Eastwood
CONSULTING ENGINEERS

GEOTECHNICAL AND GEO-ENVIRONMENTAL SITE INVESTIGATION

NEWARK ROAD SUTTON-IN-ASHFIELD

FOR

HARRON HOMES LIMITED

ISSUE 2

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1.0 EXECUTIVE SUMMARY

1. The approximately 21.4-hectare site is located south of Newark Road and west of Coxmoor Road in Sutton-in-Ashfield. The site currently comprises arable farmland, sloping down at around 1 in 16 on average from the southeast to the west and northwest.

2. The solid geology beneath the site is shown to comprise the Lenton Sandstone Formation (i.e. sandstone with subordinate mudstone and siltstone. Two tongues of superficial deposits are shown to overlie part of the southern end of the site; a wide tongue of glaciofluvial deposits and a thinner tongue of superficial Head to the east.

3. The solid bedrock is classified as a Principal Aquifer. The site lies within a Total Catchment (Zone 3) Groundwater Source Protection Zone.

4. Topsoil was encountered across the site to between 0.10 and 0.50 m bgl (average 0.30 m). Deep made ground was encountered across the northern 20% of the site to depths of between 0.80 and 13.0 m bgl, generally comprising dark grey brown silty sandy gravel and/or gravelly sand, with scrap metal, plastics, wood and gravel of shale, mudstone, brick, sandstone, concrete, glass, wood and ceramics. Reworked natural ground was found to overlie the made ground in the former sand pit area.

5. Natural ground comprises a red brown fine to medium sand over sandstone bedrock.

6. Groundwater was only encountered in three trial pits, TP09, TP32 and TP33, between 2.10 and 2.80 m. “Wet pockets” were recorded below 6.00 m, and between 4.80 m and 5.00 m in CP02 and CP03 respectively.

7. Across the southern 80% of the proposed development, the most suitable foundations are considered to be strip or trench fill footings taken into the natural sand.

8. For plots in the former sand pit area, steel piled foundations could be allowed for. Pre-drilling may also be required due to frequency of obstructions. The most appropriate piling solution should be confirmed by a specialist piling contractor.

9. An earthworks turnover could also be undertaken to create a development platform suitable for the use of spread footings. Further assessment of the deeper made ground is required to confirm risk of future settlement is minimal, and settlement monitoring of the engineered fill may be required. A cut fill model is recommended to confirm volumes of fill required to form this platform.

10. Should an earthworks turnover be carried out for the sand pit area, plots overlying the highwalls will require piling, with piles socketed into the sloping highwall. An alternative option

would be for the highwall to be benched during the earthworks which would then allow a spread footing to be utilised, subject to regulatory approval.

11. Obstructions were noted throughout the sand pit backfill, some of which damaged drilling equipment. Overbreak of trenches should also be allowed for in shallow excavations in the pit. Outside of the pit, bedrock is likely present as shallow as 1.8 m which may require breaking out, and a water main and culverted drain are present which need to be taken into account in the new development.

12. It would be prudent to allow for the installation of a suitable geogrid, as well as a thickened construction, where adoptable highways cross the pit's highwall.

13. Effects of differential settlement will need consideration for plots within the sand pit area and include allowing for extra brick facing, flexible surfaces and service connections.

14. Soakaway drainage is not considered to be viable.

15. No radon precautions are required. Amber 2 gas precautions are proposed for plots within the sand pit. This level of precautions could be reviewed should a turnover be undertaken. Amber 1 gas precautions are proposed in all plots within 30 m of the pit. No gas precautions are considered to be necessary for the remainder of the site.

16. Although a number of samples recorded elevated concentrations of PAHs, the topsoil can be considered to be chemically suitable for use. Vigilance on site must be maintained when excavating topsoil from the sand pit area to ensure no cross contamination occurs.

17. The BS3882 testing shows the topsoil, in its current state, is non-compliant with the specified requirement for reuse as multipurpose topsoil; the addition of fertiliser/organic matter should improve its nutrient content.

18. Where made ground underlies the gardens and landscaped areas, a 600 mm thick capping layer of clean soil (of which at least 100 mm should consist of topsoil) is required.

19. Where made ground is present in the former sand pit area, concrete in contact with this material will require DS-3 AC-3 sulphate measures. Where only natural ground is present, no sulphate measures are required. Protective supply pipes should be allowed for within the sand pit area.

20. The conclusions made in this report are subject to agreement by the approving bodies, such as the Local Authority, and your warranty provider.

2.0 INTRODUCTION

2.1 Terms of Reference

This report presents the findings of a Geotechnical and Geo-environmental Site Investigation carried out by Eastwood & Partners (Consulting Engineers) Limited for, and on the instructions of, Harron Homes Limited. Any other parties using the information in this report do so at their own risk and any duty of care is excluded.

2.2 Context

Rodgers Leask Environmental (RLE) has previously undertaken a *Phase 1 Desk Study* which encompassed the site on behalf of Hallam Land Management Limited, dated 26 January 2017.

RLE also completed an intrusive investigation in 2017 on this site which comprised six infiltration tests (TPSA01 to TPSAS04), two cable percussion boreholes in the sand pit area (CP01 and CP02) and eight window sample boreholes across the site (WS01 to WS08) to install ten monitoring wells to facilitate an initial gas monitoring programme. RLE issued a Technical Note, dated 13 September 2017, summarising the infiltration test and ground gas monitoring results.

RLE installed a further nine wells along the site's eastern boundary in 2018 to target the off-site landfill. RLE issued a Technical Note, dated 18 May 2018, summarising the revised ground gas risk assessment for the site.

This report should therefore be read in conjunction with RLE's previous reports.

Eastwood & Partners are not aware of any other previous investigations having been undertaken across the site.

2.3 Aims and Objectives

The aims and objectives of this investigation were as follows:

- Detail the ground conditions and their geotechnical properties enabling outline foundation proposals to be made for the proposed residential development;
- Carry out tiered risk assessment to establish the likely risks to future receptors, involving the use of generic assessment criteria and where unacceptable risks are identified, site specific assessment criteria within a detailed quantitative risk assessment;
- Identify feasible remediation options if unacceptable risks are highlighted; and
- Develop an appropriate remediation strategy, where remediation is required.

2.4 Scope of Investigation

This document is split into two sections. These constitute the findings of the Phase 1 and Phase 2 investigations, consecutively.

2.4.1 Phase 1

The Phase 1 investigation involved a review of information extracted from published documentation as well as that obtained from a site reconnaissance. Information regarding the current and former land uses both on and surrounding the site, as well as the environmental sensitivity of the site location as determined by factors including geology, hydrogeology and hydrology have been examined.

Information analysed in this section of the report has been obtained from a variety of sources and included the following:

- A Landmark Envirocheck;
- A Consultants Coal Mining Report;
- Geological maps;
- The British Geological Survey website; and
- A site walkover.

The results of the Phase 1 investigation were used to derive an outline conceptual model from which a preliminary risk assessment was made.

2.4.2 Phase 2

This part of the investigation consisted of intrusive works and laboratory analysis. The findings were used to test the conceptual model and produce a final risk assessment. The intrusive works comprised trial pits and cable percussive boreholes to enable:

- Examination of the upper few meters of ground;
- In situ description of soils, enabling any localised lateral and vertical changes in soil conditions to be logged;
- Assessment of any contamination identified using visual and olfactory methods; and
- Collection of soil samples for chemical testing.

2.5 Limitations of Investigation

This report is based on the assumption that the site will be developed with low-rise housing of conventional construction, with private gardens and areas of public open space. It is assumed that existing ground levels will not alter significantly. If this is not the case, then the advice given in this report may not be appropriate.

Where assessments of site areas affected in particular ways are given, these are approximate. All information, comments and opinions given in this report are based on the ground conditions encountered during the site work, on the results of laboratory testing carried out as part of the investigation and information gained from a geological, historical and environmental desk study. However, there may be conditions at the site that have not been taken into account, such as unpredictable soil strata and water conditions between or below investigation points. It should be noted that groundwater levels vary due to seasonal or other effects, and may at times differ from those measured during the investigation.

This report considers the ground and groundwater and does not cover any buildings or their fabric, or the constituents of any existing hardstanding materials. Generally, testing has only been carried out for contaminants identified as potentially present with no assessment made of biological contamination. Risks to ecological receptors, such as bats, have not been considered.

3.0 THE SITE

3.1 Description

The approximately 21.4-hectare site is located south of Newark Road and west of Coxmoor Road, to the east of Sutton-in-Ashfield. The site is centred on grid reference 451630, 357990, and is accessed via Newark Road, though a layby and gap in the hedgerow along the site's northern boundary.

The site comprises a large rectangular field trending northwest to south east, and a smaller roughly square field to the south west, separated by a hedgerow. Both parcels of land are currently used as arable farmland, and bounded on all sides by hedgerows. A small area of the south east corner of the site, occupying less than 5% of the site's total area, comprises a patch of overgrown woodland.

An existing residential development lies immediately northwest of the site. More arable farmland lies to the south and south west, and open, pastural farmland lies to the east and north east of the site. A small commercial industrial estate lies immediately north of the site, on the northern side of Newark Road.

Generally, the majority of the site slopes down to the west and north west, from 177 m AOD in the site's south east corner, down to 149 m AOD midway along the site's western boundary, shared with the existing residential developments, at a gradient of approximately 1 in 16. The steepest slopes on site lie in the south east corner of the site, where a steep-side hill drops away to the west and north, at a gradient of approximately 1 in 8. The south west parcel of land similarly slopes down to the north and north west from 164 m AOD along the southern boundary, down to 152 m AOD adjacent to the existing residential developments, at a gradient of roughly 1 in 18.

3.2 History

The historical maps encompassing the site and surrounding area have been reviewed. A summary of the historical features of the site and surrounding land are summarised below.

Map Date	Site Features	Surrounding Area Features
1878 - 1880	Three small sand pits are shown: two in the northern quarter and one in the south east corner. A building labelled 'Redhouse' lies midway along the site's northern boundary. A small area of fenced garden areas is shown in north east corner of the site. The remainder of the site is shown to comprise open, presumably arable farmland.	Surrounding area mostly used for agricultural, presumably arable, farmland. Newark Road and Coxmoor Lane form the site's northern and eastern boundary as present. 'Sutton Forest Mills (bone)' and a small sand pit are shown on the land immediately north of the site, north of Newark Road. Two small sand pits are also show to lie on the land to the east of Coxmoor Road, to the north east of the site. 'Sutton Flour Mill' lies 250 m west of the site.

1899 – 1900	The two sand pits in the north of the site have expanded to occupy twice their original area. The sand pit in the south east corner is now shown as 'old sand pit', presumably disused. The building labelled 'Redhouse' is now renamed 'Greenhill Farm'.	The sand pits adjacent to the east of the site have expanded.
1916 - 1921	The sand pits in the north have expanded further to cover roughly 15% of the site. Two access tracks are shown to enter the sand pit, entering the site in the north west corner and north east corners respectively. A silt pond is shown to lie close to the southern highwall.	Sand pits to the north east of the site now shown to have expanded to occupy the majority of the land to the north east of the site. 'Sutton Forest Mills' has expanded to now comprise a series of large factory buildings. The 1921 map shows two 'Tanks' to lie immediately north of the site within the Sutton Forest Mills site.
1938 - 1939	A second larger silt pond is shown to lie within the sand pit, in the north east corner. The south eastern tip of the sand pit is also shown to have encroached further south along Coxmoor Road.	The 'Sutton Forest Mills' buildings are no longer shown – presumably demolished. The tanks remain.
1955 - 1958	The large sand pit in the north of the site is now shown as 'Disused Sand Pit', and a pavilion and playing field now lie within the eastern half of the pit boundary. Both silt ponds are no longer shown, presumably backfilled.	The 1955 map shows residential development 200 m west of the site. The sand pits to the north east of the site are no longer labelled, presumably disused.
1967	No further change.	Further residential development has occurred up to the west boundary. Three large warehouses labelled as 'Works' lie immediately north of the site within the former Sutton Forest Mills area.
1976	'Greenhill Farm' is no longer shown – presumably demolished.	Sand pits to the north east are labelled 'Pit (disused)'. Houses are shown along Coxmoor Road around 100 m south of the site.
1994	The disused sand pit and playing field in the north of the site, and the small old sand pit in the south east corner of the site are no longer shown – all presumably backfilled.	Housing lies adjacent to the site's southeastern corner.

The 2001 aerial satellite imagery of the site shows what appears to be a drainage excavation crossing the south of the site from midway across the southern boundary, directed towards the residential estate in the northwest. This feature appears to have been infilled on later images and correlates with the culvert shown on a plan provided by Harron Homes.

No further changes are shown in subsequent aerial images.

3.3 Geology

The geological maps Chesterfield Sheet 112 (1:50,000); Sheet SK55NW (1:10,560) and the British Geological Survey (BGS) Online Viewer show that the solid geology beneath the site is anticipated to

comprise strata of the Lenton Sandstone Formation (i.e. sandstone with subordinate mudstone and siltstone).

Two tongues of superficial deposits are shown to overly part of the southern end of the site. A wide tongue of glaciofluvial deposits, i.e. sand and gravel, is shown to overlie roughly 15% of the south west of the site. A thinner tongue of superficial Head lies east of the glaciofluvial deposits, which overlies around <10% of the site.

The underlying strata generally shallowly dip at around 2º to the southwest.

A fault is inferred to cross the northwest corner of the site, however neither the fault type or displacement are given.

The geological map indicates infilled ground to lie beneath the northern 20% of the site in the former sand pit area, and beneath two areas of land immediately to the north and to the east of the site boundary.

3.4 Hydrogeology

The solid bedrock is classified as a Principal Aquifer. The superficial glaciofluvial sand and gravel deposits are classified as a Secondary A Aquifer. The superficial Head deposits are classified a Secondary Undifferentiated Aquifer.

The site lies within a Total Catchment – Zone 3 Groundwater Source Protection Zone.

There are no water abstractions within 250 m of the site.

3.5 Hydrology

The nearest surface water feature is an inland river located 140 m southwest of the site boundary. The closest named water feature is an inland river, the River Maun, located Maghole Brook located 422 m north west of the site.

3.6 Extractive Industries

Sand Extraction

The Lenton Sandstone Formation has been worked for sand at a number of sand pits located both on site, and within the local area.

Coal Mining

No coal seams are shown by the geological maps to outcrop within 1000 km of the site, however the site is underlain by coal-bearing strata at depth. The High Main coal is the shallowest named coal seam to underlie the site at depth.

The Coal Authority report states that there are known past underground workings in four named coal seams (the High Main, the Top Hard, the Deep Soft, and the Deep Hard), at depths of between 193 and 709 m below the site, last worked in 1977.

The report also states that the site is not within an area with probable unrecorded shallow workings, there are no mine entries are recorded within 100 m and no recorded mine gases within 500 m of the site boundary.

The property is not within 200 m of an area where the Coal Authority has plans to grant a license to remove coal by underground methods.

No notices have been given under section 46 of the Coal Mining Subsidence Act 1991, stating that the land is at risk of subsidence, and there are no damage notices or claims on the site, or within 50 m of the site boundary.

The site is within an area where a notice to withdraw support was given in 1946. The site is not in an area where a notice has been given under section 41 of the Coal Industry Act 1994, cancelling the entitlement to withdraw support.

The Coal Authority is not aware of any damage due to geological faults or other lines of weakness that have been affected by coal mining and the property is not within 500 metres of the boundary of an opencast site from which coal has been removed by opencast methods or a Coal Authority managed tip.

3.7 Ground Gas

The site lies within a lower probability radon area. No radon protective measures are therefore considered necessary.

A backfilled sand pit is recorded by the historical maps, geological maps and Envirocheck to underlie the northern 20% of the site. The Envirocheck specifically records the former sand pit as a Historical Landfill Site, licenced by Stamford Waste Disposal Limited, and permitted the disposal of inert waste (excavated natural materials, hardcore and rubble) between March 1980 and November 1983.

Two other Historical Landfill sites are recorded to lie within 250 m of the site: 8 and 12 m north east of the site respectively, which the Envirocheck record as both containing inert, commercial and household waste. A waste management facility is also recorded to have formed part of the landfill site 8 m north east of the site boundary at the Sutton Quarry Landfill Site, which was licensed for the disposal of household, commercial and industrial waste. Both of the off-site recorded landfills and the waste transfer site are now decommissioned.

One potentially infilled feature is recorded on site, associated with the former sand pit. Seven potentially infilled features are also recorded within 250 m of the site between 8 and 222 m. Most of the features relate to the sand pits, with one of the features correlating with an infilled watercourse.

Given the presence of a recorded historical landfill within the site boundary, and two other historical landfills within 250 m of the site, a risk of ground gas migration beneath, and onto the site is presented.

RLE installed ten gas monitoring wells within the former sand pit area to depths of between 1.0 and 4.0 m, with one well extending to 9.0 m, and completed six rounds of gas monitoring between April and July 2017. A summary of RLE's gas monitoring programme is given below.

- Methane was detected in four of the monitoring wells (CPBH01, CPBH02, WS04 and WS05) with a maximum concentrations of 3.4%v/v. Generally, the peak methane concentrations coincided with visits completed during times of low or falling atmospheric pressure;
- Carbon dioxide was detected in all eight of the monitoring wells, recording a maximum concentration of 13.9 %v/v;
- Limited concentrations (<1 ppm) of carbon monoxide were recorded in all wells during every monitoring visit;
- A peak positive gas flow of 0.1% was recorded.

A further nine wells were installed along the site's eastern boundary in 2018 to depths of 1.0 and 10 m to target the offsite landfill. Six rounds of monitoring were undertaken between February and May 2018 of both the new and 2017 sets of wells; only CPBH02 recorded elevated methane concentrations (<2.2%) whilst the highest carbon dioxide concentration was 8.4%.

Based on these results, RLE initially recommended Amber 1 gas precautions for the site.

RLE's exploratory hole positions are shown in the Exploratory Hole Location Plan, Drawing Number 46924/003, also in Appendix 2.

3.8 Pollution Incidents to Controlled Waters

The Envirocheck notes two incidents within 250 m of the site, located 103 m north and 138 m east. The northern incident occurred in 1999 and involved oils introduced into a watercourse whilst the eastern incident occurred in 1998 and involved an algal bloom. Both were deemed 'minor incidents'.

3.9 Local Authority Pollution Prevention and Controls

There is one Local Authority Pollution Prevention and Controls (LAPPC) recorded within 250 m of the site, positioned 208 m north west of the site boundary, dated 10 May 1933 and issued by Ashfield District Council, Environmental health for the coating of metal and plastic.

3.10 Flooding

The majority of the site is recorded as having limited potential for groundwater flooding to occur. Approximately 40% of the site, across the western half of the site along the boundary shared with the adjacent existing properties, is recorded as having potential for groundwater flooding of property situated below ground level.

The site does not lie within a flood zone relating to flooding from rivers or the sea, and the majority of the site is not at risk of flooding from surface water.

A small portion of the site (<5% by area) parallel to the recorded culvert, is shown as being at low (1000-year return) risk of flooding form surface water.

3.11 Soil Geochemistry

The Envirocheck estimates the following concentrations of arsenic, cadmium, chromium, nickel and lead to be present in the natural soil at the site:

Contaminant	Estimated Concentration (mg/kg)	Assessment Value (mg/kg)
Arsenic	<15	37
Cadmium	<1.8	11
Chromium	20 to 60	910
Lead	<100	200
Nickel	<15	180

The concentrations of these contaminants are therefore not expected to be elevated within the natural ground.

3.12 Contemporary Trade Directory Entries and Fuel Station Entries

There are twenty-five contemporary trade directory entries recorded within 250 m of the site, including, but not limited to, precision engineering, blast cleaning equipment manufacture, air purification equipment production, hydraulic engineering, injection moulding plastics and a dyers.

There are no fuel station entries recorded within 250 m of the site.

4.0 OUTLINE CONCEPTUAL MODEL

The site is being considered for the construction of low-rise residences of conventional construction with private gardens.

4.1 Potential Sources of Contamination

A backfilled sand pit is recorded to underlie the northern 20% of the site, which is recorded specifically as a Historical Landfill Site, licenced by Stamford Waste Disposal Limited, and permitted the disposal of inert waste (excavated natural materials, hardcore and rubble) between March 1980 and November 1983.

Given the past use of the northern 20% of the site, a significant thickness of made ground is anticipated to be present. Any made ground which is present on the site may contain elevated concentrations of metals/metalloids, polycyclic aromatic hydrocarbons (PAHs), asbestos and sulphates.

There is no reason to expect that elevated concentrations of contaminants will be recorded in the underlying natural ground.

4.2 Ground Gas

No radon protective measures are necessary in the construction of new dwellings or extensions.

Given the presence of a recorded historical landfill within the site boundary, and two other historical landfills within 250 m of the site, a risk of ground gas migration beneath, and onto the site is presented.

Based on their previous two gas monitoring programmes, RLE initially suggested Amber 1 gas precautions for the site. RLE's gas monitoring results and ECE's recent chemical data are reviewed with regards to gas risk further in Section 9.4. Gas precautions are anticipated to be required.

4.3 Potential Pollutant Linkages

The table overleaf details the possible sources and associated contaminants of concern, pathways and receptors, highlighted by the Phase 1 investigation as potentially present.

Source	Potential Contaminants	Potential Pathways	Potential Receptors
Made ground in the former sand pit/landfill area.	Heavy metals/metalloids Polycyclic aromatic hydrocarbons Asbestos	Ingestion, inhalation, direct contact Biological uptake Migration through ground	Site residents and visitors Site construction workers Principal Aquifer Plants Water supply pipes
Made ground in the area around the former building to north of the site.			
Made ground in the former sand pit/historical landfill, and surrounding historical landfill sites.	Ground Gas	Migration through ground	Site residents and visitors
Sulphates and low pH in made ground or natural ground	Sulphates Low pH	Direct contact	Below ground concrete

5.0 GROUND INVESTIGATION

5.1 Site Works

Eastwood & Partners completed an intrusive investigation across eight days on 16, 17, 24, 25 and 28 to 31 March 2022. The intrusive investigation comprised the excavation of forty-five trial pits (TP01 to TP42 including TP20A to TP20D) to assess the upper few metres of ground and collect samples for chemical testing. Two trial trenches (TT01 and TT02) were also completed to locate the culvert and the sand tip highwall respectively.

Nine rotary boreholes (RBH01 to RBH09) were completed in conjunction with five rotary borehole transects (TBH1 to TBH5) to prove the depth of the former sand pit and profile the sand tip highwall.

Two cable percussion boreholes, CP02 and CP03, were also completed within the former sand pit area to acquire SPT data and samples to aid pile design.

Infiltration tests were not completed, and no groundwater or gas monitoring wells were installed as part of E&P's site investigation.

The depths for each exploratory hole type are summarised in the table below.

Exploratory Hole Type	No.	Exploratory Hole ID(s)	Minimum Depth of Investigation (m)	Maximum Depth of Investigation (m)
Trial Pits	45	TP01 to TP42	1.70	4.20
Trial Trenches	2	TT01 to TT02	2.40	2.40
Rotary Boreholes	9	RBH01 to RBH09	15.00	15.00
Rotary Borehole Transects	5	TBH1a-e to TBH5a-e	5.00	13.00
Cable Percussion Boreholes	2	CP02 and CP03	10.66	11.62

The trial pit, trial trench, rotary borehole, rotary transect borehole and cable percussion borehole logs, photographs of the trial pits and site photographs are all presented in Appendix 2. The exploratory hole positions are plotted on the Exploratory Hole Location Plan, Drawing Number 46924/003, also in Appendix 2.

5.2 Laboratory Testing

Twenty-five samples of topsoil, nine samples of natural ground and nineteen samples of made ground were dispatched for chemical testing. Three additional samples of topsoil were also sent for BS3882 testing. Soil samples were taken in 500 g plastic tubs and 250 ml amber jars. All samples were analysed at Eurofins Chemtest Limited, using MCERTs accredited methodologies where available. The chemical test results are presented in Appendix 3 and discussed further in Sections 7 and 8.

6.0 GROUND CONDITIONS

6.1 Surface Cover

Grass over topsoil is present from surface across the site. Topsoil was encountered from surface in all exploratory holes and excavations to between 0.10 and 0.50 m bgl (average 0.30 m) and typically comprised a red brown clayey, occasionally slightly gravelly, fine to medium sand with rootlets. The gravel generally comprised rounded to sub rounded fine to coarse quartz.

6.2 Reworked Ground

Reworked ground was encountered beneath the topsoil in fifteen trial pits and both trial trenches to depths of between 0.50 and 1.40 m bgl, and generally comprised red-cream-brown slightly clayey, often slightly gravelly fine to medium sand, often with clay pockets. The gravel comprised angular to sub angular fine to coarse sandstone and brick.

Spatially, the reworked material was strictly limited to northern 20% of the site, and was always found to overly the deep made ground within the former sand tip area. The reworked material therefore comprised what could be considered a ‘capping layer’.

Similar reworked ground was found to extend to 1.40 m bgl in TT01 surrounding the culvert, and also encountered beneath the deep made ground in the former tip area in TP05 from 2.70 m to >4.10 m bgl.

6.3 Made Ground

Sand Pit Area

Made ground was encountered in nineteen trial pits, both trial trenches, both cable percussion boreholes and all boreholes within the former sand-pit area.

The made ground consistently comprised dark grey brown silty sandy gravel and/or gravelly sand, with scrap metal, plastics, wood and gravel of shale, mudstone, brick, sandstone, concrete, glass, wood and ceramics.

The base of the made ground was only proven in four of the trial pits (TP01, TP03, TP20D and TP21), found between 0.80 and 2.20 m. These pits were located north of the sand pit, or on its southern edge

Fifteen trial pits excavated within the sand pit terminated within the made ground between 1.70 and 4.10 m bgl either at the maximum reach of the machine, at the target depth for chemical sampling, or due to refusal on obstructions.

The made ground was found to extend to 8.35 m and 10.40 m respectively bgl in CP02 and CP03. Frequent obstructions were recorded below 5.8 m. Standard Penetration Tests were undertaken at 1.0 m centres from 1.0 m bgl; the results are discussed in Section 6.1.

Within the rotary holes, the base of the made ground was found between 5.00 and 13.00 m bgl. There is bit of discrepancy between the depth of the made ground in the rotary logs compared to the cable percussive holes for example, the base of made ground in CP01 was record to be 9.30 m (equivalent to 150.40 m AOD) whilst RBH6, drilled just 18 m east recorded the base at 13.0 m, or 147.9 m AOD. Similarly, CP02 recorded the base of the made ground at 149.05 m AOD, whilst rotary holes to the north and south recorded the base at around 147.4 and 148 m AOD. The rotary boreholes may therefore have over-exaggerated the base of made ground by around 1.0 to 2.0 m.

Sand Pit High Wall – Northern Area

Our appended Exploratory Hole Location Plan shows the mapped extent of the former sand pit as shown on the 1958 historical map. To locate the actual extent, we carried out a number of exploratory holes including trial pits, trenches and transects of rotary boreholes drilled at approximately 3.0 m centres.

In the northwest, transect TBH1 recorded a drop in depth of made ground between 1B and 1C between 3.0 and 7.5 m, with a further step down to 10 m at 1D. This generally correlates with the mapped extent of the pit.

In the far northern corner, the map shows the pit may have extended almost into the site corner. However, our TP01 found 1.40 m of made ground and TP02 did not encounter any made ground, indicating the high wall is further south than TP02. Transect TBH2 recorded a step in the base of the made ground between 2C (3.5 m) and 2D (9.5 m), which lies around 15 m south of TP2.

In the southwest, transect TBH3 recorded steps between 3C (1 m) and 3D (5 m) and 3E (7.5 m), also correlating with the mapped extent. Steps were also noted in TBH4 between 4B (1.0 m) and 4C (8.0 m), which lies around 6 m south of the mapped extent.

In the southeast of the area, transect TBH5 recorded steps between 5C (3.0 m) and 5D (9.0 m) and 5E (11.0 m). Further east, a near vertical high wall was noted in TT02 in the centre of the trench which correlates with the mapped extent.

Sand Pit High Wall – South Eastern Area

This sand pit outline appears on historical maps as late as the 1990s, indicating the feature has not been completely backfilled.

The sand pit is located on a steep slope, such that the northern edge of the pit lies at approximately 170 m AOD, and roughly 7.0 m lower than the southern highwall at 177 m AOD. A steep slope exists from the top of the pit's southern highwall down to the base of the former pit in its centre, at an approximate gradient of 1 in 5. The base of the pit area then remains relatively level up to the northern boundary.

TP42, excavated on the western edge of the sand pit highwall, encountered natural ground of red-brown gravelly fine to medium sand, beneath a limited 0.30 m thickness of topsoil made ground, containing sandstone gravel and bricks. No significant thickness of made ground was therefore encountered, and given the topography of the feature, deep made ground is not anticipated to be present in the area.

Culvert

TT01 was excavated to locate the culvert and found a 150 mm diameter clay pipe at 0.60 m bgl, filled with silt.

6.4 Natural Ground

Natural ground was encountered in twenty-nine of the trial pits, one of the trial trenches (TT01), both of the cable percussion boreholes and in all rotary boreholes.

The natural ground consistently comprised a red brown fine to medium sand, commonly becoming gravelly with depth in which the gravel comprises sub angular fine to coarse sandstone. Cobble-sized firm to stiff clay pockets were also noted within the natural sand in three trial pits, TP10, TP26 and TP43.

Superficial deposits, comprising red-brown sand and gravel, was only encountered in one exploratory hole, TT01, from 1.20 m to 2.40 m bgl. Extensive superficial deposits were not encountered.

Extremely weak to weak red brown weathered sandstone, recovered as very sandy angular fine to coarse sandstone, was encountered in twenty-eight trial pits, between 1.90 m and 4.20 m bgl. The cable percussive boreholes recorded weathered sandstone at the base of the made ground, with CP03 noting mudstone bands between 10.8 and 11.0 m in CP03. The rotary holes also recorded the presence of sandstone below the sand pit.

The RLE investigation recorded similar ground conditions, with three trial pits encountered cohesive ground: TPSA01 from 1.1 m bgl, in TPSA03 between 0.2 and 0.5 m and in TPSA94 from 1.0 m bgl.

6.4 Groundwater

Groundwater was encountered in the following exploratory holes and excavations.

Exploratory Hole	Depth (m)	Description
TP09	2.80 m	Groundwater
TP32	2.20 m	Groundwater
TP33	2.10 m	Groundwater
CP02	>6.00 m	'Wet pockets' in made ground
CP03	4.80 to 5.00 m	'Pockets of water' in made ground

Within the RLE investigation, water was only noted in WS08 at 2.5 m within the weathered sandstone.

7.0 GEOTECHNICAL APPRAISAL

7.1 General

The proposed development is to comprise low rise housing of conventional construction with private gardens, soft landscaped areas and areas of public open space.

Ground Conditions

Topsoil was encountered across the site to between 0.10 and 0.50m bgl (average 0.30 m).

Deep made ground was encountered across the northern 20% of the site to depths of between 0.80 and 13.0 m bgl, generally comprising dark grey brown silty sandy gravel and/or gravelly sand, with scrap metal, plastics, wood and gravel of shale, mudstone, brick, sandstone, concrete, glass, wood and ceramics.

Reworked natural ground, comprising red-cream-brown slightly clayey, often slightly gravelly fine to medium sand, often with clay pockets and gravel of sandstone and brick, was found to overlie the made ground in the former sand pit area.

Natural ground comprises a red brown fine to medium sand over sandstone bedrock.

Groundwater was only encountered in three trial pits, TP09, TP32 and TP33, between 2.10 and 2.80 m. “Wet pockets” were recorded below 6.00 m, and between 4.80 m and 5.00 m in CP02 and CP03 respectively.

Strength Testing

SPTs were completed in both cable percussion boreholes, CP02 and CP03 from 1.05 m bgl at 1 m centres. N values of between N=3 and N=28 indicative of very loose to medium dense granular soils were recorded in the made ground. Refusals (N=50) were recorded in both boreholes due to obstructions at 4.05 m and 7.20 m in CP02, and at 6.10 m in CP03.

SPTs were completed within the natural strata (slightly gravelly sand or sandstone with mudstone bands), recording N values of at least 50 in all but one test; the exception was the test at 9.1 m bgl, which started in made ground and terminated in natural sand, recording N=12. This lower value is still indicative of medium dense granular strata.

Other Considerations

A sketch development plan has been reviewed; levels are being regraded but no significant change (i.e. cut or filled by more than 1 m) is noted.

In the larger field area, there will be around a 30 m width of POS area where levels will remain unchanged on the northeastern boundary. Further south, this widens to around 60 m. The majority of the southwestern field will be redeveloped.

The highwalls for the sand pits have been located. Within the larger northern pit, these highwalls are discussed in the following sections. With regards to the smaller southeastern pit, since no development is to take place in this area and no change to ground level is proposed, no remedial work is proposed for this pit.

Obstructions were encountered throughout the former sand pit between 1.80 and 7.00 m bgl. Given the overall depth of made ground encountered (up to 13.00 m deep), and the broad range of depths at which the obstructions were encountered, a turnover or construction of an engineered earthworks platform or similar is at this stage not considered to be economically viable.

The fill within the sand pit is predominantly granular, meaning that future settlement should be minimal. To further reduce the effects of the potential settlement of external areas within the sand pit area, the following provisions could be made:

- Extend the facing brickwork so that ground settlement does not result in exposing the underground portions of walls and foundations. We would suggest a couple of additional courses should be more than adequate;
- Consider flexible surfacing such as gravel drives and pathways;
- Flexible connections (e.g. rocker pipes) in drainage and service pipes passing through the buildings to accommodate the expected settlement; and
- Ensure drainage is laid with generous falls to account for any settlement. This is particularly important where drains pass over deep made ground and natural ground.

The Party Wall Act will need to be considered for structures associated with neighbouring properties along the site boundaries.

7.2 Foundations

Across the southern 80% of the proposed development, the most suitable foundations are considered to be strip or trench fill footings, taken through any made, or soft/loose ground onto the natural sand. An allowable bearing capacity of at least 150 kN/m² is considered appropriate for the natural granular soils, which will increase with depth.

A minimum foundation depth of 600 mm is considered suitable for foundations within any granular soils or onto sandstone bedrock. As no significant thickness of natural cohesive ground was

encountered in this investigation (the RLE investigation encountered occasional thin clay bands), deepening foundations due to tree influence is not considered to be required.

For plots in the former sand pit area, piled foundations could be considered, taken down through any loose or made ground, into the underlying competent sandstone bedrock. Steel piles should be allowed for given the frequency of obstructions which were encountered in both the trial pits and cable percussion boreholes. Pre-drilling may also be required; the CP drillers noted damage to their rig and equipment during boring of CP02 and CP03 through theses obstructions. The most appropriate piling solution should be confirmed by a specialist piling contractor.

A partial turnover of the made ground could also be considered. This would likely comprise excavation to a depth of around 2.5 to 3 m below proposed foundation level, screening of arisings to remove oversize fragments and replacement of material as engineered fill to form a development platform. This work may require additional fill to build up to finished levels, and potentially be subject to settlement monitoring. A cut fill model is recommended to confirm volumes of fill required to form this platform. If the works are successful, reinforced spread footings could be utilised. Assessment of the remaining, untreated made ground below this 'engineered crust' would also be required to ensure no significant future settlement would occur.

Should an earthworks turnover be carried out for the sand pit area, plots overlying the highwalls will require piling, with piles socketed into the sloping highwall. An alternative option would be for the highwall to be benched during the earthworks which would then allow a spread footing to be utilised, subject to regulatory approval.

7.3 Ground Slabs

Gas precautions are proposed for plots within and adjacent to the former sand pit area, which will require a precast concrete floor with a ventilated void beneath and fully lapped and sealed gas membrane system. Gas precautions are discussed further in Section 9.4.

For plots constructed across the remainder of the site, no gas measures are required. Ground bearing slabs could be utilised should less than 600 mm of made ground is present. If more than 600 mm is present, precast concrete floors with underlying ventilated voids or reinforced suspended slabs are required.

7.4 Superstructure Precautions

No additional superstructure precautions are considered to be required based on the ground conditions encountered for the majority of the site.

Should an earthworks turnover be undertaken, additional superstructure reinforcement will likely be required for plots overlying the former sand pit.

7.5 Excavation Problems & Obstructions

Trial pits excavated within the former sand pit area were generally noted to be unstable within the made ground. Shallow excavations in the natural strata are expected to be stable in the short term.

Temporary shoring or support will be required where access to trenches greater than 1.2 m depth, or less where there is risk of collapse, is required in accordance with current Health & Safety Regulations.

The table below summarises the obstructions which were encountered during both ECE's and RLE's site investigations.

Exploratory Hole	Obstruction	Depth of Obstruction (m)
TP04	Pit terminated on concrete.	1.70
TP06	Pit terminated on concrete.	2.20
TP07	Pit terminated on concrete.	2.20
TP16	Pit terminated on concrete.	2.30
TP17	Pit terminated on concrete.	1.10
TT02	Concrete boulder (dug past)	1.20 m
CP02	Concrete boulder (drilled through)	5.90 m
	Concrete boulder (drilled through)	7.00 m
CP03	Concrete boulders (drilled through)	5.80 to 6.80 m
WS02*	"Hard drill" (drilled through)	1.50 to 2.00 m
WS03*	"Hard drill" (drilled through)	0.60 to 1.00 m
WS05*	"Concrete cobble" (drilled through)	3.10 m
WS06*	"Hard drill" (drilled through)	1.00 to 1.40 m
RO03*	Hole terminated on "Solid concrete obstruction"	1.00 to 4.00 m
RO03A*	"Solid concrete obstruction" (drilled through)	1.00 to 5.00 m

*Denotes RLE's exploratory holes.

A number of RLE exploratory holes also encountered obstructions between 1.06 and 2.3 m.

Overbreak of trenches is therefore to be allowed for in shallow excavations within the sand pit area.

Bedrock was encountered at a minimum depth of 1.80 m bgl outside of the sand pit area. Deeper excavations may therefore require a rock breaker.

A water main crosses the south west corner of the site, passing from the centre of the site's eastern boundary along Coxmoor Road, and exits midway along the site's southern boundary. A culvert

passes beneath the south of the site but is silted up. A suitable easement will need to be maintained for the proposed development for both features if they are to remain.

7.6 Roads

A CBR value of at least 2% is likely to be appropriate for road design. The ground should be assumed to be frost susceptible and a minimum construction thickness of 450 mm will therefore apply. It is recommended that CBR tests are undertaken along any proposed roads prior to construction so that more accurate CBR values can be obtained.

It would be prudent to allow for the installation of a suitable geogrid, as well as a thickened construction, where adoptable highways cross the highwall.

7.7 Surface Water Drainage

Groundwater was only encountered in three trial pits, TP09, TP32 and TP33, between 2.10 m and 2.80 m. “Wet pockets” were recorded below 6.00 m, and between 4.80 and 5.00 m within the made ground in CP02 and CP03 respectively.

Infiltration testing was not completed as part of E&P’s investigation. RLE completed six soakaway tests (TPSA01 to TPSA06) during their 2017 site investigation. Where possible, RLE allowed each soakaway test to run for a minimum of twenty-four hours. After the testing period, the water had not drained to the 25% effective depth in four of the six test pits, meaning it was not possible to calculate a BRE365 rate.

The soil infiltration rates calculated from RLE’s 2017 site investigation are summarised in the following table.

Trial Pit ID	Strata	Infiltration Rate ($x10^{-6}$ m/s)
TPSA01	Sand and Clay	0.128
TPSA02	Sand	*2.02
TPSA03	Sand and Clay	*3.02
TPSA04	Sand and Clay	*1.51
TPSA05	Sand	7.87
TPSA06	Sand	*4.24

*Infiltration rates derived from extrapolated data.

RLE concluded that the Lenton Sandstone Formation displays variable infiltration rates, generally towards the lower end of what would be considered feasible for use in a soakaway drainage system. Soakaway drainage is therefore not considered a viable means of surface water drainage.

8.0 REFINEMENT OF OUTLINE CONCEPTUAL MODEL

8.1 Source Characterisation

An outline conceptual model, detailing the possible sources and associated contaminants of concern, potential pathways and receptors identified, is detailed in Section 4.

This section of the report documents the works undertaken to obtain information to test and refine this model enabling a risk assessment to be produced and, where significant risks are expected, remediation recommendations.

8.2 Investigation of Potential Contamination Sources

The investigation works undertaken to cover each of the sources of potential contamination outlined in Section 4, are detailed in the table below:

Source	Potential Contaminants	Exploratory hole used to investigate source
Made ground in the former sand pit/landfill area.	Heavy metals/metalloids Polycyclic aromatic hydrocarbons Asbestos	Made ground was encountered in nineteen trial pits, both trial trenches, both cable percussion boreholes and all rotary boreholes.
Made ground in the area around the former building to north of the site.		Reworked ground was encountered beneath the topsoil in fifteen trial pits and both trial trenches
Deep made ground in the former sand pit/historical landfill (plus surrounding historical landfill sites <250 m from site).	Ground Gas	Covered with RLE investigation
Sulphates and low pH in made ground or natural ground	Sulphates Low pH	Made ground was encountered in nineteen trial pits, both trial trenches, both cable percussion boreholes and all nine rotary boreholes. Natural ground was encountered in twenty-nine of the trial pits, one of the trial trenches (TT01), both of the cable percussion boreholes and in all nine of the rotary boreholes.

8.3 Ground Gas

No radon protective measures are required.

A risk of ground gas generation is presented due to the presence of the backfilled sand pit beneath the northern 20% of the site, and the proximity of the two additional landfill sites and potentially infilled ground features within 250 m of the site boundary.

Made ground up to 13.0 m deep was encountered within the former sand pit, comprising dark grey brown silty sandy gravel and/or gravelly sand, with scrap metal, plastics, wood and gravel of shale, mudstone, brick, sandstone, concrete, glass, wood and ceramics.

A hydrocarbon-like odour was encountered in the made ground in three trial pits (TP12, TP13 and TP17). A strong solvent-like odour was encountered in the made ground in TP15, and a volatile odour was encountered in both cable percussion holes CP02 and CP03.

As discussed in Section 3.6 RLE initially installed eight gas monitoring wells within the sand pit and completed six rounds of gas monitoring between April and July 2017. A further nine wells were installed along the site's eastern boundary in 2018 to depths of 1.0 and 10 m to target the offsite landfill. Six rounds of monitoring were undertaken between February and May 2018 of both the new and 2017 sets of wells. The results are discussed in Section 8.4.

8.4 Unexpected Contamination

The table below summarises the visual and olfactory evidence of contamination which was noted during the investigation.

Odour/Visual Evidence of Contamination	Exploratory Hole(s) Encountered
Organic odour in made ground.	TP03, TP04, TP06, TP09, TP14 and TP16
Hydrocarbon odour in made ground.	TP12, TP13 and TP17
Strong solvent/volatile odour in made ground.	TP15
Volatile odour in made ground	CP02 and CP03

8.5 Chemical Testing

Twenty-five samples of topsoil, nine samples of natural ground and nineteen samples of made ground were dispatched for chemical testing. Each of these samples was analysed for the suite of contaminants listed in the table below:

Contaminant Type	Actual Contaminants
Metals/Metalloids	Arsenic, cadmium, chromium, lead, mercury, nickel, selenium, copper and zinc
pH	pH
PAHs	Speciated PAH
Sulphates*	Water soluble sulphate, acid soluble sulphate and sulphur
TOC**	Total Organic Carbon content
TPH CWG**	Aliphatic-Aromatic Hydrocarbons

*Selected natural and made ground samples only.

**Selected made ground samples only.

In addition to the above tests, all of the topsoil and made ground samples were screened for asbestos fibres.

Three samples of topsoil also underwent BS3882 Specification of Topsoil testing.

8.6 Assessment Criteria

The proposed development of the site is to comprise residential properties with private gardens and associated soft landscaped areas, and areas of public open space (POS). The assessment criteria relating to a residential with home-grown produce end use have therefore been used. Tables detailing the relevant assessment concentrations used are included in Appendix 3.

8.7 Chemical Test Results

8.7.1 Topsoil

The results have been compared to assessment values derived using 1% soil organic matter (SOM).

No asbestos was detected.

Six samples recorded elevated concentrations of PAHs above their respective residential with homegrown produce assessment values with regards to human health, as detailed in the table below:

Determinant	Assessment Value (mg/kg)	Sample ID and Concentration (mg/kg)						Modified Mean (mg/kg)
		TP01 (0.20 m)	TP07 (0.20 m)	TP08 (0.30 m)	TP11 (0.20 m)	TP17 (0.20 m)	TP21 (0.20 m)	
Naphthalene	2.30	2.30	2.60	3.70	2.60	2.70	< 0.10	1.19
Benzo[b]fluoranthene	2.60	2.00	0.45	0.56	0.54	0.22	3.00	0.60
Benzo[a]pyrene	2.20	2.50	0.28	0.49	0.56	0.26	3.20	0.65
Dibenz[a,h]Anthracene	0.24	0.35	0.17	0.10	0.19	0.10	0.49	0.17

Highlighted boxes denote values which exceed the assessment value.

None of the samples recorded elevated concentrations of any determinants above their respective phytotoxic assessment values.

Three samples of topsoil were sent for BS3882 testing. The laboratory testing results (Eurofins Chemtest Report No. 22-12706) are appended. All three samples were non-compliant with the specified requirement for reuse as multipurpose topsoil with regards to soil texture class, mass loss on ignition (MLOI), clay content, stone content and available nutrient content:

Parameter	Multipurpose Range	Sample ID and Concentration (mg/kg)		
		TP11 0.20 m	TP30 0.15 m	TP32 0.20 m
Soil Texture Class	-	Loamy Sand	Sand	Sand
MLOI Clay Content(%)	3.0 – 20.0	1.70	3.10	1.90
Stone Content >2 mm	0 – 30	2.9	32	0.61
Stone Content >20 mm	0 – 10	<0.02	11	<0.02
Nitrogen Content(%)	>0.15	0.050	0.090	0.040
Extractable Phosphorous (mg/l)	16 – 140	44	12	25
Extractable Potassium (mg/l)	121 - 1500	120	210	120
Carbon : Nitrogen Ratio	<20 : 1	19.8 : 1	20.1 : 1	27.6 : 1

Highlighted values do not comply with the multipurpose range for the respective parameter.

The three samples were also non-compliant with the specific purpose ranges for acidic, low fertility and calcareous topsoil with regards to MLOI clay content, soil pH, available nutrient content and the carbon-nitrogen ratio.

8.7.2 Reworked Ground

The results have been compared to assessment values derived using 1% SOM.

No asbestos was detected.

None of the samples recorded elevated concentrations of any determinants above their respective human health or phytotoxic assessment values.

8.7.3 Made Ground

Total organic content was analysed in nine samples and recorded an average TOC of 3.24%. The made ground results have therefore been compared to the assessment values derived using 6% SOM.

No asbestos was detected.

Seven samples of shallow made ground recorded elevated concentrations, as detailed in the following table.

Determinant	Assessment Value (mg/kg)	Sample ID and Concentration (mg/kg)						
		TP03 (1.70 m)	TP05 (2.10 m)	TP12 (1.40 m)	TP13 (1.60 m)	TP14 (2.10 m)	TP15 (3.20 m)	TP16 (0.80 m)
Cadmium	11.00	0.70	12.00	0.42	0.86	0.85	1.30	0.17
Lead	200.00	140.00	830.00	110.00	86.00	130.00	85.00	88.00
Aromatic C21-C35	1,700	< 1.00	-	< 1.00	130.00	2000	430.00	240.00
Benzo[b]fluoranthene	3.70	3.40	2.10	8.50	6.30	7.70	5.80	3.80
Benzo[a]pyrene	3.00	2.80	1.90	8.30	5.50	6.50	5.40	3.80
Dibenz(a,h)Anthracene	0.30	0.47	< 0.10	0.62	0.64	0.62	0.77	0.52

Highlighted boxes denote values which exceed the assessment value.

The sample, TP05 at 2.10 m, also recorded elevated concentrations of cadmium, copper, lead and zinc above their respective phytotoxic assessment values.

Five samples of deep made ground from within the former sand tip were also sent for a full suite of chemical testing. Total organic content was analysed in all five samples, which recorded an average TOC of 3.34%. The deep made ground results have therefore been compared to the assessment values derived using 6% SOM.

No asbestos was detected in any of the samples.

Three of the deep made ground samples recorded elevated concentrations of TPHs and PAHs, as detailed in the table below.

Determinant	Assessment Value (mg/kg)	Sample ID and Concentration (mg/kg)				
		CP02 5.75 m	CP02 6.25 m to 6.70 m	CP02 6.80 m	CP03 6.10 m to 6.35 m	CP03 7.10 m to 7.55 m
Aromatic TPH >C16-C21	930	1100	450	970	150	13
Aromatic TPH >C21-C35	1,700	2600	1200	3300	1000	110
Benzo[a]anthracene	13.00	36	48	38	2.5	1.8
Chrysene	27.00	36	47	37	2.5	1.7
Benzo[b]fluoranthene	3.70	33	45	35	2.3	1.9
Benzo[a]pyrene	3.00	32	43	33	2.1	1.7
Dibenz(a,h)Anthracene	0.30	2.5	3.7	3.2	0.21	0.18

Four of the deep made ground samples also recorded above limit of detection (LOD) concentrations of a further three contaminants, for which standardised assessment values have not been derived, as detailed in the table below.

Determinant	Assessment Value (mg/kg)	Sample ID and Concentration (mg/kg)				
		CP02 5.75 m	CP02 6.25 m to 6.70 m	CP02 6.80 m	CP03 6.10 m to 6.35 m	CP03 7.10 m to 7.55 m
2-Methylnaphthalene	-	3.6	1.9	1.1	6.5	< 0.50
Dibenzofuran	-	13	7.5	6.2	1.4	< 0.50
Carbazole	-	11	4.4	3.8	0.80	< 0.50

The modified means for each of the elevated contaminants recorded in the made ground samples are given in the table below.

Determinant	Assessment Value (mg/kg)	Modified Mean (mg/kg)
Aromatic TPH >C16-C21	930	-
Aromatic TPH >C21-C35	1,700	-
Cadmium	11.00	2.49
Lead	200.00	98
Benzo[a]anthracene	13.00	16.84
Benzo[b]fluoranthene	3.70	16.27
Benzo[a]pyrene	3.00	15.42
Dibenz(a,h)Anthracene	0.30	1.39
Chrysene	27.00	16.75

8.7.4 Natural Ground

Results have been compared to the assessment values derived using 1% soil organic matter (SOM).

None of the samples recorded elevated concentrations of any determinants above their respective human health or phytotoxic assessment values.

8.7.5 Sulphates

In accordance with BRE Special Digest 1 (2005), the site has been conservatively taken to be brownfield in relation to the Aggressive Chemical Environment. Groundwater is assumed to be mobile through the near surface soils.

The following results were recorded:

Made Ground	Range of Results	Characteristic Value
pH	7.9 to 10.7	7.95
Water soluble sulphate mg/l	16 to 880	740
Total Potential Sulphate %	0.042 to 0.99	0.91
Reworked Ground	**Range of Results**	**Characteristic Value**
pH	8.1	8.1
Water soluble sulphate mg/l	12 to 13	13
Total Potential Sulphate %	0.03 to 0.33	0.33
Natural Ground	**Range of Results**	**Characteristic Value**
pH	6.7 to 8.8	7.3
Water soluble sulphate mg/l	11 to 17	16
Total Potential Sulphate %	0.03 to 0.04	0.03

8.8 Significant Pollutant Linkages

The significant pollutant linkages identified are documented in the following table:

Contaminants	Pathway	Receptor
PAHs within topsoil Heavy metals/metalloids, PAHs TPH in made ground	Ingestion, inhalation, direct contact Migration through ground	Future residents or visitors Construction workers Plants Principal Aquifer Water supply pipes
Elevated sulphates within made ground	Direct contact	Below ground concrete
Ground gas from made ground/landfills	Inhalation, migration through ground	Future residents or visitors Construction workers Buildings

9.0 RISK ASSESSMENT

9.1 Human Health: Future Site Users

Topsoil

Although a number of samples recorded elevated concentrations of PAHs, the modified means do not exceed the respective assessment values. One of the PAHs which recorded elevated concentrations was naphthalene, a volatile hydrocarbon. The main expose pathway for this contaminant is indoor inhalation; since the topsoil will not underlie plots, the contaminant is not considered to pose a risk to site end users.

The topsoil can therefore be considered to be chemically suitable for use.

Most of the pits recorded reworked ground above the made ground which provides a 'clean' buffer between the topsoil and the impacted made ground. However, vigilance on site must be maintained when excavating topsoil from the sand pit area to ensure no cross contamination occurs.

The BS3882 testing shows the topsoil, in its current state, is non-compliant with the specified requirement for reuse as multipurpose topsoil with regards to soil texture class, MLOI clay content, stone content and available nutrient content. With the addition of a suitable fertilizer and mulch/organic matter, it is expected that the material could be improved such that the material complies with the multipurpose or low fertility ranges. It is advised that confirmation of the topsoil quality with your landscape architect is undertaken.

Made Ground & Reworked Ground

No elevated concentrations were recorded within the reworked ground, but the underlying sand pit backfill made ground recorded elevated concentrations of PAHs within five samples of shallow made ground. One sample (TP14 2.1 m) also recorded an elevated concentration of carbon fraction Aromatic C21-35. Elevated concentrations of PAHs and carbon fractions Aromatic >C16-C21 and >C21-C35 were also recorded in three samples of deep made ground in the former sand pit. Above LOD concentrations of 2-Methylnaphthalene, Dibenzofuran and Carbazole were also detected in three samples of deep made ground.

It is recommended that a 600 mm thick capping layer of clean soil (of which at least 100 mm should consist of topsoil) is placed over the made ground wherever it remains below private gardens or other areas of soft landscaping.

Care should be taken during construction to ensure made ground arisings are kept within the sand pit area of the development and not spread across the 'clean' part of the site.

Natural Ground

No significant contamination was identified therefore natural ground arisings are considered suitable for re-use. A growing medium of 100 mm topsoil is considered appropriate for gardens and landscaped areas overlying

9.2 Human Health: During Construction

Groundworkers employed during the construction phase of the development are most at risk of harm due to them having direct contact with the affected soils. However, the contact is generally of short duration, and all competent ground workers will be aware of the potential risks associated with the made ground soils. Therefore, the overall risk to the health of construction workers is considered to be low.

Normal site procedures, such as the wearing of gloves when handling soils and the washing of hands prior to eating, should be implemented at all times.

9.3 Plants

One sample of made ground recorded elevated concentrations of cadmium, copper, lead and zinc above their respective phytotoxic assessment values. As the made ground will require capping, the overall risk to plant health posed by the elevated contaminants is considered low.

9.4 Ground Gas

No radon protective measures are considered necessary.

The following table displays the maximum methane and carbon dioxide concentrations in RLE's 2017 wells, with equivalent concentrations highlighted in yellow for Amber 1 and orange for Amber 2 (as designated in accordance with C665):

Methane	27.04.17	02.05.17	17.05.17	26.05.17	29.06.17	19.07.17	14.02.18	21.02.18	08.03.18	16.04.18	30.04.18	11.05.18
WS01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS02	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS03	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS04	<0.1	<0.1	<0.1	<0.1	3.4	3.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS05	<0.1	<0.1	0.1	<0.1	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS06	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	-	-	-	-	-	-
WS07	<0.1	<0.1	0.1	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
WS08	<0.1	<0.1	<0.1	<0.1	-	<0.1	-	-	-	-	-	-
CPBH01	<0.1	<0.1	2.1	2.2	2.6	2.6	0.1	0.1	<0.1	0.1	0.1	0.1
CPBH02	0.2	<0.1	0.1	1.7	-	0.9	2.2	0.6	2.1	1.9	2.2	1.2

Carbon Dioxide												
WS01	6.5	5.8	4.9	4.9	4.1	3.9	3.8	3.6	3.0	3.3	3.8	3.9
WS02	0.1	<0.1	3.0	7.2	-	13.9	3.9	3.1	2.3	3.7	3.9	3.5
WS03	1.7	0.2	1.1	9.1	-	9.7	0.5	0.7	0.3	0.5	0.5	0.5
WS04	1.6	2.0	7.6	4.2	6.3	6.3	2.0	2.0	0.9	2.2	2.0	1.7
WS05	7.7	0.2	4.1	6.9	-	7.5	5.5	5.0	0.3	5.5	5.5	5.9
WS06	1.4	3.1	2.1	6.9	6.2	8.8	-	-	-	-	-	-
WS07	2.0	1.8	1.1	-	-	4.5	1.0	1.9	0.6	1.9	1.9	1.9
WS08	0.7	0.9	0.8	1.6	-	1.4	-	-	-	-	-	-
CPBH01	0.3	0.1	2.2	2.3	3.4	3.3	0.9	1.8	1.2	1.8	1.8	1.8
CPBH02	2.0	0.2	1.1	6.9	-	7.6	3.2	2.3	4.0	4.1	4.1	4.0
Atmos. P (mb)	**1005-1004**	**1006-1004**	**1001-999**	**1003**	**992**	**990-987**	**999-998**	**1000-1001**	**979-976**	**993-996**	**989-988**	**994-993**
Max. Flow (l/hr)	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.4**	**0.1**	**0.1**	**0.1**

The 2018 carbon dioxide results are below; all methane concentrations were below 0.1%.

Carbon Dioxide	14.02.18	21.02.18	08.03.18	16.04.18	30.04.18	11.05.18
WS101	0.5	1.1	0.5	0.8	1.5	0.8
WS102	2.6	7.3	1.8	4.9	7.7	4.9
WS103	2.6	4.4	2.8	4.9	4.4	4.5
WS104	1.1	1.7	0.5	0.7	1.7	0.7
WS105	0.6	4.2	1.6	3.0	4.5	2.9
RO01	4.5	8.1	<0.1	6.6	8.4	6.8
RO02	3.5	8.0	1.0	1.9	8.1	1.9
RO03	4.8	4.5	4.3	3.6	4.8	4.1

The RLE2018 report also includes data from the Environment Agency for wells located on the perimeter of the adjacent Sutton Quarry landfill site, which recorded maximum 0.1% methane and 2.3% carbon dioxide. RLE subsequently recommended Amber 1 gas precautions for the site.

We have undertaken our own review of the results recorded. Almost all of the wells installed in the sand pit area recorded methane and/or carbon dioxide concentrations equivalent to Amber 1. The 13.9% concentration of carbon dioxide recorded in 6th round in WS02 appears to be anomalously high as concentrations within this well were generally less than 3.9% except for the 7.2% recorded in the 4th round. The only wells where no exceedances were recorded were WS07 (centre-south edge of pit), RO03 (eastern site boundary) and WS103 to 105 (eastern site boundary). It can therefore be

considered reasonable to allow for gas measures in plots overlying the sand pit. Given that the wells outside of the pit did not record exceedances, this would indicate that ground gas is not migrating; this correlates with the low flows recorded during the 12 rounds. We therefore propose to allow for a 30 m buffer zone outside of the known extent of the sand pit within which plots will also require gas measures.

The remainder of the site should then not require gas measures.

Given the elevated concentrations of Aromatic TPH fractions, 2-Methylnaphthalene, Dibenzofuran and Carbazole within the deep made ground across the area, it would be prudent to allow for Amber 2 gas measures to be installed in all plots within the former sand pit. Amber 1 gas measures should then be allowed for in all plots within 30 m of the sand pit boundary. We have extended this Amber 1 extent to within 30 m of the offsite landfill for robustness, although the two nearest monitoring wells did not record concentration exceedances. Our appended Gas Precautions Plan displays the approximate extents.

Should an earthworks turnover be undertaken, the level of gas measures may be reviewed and potentially downgraded.

9.5 Construction Materials

The majority of the site us underlain by topsoil over natural ground. This assessment assumes any regrade in ground levels does not 'spread' the material from the sand pit area (made ground, reworked ground, natural ground) across the rest of the 'clean' site.

Where made ground is present in the former sand pit area, concrete in contact with this material will require DS-3 AC-3 sulphate measures.

Concrete in contact with natural ground only would be assigned a Sulphate Class of DS-1 and Aggressive Chemical Environment for Concrete (ACEC) Class of AC-1. Therefore, no sulphate precautions are required for concrete in contact with the reworked natural ground.

The reworked ground samples also indicate no sulphate measures are required for concrete in contact with this material, however, the bulk of the material is present overlying the sand pit area, therefore DS-3 AC-3 will still apply.

The results of the chemical testing will need to be forwarded to the water company so that appropriate water supply pipes can be selected. Protective supply pipes should be allowed for within the sand pit area.

9.6 Controlled Waters

The nearest surface water feature is an inland river located 140 m south west of the site boundary. The closest named water feature is an inland river, the River Maun, located Maghole Brook located 422 m north west of the site.

The solid bedrock is classified as a Principal Aquifer. The site lies within a Total Catchment (Zone 3) Groundwater Source Protection Zone, and there are no water abstractions within 250 m of the site.

Elevated concentrations of PAHs are present locally within the made ground, but samples of the shallow natural ground do not record similar elevated PAH concentrations (most are actually below the laboratory's detection limit). The risk to controlled waters is considered to be low, although further assessment will be required when piling into the principal aquifer in the sand pit area.

Standard good site practice during the construction phase of the development must still be adhered to in terms of surface water run-off control measures, to ensure there is no risk to controlled waters.

9.7 Unexpected Contamination

Should any unusual, brightly coloured, ashy, fibrous or odorous material or material suspected of containing asbestos be encountered during construction this should be brought to the attention of the site staff and investigated.

9.8 Disposal of Material

If material needs to be removed, it should to be taken to a suitably licensed landfill or waste treatment facility. The costs of disposal and landfill tax can be substantial. The disposal of material should therefore be seen as a last resort with options such as treatment and reuse either on-site or off-site considered where possible.

The category of landfill which can accept the waste (inert, non-hazardous or hazardous) would need to be determined and will also have a significant effect on the costs. Additional testing may be required by the landfill operator and the acceptance of material is generally at their discretion.

Appendix 1

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Consultants Coal Mining Report

Historical Mapping Legends

Ordnance Survey County Series 1:10,560

Gravel Pit
Sand Pit
Other Pits
Quarry
Shingle
Orchard
Osiers
Reeds
Marsh
Mixed Wood
Deciduous
Brushwood
Fir
Furze
Rough Pasture
Arrow denotes flow of water
Trigonometrical Station
Site of Antiquities
Bench Mark
Pump, Guide Post, Signal Post
Well, Spring, Boundary Post
285 Surface Level
Sketched Contour
Instrumental Contour
Main Roads
Fenced
Un-Fenced
Minor Roads
Fenced
Un-Fenced
Sunken Road
Raised Road
Road over Railway
Railway over River
Railway over Road
Level Crossing
Road over River or Canal
Road over Stream
Road over Stream
County Boundary (Geographical)
County & Civil Parish Boundary
Administrative County & Civil Parish Boundary
Co. Boro. Bdy.
County Borough Boundary (England)
Co. Burgh Bdy.
County Burgh Boundary (Scotland)
R.D. Bdy.
Rural District Boundary
Civil Parish Boundary

Ordnance Survey Plan 1:10,000

Chalk Pit, Clay Pit or Quarry
Gravel Pit
Sand Pit
Disused Pit or Quarry
Refuse or Slag Heap
Lake, Loch or Pond
Dunes
Boulders
Coniferous Trees
Non-Coniferous Trees
Orchard
Scrub
Coppice
Bracken
Heath
Rough Grassland
Marsh
Reeds
Saltings
Building
Direction of Flow of Water
Shingle
Sand
Glasshouse
Pylon
Electricity Transmission Line
Pole
Sloping Masonry
Cutting
Embankment
Standard Gauge Multiple Track
Road Under
Road Over
Level Crossing
Foot Bridge
Standard Gauge Single Track
Siding, Tramway or Mineral Line
Narrow Gauge
Geographical County
Administrative County, County Borough or County of City
Municipal Borough, Urban or Rural District, Burgh or District Council
Borough, Burgh or County Constituency
Shown only when not coincident with other boundaries
Civil Parish
Shown alternately when coincidence of boundaries occurs

BP, BS	Boundary Post or Stone	Pol Sta	Police Station
Ch	Church	PO	Post Office
CH	Club House	PC	Public Convenience
F E Sta	Fire Engine Station	PH	Public House
FB	Foot Bridge	SB	Signal Box
Fn	Fountain	Spr	Spring
GP	Guide Post	TCB	Telephone Call Box
MP	Mile Post	TCP	Telephone Call Post
MS	Mile Stone	W	Well

1:10,000 Raster Mapping

Gravel Pit
Refuse tip or slag heap
Rock
Rock (scattered)
Boulders
Boulders (scattered)
Shingle
Mud
Sand
Sand Pit
Slopes
Top of cliff
General detail
Underground detail
Overhead detail
Narrow gauge railway
Multi-track railway
Single track railway
County boundary (England only)
Civil, parish or community boundary
District, Unitary, Metropolitan, London Borough boundary
Constituency boundary
Area of wooded vegetation
Non-coniferous trees
Non-coniferous trees (scattered)
Coniferous trees
Coniferous trees (scattered)
Positioned tree
Orchard
Coppice or Osiers
Rough Grassland
Heath
Scrub
Marsh, Salt Marsh or Reeds
Water feature
Flow arrows
MHW(S) Mean high water (springs)
MLW(S) Mean low water (springs)
Telephone line (where shown)
Electricity transmission line (with poles)
BM 123.45 m Bench mark (where shown)
Triangulation station
Point feature (e.g. Guide Post or Mile Stone)
Pylon, flare stack or lighting tower
Site of (antiquity)
Glasshouse
General Building
Important Building

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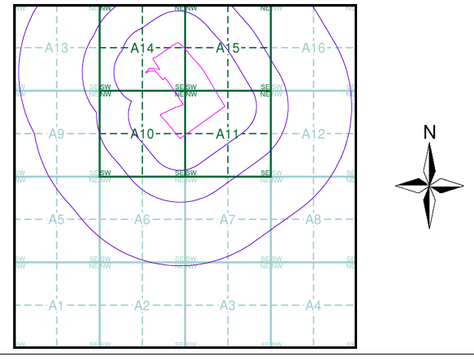
Historical Mapping & Photography included:

Mapping Type	Scale	Date	Pg
Nottinghamshire	1:10,560	1886	2
Nottinghamshire	1:10,560	1900	3
Nottinghamshire	1:10,560	1920 - 1921	4
Nottinghamshire	1:10,560	1921	5
Nottinghamshire	1:10,560	1938	6
Ordnance Survey Plan	1:10,000	1955	7
Ordnance Survey Plan	1:10,000	1967	8
Ordnance Survey Plan	1:10,000	1976	9
Ordnance Survey Plan	1:10,000	1992	10
10K Raster Mapping	1:10,000	2000	11
10K Raster Mapping	1:10,000	2006	12
VectorMap Local	1:10,000	2021	13

Historical Map - Slice A



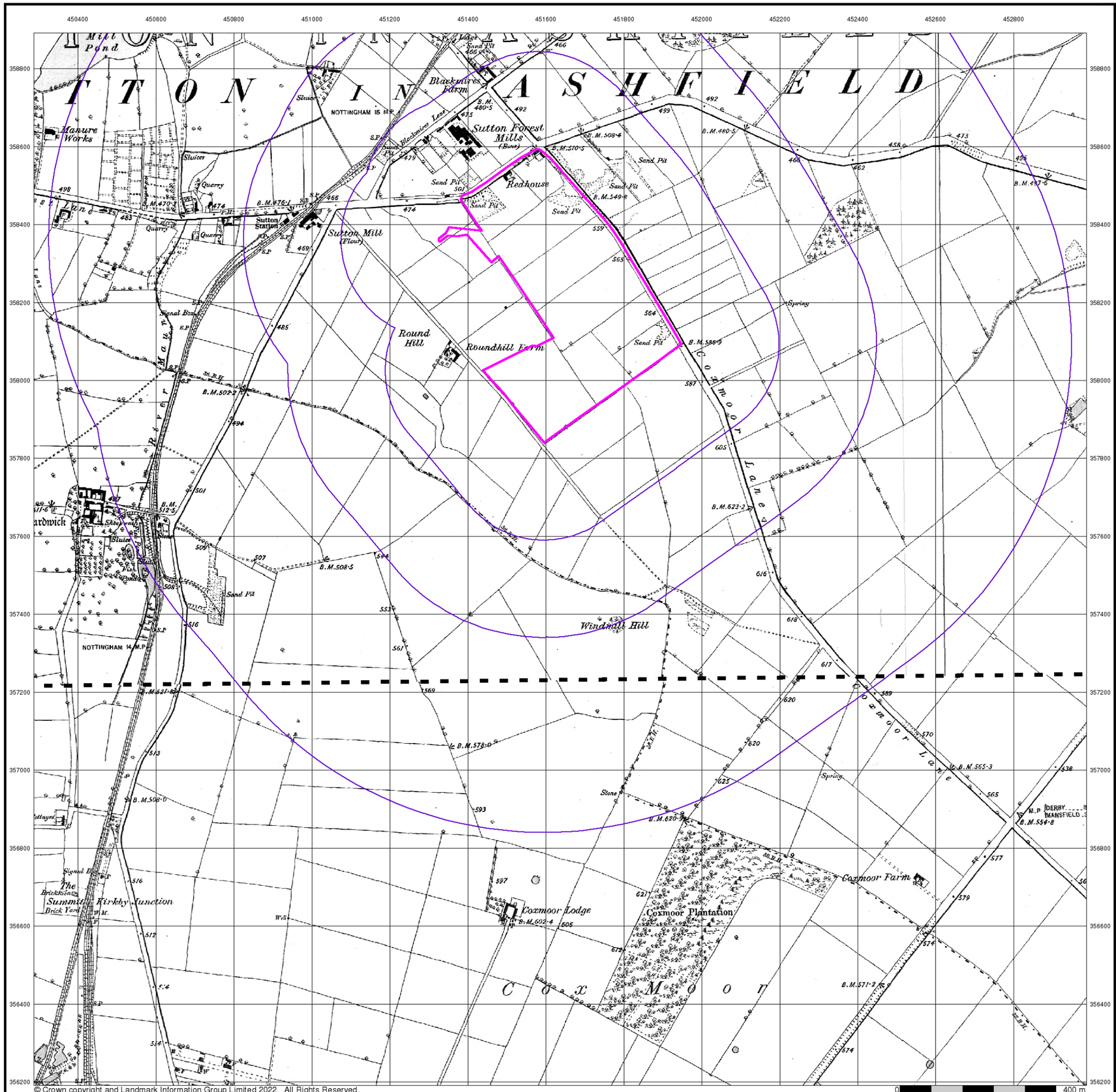
Order Details

Order Number: 290988033_1_1
Customer Ref: 46924
National Grid Reference: 451630, 357990
Slice: A
Site Area (Ha): 21.38
Search Buffer (m): 1000

Site Details

Site at 451680, 358260

Landmark INFORMATION GROUP
Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk



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Nottinghamshire

Published 1886

Source map scale - 1:10,560

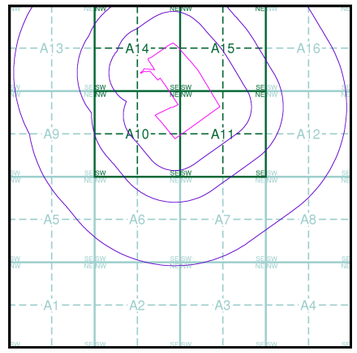
The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840`s. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940`s, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)

027NE
1886
1:10,560

027SE
1886
1:10,560

Historical Map - Slice A



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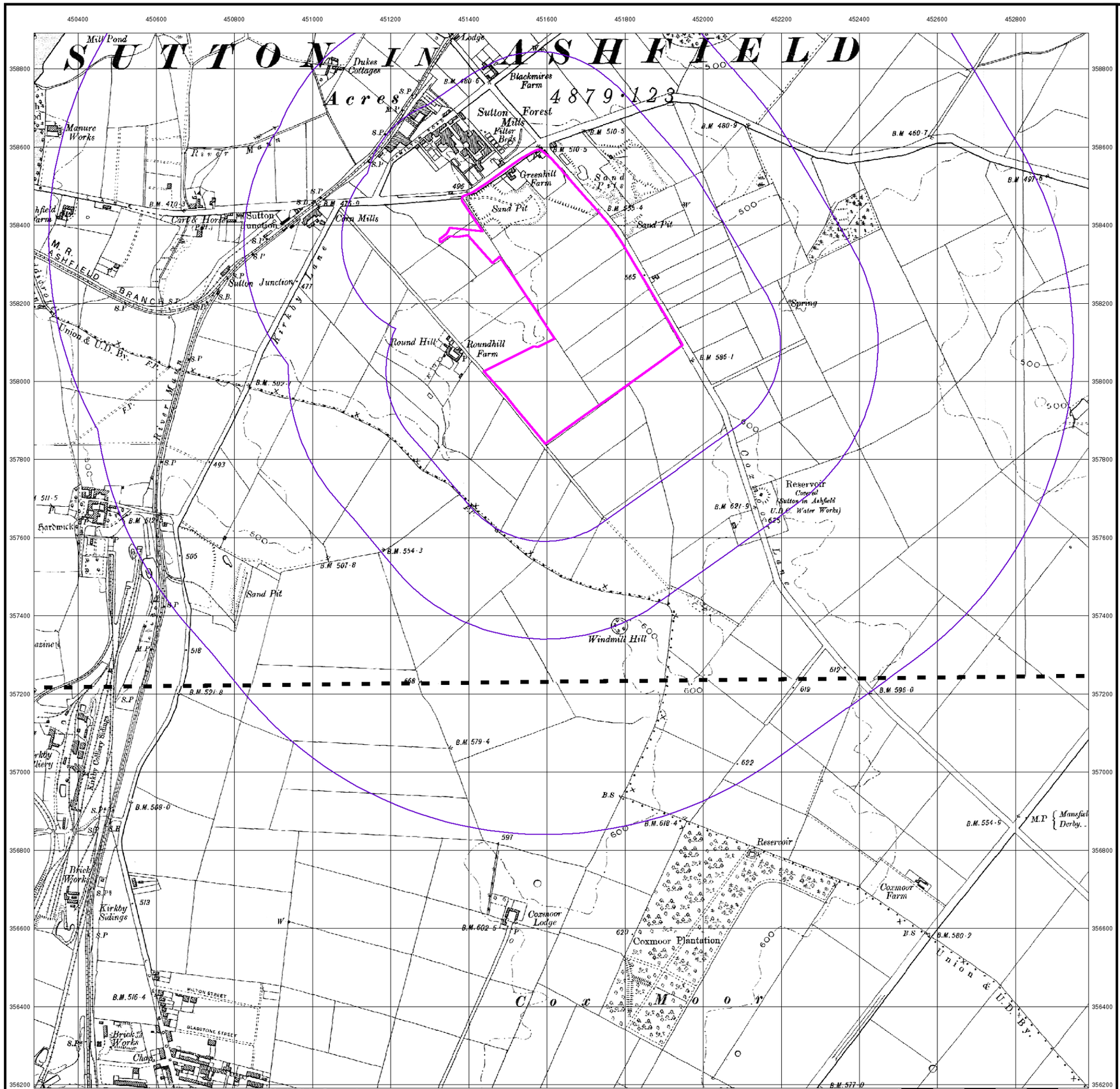

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LANDMARK INFORMATION GROUP®

Nottinghamshire

Published 1900

Source map scale - 1:10,560

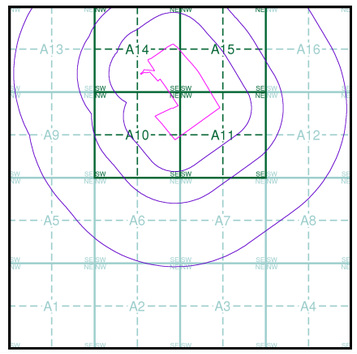
The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840`s. In 1854 the 1:2,500 scale was adopted for mapping urban areas; these maps were used to update the 1:10,560 maps. The published date given therefore is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas. In the late 1940`s, a Provisional Edition was produced, which updated the 1:10,560 mapping from a number of sources. The maps appear unfinished - with all military camps and other strategic sites removed. These maps were initially overprinted with the National Grid. In 1970, the first 1:10,000 maps were produced using the Transverse Mercator Projection. The revision process continued until recently, with new editions appearing every 10 years or so for urban areas.

Map Name(s) and Date(s)

027NE
1900
1:10,560

027SE
1900
1:10,560

Historical Map - Slice A



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