7.13 The updated source – pathway – receptor matrix is presented below, taking into account the findings of the investigation. Any pathways in italics are deemed not to be viable and the reason given.

Viable Source - Pathway - Receptor Matrix (Finished Development)

Contamination Sources	Pathways	Receptors	Severity of Consequence	Probability of Event	Risk
Made ground on west of site: - elevated TPH and PAH	• Inhalation, ingestion and dermal contact with soil and dust • Fruit and vegetable intake, with soil • Vapour inhalation outdoor • Vapour inhalation indoor	**Humans:-** • Future occupants • Maintenance workers • Adjacent residents and general public	**Medium**	**Low Likelihood**	**Moderate/ Low**
	• Migration in surface water	• Surface water (nearest downslope is 140m to south). There are no abstractions within 1km.	**Medium**	**Unlikely**	**Very Low**
	• Migration in groundwater	• Groundwater (Secondary A Aquifer, no abstractions within 1km)	**Medium**	**Unlikely**	**Very Low**
	• Root uptake	**Vegetation:-** • Landscape areas • Private gardens	**Medium**	**Low Likelihood**	**Moderate/ Low**
	• Migration	**Services/Utilities:-** • Potable water supply	**Medium**	**Low Likelihood**	**Moderate/ Low**
Ground Gas: methane and carbon dioxide	• Asphyxiation • Explosive risk	• Construction/de-molition workers • Future occupants • Buildings	**Severe**	**Low Likelihood**	**Moderate**
Possible asbestos within existing buildings and sheeting on the ground to rear of large warehouse building.	• Inhalation	• Future occupants • Maintenance workers • Adjacent residents and general public	**Severe**	**Low Likelihood**	**Moderate**

7.14 It can be seen from the above matrix that several pathways to receptors are operative, and this may affect users of the finished development, with up to a moderate risk applicable. Some form of remedial action is, therefore, considered necessary to allow residential development without excess risk.

Risk Based Assessment of Remedial Options

Asbestos Within Existing Buildings and Sheeting on the Ground Surface

7.15 Provided an asbestos survey is carried out prior to any demolition or work on the existing buildings on the site, and any identified asbestos (including the cement sheets on the ground to the rear of the large warehouse building) is removed and disposed to a licenced facility, then the risk to receptors is low. The work should be carried out by appropriately qualified Contractors and records of the removal should be kept, including any method statements for the work, as the Local Authority may request this to prove that soils have not been subsequently impacted by asbestos contamination.

Landfill and Mine Gases

7.16 To address the potential risk from landfill, and the low risk of mine, gases, monitoring of borehole wells is in progress. This will determine whether or not protection measures are likely to be necessary. Currently, CS2 mitigation measures have been identified as necessary. This will be confirmed by separate letter report on completion of the monitoring.

Made Ground - Ingestion, Dust Inhalation, Dermal Contact, Root Uptake, and Fruit and Vegetable Intake, With Soil

7.17 This pathway is automatically blocked where buildings or hardstanding are present above the material. However, in garden areas, provision of a cover blanket of a minimum 0.6m thickness will be required in the western area of the site ,where required, due to elevated contamination, to reduce the risk to future users of the site to acceptable levels from these pathways. This assumes a worst case double dig scenario (i.e. 2 x spade depths). Although the contamination was identified to be present on the west of the site, made ground was extensive across the site and, for aesthetic reasons, it is likely that a minimum of 0.3m of topsoil will be required for all gardens. This will need to be agreed with the Local Authority.

As made ground is very variable, the presence of contaminated material on areas of the site other than the west cannot be ruled out, and in the event of such unexpected or suspected contamination on the wider site, then a cover blanket 0.6m should be provided in gardens and landscaping.

Made Ground - Surface Water and Groundwater Pathways

7.18 Risks to groundwater and surface water are considered minimal, but can be reduced further by ensuring that where the cover blanket, required in the west of the site, includes at least 0.45m thickness of material with at least 35% silt/clay content (at least 35% passing a 63 micron sieve), for example clay, sandy clay, or gravelly clay. If cohesive cover blankets are used, external levels and surface water drainage will need to be carefully designed to avoid localised surface water ponding.

Migration to Utilities

7.19 Localised hydrocarbon contamination has been identified on this site and, therefore, it is considered likely that water supply pipework will need to be protected from migration. The local water company should be consulted.

Risks During Construction Period

7.20 It is also necessary to consider the effects of the contamination present on the site in relation to the risks to adjacent residents, construction workers and the general public during construction. This is assessed in the following matrix.

Source	Pathway	Potential risk	Risk after employing suitable Health and Safety plan.
Existing made ground	Inhalation	Moderate	Damping down of the site during dry periods and timely placement of the existing made ground below barriers should block this pathway and reduce the risk to negligible.
Existing made ground	Ingestion	Moderate	Site fencing will exclude access to members of the public. Existing made ground will be contained within the site boundary, and placed below barriers as soon as possible. Washing facilities and a clean mess room from which work boots and overalls are excluded should be provided. These measures should block this pathway and reduce the risk to negligible.
Existing made ground	Contact	Moderate	Education of workers to use adequate hygiene and PPE should block this pathway and reduce the risk to negligible.
Existing made ground	Surface water	Moderate	Preventing surface water run off by minimising open exposure times of the existing made ground, and using bunds or cut off trenches as necessary should block this pathway and reduce the risk to negligible.
Asbestos in existing buildings and on surface of site	Inhalation	High	Provided an asbestos survey is carried out, and any identified asbestos is removed from site prior to any other works commencing, the pathway is blocked and the risk is negligible.

7.21 Provision of all the above measures will ensure that all the identified pathways for the contamination will be blocked.

Summary of Contamination Identified and Remedial Options

7.22 The site is underlain by up to 2.8m thickness of made ground, overlying residual clay and then weathered mudstone or weathered sandstone bedrock. Monitoring of ground gases, by means of borehole well installations, is in progress. This will determine whether or not protection measures are likely to be necessary. This will be confirmed by separate letter report on completion of the monitoring.

7.23 The made ground was found to contain localised elevated concentrations of lead, PAH and TPH in the west of the site only.

7.24 The contamination risk assessment, and assessment of remedial options, has indicated that, provided that the following remedial measures are adopted, then the risks to the identified receptors are deemed acceptable for the proposed development of residential properties with private gardens.

7.24.1 An asbestos survey should be carried out prior to any demolition or work on the existing buildings on the site, and any identified asbestos should be removed and disposed to a licenced facility. A small stockpile of asbestos sheeting was noted on the ground to the rear of the large warehouse building on site. This should be removed from site also. The work should be carried out by appropriately qualified Contractors and records of the removal should be kept, including any method statements for the work, as the Local Authority may request this to prove that soils have not been subsequently impacted by asbestos contamination.

7.24.2 Where any garden or landscape areas overlie the existing made ground that has been identified to be contaminated in the west of the site, a minimum 0.6m thickness of uncontaminated soils (topsoil and subsoil) should be provided. Due to the extent of made ground across the site, it is recommended that all gardens have at least a 0.3m covering of clean topsoil. This is subject to the agreement of the local authority. In areas of hardstanding or building footprints, the cover blanket is not required. If any contamination is found or suspected on the wider site where only 0.3m soils are being provided, then a cover blanket should be placed similar to that specified for the west of the site.

7.24.3 Where a cover blanket is required on site in garden areas, i.e. in the west of the site, it should include at least 0.45m thickness of material with a minimum 35% silt/clay content (at least 35% passing a 63 micron sieve), for example clay, sandy clay, or gravelly clay, to minimise leaching of contamination. If cohesive cover blankets are used, external levels and surface water drainage will need to be carefully designed to avoid localised surface water ponding.

7.24.4 Any imported soils used within the cover blanket will need to be verified as suitable by inspection and testing, in accordance with guidance supplied in the document produced by the Yorkshire and Lincolnshire Pollution Advisory Group (YALPAG): "Guidance on the Verification Requirements for Cover Systems".

7.25 Protected surface water supply pipes may be required. The local water company should be consulted.

7.26 A Contamination Remediation Statement is included in Appendix E.

8.0 GEOTECHNICAL TESTING

8.1 Selected samples of the natural strata were delivered to PSL in Doncaster for testing with regard to plasticity indices and moisture content. Test certificates are presented in Appendix C and a summary of the results, including Modified Plasticity Indices, is given below.

Location	Depth (m)	MC	LL	PL	PI	<425µm	I'p
TP3	1.8-2.0	18	46	21	25	100	25
TP11	2.8-3.0	15	41	20	21	100	21
TP12	2.0-2.2	12	Designated as non-plastic material				
WS3	1.8-2.0	19	61	26	35	100	35
WS4	2.7-3.0	10	38	19	19	88	17
	No. of results	5	4	4	4	4	4
	Min.	10	38	19	19	88	17
	Max.	19	61	26	35	100	35

I'p	VCP
>40%	High
20% - <40%	Medium
10% - <20%	Low

MC= Moisture Content (%) LL= Liquid Limit (%) PL= Plastic Limit (%)

PI= Plasticity Index (%) I'p= Modified PI (%) VCP= NHBC Standard Chapter 4.2 Volume Change Potential

8.2 The plasticity test data shows the clay strata to be of intermediate to high plasticity, in accordance with BS 5930:2015 +A1:2020 "Code of Practice for Site Investigations". When the percentage retained on the 425 micron BS sieve is considered, the Modified Plasticity Index, in accordance with NHBC Standard Chapter 4.2 "Building Near Trees" is a maximum of 35. In accordance with the Standard, this equates to Medium Volume Change Potential.

8.3 Geochemical testing (water soluble sulphate and pH) was undertaken on selected samples by DETS (as a subcontracted lab to PSL) and Chemtech, comprising seven samples of natural strata and 20 samples of made ground. In accordance with the BRE Special Digest 1

"Concrete in aggressive ground", the characteristic values for the two materials are given below:

Characteristic Values

Material	pH	SO_4
Made Ground	6.8	134
Natural Strata	4.8	133

SO_4 = Sulphate content in mg/l on a 2:1 water : soil extract pH = Acidity

8.4 The geochemical analyses show the natural strata to have low water soluble sulphate content but a relatively low pH. The Aggressive Chemical Environment for Concrete (ACEC) class is AC-1 for the natural ground and AC-2z. for the natural soils. Therefore, the use of FND2z designated concrete will be necessary for unreinforced buried concrete, in accordance with BS 8500. For any reinforced buried concrete, other design-specific mixes will apply.

9.0 COMMENTS AND CONCLUSIONS

Site Description

9.1 The site comprises the disused, former Balmoral Tanks factory site. The site is occupied by a large (approximate 130m long and 15m wide) warehouse type building just south of the centre of the site, and numerous other factory buildings that are located closer to the access to the site off Hough Lane. A large telephone mast with associated small substation is located in the southwest of the site. The site is covered in a combination of concrete and bituminous hardstanding, and rough open ground.

9.2 The main area of the site is relatively flat, but the access from Hough Lane into the main site area slopes downwards from the road. The southern and southwestern boundary of the site is higher than the surrounding land. There are some large mature trees around the boundaries.

9.3 The site is bounded by housing, Hough Lane, and then a cricket ground to the north, by housing and open fields to the east and south, and by a housing estate to the west.

Site History

9.4 Ordnance Survey archive maps show no development on the site prior to the 1930s. Development on the site was progressive after this time. A garage has been present in the north of the site and a works in the northwest. The wider buildings have been used for the manufacture of galvanised steel and fibreglass tanks and containers. It is known that associated engineering work, fuel and lubricant oil storage also will have been undertaken on site. A reservoir and an old quarry were also present to the north. A foundry was adjacent to the west, recently replaced by a housing estate.

Geology

9.5 The geological maps show the site to be underlain by the Pennine Middle Coal Measures Formation comprising interbedded pale grey sandstone, siltstone, grey mudstone and coal seams. There are no faults shown to affect the site. The Swinton Pottery Coal is identified to outcrop approximately 55m to the northeast of the site and the Newhill Coal seam is identified to outcrop 45m to the southwest of the site. The strata are progressively younger towards the northeast, and of the two outcrops, only the Newhill Coal will underlie the site.

Coal Mining and Coal Recovery

9.6 The Coal Mining Report indicates that the site is situated within 20 metres of a known coal seam outcrop and that, due to this, the site is located within a "High Development Risk Zone", as defined by the Coal Authority. The report does not identify any mine shafts or adits to exist on or adjacent to the site.

9.7 A Coal Mining Risk Assessment (dated 2nd July 2020) has been produced by ARP Geotechnical and reviews the Coal Mining Report and all of the available geological information in detail. It is recommended that the CMRA is read in entirety but it is concluded that the Swinton Pottery Coal does not underlie the site, and there is a low to very low risk that workings are present within the Newhill Coal seam that could affect some of the site. An intrusive investigation is recommended to be undertaken to confirm the low/very low risk presented by the Newhill Coal.

Environmental Data

9.8 The bedrock strata beneath the site are classified as a Secondary A Aquifer (there are no superficial deposits). There are no groundwater abstractions within 1km of the site.

9.9 The nearest surface water feature downslope is a river located 140m (taken from the Envirocheck Report data) to the south of the site. However, there are no surface water abstractions within 1km of the site.

9.10 No radon protective measures are stated to be necessary for new dwellings or extensions on the site but the site is within an "intermediate probability radon area". In these circumstances of apparent conflict, it may be prudent to assume basic radon protection is required, to prevent conveyancing difficulties. However, ground gas protection is required in any event, as discussed below.

9.11 There is a landfill located adjacent (identified possibly to be as close as 25m) to the south of the site. Gas monitoring to date has identified maximum carbon dioxide and methane concentrations of 0% and 9.6% respectively. Risk assessment indicates that gas protection of properties, against carbon dioxide, is required, as CS2 conditions are indicated. However, this will be confirmed by separate letter report on completion of the monitoring.

9.12 The specific design of the protection measures, and the verification required, is dependent on the detailed foundation design, the selection of products/suppliers, the gas regime, and who installs the protection. Once more of these factors are known, as a minimum following foundation design and design of the protection measures, a Statement on Gas Protection should be prepared. The document should provide information for the Client and other interested parties, such as the regulatory authorities, outlining how gas protection measures for properties on the site will be implemented and the installation verified as satisfactory. The document should be agreed, prior to implementation, with the relevant Regulatory Authorities, usually the local Planning Authority and NHBC or other building control provider.

9.13 The site is not at risk from river flooding. The risks of flooding from other causes such as adverse topography or insufficient surface water drainage are not considered here. If such risk needs to be quantified, a separate specialist Flood Risk and Drainage Report should be commissioned, if not already available. BGS data indicates the general area has the

"potential for groundwater flooding of property situated below ground level" (i.e. basements or similar).

Ground Conditions Encountered

9.14 The ground investigation revealed the made ground over the majority of the site was present as a mixture of granular and cohesive made ground to depths of between 0.2m and 1.7m, with a typical depth of approximately 1m. Deeper made ground, typically as clay with gravel of mixed lithologies, was identified in the southwest of the site, behind the large warehouse building. Made ground in this area was up to 2.8m deep. Hydrocarbon odours were noted in TP9 from 0.8m to 1.2m depth and in TP11 from 0.5m to 1.5m depth.

9.15 Below the made ground was typically a firm to stiff clay (residual Pennine Middle Coal Measures Formation (PMCMF)), which slowly graded into a weathered mudstone bedrock or weathered sandstone bedrock (weathered PMCMF). Occasionally, a weathered siltstone was identified. The weathered bedrock was encountered at depths of between 1.3m (TP4) and 3.9m (WS5) but is typically encountered across the site at depths of between 2m and 3m. Groundwater was rarely encountered during the site investigation. Recent monitoring visits showed groundwater at depths of between 1.03m an 2.8m below existing ground level.

Contamination Assessment

9.16 The contamination assessment identified the made ground to contain localised elevated concentrations of lead, PAH and TPH in the west of the site only.

9.17 The contamination risk assessment confirmed that, provided remedial measures are implemented, comprising clean cover soils to soft areas in the west of the site, the materials present on the site are compatible with the proposed residential with private garden usage. A cover of 0.3m thickness of clean soils is proposed on the rest of the site, for aesthetic purposes. A Contamination Remediation Statement, which includes further detail on the remediation measures for the site, is presented in Appendix E.

9.18 Protection of water supply pipes from hydrocarbons are likely to be required. The local water company should be contacted for advice.

Foundations

9.19 The existing made ground present across the site is considered unsuitable for support of foundation loads. The depth of made ground across the site is typically around 1m (but locally up to 2.8m). Residual soils (residual PMCMF) are present beneath, comprising firm to stiff clay. Weathered bedrock is then encountered below, of either weathered mudstone or sandstone (occasionally weathered siltstone is present) at depths of around 2.5 to 3.0m. As such, strip/trench fill foundations will be suitable for the vast majority of the site. An allowable bearing pressure of 100kN/m^2 is considered applicable for the firm to stiff clay encountered on site. Increasing allowable bearing pressures are likely to be available with depth, of 150kN/m^2 where the clay improves to a granular material, and 300kN/m^2 on bed rock. A geotechnical engineer should be contacted for advice on the appropriate depth, if more than 100kN/m^2 is required.

9.20 In the southwest corner of the site, made ground has been identified up to 2.8m thick. Exploratory hole positions WS5, TP10 and TP11 identified made ground to depths of 2.2m, 2.4m and 2.8m respectively. Excavation faces within the made ground in this area of the site were unstable to varying degrees. If houses are to be located in this area then the proposed foundations will need to be considered carefully. Based on the proposed plan for the site, most of this area where deep made ground has been identified will comprise Public Open Space (POS). However, If foundations are required in this area, then the option of piling should be considered along with the possibility of deep trench fill foundations or a temporary reduced level excavation in the area to reduce the depth of the required foundation excavations.

9.21 The southern boundary of the site is formed by a slope which slopes downwards to the adjacent land. The position and proximity of any plots, and roads or any other structures, to

this slope should be considered so that additional loading is not applied to the slope and its stability is maintained.

9.22 The clays were shown to be of Medium Volume Change Potential. Therefore, in accordance with NHBC Standard Chapter 4.2 "Building Near trees", in the absence of trees, a minimum foundation depth of 0.9m below existing or proposed ground level is applicable, whichever is the lower. However, in the presence of any proposed, existing or removed trees, the foundation may need to be deepened, depending on the type of tree and its distance from the face of the foundation. If not already available, a tree survey may be required to enable a foundation schedule to be prepared. The tree survey will also need to consider trees on third party properties.

9.23 The foundation should be taken below the depth of any existing foundations or obstructions, onto natural ground. The whole plan area of the foundation should be placed on similar natural material. If plots are located partly on weathered mudstone (as a stiff to hard clay) and partly on more competent sandstone then Foundations should be reinforced to accommodate this transition.

9.24 If bedrock is encountered on part of a foundation excavation, the rest of the plot should be deepened to ensure founding on similar material. However, if rock is not encountered by 2.5m depth on the remainder of the plot, then the Engineer should be contacted for further advice.

9.25 The above foundation advice is subject to confirmation that shallow underground mine workings are not present beneath the site. The risk of this is very low to low, but needs to be confirmed by rotary drilling investigation. The presence of any such workings is not a bar to development, and there are tried and tested techniques for rendering development over such ground safe, for example injection of grout. Such treatment is commonplace and it if required, is usually covered by an appropriate planning condition. Following such treatment, the only change to the foundation design is usually the incorporation of mesh reinforcement.

Excavations

9.26 It is likely that excavations into the natural strata will remain stable in the short term, requiring minimal trench support, in accordance with the prevailing statutory guidance. However, instability can be anticipated within the made ground present on the site.

9.27 Slight groundwater seepages were recorded in TP5 and TP6, at 3.4m and 3.75m respectively. Water was also encountered at 3.0m within WS7. Any such encounters of groundwater should be controllable by pumping from an artificial sump.

9.28 Excavations should be readily achieved using conventional hydraulic plant. However, excavations into intact bedrock or buried foundations and structures are likely to require a hydraulic breaker.

Chemical Precautions

9.29 The Aggressive Chemical Environment for Concrete (ACEC) class is AC-2Z. Therefore, the use of FND2z designated concrete will be necessary for unreinforced buried concrete, in accordance with BS 8500. For any reinforced buried concrete, other design-specific mixes will apply.

Road Pavement Construction

9.30 Due to the history of the site, the depth and nature of the made ground can vary significantly over relatively short distances. For the main area of the site (anywhere in front of the large warehouse building) made ground is typically around 1m deep (but was identified up to 1.7m deep). Formation of roads on the existing made ground are unlikely to be acceptable (especially for any adoptable roads). For any areas of road pavement, including parking areas, the formation will therefore need to be the natural strata, comprising either firm to stiff clay, the more competent weathered mudstone bedrock or, locally, sandstone bedrock, which are all present beneath the made ground. Typically, the formation would be expected

to be the firm to stiff clay. Based on the observed characteristics of the material, and the results of the plasticity testing a design California Bearing Ratio (CBR) value of around 2-3% is considered applicable for the firm to stiff clay, below any obvious soft spots, and at equilibrium moisture content. The CBR value will be significantly higher for the more competent weathered mudstone and especially the sandstone bedrock. If considered necessary, this should be confirmed by testing at proposed subgrade level before construction.

9.31 Deep made ground (up to 2.8m) is present in the southwest of the site. A formation for any adoptable road pavement on natural strata at this depth will present problems. There are several potential solutions for this situation, including complete excavation of the made ground to natural strata, and placement of engineered fill to a controlled specification, partial excavation and replacement, with or without layers of geogrid, or the use of vibro stone columns overlaid by a geogrid reinforced stone blanket. The proposed measures will need to be agreed with the adopting authority and, therefore, consultations with the relevant authority should be undertaken at the earliest stage.

Soakaways

9.32 The majority of the site is underlain by clay and mudstone, which is not considered to be sufficiently permeable for the use of soakaways. There is a localised band of sandstone present across the site, but with clay/mudstone present to either side The general topography of the site, surrounding area and, presumably, the groundwater flow direction, is downwards to the south and west. There is a slope with lower ground level off the site to the south and west and, therefore, soakaway drainage could represent a risk of flooding off site. The disposal of surface water using soakaways is, therefore, unlikely to be practical on the site.

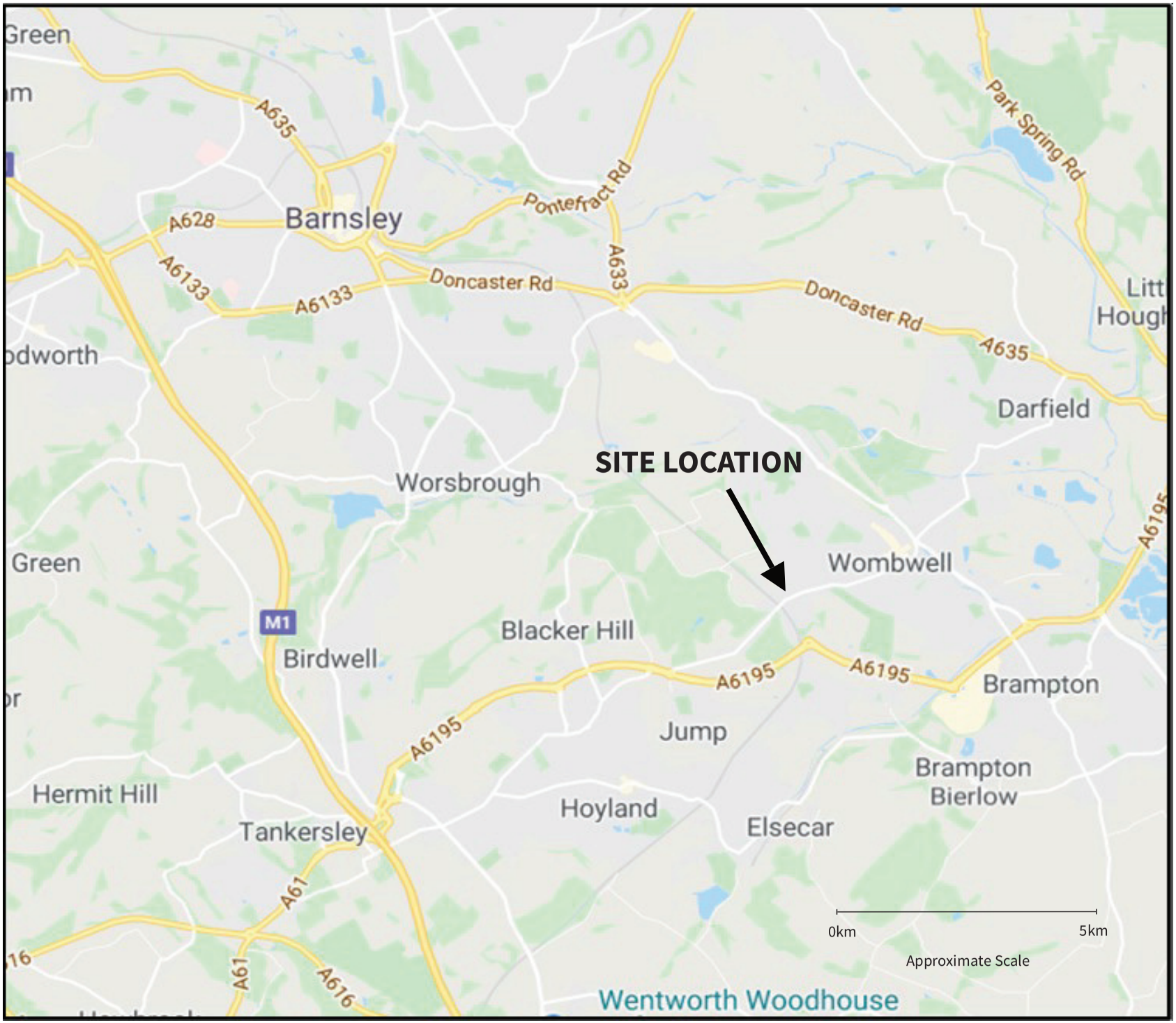
Suggested Further Work

9.33 A rotary borehole investigation should be carried out to confirm the situation with regard to shallow underground coal workings beyond doubt.

9.34 Once the gas regime has been established, and following detailed foundation design, and decisions from the client in relation to selection of products/suppliers for gas protection, and who installs the protection, a Statement on Gas Protection should be prepared, outlining how gas protection measures will be implemented and the installation verified as satisfactory. The document should be agreed, prior to implementation, with the relevant Regulatory Authorities.

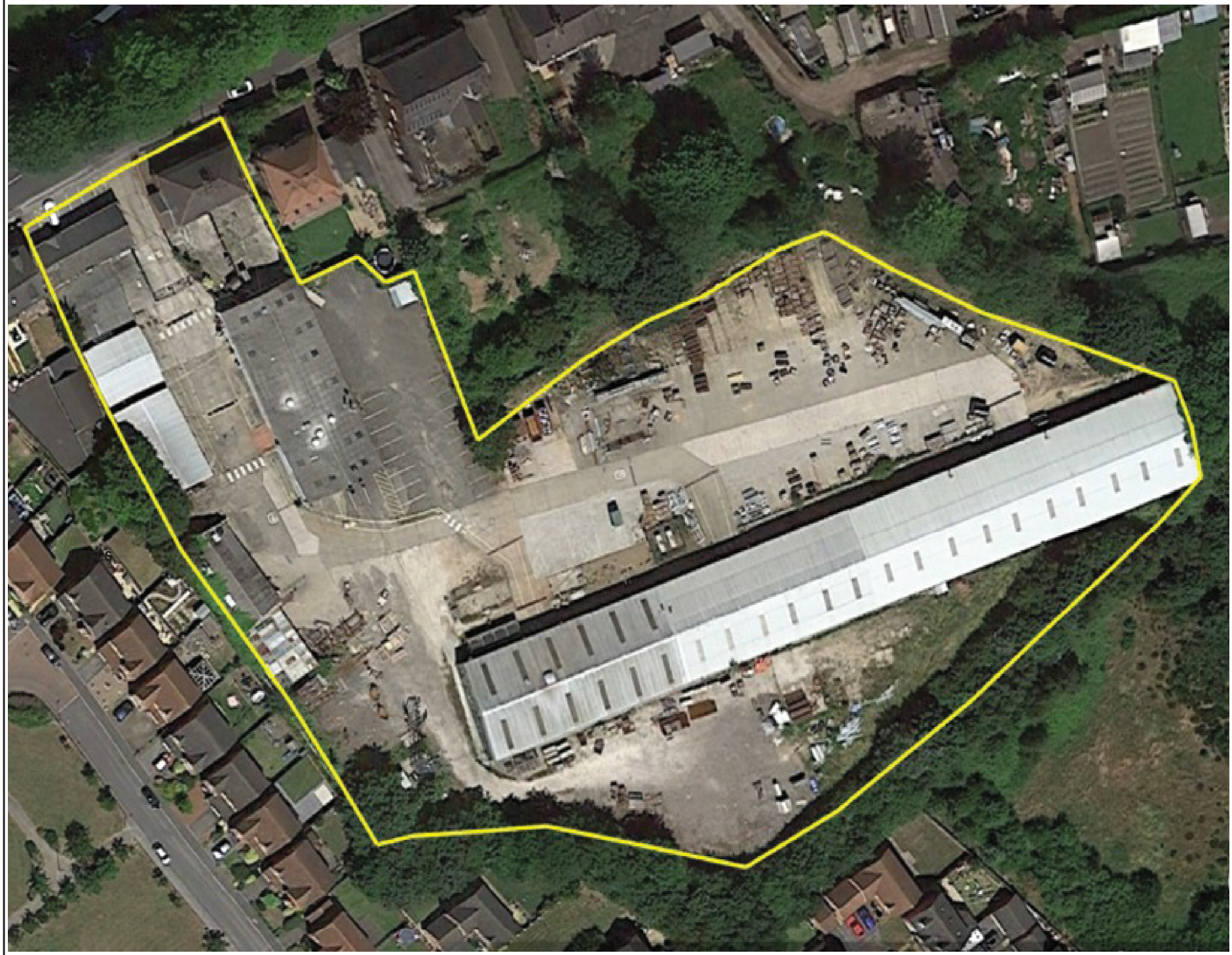
APPENDIX A

SITE LOCATION PLAN, AERIAL PHOTOGRAPH AND PROPOSED LAYOUT



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Project	HOUGH LANE BARNSLEY
Client	HOOBER HOMES LTD
Title	SITE PLAN
Date	JULY 2020
Drawn	V1 @A3
Scale	AS SHOWN
Job No.	HOO/01



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Project	Hough Lane Wombwell
Client	Hoober Homes Ltd
Title	Aerial Photograph Plan
Date	July 2020
Drawn	AMJ
Scale	NTS
Job No.	HOO/01