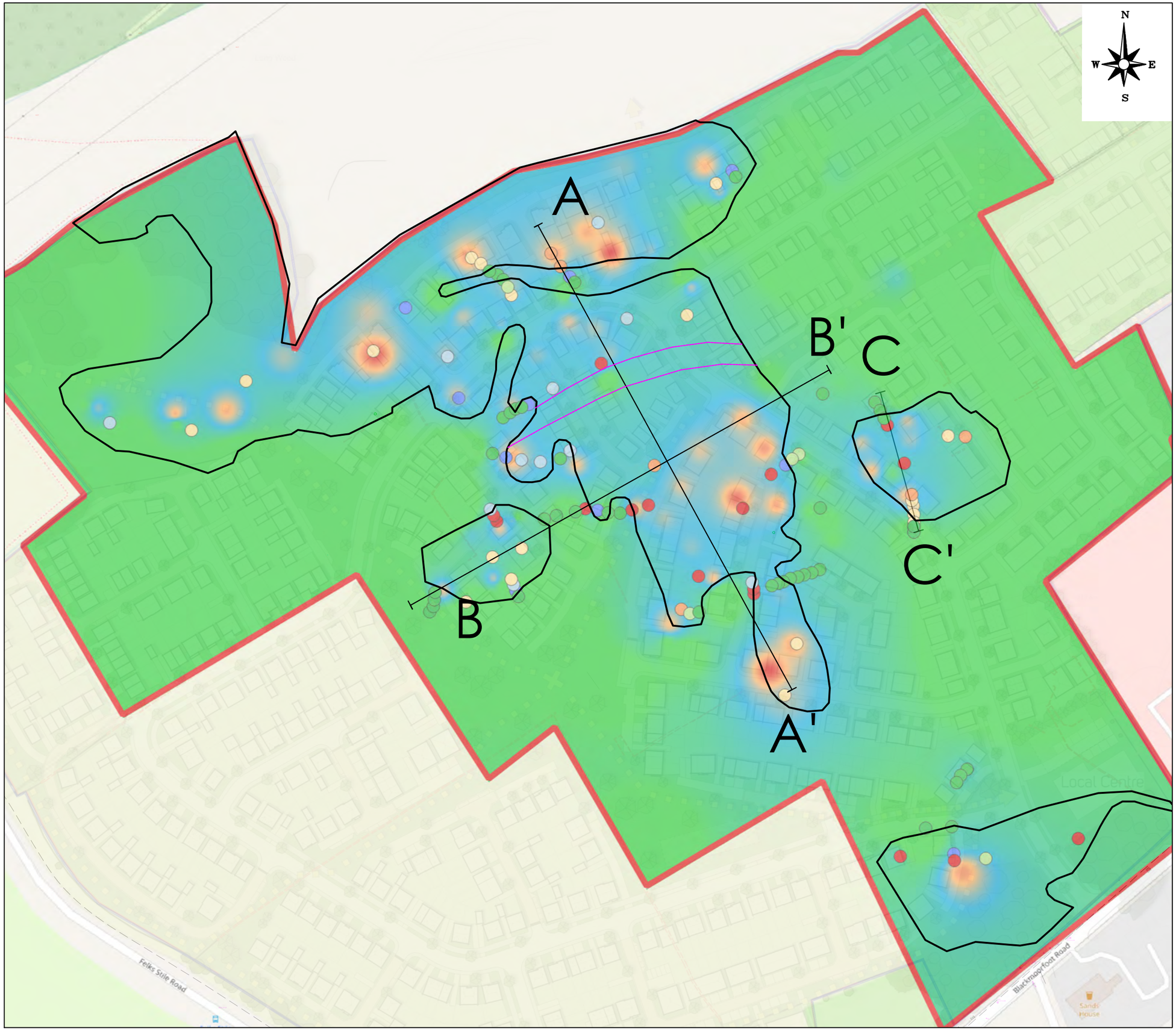

NOTES

MADE GROUND/QUARRY DEPTHS

- 0.0m - 2.0m
- 2.0m - 4.0m
- 4.0m - 8.0m
- 8.0m - 12.0m
- 12.0m - 16.0m
- 16.0m - 20.0m
- 20.0m - 24.0m

APPROXIMATE QUARRY HIGHWALL

A A' LINE OF CROSS SECTION

POSSIBLE 'LAND BRIDGE' - TBC

NOTE: THIS DRAWING IS **SCHEMATIC**. FOR ABSOLUTE DEPTHS, INDIVIDUAL EXPLORATORY HOLE LOGS SHOULD BE CONSULTED.

REV.	DESCRIPTION	DATE

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CLIENT

VISTRY HOMES, COUNTRYSIDE PARTNERSHIP, MILLER HOMES & EMPIRE KNIGHT GROUP

JOB TITLE

BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE

APPROXIMATE QUARRY DEPTHS

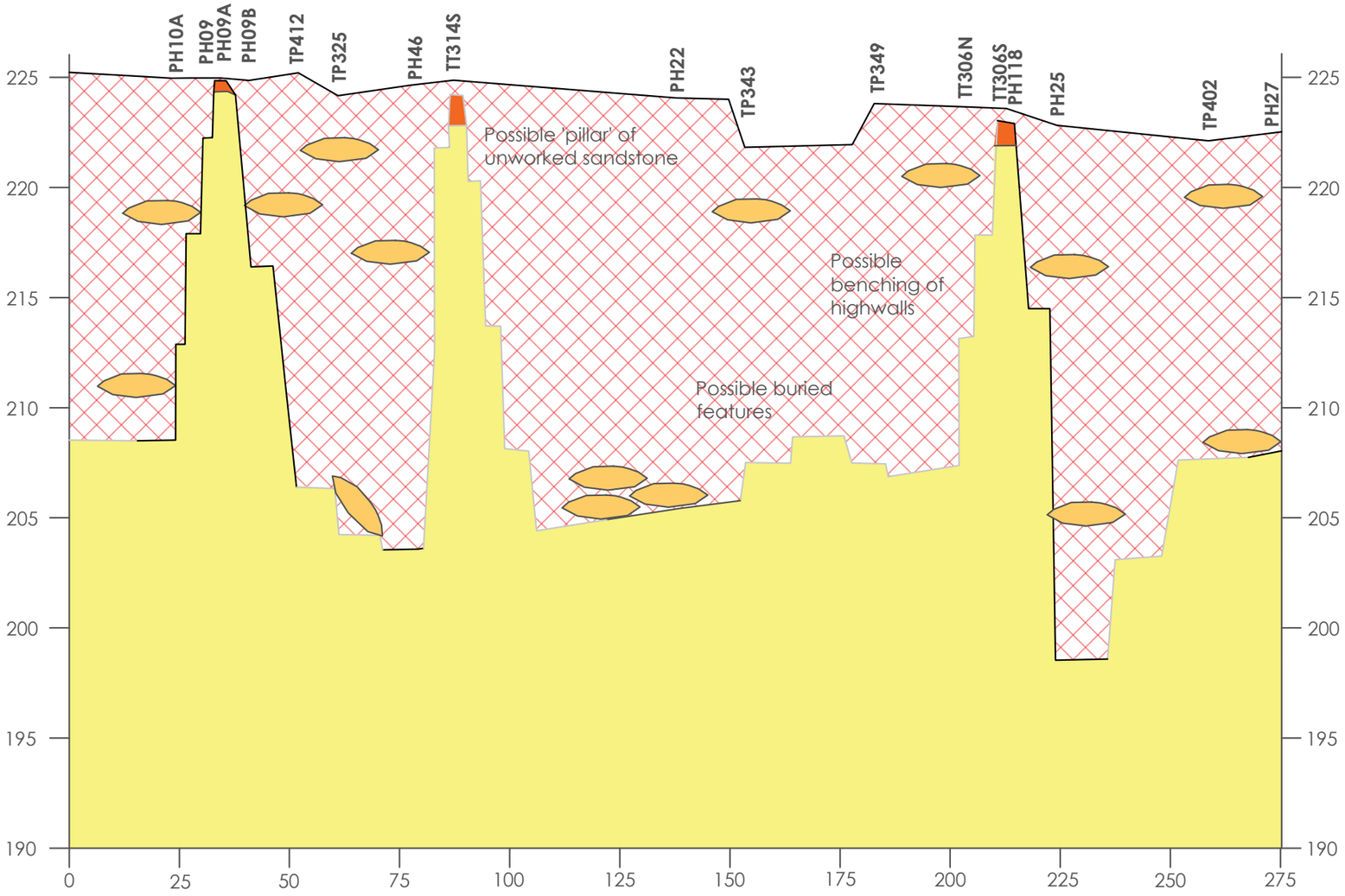
DRAWN	DATE	STATUS
CC	14 11 2023	FOR COMMENT ☐
		FOR APPROVAL ☐
CHECKED	DATE	DRAFT ☑
REG	14 11 2023	FINAL ☐

SCALE	SHEET	DRAWING NO.	REVISION
1:2000	A3	4486/11	

Geological Cross Section A-A'
(approx. vertical exaggeration 1 in 5)

A
(NORTH)

A'
(SOUTH)



N
W E
S

NOTES

- QUARRY BACKFILL (DEEP MADE GROUND)
- RESIDUAL SOILS
- ROUGH ROCK SANDSTONE BEDROCK
- ROUGH ROCK SANDSTONE BEDROCK (INFERRED)
- BOULDERS (SHOWN INDICATIVELY)
- STRATA BOUNDARY (PROVEN)
- STRATA BOUNDARY (INFERRED)

REV.	DESCRIPTION	DATE

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GEOLOGICAL CROSS SECTION LINE A

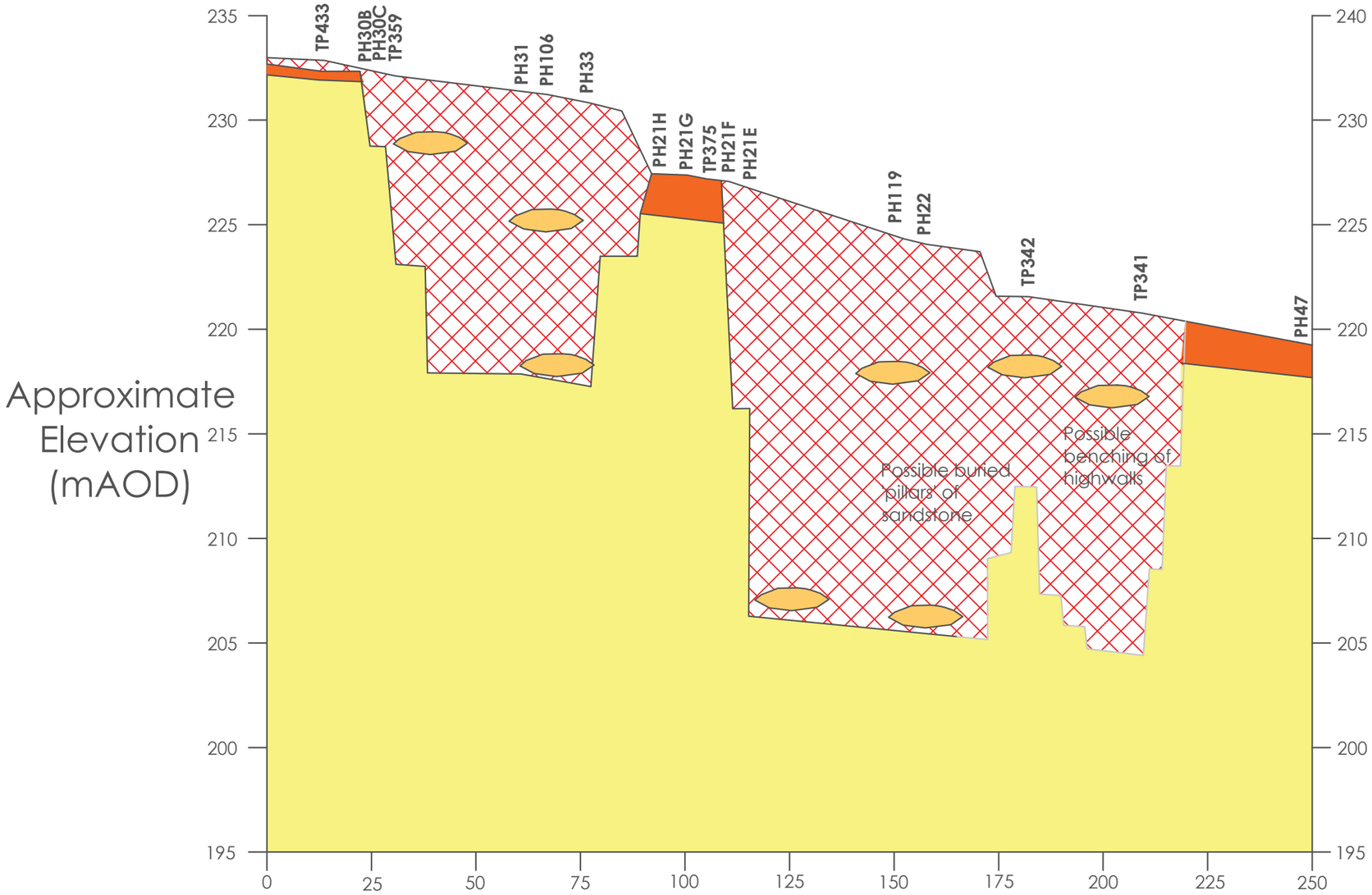
DRAWN	DATE	STATUS
JBR	14 11 2023	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	14 11 2023	DRAFT ☑
		FINAL ☐

SCALE	SHEET	DRAWING NO.	REVISION
NOT TO SCALE	A3	4486/12	

B
(WEST)

B'
(EAST)

Geological Cross Section B-B'
(approx. vertical exageration 1 in 5)



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NOTES

- QUARRY BACKFILL (DEEP MADE GROUND)
- RESIDUAL SOILS
- ROUGH ROCK SANDSTONE BEDROCK
- ROUGH ROCK SANDSTONE BEDROCK (INFERRED)
- BOULDERS (SHOWN INDICATIVELY)
- STRATA BOUNDARY (PROVEN)
- STRATA BOUNDARY (INFERRED)

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JOB TITLE

BLACK CAT
FIREWORKS,
HUDDERSFIELD

DRAWING TITLE

GEOLOGICAL CROSS SECTION
LINE B

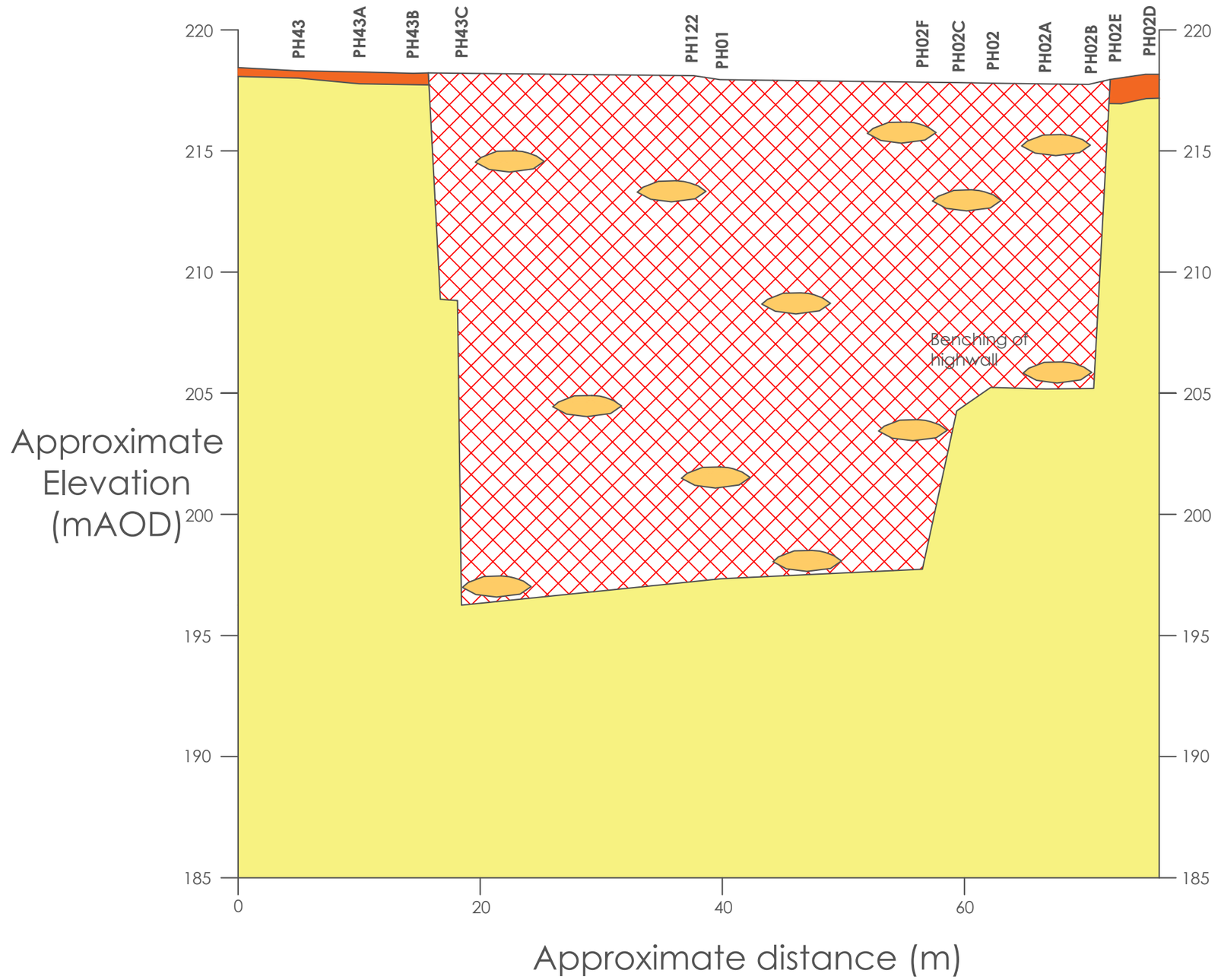
DRAWN	DATE	STATUS
JBR	14 11 2023	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	14 11 2023	DRAFT ☑
		FINAL ☐

SCALE	SHEET	DRAWING NO.	REVISION
NOT TO SCALE	A3	4486/13	

Geological Cross Section C-C'
(approx. vertical exageration 1 in 2)

C
(NORTH)

C'
(SOUTH)



N
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S

NOTES

- QUARRY BACKFILL (DEEP MADE GROUND)
- RESIDUAL SOILS
- ROUGH ROCK SANDSTONE BEDROCK
- ROUGH ROCK SANDSTONE BEDROCK (INFERRED)
- BOULDERS (SHOWN INDICATIVELY)
- STRATA BOUNDARY (PROVEN)

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JOB TITLE

BLACK CAT
FIREWORKS,
HUDDERSFIELD

DRAWING TITLE

GEOLOGICAL CROSS SECTION
LINE
C

DRAWN	DATE	STATUS
JBR	14 11 2023	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	14 11 2023	DRAFT ☑
		FINAL ☐

SCALE	SHEET	DRAWING NO.	REVISION
NOT TO SCALE	A3	4486/14	

NOTES

- HIGH CONFIDENCE LEVEL (PROVEN)
- MODERATE CONFIDENCE LEVEL (EXPLORATORY HOLE WITHIN C.15M, PROVING NATURAL STRATA OR QUARRY BACKFILL)
- LOW CONFIDENCE LEVEL (NO DATA WITHIN C. 15M)
- APPROXIMATE SITE BOUNDARY
- GEOGRIDS REQUIRED. EXACT TYPE, DEPTH, LOCATION & NUMBER TBC. ASSUME TENSAR TRIAX TX160 (OR EQUIVALENT)

REPRODUCED FROM NINETEEN47'S DRAWING REFERENCE n2114 007 REV H, DATED 24.04.2024

NOTE: EXACT HIGHWALL LOCATIONS SHOULD BE CONFIRMED BY INVESTIGATION PRIOR TO CONSTRUCTION. LOCATION OF HIGHWALLS SHOWN ON PLAN ARE NOT ABSOLUTE, EXCEPT WHERE ALREADY PROVEN (GREEN LINE).

WHERE ADOPTABLE HIGHWAY CROSSES PERPENDICULAR TO HIGHWALL, GEOGRID SHOULD BE FULL WIDTH OF ADOPTABLE HIGHWAY & EXTEND 5M EITHER SIDE OF HIGHWALL.

WHERE ADOPTABLE HIGHWAY CROSSES PARALLEL TO HIGHWALL, GEOGRIDS SHOULD EXTEND ACROSS THE HIGHWALL AND AT LEAST 2.5M INTO NATURAL STRATA.

REV.	DESCRIPTION	DATE

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JOB TITLE

BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE

PROPOSED HIGHWAY REINFORCEMENT

DRAWN	DATE	STATUS
CC	22 05 2024	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	22 05 2024	DRAFT ☑
		FINAL ☐

SCALE	SHEET	DRAWING NO.	REVISION
1:2500	A3	4486/17	A

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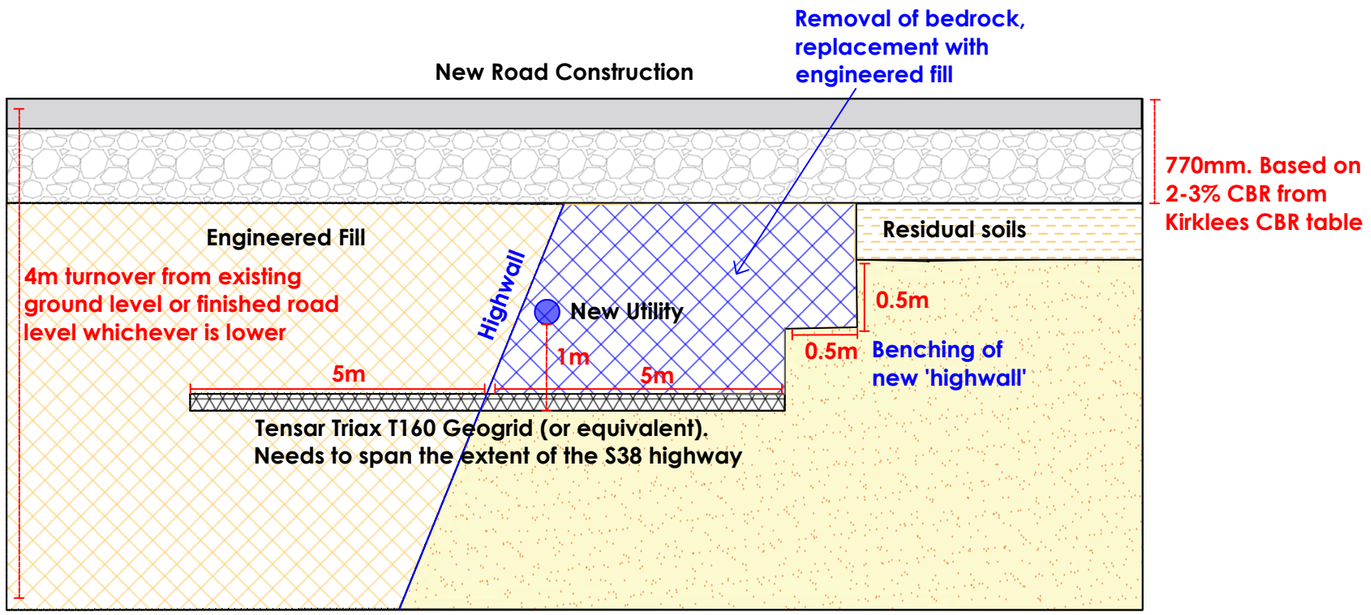
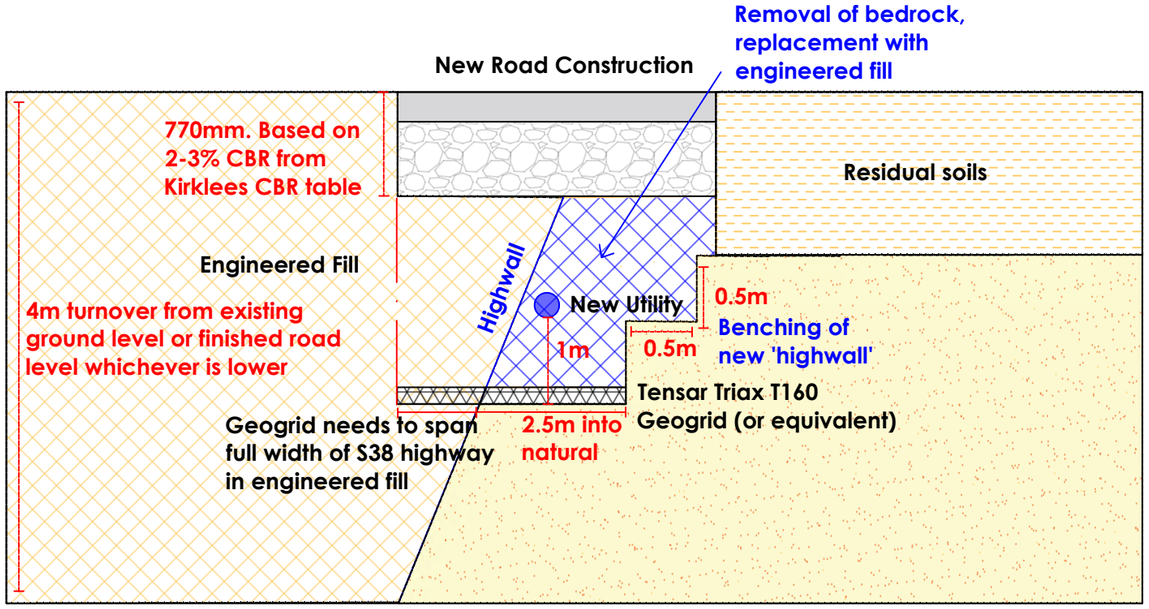
GEOGRID CONSTRUCITON - ROAD PERPENDICULAR TO HIGHWALLS



GEOGRID CONSTRUCITON - ROAD PARALLEL TO HIGHWALLS



NOTES

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WHERE ADOPTABLE HIGHWAY CROSSES PARALLEL TO HIGHWALL, GEOGRIDS SHOULD EXTEND ACROSS THE HIGHWALL AND AT LEAST 2.5M INTO NATURAL STRATA.

DEPTH OF GEOGRID IS DEPENDENT ON THE DEPTH OF THE SEWER INVERT. WHERE SEWER INVERTS ARE LOWER THAN 4M INSIDE THE QUARRIES, OR 2M OUTSIDE THE QUARRIES, THE TURNOVER NEEDS TO CONTINUE 1M BELOW THE LOWEST SEWER INVERT, UNLESS NATURAL GROUND IS ENCOUNTERED BEFORE THIS.

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JOB TITLE

BLACK CAT FIREWORKS, HUDDERSFIELD

DRAWING TITLE

PROPOSED HIGHWAY REINFORCEMENT - CROSS SECTIONS

DRAWN	DATE	STATUS
CC	22 05 2024	FOR COMMENT ☐
CHECKED	DATE	FOR APPROVAL ☐
REG	22 05 2024	DRAFT ☑
		FINAL ☐

SCALE	SHEET	DRAWING NO.	REVISION
NOT TO SCALE	A3	4486/17A	

APPENDIX B
LITHOS TIER 1 VALUES

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 and 10) outlining the UK approach to the assessment of risk to human health from land contamination. In 2008 CLR 7, 9 and 10 and all corresponding SGV and Tox reports were withdrawn and superseded by new guidance including:

- Guidance on Comparing Soil Contamination Data with a Critical Concentration - CL:AIRE and CIEH, May 2008
- 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 2 A 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).

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

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

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

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

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

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

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

D - Commercial/industrial with landscaping

E – Importation of soil cover

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

Scenario	Land use	Pathways	Justification
A	Residential with garden, but no cover (or only up to 300mm)	• Direct ingestion of soil • Dermal contact • Consumption of vegetables & soil attached to vegetables • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	Minimal cover – insufficient to break any pathways therefore all exposure pathways are relevant.
B	Residential with garden minimum 600mm cover	• Inhalation of indoor vapours • Inhalation of outdoor vapours	The 600mm cover removes the risk from all pathways other than inhalation.
C	Residential apartments with landscaped areas and minimum 300mm cover	• Direct ingestion of soil • Dermal contact • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	All pathways applicable due to possible exposure from landscaped areas. However consumption of home grown produce not included as unlikely to be grown in landscaped areas. Where vegetables are to be grown site specific QRA may be required.
D	Commercial/ industrial with landscaped areas no cover	• Direct ingestion of soil • Dermal contact • Inhalation of indoor vapours and dust • Inhalation of outdoor vapours and dust	All pathways applicable due to possible exposure from landscaped areas. Assumed the commercial development consists of offices to provide a conservative assessment.
E	Importation of soil for cover in garden and landscaped areas	• Direct ingestion of soil • Dermal contact • Consumption of vegetables & soil attached to vegetables • Inhalation of outdoor vapours and dust	Material used as cover to break existing pathways therefore all direct and indirect pathways relevant; however cover is **not** placed below plots therefore indoor inhalation is not relevant.

Lithos have assumed the source of contamination is directly below the building foundations; 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; and
- Controlled waters

Inorganic Tier 1 values for scenarios A to E

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

Organic Tier 1 values for scenarios A to E

Organic contaminant (all sourced via CLEA)	Tier 1 assessment criteria (mg/kg) for Scenarios A to E							Comments/notes
	SGV*	C4SL*	A	B	C	D	E	
Benzene	0.33	0.87	0.7	<1^	<1^	63	<1	<1 based on professional judgement and lower than calculated value.
Toluene	610		836	2,048	1,912	5,000	<1	Scenario D based on professional judgement and lower than calculated value.
Ethyl Benzene	350		379	592	566	5,000	<10	
Xylenes	240		535	590	585	5,000	<10	Scenario E based on professional judgement and lower than calculated value.
Phenol	420		1,434	3,360	2,264	5,000	<10	
PCBs			2	8	2	38	N/A	Based on toxicity of EC7
Benzo(a)pyrene		5	5	25	5	76	5	C4SL adopted. Scenario B 5 times scenario A
Naphthalene			6	6	6	619	<10	Scenario E based on professional judgement and lower than calculated value
Gasoline Range Organics			22	23	23	2,178	626	See 3-step assessment of TPH below ^Based on professional judgement and lower than calculated value
Diesel Range Organics			215	218	215	^5,000	1429	
Lubricating Range Org			3,299	5,000	3,829	^5,000	3,299	

* *For a residential end use*

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

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

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

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

Similarly, **TPH** cannot be assessed as a single "total" value, and reference has been made to the Environment Agency's document P5-080/TR3, "The UK approach for evaluating human health risks from petroleum hydrocarbons in soils". This document supports the assumptions and recommendations made by the US Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG). The TPHCWG have broken down "TPH" into representative constituent fractions or "EC Bandings". The TPHCWG have derived a series of physiochemical and toxicological parameters for each of the bandings.

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

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

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

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

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

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

Statistical Assessment

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

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

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

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

The 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).

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

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

However, broadly speaking the following applies:

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

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

Other screening values used by Lithos

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

- Approved Document C, Building Regulations 2000
- Boyle & Witherington (2007) – Guidance on evaluation on development proposals on sites where methane and carbon dioxide are present, incorporating "traffic lights". Report Ref. 10627-R01-(02), for NHBC
- CIRIA C665 (2007) – Assessing risks posed by hazardous ground gases to buildings
- BS 8485:2015 – Code of Practice for the characterisation & remediation from ground gas in affected developments

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

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

With respect to the interpretation of the **calorific values**, at present there are no accepted methods to assess whether a sample is combustible and under what circumstances it might smoulder. Some guidance is given in ICRCL Note 61/84 "Notes on the fire hazards of contaminated land" which states that: "*In general … it seems likely that materials whose CV's exceed 10MJ/kg are almost certainly combustible, while those with values below 2MJ/kg are unlikely to burn*".

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

Waste classification & WAC

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

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

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

Landfill operators require Waste Acceptance Criteria (WAC) laboratory data, if soil waste is classified as **hazardous**. However, subject to WAC testing it may be possible to classify it as stable, non-reactive hazardous waste, which can be placed within a dedicated cell within the non-hazardous landfill.

Lithos typically only include WAC analysis in site investigation proposals and reports, if significant off-site disposal (of soil classified as hazardous waste) is anticipated, for example where redevelopment proposals include basement construction etc. If off-site disposal of soils classified as hazardous waste during redevelopment is anticipated, then WAC analysis should be scheduled at an early stage in the remediation programme. However, organic compounds (BTEX, TPH, PAH etc) are the most common contaminants that result in soils being classed as hazardous, and these contaminants can often be dealt with by alternative technologies (e.g. by bioremediation or stabilisation) and consequently retention on site is often possible.

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

APPENDIX C

LITHOS PROTOCOL FOR THE PLACEMENT OF NON-ENGINEERED FILL

1 INTRODUCTION

1.1 This protocol is aimed at providing general guidance to contractors in the placement of general earthworks fill materials in areas of a site that do not require high quality, controlled engineering eg Public Open Space. No guarantee can be made as to the degree of settlement that may occur in such fill masses; however, the protocol should mitigate significant differential settlements.

1.2 General fill will be either inert soil or contaminated soil that is deemed chemically suitable for reuse in certain specific site areas or beneath a specified 'clean' soil cover layer. All soft and compressible soils or existing fill shall, if comprising unsuitable fill be removed from site. Suitable fill materials may be compacted on site.

1.3 Unsuitable fill shall comprise:

- Cohesive soils having a liquid limit in excess of 90% or Plasticity Index in excess of 65%
- Chalk having a fine fraction (<400μm) in excess of 10% at the borrow pit
- Any material containing topsoil, wood, peat or lignite
- Any material containing biodegradables
- Any material containing scrap metal
- Frozen or waterlogged substances
- Material defined as unsuitable by the Engineer because of its type or level of contamination
- Material which, by virtue of its particle size or shape, cannot be properly and effectively compacted (eg oversize material, gravels which are tabular and some slate wastes)
- Expansive steel slag
- Non-inert or contaminated material
- Putresible waste
- Materials containing minerals hostile to the built environment such as pyritic shales, gypsiferous clays, burnt colliery discard, pulverised fuel ash, spent oil shale or incinerator waste

1.4 The base of the area to be filled shall be proof rolled with a dead weight roller and all soft materials removed and replaced with compacted fill. Where unsuitable material has been excavated, the underlying ground shall be compacted to the same specification as adopted for subsequent compaction works.

1.5 Fill shall be placed and compacted in near-horizontal layers of maximum 200mm thicknesses and be brought up at a uniform rate so that all parts of the site or particular sections of the site reach finished (formation) level at the same time. Each layer will be subjected to nominal compaction, comprising at least two passes with a towed vibratory roller of at least 2,900 kg per metre width (or equivalent). If the compacted fill demonstrates excessive rutting, excessive roller 'bow-waving' or other soft behaviour then it shall be deemed unsuitable.

1.6 Cobbles, boulders, rock or waste fragments, the largest dimension of which is greater than two-thirds of the compacted layer thickness (or greater than 250mm in any dimension), shall not be incorporated into the fill.

1.7 When compacting fill in the vicinity of existing trenches, excavations, retaining walls or other structures all work shall be performed in such a way as to ensure that their existing stability is not impaired; this will require careful selection of both compaction plant and compaction method.

1.8 When placing fill against structures the Contractor must only use only the following types of compaction plant for fill within 2m of a structure:

- Vibratory roller, mass per metre width of roll not exceeding 1300 kg and total mass not exceeding 1000 kg
- Vibrating plate compactor, mass not exceeding 1000 kg
- Vibro-tamper, mass not exceeding 75 kg

1.9 If weather conditions are such that the fill is adversely affected, the Contractor shall cease work until such time as the fill can be placed and compacted to meet the protocol requirements. No fill shall be placed and left uncompacted at the end of the working day. Compacted fill shall be graded to falls to ensure free run-off of rainwater without ponding.

1.10 Drainage grips or trenches shall be excavated, as necessary, uphill of the area to be filled to prevent the area becoming flooded. Drainage shall be affected without causing siltation or erosion and water shall be disposed of. The area to be filled shall be graded to falls, and sump pumping or other suitable dewatering facilities shall be provided as necessary by the Contractor to keep the base of the excavation dry at all times.

APPENDIX D

LITHOS PROTOCOL FOR IMPORTATION & USE OF SOIL COVER (CAPPING)

1 INTRODUCTION

1.1 Isolation of made ground in garden and landscaped areas beneath a cover of "clean" subsoil, and topsoil is often recommended on new developments; most notably when the made ground contains inorganic (and non-volatile organic) contaminants at concentrations above relevant guidance threshold values. A cover solution is not appropriate for volatile or semi-volatile organic contaminants (fuels, solvents etc); removal or treatment will usually be required.

1.2 The thickness of cover is dependent on the end use of the development, nature and degree of contamination (and sometimes the Local Authority whose area the site lies within), Typically for a commercial development between 300mm and 1,000mm thickness is required and for a residential development between 600mm and 1,000mm thickness is required. Regardless of the type of development, where contamination is more significant a granular hard-dig layer or geotextile marker membrane may also be required at the base of the cover.

1.3 The "clean" soil cover blocks potential linkages between the contaminated made ground and future site users. Soil cover is not required beneath areas of hardcover including buildings, private drives, carparking and roads.

1.4 If the made ground is essentially "clean", but contains materials generally considered undesirable as near-surface material in garden and landscaped areas (e.g. oversize materials such as construction/demolition rubble) then placement of cover is also required. In private gardens, in accordance with NHBC Standards Chapter 10.2, a 450mm thick soil cover should be adequate. In landscaped areas a 300mm thick soil cover should be adequate. For both gardens and landscaped areas if the made ground is essentially "clean" and comprises reworked natural soil, the only cover likely to be required is 100mm topsoil.

1.5 The **CML initiative** came into force in April 2003 and relates specifically to residential developments. It requires housebuilders to submit to NHBC (or other warranty providers) a validation report confirming the thickness and quality (i.e. contaminant-free) of the placed soil cover. Validation reports should normally be prepared by independent geoenvironmental consultants.

1.6 Failure to submit cover validation reports promptly will delay issue of the cover note by the warranty provider, which will subsequently delay the release of mortgage funds and hence legal completion; i.e. the financial implications are significant. Consequently, it is essential that cover validation is requested at least 2 weeks prior to the anticipated finalling date.

1.7 For all land uses soil cover is usually placed many weeks after completion of the preparatory/remediation works, and issue of the associated Verification Report, typically at a relatively late stage in the construction programme.

1.8 Prior to placement of soil cover, the appointed remediation contractor and/or groundworker should ensure that ground levels are low enough to accommodate the required cover thickness, taking account of any boundary issues, and, where relevant, without compromising the DPC and any sub-floor ventilation.

1.9 Ideally soil quality should initially be determined by sampling of the source (at least 7 working days before importation to the development site) to demonstrate suitability for use. Further sampling of the material at the site may also be required to demonstrate cross contamination did not occur during the importation process. Samples could also be obtained from stockpiles of site won material on site; there may comprise surplus natural ground development arisings. Soil samples could be obtained after placement of the cover layer, but this is not recommended.

1.10 Imported topsoil should be subject to testing, unless it is being sourced from a reputable commercial supplier able to provide robust certification (certificate date less than 2 months prior to import date). In addition, some analysis in accordance with BS3882 may occasionally be appropriate.

1.11 Where sampling of the source has been carried out, and on receipt of the laboratory results, Lithos will issue a confirmation of soil suitability for importation to the client, who will in turn instruct his contractor to commence importation.

1.12 Clearly, if soil cover is imported and placed before confirmation of its suitability, no guarantee can be given that validation work will yield the desired results. It may therefore be necessary to excavate and export the placed soil cover and/or import further "clean" soil.

1.13 It is likely that it will be necessary to stockpile imported soil cover material at the site. Where soils have been confirmed as suitable for use and temporarily stockpiled on site, stockpiles should be fenced-off and marked as containing certified topsoil/subsoil. The soil should be inspected prior to placement to confirm that it is the same material as previously tested, and that it has not been cross-contaminated with miscellaneous arisings generated during the construction works. Where material has been stockpiled on site for an extensive period of time further sampling may be required at the development site to demonstrate cross contamination has not taken place.

1.14 Soil **thickness** can only be checked after placement; this should be done before turfing / landscaping, but ideally after scaffolding has been dismantled.

1.15 *Sampling Frequency (to check Soil Quality):* The number of samples tested will be dependent on the nature of the source, and the quantity of material to be imported. However, in accordance with current YALPAG (Yorkshire & Lincolnshire Pollution Advisory Group) guidance[1], the testing frequency should be as follows:

Nature of source	Number of samples (from any single source material)	
	Up to 500m³	Per additional 500m³
Greenfield	At least 3#	1*
Brownfield	At least 6#	1*
Crushed product	At least 3	1*

* To be agreed with the relevant Local Authority

\# But could be up to 10 samples (if 500m³), depending on the Local Authority area within which the site is located.

1.16 On a typical residential development where gardens comprise a total area of 100m² (front and rear), and a soil cover thickness of 600mm including 100mm topsoil, for a brownfield source this testing frequency equates to approximately one topsoil sample per ten plots and one subsoil sample per two plots. Given the requirement to test a minimum number of samples from any one source, the testing frequency effectively increases for sites with only a small number of plots.

[1] *Verification Requirements for Cover Systems: Technical Guidance for Developers, Landowners & Consultants; Version 4.1, June 2021.*

1.17 **Inspection Frequency (to check soil thickness):** The number of inspection pits excavated to check cover thickness (and collect samples, if required) should be dependent on the end use of the development.

1.18 For **residential developments** the number of plots associated with a given site will dictate the number of inspection pits. The following frequencies are recommended for residential plots.

No. plots within development	Frequency of inspection pits	Remarks
1 to 5	1 pit per plot	e.g. for 3 plots, dig 3 inspection pits
6 to 20	1 pit per 2 plots	e.g. for 9 plots, dig 5 inspection pits
21 to 30	1 pit per 3 plots	e.g. for 23 plots, dig 8 inspection pits
≥ 30	1 pit per 4 plots	e.g. for 39 plots, dig 10 inspection pits

1.19 For **areas of landscaping**, regardless of development type, a minimum of 3 pits per area of soft landscaping are recommended where the landscaped area is greater than 25m^2. In individual landscaped areas smaller than 25m^2 inspection pits are not required.

1.20 Photographs should be taken of each inspection pit to show:

- The thickness of cover material present
- The presence of any geotextile marker or granular hard-dig layer (if required)
- The position of each inspection pit in relation to the plot/area of landscaping

1.21 **Soil Material Suitability**: Inspection pits should be excavated through the entire thickness of any proposed in-situ source material, or cover material (if inspection is post-placement). Stockpiles should be assessed from both the surface and by digging into the "core", to ensure the material is reasonably homogenous.

1.22 The soil material should comply with the following requirements:

- Be clean and free of foreign debris, building waste materials, glass sharps, and contaminants
- Topsoil should not have a gravel content of greater than 30% by dry weight and should generally have a maximum stone size of 50mm in any one direction
- Subsoil should generally have a maximum stone size of 75mm in any one direction
- Not have been sourced from an area within 7m laterally, or 3m vertically, of Japanese Knotweed plants, and not contain any Japanese Knotweed fragments (rhizomes, leaves, stems etc)

1.23 **Laboratory Analysis:** Whether samples are taken at source, from stockpiles on site, or from gardens and landscaped areas after placement, they should be forwarded to an analytical laboratory for testing in accordance with one of the Schedules detailed in Table 1 overleaf.

1.24 Additional determinands may be scheduled dependent on the history of the source site, although if this is considered necessary it may suggest the material is unlikely to be suitable for use as clean cover.

Table 1 – Test schedule

Source	Test schedule
Greenfield & Manufactured topsoil	pH, total metals (Cu, Ni, Zn, Cr III, Cr VI, As, Hg, Se, Cd & Pb), water soluble boron. TOC & speciated PAH Asbestos ID
Brownfield & Soil transfer stations	pH, total metals (Cu, Ni, Zn, Cr III, Cr VI, As, Hg, Se, Cd & Pb), water soluble boron. TOC, Speciated PAH & banded TPH* Asbestos ID
Crushed product	pH, total metals (Cu, Ni, Zn, Cr III, Cr VI, As, Hg, Se, Cd & Pb), water soluble boron. TOC & Speciated PAH Asbestos ID

Note: The schedules detailed above have been prepared in accordance with the Secondary Model Procedures and Land Contamination Risk Management, 2020. This document states that analysis should be relevant to potential sources and not merely a set list of parameters applied to each site.

* The YALPAG guidance recommends speciated TPH (TPH CWG) analysis for brownfield sources, but this should not be necessary unless the banded TPH analysis fails the assessment criteria detailed in Table 2 below.

Where crushed product is used at least 600mm below finished garden level, only asbestos analysis will be required.

1.25 Chemical assessment (Tier 1) criteria for imported soils are provided in Table 2, these reflect exposure and toxicological amendments proposed within the C4SL report. Where no C4SL value has been published generic assessment criteria have been derived based on the C4SL assumptions using the CLEA model (version 1.701).

Table 2 - Chemical assessment criteria for imported soils

Contaminant	Source	Tier 1 assessment criteria (mg/kg)	Comments/notes
pH	CLEA		
As	C4SL	37	
Cd	C4SL	26	
Cr (III)	CLEA	4000	
Cr (VI)	C4SL	21	
Pb	C4SL	200	
Ni	CLEA	109	Assessment of human health risk only.
Se	CLEA	434	
Hg	CLEA	199	Assumes mercury present as an inorganic compound (cf elemental metal or within organic compound). See Science Report SC050021/Mercury SGV.
Vn	CLEA	584	
B	Lithos	5	Based on phytotoxic risks as plants are the more sensitive receptor (Cu is pH dependent).
Cu	DoE	100	
Zn	DoE	200	
Benzo(a)pyrene	C4SL	5	
Naphthalene	CLEA	6	
GRO	CLEA	22	Conservative value based on value for aromatic fraction C7 to C8 range, but assuming indoor inhalation pathway still relevant (it shouldn't be).
DRO	CLEA	215	Conservative value based on value for aliphatic fraction C10 to C12 range, but assuming indoor inhalation pathway still relevant (it shouldn't be).
LRO	CLEA	1,000	Calculated value above hazardous waste screen in WM3, therefore 1,000mg/kg adopted. This may be reviewed on a site specific basis depending on the source and nature of transfer.

2 VALIDATION REPORTS

2.1 The analytical testing will usually be undertaken on a 3 or 5-day turnaround and the Client/Contractor will be notified of the soil's suitability (or otherwise) immediately after receipt of the results.

2.2 Interim plot validation certificates for residential plots should be issued to warranty providers on a plot by plot (or block by block) basis as development proceeds. Once the full development has been completed these should be pulled together into a final verification report, for submission to the Local Authority to satisfy planning conditions.

2.3 Interim validation certificates will be issued by Lithos for each landscaped area or set of landscaped areas once completed. After Lithos have been able to confirm placement of agreed thicknesses of suitable soil cover in all landscaped areas across the site, and where required to satisfy a Local Authority planning condition, we will prepare and submit a final validation letter report.

APPENDIX E

EA GUIDANCE: DECOMMISSIONING REDUNDANT BOREHOLES AND WELLS

Good practice for decommissioning redundant boreholes and wells

October 2012

What's the purpose of this guidance?

Redundant boreholes and wells must be dealt with appropriately to make them safe and secure, and also to ensure they don't cause groundwater pollution or loss of water supplies. This guidance focuses on groundwater protection aspects but there are many other important factors owners and developers need to consider when designing and carrying out decommissioning works. These will be site specific, depending on the situation and intended afteruse. For example, boreholes near landfills or other sources of soil gas may require an opening to the air to prevent the build-up of noxious, explosive or flammable gas. Therefore, you should seek expert site-specific advice.

Legal framework

The Environment Agency (EA) has a duty to promote the sustainable use of water and to ensure it is protected from pollution. The Environmental Permitting (England and Wales) Regulations 2010 require the EA to take all necessary measures to prevent input of so called hazardous substances (for example pesticides) and limit the input of other non-hazardous pollutants (such as nitrate) into groundwater*, including for example contaminated run-off directly entering groundwater via an uncapped borehole.

**Groundwater is defined as water that is below the surface of the ground in the saturated zone and is in direct contact with the ground or subsoil.*

Why is it important to decommission properly?

Boreholes and wells are constructed for a variety of purposes including water supply, de-watering excavations, collecting geological information, investigating or sampling soils and groundwater and, increasingly, for ground source heating and cooling and geothermal (non-carbon) energy production. Many old water wells and boreholes are redundant as most properties are now connected to a mains water supply.

Improperly abandoned boreholes and wells can provide preferential pathways for groundwater or contaminant movement. This may result in the contamination of groundwater, the mixing of groundwaters of variable quality from different aquifers, or contribute to the loss of aquifer yield and water pressure (referred to as the potentiometric or piezometric head) as groundwater flows out of the system. This can threaten the availability and quality of groundwater resources for other users and potentially have an impacts on wetlands. Abandoned boreholes and wells can also present a physical hazard to people and property.

Artesian boreholes (where groundwater at depth in a 'confined aquifer' is at sufficient pressure to cause water to discharge either at the ground surface or into another overlying aquifer without any pumping) can be particularly problematic. They require special attention to prevent uncontrolled discharge of groundwater or cross-contamination of different aquifer units.

Therefore, site owners need to ensure that redundant boreholes and wells are made both safe and structurally stable, and also backfilled or sealed to prevent groundwater pollution and flow of water

between different aquifer units. This is particularly important where other potable groundwater supplies are at risk.

However, in certain circumstances they may be adapted for use as a groundwater monitoring facility. **You must not use wells or boreholes as soakaways for foul or surface water drainage** because they provide a direct discharge route into groundwater and, as such, pose a risk of groundwater pollution.
This is prohibited by the Environmental Permitting (England & Wales) Regulations 2010.

Firstly, what are the construction details?

When considering how best to backfill and seal a borehole or well, or whether it could be adapted for monitoring purposes – you should first obtain information on the geological strata encountered by the borehole and how it was constructed (including depth, diameter and casing details). These can usually be obtained from site records or the original driller's log; the British Geological Survey holds the national water well archive and other borehole databases.

Is the site suitable for groundwater monitoring?

There are many good reasons for collecting groundwater samples or measuring groundwater levels; the information can, for example, help to validate the success of any remedial works being undertaken on a contaminated land site. Therefore, before decommissioning a borehole you should consider whether you wish to retain it as a monitoring facility. If it is to fulfil part of a planning condition or other legal monitoring requirement you may wish to discuss the details of how you do this with the Environment Agency.

If not, it is still worth contacting us via our National Customer Contact Centre (NCCC) to check whether we would be interested in incorporating it into our strategic groundwater level or quality monitoring networks.

If the borehole is not going to be converted then it should be abandoned using the guidelines below and the British Geological Survey should be informed.

Decommissioning

Each situation is different in terms of its location, geological setting, borehole construction, dimensions, hazards and, very importantly, intended site afteruse. Therefore the most appropriate abandonment procedure will vary from site to site. It is strongly recommended that you engage the services of a proficient well contractor with a good knowledge of the local geology and well abandonment procedures. For large boreholes and wells you may need to seek engineering advice. (**Note that structural aspects are outside the scope of this guidance.**)

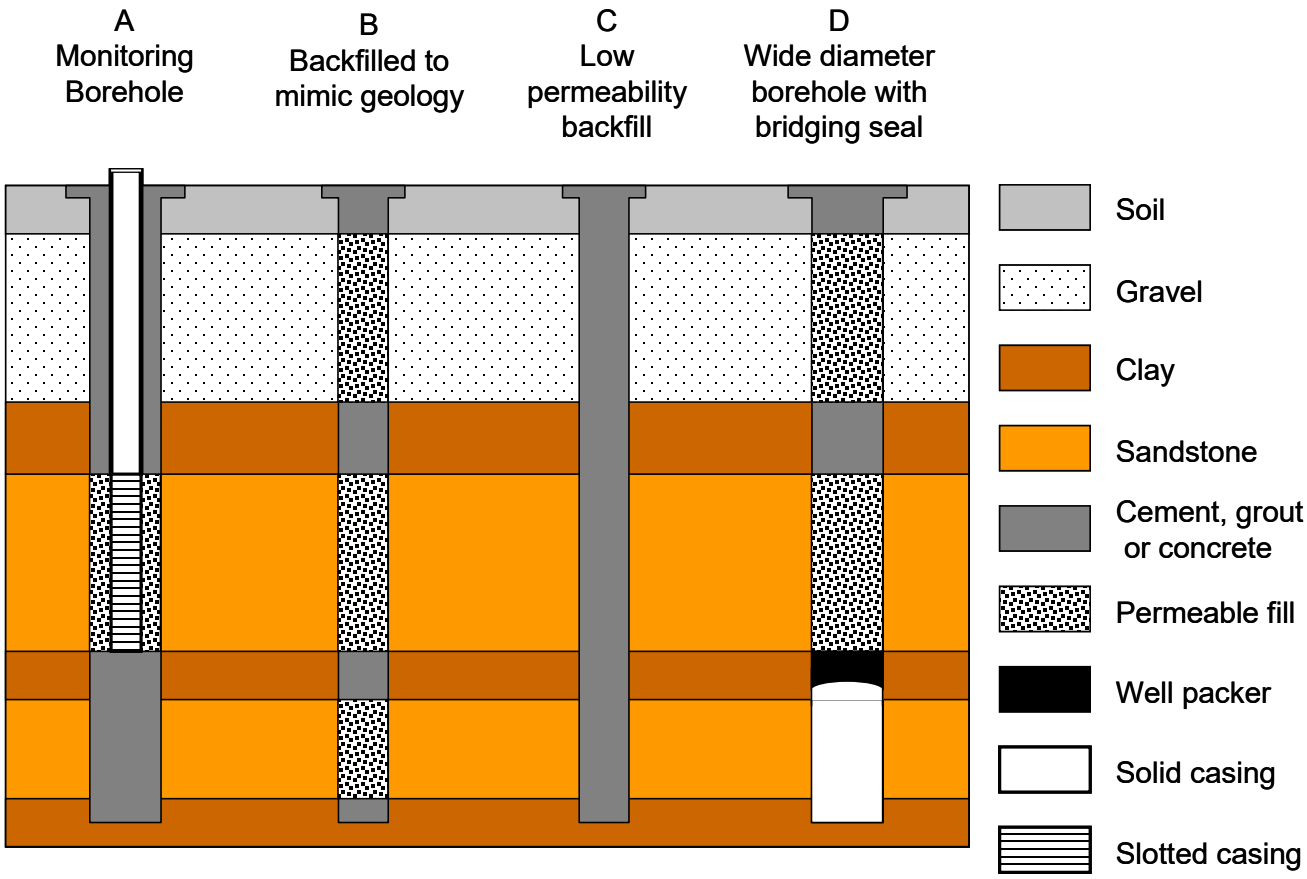

Figure 1: Schematic options (B–D) for decommissioning wells and boreholes

Step 1 - Defining the objectives

When planning the decommissioning works, in addition to any site specific afteruse considerations, the method should address the following objectives:

- Remove the hazard of an open hole (safety issues).
- Prevent the borehole acting as a conduit for contamination of groundwater.
- Prevent the mixing of contaminated and uncontaminated groundwater from different aquifers.
- Prevent the flow of groundwater from one geological horizon to another.
- Prevent the wastage of groundwater from the overflow of artesian boreholes.

Step 2 - Removing headworks and casing

It is crucial to ensure that the borehole or well is free from all obstructions that may interfere with the sealing of the hole. In particular, the pump and pipework should be removed, together with any other infrastructure (dip tubes etc).

The condition of any borehole casing and grout must be examined to ascertain whether its retention in the hole would prejudice any of the objectives of the abandonment. For many holes, examination of the casing from the ground surface will be adequate. However, deep boreholes may require the use of closed-circuit television (CCTV) to examine the casing at depth.

Where the casing has corroded or broken, or the grouting has failed, depending on the setting it may be necessary to remove those materials to prevent any flow of groundwater around the outside of the borehole. However, this is not without its own risks since removal of the well casing can result in collapse of the borehole walls (particularly in unconsolidated materials) and possible subsidence at ground level. If the well casing needs to be removed, a specialist well contractor can advise on appropriate techniques and associated risks.

Step 3 - Backfilling

General considerations

For most purposes the ground should be restored as closely as possible to its pre-drilled condition. The borehole or well should be backfilled with clean (washed), uncontaminated materials so that the permeability of the selected materials are similar to the properties of the geological strata against which they are placed. The backfilled borehole will then mimic the surrounding natural strata and groundwater flow and quality will be protected.

Restoration will require a variety of materials to be used so that permeable aggregates (for example pea gravel and sand) are positioned adjacent to aquifer horizons, whilst low permeability materials (usually clay, bentonite cement grout, or concrete) are positioned adjacent to low permeability horizons (see Fig. 1(B)). Alternatively, the entire borehole or well can be backfilled with low permeability

materials that will prevent significant vertical or horizontal movement of groundwater through or along the borehole (see Fig. 1(C)).

The backfill materials must be clean, inert and non-polluting. Suitable materials include pea gravel, sand, shingle, concrete, bentonite, cement grout and uncontaminated rock. There are also a range of recycled products, like crushed glass, on the market that are designed for use in boreholes

IMPORTANT - Never use backfill materials that can cause pollution.

You should also consider the geochemical environment into which these materials will be placed, as the behaviour of materials may change under different environmental conditions (for example, iron-rich sands may contaminate the aquifer; phenol contamination may prevent bentonite grouts curing).

Aggregates (pea gravel, shingle, sand etc) should be selected such that they have a grain size that allows easy delivery into the borehole and should be introduced in a controlled manner to ensure that accidental 'bridging' does not occur within the borehole. Concrete and grouts that are introduced in a liquid form should be introduced through an appropriate delivery pipe (e.g. tremie pipe), to ensure that voids do not form. **Note**: It is good practice to monitor the volume of backfill material that is being emplaced, compared to that calculated at the design stage, to check if bridging within the borehole, or loss to the formation is occurring.

Boreholes that penetrate highly fissured aquifers, such as some limestones and gypsum bearing units, present additional problems. Liquid grouts (particularly those injected under pressure), or fine-grained aggregates (e.g. sand) may be transported out of the borehole into the body of the aquifer through fissures. Careful monitoring of the process is required if these techniques are used, and in these cases it may be more appropriate to use coarser aggregates such as gravel as a backfill.

Deep and large diameter boreholes/wells

When dealing with very deep or large diameter boreholes and wells (note, this does not apply to mine shafts), the volume of the hole may be considerable. In such circumstances it may be appropriate to adopt an alternative approach to completely backfilling the void, as long as this will not prejudice any of the design objectives.

Provided that the long-term structural stability of the borehole can be demonstrated, it may be possible to place a permanent bridging seal within the borehole and then to infill above this level using the approach summarised above (see Fig. 1(D)). The bridging seal should ideally be positioned below the lowest aquifer horizon. However, where this is not possible, it is important that the open borehole beneath the bridging seal penetrates no more than a single aquifer unit, thereby preventing the flow of groundwater between different aquifers.

The material commonly used as a bridging seal is cement, although a combination of a mechanical plug (packer) and cement can be used. Cement seals must be allowed to set (cure) in place before backfilling is continued and completed.

Again, this is a specialist area of work that requires high standards of design and workmanship to ensure an effective permanent seal is achieved.

Artesian boreholes

For artesian boreholes, the decommissioning process should aim to confine the groundwater to the aquifer from which it came – in order to prevent loss of confining pressure and the loss of water resources to the surface or other formations.

The first step is to control the artesian flow. There are a number of ways to accomplish this depending, in part, on the water pressure in the confined aquifer and the depth to which the water level must be lowered. These include:

- Pumping the borehole to produce the necessary drawdown.
- Pumping nearby boreholes.
- Extending the casing above ground level beyond the elevation to which water will rise in the borehole. (the potentiometric or piezometric surface).
- Introducing dense, non-polluting fluids into the borehole.
- Introducing a pre-cast plug at an appropriate level within the hole.
- Using an inflatable packer and pressure grouting the void space below it.

In aquifers that have large seasonal fluctuations in water level, decommissioning artesian boreholes is likely to be easiest in late summer, when groundwater levels and artesian flows are at their lowest.

The importance of the potential pathways in and around the casing should also be considered.

Decommissioning artesian boreholes is a specialist job and requires expert advice.

Step 4 - Sealing the top of the borehole

The backfilled borehole/well should be completed with an impermeable plug and cap to prevent entry of potentially contaminated surface run-off or other liquids. The top two metres should be filled with cement, concrete or bentonite grout. A concrete cap of suitable strength, with a diameter at least one metre greater than the width of the backfilled borehole (see Fig. 2), should then be installed. The exact finished depth of this cap will depend on the setting and planned afteruse of the site. It should be at least 2 metres below plough depth in agricultural areas and at least 1 metre below formation level for sites proposed for redevelopment. Never build structures directly onto well caps or linings.

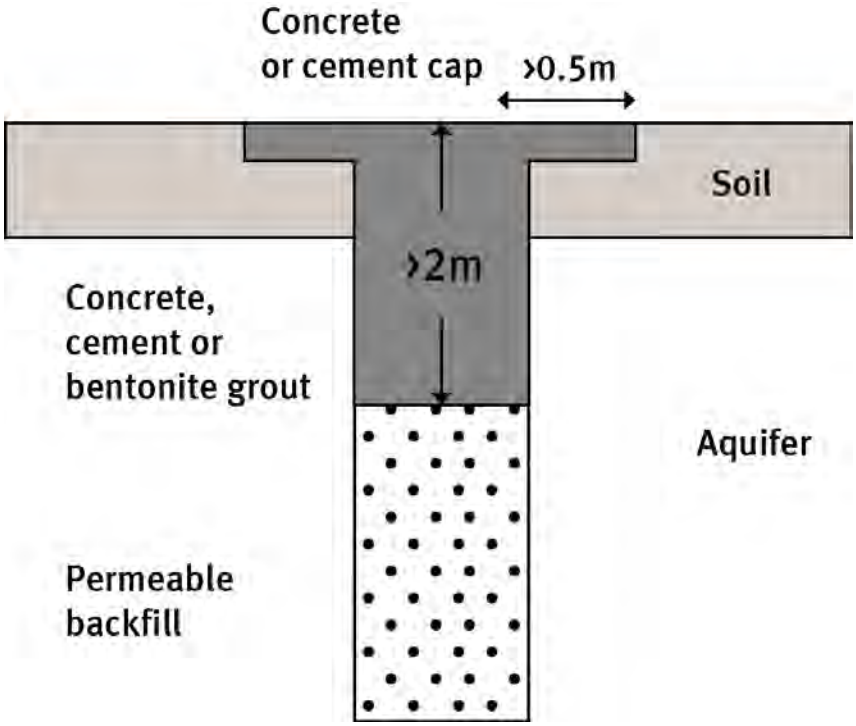

Figure 2: Schematic diagram for borehole seal and cap

Step 5 - Recording details and informing others

You should keep an accurate record of the abandonment details for future reference, including:

- The reasons for abandonment (for example water quality problems).
- Measurement of groundwater level prior to backfilling.
- The depth and position of each layer of backfilling and sealing materials.
- The type and quantity of backfilling and sealing materials used.
- Any changes made to the borehole/well during the abandonment (for example casing removal).
- Any problems encountered during the abandonment procedure.

The location of abandoned borehole and wells should be clearly marked on site records This is essential where any part of the well has not been filled.

It is also very good practice to mark or deeply inscribe well caps with the word "WELL". Even if done crudely it can avoid considerable risk, delay or uncertainty in the event of the structure being discovered during excavation by others in the future, who may not otherwise know what the feature is.

Always notify the Environment Agency and British Geological Survey of the abandoned well location and structure.

Conversion to soakaways

Wells and boreholes should not be converted to soakaways, as these allow the direct discharge of pollutants into groundwater without any potential for attenuation, and will often result in groundwater pollution. The direct discharge of hazardous substances to groundwater, via a borehole, is effectively prohibited by the Environmental Permitting (England & Wales) Regulations 2010, and the pollution risk from any direct discharge of non-hazardous pollutants, such as sewage effluent, is so great as to make it highly unlikely to be acceptable.

Further advice and guidance

It is recommended that the advice of a specialist well contractor should always be sought, Details can be obtained from:

- **The British Drilling Association**. Wayside, London End, Upper Boddington, Daventry, Northamptonshire, NN11 6DP. Tel: 01327 264 622, email: office@britishdrillingassociation.co.uk

The Environment Agency cannot provide an advisory service on decommissioning individual boreholes and wells but your local Groundwater & Contaminated Land team may have some generic advice to help you; and would appreciate a copy of your abandonment details. They can be contacted via our National Customer Contact Centre (NCCC)

- **Environment Agency NCCC** Tel: 03708 506 506

The British Geological Survey are the national custodian of water well records in addition to other borehole records and geological information. They may have a record of the borehole or well you are dealing with, and will be interested in the abandonment details

- **British Geological Survey. National Geosciences Data Centre (NGDC)**, Keyworth, Nottingham, NG12 5GG. Tel: 0115 936 3143.

Useful references

- Environment Agency GP3 (Groundwater Protection Principles and Practice) http://www.environment-agency.gov.uk/research/library/publications/40741.aspx
- American Society for Test and Materials (ASTM) D5299 - 99(2005) Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities
- Driscoll, F.G., 1986. Groundwater and Wells. Second Edition, Johnson Division.

Note: *This guidance supersedes the document ' Good practice for decommissioning redundant boreholes and wells' produced by our former National Groundwater and Contaminated Land Centre*

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