



Jones Homes (Yorkshire) Limited

Land off Bloomhouse Lane, Darton

Geo-environmental site assessment and coal mining risk
assessment report

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RSK GENERAL NOTES

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Land off Bloomhouse Lane, Darton

Client: Jones Homes (Yorkshire) Limited, Green Bank House, Green Bank,
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EXECUTIVE SUMMARY

Site description and proposed development	The site is located to the south of Bloomhouse Lane, Darton, South Yorkshire. The site covers an area of approximately 11.9 hectares and is currently occupied by vacant fields. The intention is to redevelop the site for residential end-use.
Purpose of assessment	In accordance with the tender documentation, this assessment was undertaken to support an outline planning application.
PRELIMINARY RISK ASSESSMENT	
History of site and surrounding area	The site has remained largely undeveloped historically, except for a building associated with Manor House in the south western area of site, a school in the south eastern part of site and a tramway in the eastern part of site. An area of raised ground remains in the central northern part of site, the origin of which is unknown, however may be associated with coal mining or quarrying activities in the vicinity of site.
Geology, hydrogeology and hydrology	The site is underlain by the Pennine Middle Coal Measures Formation, a secondary A aquifer. The site does not lie within a source protection zone and no potable water abstractions are situated within 1km of site. The Barnsley Rider Coal and Barnsley Coal are indicated to outcrop within the site boundary. Additionally, an unnamed seam and the Top Haigh Moor Coal Seam outcrop to the southwest of the site. There are five recorded mine entries on-site. The nearest identified surface water feature to the site is the River Dearne, approximately 177m west of site. The site does not lie within a designated fluvial floodplain.
Potentially contaminative uses on site and in surrounding area	The historical research indicates that potentially contaminative activities have occurred on the site, including a tramway in the eastern part of site and areas of made ground associated with the demolition of former buildings (near Manor House and the former school), as well as an area of raised ground in the central northern part of site. Potentially contaminative current activities have been identified in the area surrounding the site, including various industrial land uses (factory, works/ laboratory), an infilled former quarry adjacent to the south west and a railway, 100m south west.
Conceptual model	Potentially complete pollutant linkages identified with a risk estimate of moderate or above include: 1) Direct contact of contaminated soils to future site users 2) Inhalation exposure of future site users to asbestos fibres 3) Plant uptake of contaminants within the soils, which may affect

	plant growth 4) Chemical attack on infrastructure including concrete and potable water supply pipes from contaminated soils 5) Inhalation and explosion of hazardous ground gases from build up within buildings
SITE ASSESSMENT	
Site investigation and refinement of conceptual site model	An intrusive investigation consisting of 32 trial pits, 19 trial trenches, 6 rotary boreholes and 8 probeholes with laboratory analysis and two initial rounds of gas monitoring have been undertaken. The ground conditions encountered generally confirmed the stratigraphical succession described within the initial conceptual model. Made ground was encountered to an average depth of 0.15m to 0.60m, with some localised deeper areas (up to at least 4.6m). Pennine Middle Coal Measures strata were encountered beneath the topsoil or made ground, comprising clay grading into mudstone and sandstone. Coal seams were encountered at depths of between 0.65m and 26.80m. The mine probing investigation encountered evidence of shallow workings (broken ground or possible voids) at depths ranging between 2.0m and 6.4m. The trial trenching exercise identified one of the aforementioned recorded mine adits. No significant visual or olfactory evidence of anthropogenic contamination was noted during the investigation. A selection of soil samples were analysed for a general suite of contaminants. Shallow groundwater was encountered as seepages in the trial pits at various depths and differing strata, indicating the presence of localised perched water. During groundwater monitoring, standing water level was recorded between 0.88m and 8.5m bgl. Concentrations of ground gas were found to be low in the first two rounds of monitoring. However, it is considered that the monitoring carried out to date is insufficient to characterise adequately the ground gas regime.
CONCLUSIONS AND RECOMMENDATIONS	
Environmental assessment	On completion of the GQRA the following pollutant linkages that require further action are: 1. Direct contact of contaminated soils to future site users associated with localised contamination in made ground 2. Inhalation exposure of future site users to asbestos fibres 3. Plant uptake of contaminants within the soils, which may affect plant growth in certain areas of the site

	4. Permeation of contaminants to water supply pipes in certain areas of the site 5. Inhalation and explosion of hazardous ground gases from build up within buildings Localised soil contamination was encountered associated with localised made ground. Additional sampling and analysis is recommended to further investigate linkages 1 and 3. It is recommended that a clean cover with a minimum thickness of 600mm be placed within garden areas of affected plots. Suspected ACM were encountered on site, however asbestos fibres were not detected in soil samples. It is recommended that a watching brief is undertaken during ground works and that ACM is removed from site by a suitably licensed and qualified company. The proposed routes of the potable water supply pipes are currently unknown. A targeted soil sampling and testing investigation should be completed in the route of the proposed pipes once they are known to fully assess the risk of chemical attack on the supply pipes from contaminated soils. Assessment of the ground gas regime is ongoing with a further four rounds to be completed. Currently the site is considered 'Green', however final determination of the requirement for gas protection measures should be reserved until the monitoring programme is completed.
Geotechnical assessment	The firm to stiff natural soils (weathered Coal Measures) are considered suitable to support shallow spread foundations. Trench fill foundations are considered suitable in areas of deeper made ground (less than 2.5m deep) and alternative foundation options will be required in areas where made ground is deeper than 2.5m. For areas affected by shallow underground coal workings, spread foundations will be required to be reinforced. The preliminary recommended sub-grade soil CBR value for road pavement design is 3% based on the ground conditions encountered. It is recommended that in-situ CBR determination be carried out targeting areas of hardstanding prior to construction works to confirm this value. The Aggressive Chemical Environment for Concrete classification is indicated to be AC-1, with a Design Sulphate Class of DS-1 in accordance with current BRE guidance.

Mining

The mine probing investigation encountered evidence of shallow working (broken ground or possible voids) at six locations across the site.

It is recommended that the thickness of competent rock overlying a coal / worked seam required to ensure ground stability at the surface is ten times that of the underlying coal / worked seam. On this basis there are substantial areas of the site that do not have the required 'ten times' seam thickness, and these areas will require stabilisation prior to development.

In addition, four mining adits have been identified from the Coal Authority records to be present close to the crop of the Barnsley Coal. Evidence of an adit was encountered at one location during the trial trenching exercise. The position of each of the adits should be identified and each of them stabilised to mitigate potential risk to the proposed development.

The information given in this summary is necessarily incomplete and is provided for initial briefing purposes only. The summary must not be used as a substitute for the full text of the report.

1 INTRODUCTION

RSK Environment Limited (RSK) was commissioned by Jones Homes (Yorkshire) Limited to carry out a geo-environmental assessment of the land off Bloomhouse Lane, Darton, South Yorkshire. It is understood that the site is being considered for redevelopment with a residential end use as a housing development comprising approximately 300 residential units with associated gardens and infrastructure.

This report is subject to the RSK service constraints given in Appendix A.

1.1 Objective

The objective of the work is to assess the potential geo-environmental liabilities associated with the site.

1.2 Scope

The scope of the investigation and layout of this report has been designed with consideration of CLR11 (Environment Agency, 2004a) and BS 10175: 2011 (BSI, 2011) and guidance on land contamination reports issued by the Environment Agency (EA) (2010a).

The project was carried out to an agreed brief as set out in RSK's proposal (ref.T301645/L01/JH, dated 24 June 2015). The scope of works for the assessment included:

- a preliminary risk assessment (PRA) to include a review of existing reports, geological, hydrogeological and hydrological information, a commercially available environmental database, and historical plans; correspondence with regulatory authorities; and a site walkover – this information is used to develop an initial conceptual site model to consider any potentially complete pollutant linkages
- a coal mining risk assessment including detailed review of coal mining reports, mine entry and abandonment plans
- a review of published geological data to assess ground stability
- an intrusive investigation consisting of fourteen boreholes and twenty four trial pits with laboratory analysis plus subsequent groundwater and gas monitoring
- development of a refined conceptual site model followed by generic quantitative risk assessment (GQRA) to assess complete pollutant linkages that may require the implementation of mitigation measures to facilitate redevelopment
- identification of outline mitigation measures for complete pollutant linkages or recommendations for further work

- interpretation of ground conditions and geotechnical data to provide recommendations with respect to foundations and infrastructure design
- a factual and interpretative report with recommendations for further works (i.e. undertake a remedial options appraisal to identify appropriate mitigation measures/produce a remedial implementation and verification plan) and/or remediation as necessary
- an assessment of the potential waste classification implications of soil arisings.

1.3 Existing reports

RSK are unaware of any existing reports pertaining to the site.

1.4 Limitations

The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by the investigation and therefore could not be taken into account. In particular, it should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater levels and ground gas concentrations and flows may vary from those reported due to seasonal, or other, effects.

During the site works one piece of possible asbestos containing material (ACM) was noted. This was a piece of possible cement tile associated with some localised fly tipping, which was left in-situ. A number of soil samples were tested for the presence of asbestos and whilst no asbestos was noted, the history of the site indicates asbestos may well be present. Asbestos is often present in discrete areas. Thus, although not proven to have been encountered during the site investigation, may be found during more extensive ground works.

2 THE SITE

2.1 Site location and description

The site is located to the south of Bloomhouse Lane, Darton, South Yorkshire. It is approximately 5km north west of Barnsley town centre at National Grid reference SE 316 103, as shown on Figure 1.

The area around the site is a mixture of residential and rural as detailed in Table 1.

Table 1: Site setting

To the north:	Open fields
To the east:	Residential development
To the south:	Residential development, allotments
To the west:	Open fields, a farmhouse, sports field and commercial property

The site covers approximately 11.9 hectares at an elevation of approximately 100m above Ordnance Datum (AOD) in the north east of the site, falling to approximately 70m AOD in the south west and comprises the following main attributes (some of which are shown on Figure 2). Further detailed description of the site is discussed in Section 3.1 below:

- The rectangular shaped site generally occupied by open fields, with areas of dense rough vegetation, is used for public recreation including dog walking as there is unrestricted access points around the perimeter of the site
- Manor House Farm is located in the western part of the site

2.2 Proposed development

The site is being considered for redevelopment with a housing development comprising approximately 300 dwellings. The planned layout of the site is shown on Figure 3, which has been reproduced from a plan produced by Spawfords, entitled 'Indicative Masterplan', ref 3967-0100-0002, dated February 2015.

3 PRELIMINARY RISK ASSESSMENT (PRA)

3.1 Site walkover

The site was visited on 26 January 2016 to undertake a site walkover. Photographs and the site walkover checklist are provided in Appendix C. No potentially significant ground contamination or geotechnical issues were identified during the site reconnaissance survey as the site is unoccupied.

As the site comprises a large area, it is practical to split the site into separate areas for description. The five areas are shown on Figure 2 and are each discussed in detail below.

3.1.1 Area 1: Western Area

Bloomhouse Lane bounds the Western Area to the west and south and Woolley Colliery Road to the north and east, access is from Bloomhouse Lane in the north. The area comprises two fields currently covered by grass segregated by a row of bushes and small trees running north to south as shown in photograph no. 1. There is evidence that the ground is locally waterlogged and may have been compressed by vehicle movement, as shown on photograph no.2.

3.1.2 Area 2: Central Area

The central area of the site is enclosed on all sides by wooden fencing, grass covered and is used for grazing for horses. There are a number of mature trees around the perimeter of the area. It is segregated east to west by a fence that splits the Central Area into a northern and southern area. The field to the central north area appears to be raised to a significantly higher level than the remainder of the site by approximately 2m to 3m, as shown on photograph no.3. There is a small horse stable shelter in the north of this field and is accessed through locked gates off Bloomhouse Lane.

The southernmost field in this area is accessed from Manor House Farm. There is a small area in the southern part of this field where there appears to have been a fire (possibly a bonfire) and some localised tipping of household and general waste including wheels, bathtub, brick, cabinets and metal sheeting, as shown in photograph no.4.

Japanese knotweed is a non-native, highly invasive species and spreads via rhizomes (underground 'stems') rather than seeds in the UK. It is found in a range of habitats across the UK including roadsides, riverbanks and derelict land. Japanese knotweed was unable to be identified during the site visit. However, we were advised that Japanese knotweed is located at discrete locations indicated as the northern most field in Area 2. Japanese knotweed is difficult to identify outside the growing season (March

to September/October). As the site visit was conducted in January, it was not possible to identify the knotweed accurately and, as such, we recommend that the site be resurveyed during the growing season. There are several methods by which Japanese knotweed can be treated/eradicated, all of which are detailed in the EA's (2006b) 'The Knotweed Code of Practice'. A competent knotweed contractor should be employed to manage and perform the works in line with this guidance.

3.1.3 Area 3: Eastern Area

This area is covered by rough, uncultivated vegetation including long grasses, bushes and small trees. The site slopes from the north, which is at an elevation of approximately 100m AOD, towards the south, which is at an elevation of approximately 82m AOD. There are a number of tracks around this area of the site, which is understood to be used for dog walking and general access across the site, as shown in photograph no.5. Access is possible from Bloomhouse Lane in the north and from Appleby Close, Cranborne Close and Howden Close in the east, as shown on photograph no. 6. There is also a path between the allotment gardens between the site and Bridge Street to the south of the site.

There was some potential asbestos containing material (ACM) cement noted on the surface of the site, located to the west of the Eastern Area, close to the boundary with fence of the Central Area, it is shown on Figure 2. The ACM is assumed to be associated with localised fly tipping.

3.1.4 Area 4: Manor House Farm Area

This area can be accessed from Bloomhouse Lane in the south or from Bloomhouse Lane in the north (pedestrian track only). Bloomhouse Lane is shown on mapping as one continuous road, however a fence has been erected next to Manor House Farm to prevent through access. Area 4 comprises a small grassed field in the south, used for animal grazing, as shown in photograph no.8, an area of hardstanding in the north associated with a former development, as shown on photograph no.7 and a woodland area with a pedestrian track running north to south to the north of Manor House Farm.

There are some stockpiles of made ground assumed to be associated with this demolition of the former buildings, as shown in photograph no.9. Bloomhouse Lane which leads from the south up to Manor House Farm is at a lower level than the area of hardstanding, there is a small retaining wall, as shown in photograph no. 10.

3.1.5 Area 5: Former School Area

This area is in the south eastern most area of the site and is accessed from Station Road in the south. This area was formerly Darton primary School and comprises areas of hardstanding, as shown on photograph no.11 and soft overgrown areas, as shown on photograph no. 12. The site is enclosed by a stone wall and has a locked metal double gate.

3.2 Ground conditions

3.2.1 Geology

Published records (British Geological Survey) for the area indicated the geology of the site to be the Pennine Middle Coal Measures, there is an absence of superficial deposits.

Due to the presence of the Coal Measures, the six inch to one mile scale maps were consulted which shows the Barnsley Coal seam to outcrop in the north east of the site, trending north west to south east.

A fault is shown to run north east to south west between the Eastern and Central Areas of the site, close to the line of Bloomhouse Lane, the downthrow is to the north west. There is a second fault shown to trend north to south in the Western Area of the site, the downthrow is to the east.

A number of trial pits logs are available from the British Geological Survey website associated with the development of Appleby Close to the east of the site. The logs extend to around 3m and show firm clay, clayey shale and coal. One trial pit log shows around 3m of fill material including metal, glass, timber and cloth.

Two rotary borehole logs are also available from the BGS, the location is to the south of the site on Station Road. The logs, one to 10m and one to 20m show a descending sequence of sandstone and mudstone from below the made ground at 0.20m and 0.30m. A selection of the BGS logs are provided in Appendix D.

The existing topography and history of development of the site suggests that, in addition to these natural strata, made ground should be expected beneath the site in discrete locations, this is associated with the former building near Manor House Farm and the Former Darton Primary School in the south east, although made ground is not expected to be present site-wide.

3.2.2 Radon

The environmental database report (Envirocheck report, 4 January 2016) indicates that there are two characterisations of radon affected areas for the site.

The report indicates that the 'north' of the site is located within an intermediate probability radon area, as between 1 and 3% of homes are above the action level as defined by the British Geological Survey, National Geoscience Information Service. Therefore, the risk of significant ingress of radon into structures on-site is considered to be low and no radon protective measures are required within new dwellings at the site.

The report also indicates that the 'south west' of the site is located within an intermediate probability radon area, as between 3 and 5% of homes are above the action level as defined by the British Geological Survey, National Geoscience Information Service.

Therefore, the risk of significant ingress of radon into structures on-site is considered to be medium and basic radon protective measures are required within new dwellings at the site.

The environmental database report does not define the boundary between the two classifications; therefore a supplementary basic Radon report from the British Geological Survey (BGS) was acquired however, the search was also unable to define the boundary. Information from the BGS suggests a third more detailed report can be acquired which should help to determine the boundary between the two zones.

The radon report is provided in Appendix E.

3.2.3 Landfilling and land reclamation

Evidence has been sought to identify any landfilling or land reclamation operations, past and present, which have taken place in the vicinity of the site. The sources of information referenced in this element of the desk study include:

- environmental database report
- records held by local authority
- old Ordnance Survey maps and plans (see Section 3)
- geological maps (see Section 4.1)
- a Coal Authority Mining Report (see Appendix F)

There are no records of landfill sites (former or current) within 250m of the site (i.e. within the planning consultation zone). The landfill sites recorded between 250m and 1km of the site are listed in Table 2.

Table 2: Summary of recorded landfill sites within 1km of the site

Distance and direction from site (historical landfill site/registered landfill site)	Name of Landfill site and Operator	Dates of Operation	Accepted Waste	Other Details
499m south/ 566m south	'Shaw Carpets Limited', operated by Shaw Carpets Limited	April 1980 – December 1993	Inert, Industrial and Commercial (Acceptable waste: construction and demolition waste, industrial non-hazardous waste, soil and subsoil. Prohibited waste: Asbestos, Liquids in containers over 4L capacity, slurry in containers over 4L capacity)	Max input rate: Very small (less than 10,000 tonnes a year) Only waste produced on site
573m south/ 724m south	'Between Darton Lane and Dearne Hall Road', operated by C Birkinshaw and Sons Limited	October 1985 – November 1994	Inert and Commercial (Acceptable waste: construction and demolition waste, excavated natural material, hardcore and rubble. Prohibited waste: Asbestos, biodegradable/putrescible waste, combustible/potentially combustible, Liquids in containers over 4L capacity, slurry in containers over 4L capacity)	Max input rate: Large (equal to or greater than 75,000 and less than 250,000 tonnes per year) No known restriction on source of waste
951m south east/ 999m south east	'Quarry', operated by National Coal Board	January 1978 – January 1985	Inert and Commercial (Acceptable waste: construction and demolition wastes, Prohibited waste: Liquids in containers over 4L capacity, slurry in containers over 4L capacity)	Max input rate: Very small (less than 10,000 tonnes a year) No known restriction on source of waste

The landfill gas generation potential from these types of landfill site is generally low, however consideration should be given to the potential presence of other waste deposited such as timber, plasterboard or possible domestic refuse. Given the distance of the landfill sites from the site, these landfill sites are not considered as representing a significant potential risk to the site from the generation and migration beneath the site of

landfill gases and/or leachate. An overall low/moderate risk is considered to be present from landfill gas to the site.

However, with reference to the historical data there have clearly been some phases of construction and demolition on the site and therefore the presence of made ground should be expected in Area 4 and Area 5 of the site.

3.2.4 Ground gas

Given the anticipated ground conditions the risk associated with ground gas is considered low/moderate in accordance with BS8576.

3.3 Hydrogeology

3.3.1 Aquifer characteristics

Based on the published geological map referred to above, the hydrogeology of the site is likely to be characterised by the presence of an unconfined shallow aquifer comprising the Pennine Middle Coal Measures.

The anticipated depth to the groundwater table is in the order of 10m to 20m below ground level. Shallow groundwater in the site area is anticipated to flow in a south westerly direction, i.e. towards and in the direction of flow of the River Dearne.

3.3.2 Vulnerability of groundwater resources

The site has been classified by the EA website to overlie a secondary A aquifer, which is described as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

The soils beneath the site are classified as having high urban leaching potential. Soil information for restored mineral workings and urban areas is based on fewer observations than elsewhere, so a worst-case vulnerability classification is assumed until proven otherwise.

3.3.3 Licensed groundwater abstraction

The environmental database (Envirocheck report, 4 January 2016) report indicates that there are three current licensed groundwater abstractions (two of which are public/private water supply boreholes) within a 2km radius of the site summarised in Table 3. The nearest is located approximately 413m to the south of the site and is operated by Shaw Carpets Limited for commercial use purposes.

Table 3: Groundwater abstractions

Reference	Distance and orientation from site	Comment
2/27/08/114	413m south	Operated by Shaw Carpets Limited for commercial use (pubs etc), from groundwater source, license status: active, no dates provided.
Ne/027/0008/006	710 north west	Operated by the Coal Authority, location – underground strata at Former Wooley Colliery, abstraction is environmental: pump and treat – pollution remediation, permit start date – July 2009, no end date supplied
2/27/08/048	1816m west	Operated by A I Crossley and Son, location: Spring – coal measures – Darton, abstraction for general farming and domestic from groundwater, daily rate of 5m ³ , yearly rate of 1659m ³ , permit start date – January 1966, no end date supplied.

In terms of aquifer protection, the EA generally adopts a three-fold classification of source protection zones (SPZ) for public supply abstraction wells.

- zone 1 or 'inner protection zone' is located immediately adjacent to the groundwater source and is based on a 50-day travel time from any point below the water table to the source. It is designed to protect against the effects of human activity and biological/chemical contaminants that may have an immediate effect on the source
- zone 2 or 'outer protection zone' is defined by a 400-day travel time from a point below the water table to the source. The travel time is designed to provide delay and attenuation of slowly degrading pollutants.
- zone 3 or 'total catchment' is the area around the source within which all groundwater recharge is presumed to be discharged at the source.

Information available on the EA website indicates that the site does not lie within a currently designated groundwater Source Protection Zone.

3.4 Hydrology

3.4.1 Surface watercourses

There are no ponds, streams or drainage ditches on or adjacent to the site. The nearest identified surface watercourse to the site is the River Dearne located approximately 177m to the west of the site.

The EA classification of the water quality in the stretch of the River Dearne nearest to the site is grade C (fairly good). The base flow of the River Dearne is likely to be recharged by groundwater in the shallow aquifer in the site area. A linkage between the river and any ground or groundwater contamination beneath the site may therefore exist.

3.4.2 Surface water abstractions

The environmental database report (Envirocheck report, 4 January 2016) indicates that there is one recorded surface water abstractions within a 2km radius of the site. The abstraction is located approximately 646m to the north west of the site (i.e. upstream of the site) and is operated by British Coal for general industrial purposes, no dates are supplied, however it states that the license is revoked.

3.4.3 Site drainage

Surface drainage from the site appears to drain naturally into the surface soils. Some overland flow during peak times of rainfall may flow south towards the drainage system on Station Road and other local roads, however, this is considered to be insignificant.

3.4.4 Preliminary flood risk assessment

The indicative floodplain map for the area, published by the EA, shows that the site does not lay within a designated floodplain.

3.5 History of site and surrounding area

The history of the land-use and development of the site and surrounding area has been assessed based on the historical maps within the environmental database from 1854 to 2015.

Copies of OS and County Series maps are included in the environmental database report in Appendix D. Reference to historical maps provides invaluable information regarding the land use history of the site, but historical evidence may be incomplete for the period pre-dating the first edition and between successive maps.

The development history of the site and surrounding area from the above sources is detailed in Table 4 and summarised below.

Table 4: Summary of historical development

Date	Land use/features on site	Land use/features in vicinity of site (of relevance to the assessment)
1854 to 1855	Site comprises segregated agricultural fields, Manor House is shown in the south western area of the site and there is a large 'L'	Sandstone Quarry adjacent to site in SW 100m SW, Darton Station and

Date	Land use/features on site	Land use/features in vicinity of site (of relevance to the assessment)
	shaped building opposite Manor House	associated railway line (Barnsley Branch)
1883 to 1894	No significant changes	Sandstone Quarry is no longer shown 200m N, three reservoirs are shown
1907	'Cistern' identified to the north of the building in the SW of the site	50m E, 'Excelsior Works (Chaplet Gas and Water Hooks)' identified
1930	'Tramway' shown entering the eastern boundary of the site and runs north westerly into the site for approx 100m Area of raised ground shown in the northern central most field (Area 2) School shown to be present in the south eastern tip of the site adjacent to Station Road 'cistern' now identified as a tank	10m N, Tramway running north from the site 50m E, 'Excelsior Works' now shown as disused 300m S, rug mill 300m NW, Sewage works 350m W, Quarry 500m NW, Woolley Colliery 500m W, Darton Main Colliery 500m NE, 'Longsight Works (Chaplet and gas hook)
1948	No significant changes	No significant changes
1956	Tramway in east has been removed	Tramway to north has been removed Excelsior Works, no longer shown
1966	No significant changes	NW, 'works' shown 500m W, Darton Main Colliery, no longer shown
1980	The 'L' shaped building opposite Manor House has been removed	Some residential development to east of the site 200m S, Factory shown 500m W, Factory shown
1991 - 1993	No significant changes	Building, previously identified as works adjacent to NW of site is now identified as a laboratory
2006	Number of outbuildings shown in the area of the school	Further residential development to the east of the site
2015	School has been removed	No significant changes

The majority of the site has never undergone any development, however there have been some development phases shown throughout the available historical records in certain areas of the site. A large 'L' shaped building was present associated with Manor House from the earliest available map until around the 1980s where it was removed. There was a cistern and then a tank associated with this building. The school in the far

south east was present on site between the 1930s and 2015, a number of outbuildings appeared in the early 2000s, all of which have now been removed.

The site appears to have had some industrial uses, as a tramway was present across the eastern area of the site. Possibly associated with the tramway, the northern most central field appears to have been raised, possibly with material associated with the coal mining or quarrying in the area.

The area surrounding the site has had some industrial activities, including the railway line, quarries, Collieries and factories; however they are generally over 100m from the site. An unspecified works was located adjacent to the north west of the site, it was identified as a laboratory in 1993.

3.6 Sensitive land uses

No national or internationally designated sensitive land uses such as sites of special scientific interest (SSSI) were identified in the vicinity of the site. The western part of the site is a designated Area of Adopted Greenbelt (Area 1 and Area 4), a comprehensive evaluation of ecological receptors is outside the scope of this report.

3.7 Industrial land use

There are three recorded Contemporary Trade Directory Entries listed within 250m of the site, all of which are inactive. The nearest was 1m south east of the site at Carpet Express Limited, classified as a distribution services. 27m south was a clothing and fabric manufacturers and 93m south west was a printers – glass, metal, plastics etc. The nearest active Contemporary Trade Directory is a toys, games and sporting goods manufacturers located 275m south west of the site.

3.8 Initial conceptual model

The information presented in Sections 2 and 3.1 to 3.7, has been used to compile an initial conceptual model. The identified potential sources of contamination, associated contaminants and receptors have been considered with plausible pathways that may link them. The resulting potential pollutant linkages are considered in Section 3.8.4. The risk classification has been estimated in accordance with information in Appendix G.

3.8.1 Summary of potential contaminant sources

Potential sources and contaminants of concern are summarised in Table 5.

Table 5: Potential sources and types of contamination

Potential sources	Contaminants of concern
On-site historical	
Made ground (i.e. fill material) associated with raised area in north of site and demolition of the building associated with Manor House and Darton Primary School	Unknown fill material (but potentially including heavy metals, ash, clinker, sulphates, polycyclic aromatic hydrocarbons (PAHs), asbestos etc.). Possible soil gases including methane and carbon dioxide
Tramway (1930 – 1956)	Fuel oils, lubricating oils, heavy metals, PAHs and PCBs
On-site present day	
Made ground (i.e. fill material)	Unknown fill material (but potentially including heavy metals, ash, clinker, sulphates, polycyclic aromatic hydrocarbons (PAHs), asbestos etc.)
Flooded mine workings	Hazardous ground gases
Off-site	
Various industrial land uses including: excelsior factory 50m south east (1930s to 1950s), works/laboratory to north west of site (1960s to present)	Fuel oils, lubricating oils, heavy metals, polychlorinated biphenyls (PCBs), PAHs, solvents and other common industrial contaminants
Infilled former quarry adjacent to south west of site (c.1850s to 1880s)	Landfill/ground gases, leachate
Railway, 100m south west of site (mid 1800s to present)	Fuel oils, lubricating oils, heavy metals, PAHs, PCBs, ethylene glycol, ash, sulphate, herbicides and asbestos

The site, although generally undeveloped has had several phases of construction and demolition of buildings and industrial uses (the tramline). An area in the north of the site appears to have been infilled, but the source is unknown, possibly associated with colliery spoils due to the presence of the tramlines.

Adjacent to the site are few potential sources of contamination, the railway line is down gradient of the site and is at a distance of 100m at the nearest point. The factory which was present 50m south west of the site has been removed since the 1950s and therefore any residual contamination is expected to be minimal. The former quarry located to the south west of the site was infilled in around the 1880s, which if containing putrescible material, would have ceased gas generation and therefore is not considered significant.

3.8.2 Sensitive receptors

Sensitive receptors at this site include:

- future site occupants
- adjacent site users

- vegetation
- potable water supply pipes
- buildings and infrastructure
- underlying Secondary A aquifer
- River Dearne (177m west of the site)

Please note that construction workers have not been identified in the conceptual model as receptors because risks are considered to be managed through health and safety procedures including CDM regulations.

3.8.3 Summary of plausible pathways

The plausible pathways are summarised below:

- direct contact (soil, dust and vegetable ingestion, dermal contact, dust and fibre inhalation)
- ground gas and soil gas inhalation
- root uptake
- chemical attack of infrastructure (including water supply pipes) and buildings
- vertical or lateral migration of groundwater

3.8.4 Data gaps and uncertainties

The works located to the north west of the site since 1960s identified on the historical maps is unspecified. The shape of the building has not changed and is now identified as a laboratory, therefore although the risks are unknown, it is likely to have been similar types of use.

The material used to raise the northern central field of Area 2 of the site is unknown. The presence of a tramway suggests it may be been used to transfer overburden associated with localised mining activities, however this is unconfirmed.

3.8.5 Potentially complete pollutant linkages

The outline conceptual model is shown schematically in Figure 4 and an estimate of the risk associated with each linkage is summarised in Table 6. The risk classification has been undertaken in accordance with CIRIA C552 (Rudland et al., 2001), a summary of which is included in Appendix G.

Table 6: Risk estimation for potentially complete pollutant linkages

Potential Contaminant	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
Made ground, potentially including asbestos, heavy metals, TPH and PAHs	Future site users (residents)	Direct contact including ingestion, dermal contact and inhalation	Likely	Medium	Moderate risk: The majority of the site is expected to be natural soils suitable for the proposed end use. However, in the areas of previous development and the infilled material some contaminated soils may be present. The redevelopment of the site will comprise the housing footprint and areas of hardstanding, however garden areas are proposed and future site users may come into contact with underlying potentially contaminated soils. This can however be mitigated by a clean capping layer in the areas of proposed landscaping and gardens in the areas of contaminated soils if found to be present.
	Adjacent site users (residents)	Inhalation of dust during redevelopment phase	Low likelihood	Mild	Low risk: If contaminated soils on site are allowed to dry out there may be excessive dust generated which may be blown onto adjacent properties, however the impact would be mild.
	Vegetation	Root uptake	Highly likely	Minor	Moderate/Low risk: Vegetation within the garden areas will absorb any contaminants present within the soils, however the presence of a clean capping layer will mitigate this pathway. This remains a potential pathway until the contamination status of the soils is determined
	Potable water supply pipes and buildings	Chemical attack of infrastructure	Likely	Medium	Moderate risk: The geology is potentially pyritic and it is likely that soils will come into contact with buildings and infrastructure, however the level of chemicals is not expected to be at levels that may cause significant problems. An assessment on the chemical concentrations of the soils will confirm the requirements for the type of concrete suitable for use on the site.

Potential Contaminant	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
	Groundwater beneath the site and surface water features	Vertical migration of contaminants through soils	Low likelihood	Mild	Low risk: The site lies upon a Secondary A aquifer, and is not within a source protection zone, groundwater is expected to be within 10 to 20m below ground level, therefore vertical migration would be minimal. There have been no pollutant incidents at the site and there are no known up-steam sources of contamination which may impact groundwater. There are no groundwater abstractions within 250m of the site and the nearest surface water feature is the River Dearne located 177m west of the site which is considered to be at a significant enough distance to have minimal impact from the site.
Hazardous ground gases from flooded mine workings and infilled quarry	Future site users (residents)	Inhalation from build up of hazardous gases within buildings	Likely	Severe	High/moderate risk: flooded mine workings are potentially present beneath the site. Gas generation can continue for up to 50 years. The absence of superficial deposits would increase the potential of migration of hazardous ground gases to occur.
	Buildings	Build up and explosions of hazardous ground gases	Low likelihood	Severe	Moderate risk: flooded mine workings are potentially present beneath the site. Gas generation can continue for up to 50 years. The absence of superficial deposits would increase the potential of migration of hazardous ground gases to occur.

The potential pollutant linkages with a risk of moderate or above that may drive site investigation works are:

- 1) Direct contact of contaminated soils to future site users
- 2) Inhalation exposure of future site users to asbestos fibres
- 3) Plant uptake of contaminants within the soils, which may affect plant growth
- 4) Chemical attack on infrastructure including concrete and potable water supply pipes from contaminated soils
- 5) Inhalation and explosion of hazardous ground gases from build up within buildings

Given the history of the site, the risk that significant contamination is likely to influence the groundwater or surface water receptors beneath or within the vicinity of the site is low. Therefore, the impact to groundwater has not been considered further in this investigation. However, if significant levels of soil contamination, although unexpected, are found to be present at the site, it would be recommended that consideration of the risks to groundwater receptors would be required.

3.9 Geotechnical Considerations

The environmental database report (Envirocheck, dated 4 January 2016) states the following risks of ground stability hazards may affect the site, as defined by the British Geological Survey, National Geoscience Information Service.

- Very low potential for collapsible ground stability hazards in the south west, west and north east of the site
- Low potential for landslide ground stability hazards in the north of the site
- Very low potential for landslide ground stability hazards in the south west of the site
- Very low potential for running sand ground stability hazards in the west and north east of the site
- Very low potential for shrinking or swelling clay ground stability hazards in the south west of the site

3.10 Coal mining risk assessment

A desk based Coal Mining Risk Assessment (CMRA) report has been completed using a risk based approach to assess the potential risk posed to the proposed development and identifies how coal mining issues may influence the proposed redevelopment. A CMRA is required by the local planning authority (LPA) as part of the planning process

and conforms to the guidance published by the Coal Authority (CA) “Risk Based Approach to Development Management – Guidance for Developers” Version 2 dated 2014. The requirement for a CMRA to be undertaken has been initiated by the site being located in an area classified by the CA as a high risk area i.e. where there are hazards that are likely to affect a new development.

All supporting information for the Mining Risk Assessment is provided in Appendix F.

3.10.1 Desk Study Data Review

The following sources of data have been consulted:

- i. Ordnance Survey Historical plans between 1893 and 2015;
- ii. Geological Survey of England and Wales 1:63,360/1:50,000 geological map series Sheet 87 Bedrock and Superficial 2008;
- iii. Geological Survey of England and Wales Six Inch to One mile geological map;
- iv. Mineral Resources Information in support of National, Regional and Local planning report CR/04/173N South Yorkshire (comprising Metropolitan Boroughs of Barnsley, Doncaster and Rotherham and City of Sheffield) dated 2006
- v. BGS online map and data viewer;
- vi. The Coal Authority interactive map viewer;
- vii. Non-residential Coal Authority Mining Report Ref. 51001059098001 dated 4 January 2016;
- viii. The Coal Authority Shaft Plan and Data Sheets Ref. 51001072291001 dated 19 January 2016;
- ix. Coal Authority archive abandonment records search.

Each source of data is evaluated in turn below:

i. Historical plans between 1893 and 1996

The 1854 1:10,560 OS map shows an ‘old quarry’ immediately to the west of the site.

The 1894 1:10,560 map shows the establishment of ‘Wooley Colliery’ approximately 500m to the north west of the site.

The 1893 and 1906 1:2,500 OS plans show an ‘Old Coal Pit’, ‘Old Air shaft’ and an ‘old dayhole’ (adit) approximately 120m to the north of the site, and a second ‘Old Coal Pit’, and an ‘old dayhole’ (adit) approximately 300m to the north of the site close to ‘Pye Wood’. A shaft and dayhole are shown on the 1:2,500 OS 1906 map approximately 100m to the east of the site, beyond Sackup Lane. These are also shown on the 1907 1:10,560 OS map, with the expansion of Woolley Colliery to the northwest, together with another ‘old coal pit’ 700m to the east, just to the south of Staincross Common.

The 1918 1:2,500 map shows the establishment of a school in the south east corner of the site.

The 1930 1:10,560 OS map shows a tramway to cross the eastern boundary of the site eastwards, the establishment of the 'Miners Welfare Institute' immediately to the northwest of the site, further expansion of Woolley Colliery to the northwest, and the establishment of 'Darton Main Colliery' approximately 400m to the west.

The 1938 1:10,560 OS map shows the slopes of an excavation in the northern central area of the site, and the extension of tramways to the north east of the site.

The 1956 1:10,560 OS map no longer shows the tramway in the east of the site, and shows the 'Darton Main Colliery' to be disused.

ii. Geological Survey of England and Wales 1:63,360/1:50,000 geological map series Sheet 87 Bedrock and Superficial 2011

The BGS 1:50,000 geological map series Sheet 87 Bedrock and Superficial dated 2011 shows the site to be underlain by the Pennine Middle Coal Measures Formation. This comprises mudstone, siltstone and sandstone with coal seams, ironstone and seatearth beds and marine bands. The sequence underlying the site ranges from the Top Haigh Moor Coal (THM) (0 to 4.3m thick) to the Barnsley Coal (B) (0 to 3.9m thick). This sequence of continuous and discontinuous coal seams is shown on Figure F1 in Appendix F.

The site is crossed by an unnamed northeast-southwest trending fault, with the east-west trending Mapplewell Fault immediately to the south of the site.

iii. Geological Survey of England and Wales Six Inch to One mile geological map

The Geological Survey of England and Wales Six Inch to One mile geological map shows the area of the site in greater detail with the Barnsley Rider Coal outcropping across the north eastern part of the site and the Barnsley Coal across the central area of the site, with an unnamed coal (possibly Shallow Wood Coal from the 1:50,000 sequence) cropping across the southern part of the site, with the Top Haigh Moor Coal cropping to the south of the site.

As with the 1:50,000 BGS map, the site is shown to be crossed by an unnamed northeast-southwest trending fault, with the east-west trending Mapplewell Fault immediately to the south of the site.

An extract of the geology map is provided in Appendix F as Figure F2.

iv. Mineral Resources Information in support of National, Regional and Local planning report CR/04/173N South Yorkshire (comprising Metropolitan Boroughs of Barnsley, Doncaster and Rotherham and City of Sheffield) dated 2006.

Mineral Resources Information in support of National, Regional and Local planning report CR/04/173N South Yorkshire (comprising Metropolitan Boroughs of Barnsley,

Doncaster and Rotherham and City of Sheffield) dated 2006 shows the site to be in an area underlain by shallow coal. It does not show the site to be located in an area of former open cast.

An extract of the Mineral Resources map is provided in Appendix F as Figure F3.

v. BGS online map and data viewer

The BGS online map and data viewer does not document any available borehole logs pertaining to the site itself. There are thirteen borehole logs associated with residential development immediately to the east of the site along Appleby Close, Cranbourne Drive and Howden Close. The closest of these boreholes SE31SW275, SE31SW280 and SE31SW285 show coal to be present at a depth of 1.1m to 3.0m in SE31SW275, but coal not to be present in either SE31SW280 nor SE31SW285.

Extracts from these records SE31SW275, SE31SW280 and SE31SW285 are provided in Appendix F as Figures 4,5 and 6.

vi. The Coal Authority interactive map viewer

The Coal Authority interactive map viewer shows the following:

- a. There are five recorded mine entries on or in close vicinity of the site (within 20m);
- b. The site is in an area recorded in the abandoned mines catalogue (Catalogue Nos. 16548, 7368, NE978, 5770, NE996, NE816, NE695, NE1034)
- c. The north east and southern areas of the site are shown to be in a development high risk area;
- d. The site is shown to be in a surface coal resource area;
- e. The site has five recorded locations as being located in the potential zone of influence of a mine entrance;
- f. There are no fissures or break lines recorded at or in the vicinity of the site;
- g. The site is not recorded as a mine gas site;
- h. The site is not in an area recorded as subject to past surface hazard;
- i. The site is not in an area of recorded surface mining (past and current);
- j. The north east corner of the site is in an area of recorded past shallow coal mine workings;
- k. The north east and southern areas of the site are in an area of probable shallow coal mine workings;
- l. The north east and southern areas of the site are in an area of potential coal outcrop;
- m. The site is in a Coal Mining Reporting Area.

vii. Non-residential Coal Authority Mining Report Ref. Ref. 51001059098001 dated 4 January 2016

The non-residential Coal Authority Mining Report Ref. Ref. 51001059098001 dated 4 January 2016 is presented in Appendix E. It states the following key comments:

- a. The property is in the likely zone of influence of from workings in seven seams of coal at shallow to 290m depth, last worked in 1979, but is not in the likely zone of influence of any present underground working;
- b. The property is not in an area for which the CA is determining whether to grant a license to remove coal or in an area for which a license has been granted to remove or work coal using underground methods;
- c. The property is not in an area that is likely to be affected at the surface from any planned future workings;
- d. Reserves of coal exist in the local area which could be worked at some time in the future; no notice of the risk of the land being affected by subsidence has been given under section 46 of the Coal Mining Subsidence Act 1991;
- e. There are five known coal mine entries within, or within 20m of the boundary of the property. Record 431410-015 has no treatment details; Record 431410-035 has no treatment details; Record 431410-046 has no treatment details; Record 431410-036 was not encountered during drilling and routing operation carried out beneath plot 15 Sackup Lane by Marsh Homes, and the CA have no record of what steps were taken to treat this mine entry; Record 431410-047 has no treatment details;
- f. The CA is not aware of any evidence of damage arising due to geological faults or other lines of weaknesses;
- g. The property is not within the boundary of a past opencast mine, nor does it lie within 200m of the boundary of a present opencast mine, nor is it within 800m of the boundary of an opencast site for which the CA is determining whether to grant a license to remove coal by opencast methods.
- h. The CA has not received a damage notice or claim for the subject property or any property within 50m since 31 October 1994;
- i. There is no record of mine gas emission requiring action by the CA within the boundary of the property;
- j. The property has not been subject to remedial works, by or on behalf of the CA, under its Emergency Surface Hazard Call Out Procedures;
- k. The property is not in an area for which notice of entitlement to withdraw support has been published, or where notice has been given under section 41 of the Coal Industry Act 1994, revoking the entitlement to withdraw support.

viii. The Coal Authority Shaft Plan and Data Sheets Ref. 51001072291001 dated 19 January 2016.

A Shaft Plan and Data Sheet report was gained from the CA to gain further detail on the five mine entries identified in the Non-residential Coal Authority Mining Report. A summary of the additional information gained is provided in Table 7 below and a copy of the data sheets is provide in Appendix F.

Table 7: Summary of information from Coal Authority Shaft Plan and Data Sheets

Mine entry (adit) Ref.	Colliery	Adit Azimuth	Name	Name / Treatment details	Easting & northing
431410-015	Unknown	312	Unknown	no treatment details	431686 410329
431410-035	Unknown	17	Bloomhouse Colliery Adit	no treatment details	431705 410325
431410-046	Unknown	34	Bloomhouse Colliery Adit	no treatment details	431626 410369
431410-036	Unknown	8	Bloomhouse Colliery Adit	not encountered during drilling and routing operation carried out beneath plot 15 Sackup Lane by Marsh Homes, and the CA have no record of what steps were taken to treat this mine entry	431774 410306
431410-047	Unknown	38	Bloomhouse Colliery Adit	no treatment details	431621 410374

ix. A Coal Authority archive abandonment records search

A search of the CA abandonment catalogue archive was undertaken on 19 January 2016. The search radius was for 200m and 300m from the centre of the site. It searched for all colliery, seam and working type records within the specified 200m and 300m radius. A copy of the search is included as Appendix F.

A total number of 31 search results were returned for the 300m radius. These were examined in detail and two items were deemed to have direct relevance to the site - catalogue numbers 12647 and NE979. The collieries, seams and abandonment dates are recorded as in Table 8.

Table 8: Summary of the Coal Authority archive abandonment records search

Catalogue No.	Colliery	Seam	Date abandoned
12647	Bloomhouse	Barnsley	18/01/1940
NE979	Wooley (former North Gawber)	Low Haigh Moor (Netherton Thick)	5/09/1986

Catalogue number 12647: shows workings in the Barnsley Seam underlying the site that were finally abandoned in 1940. Within the boundary of the site it shows three adits that correspond to three of the adits recorded in the CA Non-residential Coal Authority Mining Report Ref. Ref. 51001059098001. The dip of the Coal Measures strata is shown to be toward the north east.

A copy of this relevant part of this plan is provided in Appendix F as Figure F7.

Catalogue number NE979: shows the boundary of the Low Haigh Moor (Netherton Thick) seam, worked from the Wooley (former North Gawber) Colliery and dated to 1986 underlying the north east corner of the site. It also shows the workings of the Pyewood Colliery to the west underlying the north-western part of the site.

A copy of this relevant part of this plan is provided in Appendix F as Figure F8.

4 SITE INVESTIGATION METHODOLOGY

RSK carried out intrusive investigation work between 26 and 28 January 2016, with subsequent ground gas and groundwater monitoring visits on 22 February and 16 March 2013. Gas and groundwater monitoring is ongoing. The objectives of the work were to further investigate the potential pollutant linkages identified in the outline conceptual model and to inform geotechnical and mining constraints.

4.1 Sampling strategy and methodology

The techniques adopted for the investigation have been chosen considering the anticipated ground conditions, existing land use and the proposed development. The sampling strategy was focused both on the characterisation of the shallow soils and into the deeper underlying bedrock. The shallow investigation aimed to confirm or otherwise the presence of contamination, and to obtain parameters to facilitate geotechnical design. The deeper investigation was aimed at investigating the potential risk to the site from historical coal mining and also the presence of ground gas.

The layout of the investigation was designed to provide both targeted and non-targeted coverage across the site, and an exploratory hole location plan is presented as Figure 5. The investigation points were located through use of a hand held GPS.

Trial pits were excavated in order to provide both coverage across the site relatively quickly to accurately log the soils beneath the site, obtain representative samples for chemical and geotechnical laboratory testing. A number of the trial pits were used to target potential areas of contamination noted within the PRA. The trial pitting investigation was also used to investigate the presence and location of four mine adits which were highlighted within the Coal Authority Report.

A probing exercise involving the drilling of rotary boreholes was undertaken to investigate the presence or absence of shallow coal seams and/or workings located beneath the site, as previously discussed in section 3.10. They also allowed the installation of gas and groundwater monitoring wells.

4.1.1 Health and safety considerations

Prior to the excavation of the exploratory holes, the site was scanned and cleared of underground services using a Cable Avoidance Tool (CAT) and signal generator and by Ground Penetrative Radar (GPR).

4.1.2 Investigation locations

The following site work was completed as part of this investigation:

- Excavation of 32 trial pits using a 16 tonne tracked excavator
- Excavation of 14 trial trenches using a 16 tonne tracked excavator
- Drilling of 6 rotary boreholes with gas and groundwater monitoring wells using a large tracked rotary rig
- Drilling of 8 rotary probeholes using a large tracked rotary rig

The investigation and the soil descriptions were carried out in general accordance with 'BS 5930:2015. Code of Practice for Site Investigations' (BSI, 1999). The exploratory hole records are presented in Appendix H.

The locations of the intrusive investigations are shown in Figure 5. The rationale for these locations is given in Table 9. A number of the exploratory hole locations were targeted to identify impact from identified sources of contamination.

Table 9: Exploratory hole location rationale

Exploratory hole number	Location	Rationale
TP01 and TP02	North west of Area 1 (western area)	To assess potential of migration of contaminants from off-site sources.
TP03, TP04, TP05	Spread across Area 1	To provide information on the general spread of ground conditions in Area 1
TP06, TP07, TP08	Within area of former building in Area 4	To target potential contamination associated with the former building
TP09, TP10, TP11, TP12	Spread across Area 2	To provide information on the general spread of ground conditions in Area 2
TP13, TP14, TP15, TP16	Within northern 'raised' part of Area 2	To provide information on the composition and depth of filled materials within this raised area
TP17, TP18, TP19, TP22, TP23, TP24	Spread across Area 3	To provide information on the general spread of ground conditions in Area 2
TP20 and TP21	Within area of former school in Area 5	To target potential contamination associated with the former building

The investigation points were located by a hand held GPS. The ground levels at the borehole locations were interpolated from the levels shown on the site plan provided and the survey plan provided by the Client.

4.1.3 Soil sampling, in-situ testing and laboratory analysis

Soil sampling was designed to select samples at regular intervals throughout each of the encountered strata. This included in the made ground and the underlying natural ground.

Soils taken for laboratory analysis were collected in containers appropriate to the anticipated testing suite required. Samples were stored in accordance with RSK quality

procedures to maintain sample integrity and preservation, and to minimise the chance of cross-contamination.

Forty nine samples were taken and are recorded together with their depths on the exploratory hole records in Appendix H. The samples were transported to the laboratory in chilled cool boxes. Laboratory chain of custody forms can be provided if required. The rationale for soil sample chemical analysis is presented in Table 10. The results of the laboratory analysis are provided in Appendix K.

Table 10: Scheduled analysis – soil

Exploratory hole no. and sample depth (m bgl)	Analyte	Rationale
TP02 at 0.00-0.35m, TP07 at 0.30-0.50m, TP13 at 0.00-0.25m, TP13 at 0.30-0.50m, TP14 at 1.50-1.80m, TP16 at 1.10-1.40m, TP17 at 0.00-0.30m, TP20 at 0.00-0.40m, TP21 at 0.00-0.50m, TP23 at 0.00-0.30m	Metals, pH, PAH, TPHCWG	Assessment of shallow made ground for potential contaminated soils
TP05 at 0.60-1.00, TP07 at 0.80-1.00m, TP09 at 0.20-0.50m, TP18 at 0.00-0.30m,	Metals, pH, PAH	Assessment of shallow natural soils/possible made ground for potential contaminated soils
TP12 at 0.00-0.60m	Metals, pH, PAH	Assessment of shallow made ground for potential contaminated soils
TP07 at 0.30-0.50m, TP13 at 0.00-0.25m, TP14 at 1.50-1.80m, TP16 at 1.10-1.40m, TP17 at 0.00-0.30m, TP20 at 0.00-0.40m, TP21 at 0.00-0.50m, TP23 at 0.00-0.30m	Asbestos screen	Screen of made ground soils for the presence of asbestos
TP01 at 2.50m, TP03 at 0.80m, TP03 at 1.60m, TP07 at 0.30-0.50m, TP12 at 1.60m, TP14 at 2.50m, TP16 at 1.80-2.00m, TP22 at 0.70m, TP22 at 1.40m	BRE Sulphate suite	Assessment of chemical composition of soils for the risk to concrete assessment

4.1.4 Groundwater monitoring and levelling

Depths to groundwater were recorded using an electronic dip meter during the monitoring visits on 22 February 2016 and 16 March 2016. The monitoring results are given in Section 5.1.

The ground levels and the highest point of the top of casing of the monitoring wells were established in relation relative to a Ordnance Datum extrapolated from the survey plan to enable groundwater flow direction and a hydraulic gradient to be inferred.

4.1.5 Ground gas monitoring

In line with the conceptual model six monitoring rounds will be undertaken, currently two visits have been completed to date. This will include periods of low and/or falling atmospheric pressures and after/during rainfall.

An infrared gas meter was used to measure gas flow, concentrations of carbon dioxide (CO₂), methane (CH₄) and oxygen (O₂) in percentage by volume, while hydrogen sulphide (H₂S) and carbon monoxide (CO) were recorded in parts per million. Initial and steady state concentrations were recorded.

The atmospheric pressure before and during monitoring, together with the weather conditions, was recorded.

All monitoring results together with the temporal conditions are contained within Appendix J and discussed in Section 5.2.

5 GROUND CONDITIONS

The results of the intrusive investigation and subsequent laboratory analysis undertaken are detailed below. The descriptions of the strata encountered, notes regarding visual or olfactory evidence of contamination, list of samples taken, field observations of soil and groundwater, in-situ testing and details of monitoring well installations are included on the exploratory hole records presented in Appendix H.

5.1 Soil

The exploratory holes revealed that the site is underlain by a variable thickness of topsoil, possible made ground or made ground over the Pennine Middle Coal Measures, which grades from weathering Class E at the upper boundary to Weathering Class B encountered at depth (within the trial pits). This appears to confirm the stratigraphical succession described within the initial conceptual model. For the purpose of discussion, the ground conditions are summarised in Table 11 and the strata discussed in subsequent subsections.

Table 11: General succession of strata encountered

Strata	Exploratory holes encountered	Depth to top of stratum m bgl	Thickness (m)
Topsoil	TP10, TP11, TP18, PH1 – PH7 BH1 – BH4	Ground level	0.30m
Possible made ground	TP01, TP09 BH5	Ground level	0.30m – 0.50m 3.00m in BH5
Made ground	TP02, TP04 - TP08, TP12, TP13, TP14, TP15, TP16, TP17, TP19 - TP24 PH8, BH6	Ground level	0.15m – 0.60m (average) More than 4.60m in TP13, to 3.20m in TP14, to 1.80m in TP15, to 1.70m in TP16, to 3.00m in TP21
Pennine Middle Coal Measures (Weathering Class E/D)	TP01 - TP07, TP09 - TP12, TP15 – TP20, TP22 - TP24 PH1 – PH8 BH1 – BH4, BH6	Ground level – 0.60m (average) 1.80m in TP15 and 1.70m in TP16	0.40m – 2.70m
Pennine Middle Coal Measures (Weathering Class B)	TP01 - TP06, TP08, TP09, TP11, TP12, TP14, TP15, TP17 -	0.55m – 3.20m	0.20m – 2.45m

Class C/B)	TP24 PH1 – PH8 BH1 – BH6		
Pennine Middle Coal Measures (Coal)	TP01, TP02, TP04 PH4, PH8 BH1, BH2, BH3, BH3A, BH4, BH5, BH6	0.65m - 2.40m 12.00m in PH4, 10.30m, 20.80m and 26.50m in PH8 5.80m in BH1, 11.00m and 11.80m in BH2, 5.00m in BH3, 5.00m in BH3A, 0.710m in BH4, 6.70m and 9.00m in BH5, 4.70m in BH6	0.15m - 0.30m 3.80m in PH4, 0.20m – 0.30m in PH8 0.20m in BH1, 0.50-0.60m in BH2, 0.20m in BH3, 0.20m in BH3A, 0.40m in BH4, 0.10-0.50m in BH5, 0.30m in BH6

5.1.1 Made ground and Topsoil

The composition of the made ground varied across the site depending on the area. In Area 1, the Western Area, made ground generally comprised reworked natural cohesive clay, with occasional pieces of pottery and wood.

In Area 2, the Central Area, there were two areas of made ground noted. The northern field that historically had been raised according to the historical plans, indicated depths of over 4.60m of made ground in the centre of this area, tapering out at the edges to thicknesses of around 1.70m. The made ground encountered in this area comprised sandy gravelly clay with many pieces of glass, pottery, tiles, plastic, brick, metal and tarmac, often noted to have an organic odour. TP12 is located in the southern part of Area 2 and encountered made ground to 0.60m, which comprised sandy gravelly clay; the gravel comprised sandstone, brick and pottery, pieces of metal and pipes were also noted.

Area 3, the Eastern Area, was predominantly covered with natural soils or reworked natural soils with occasional pieces of plastic noted. In the south west corner of this area 3, TP17 encountered made ground to 0.30m which contained pieces of plastic, tyre and glass. The trial trenches were completed in this area to attempt to locate the presence of the mine adits. Close to the area of trial trench 4 a pile of broken tiles were noted suspected to be asbestos containing material in the form of corrugated tiles.

In the area of made ground associated with the building next to Manor House farm, Area 4, the made ground comprised concrete over sandy gravelly clay. Made ground was typical of demolition type materials including brick and concrete to a depth of around 0.60m. Brick footings were noted in this area.

In Area 5, the former school, brick footings were noted to a depth of 3.00m in TP21, which suggests that a basement may have been present which appears to have been

infilled. The made ground material comprised sandy gravelly clay with some tarmac, sandstone, brick and concrete.

5.1.2 Pennine Middle Coal Measures – Class E to D

This stratum was encountered beneath the made ground or topsoil and comprised a layer of firm to stiff slightly sandy slightly gravelly clay between 0.40m and 2.70m in thickness. Based on the in-situ and laboratory test data this layer has a modified plasticity index or between 12% and 33% and as such is likely to have a low to medium volume change potential.

A summary of the in-situ and laboratory test results in this stratum is presented in Table 12 and laboratory test results can be found in Appendix Q.

Table 12: Summary of in-situ and laboratory test results for Pennine Middle Coal Measures – Class E to D

Soil parameters	Range	Reference
Liquid limit (%)	33-61	Appendix Q
Plasticity limit (%)	20-36	Appendix Q
Plasticity index (%)	13-33	Appendix Q
Plasticity term	Low to High	Appendix Q
Moisture content (%)	13-40	Appendix Q

5.1.3 Pennine Middle Coal Measures – Class C to B

Mudstone and sandstone was encountered at a depth of between 0.55m and 3.20m below ground level and was recorded to the full extent of the investigation.

A summary of the in-situ and laboratory test results in this stratum is presented in Table 13 and laboratory test results can be found in Appendix Q.

Table 13: Summary of soil parameters for Pennine Middle Coal Measures – Class C to B

Soil parameters	Range	Reference
Liquid limit (%)	36-45	Appendix Q
Plasticity limit (%)	21-23	Appendix Q
Plasticity index (%)	15-22	Appendix Q
Plasticity term	Intermediate	Appendix Q
Moisture content (%)	12-24	Appendix Q

Coal seams were encountered at the exploratory locations and the depths and thicknesses are presented in Table 14.

Table 14: Summary of coal seams encountered

Exploratory hole location	Depth (m)	Thickness (m)
TP01	2.40–2.70	0.30
TP02	0.65–0.80	0.15
TP04	1.05–1.20	0.15
	2.45–2.70	0.25
PH4	12.00–15.80	3.80
PH8	10.30–10.50	0.20
	20.80–21.00	0.20
	26.50–26.80	0.30
BH1	5.80–6.00	0.20
BH2	11.00–11.60	0.60
	11.80–12.30	0.50
BH3	5.00–5.20	0.20
BH3A	5.00–5.20	0.20
BH4	0.70–1.10	0.40
BH5	6.70–7.20	0.50
	9.00–9.10	0.10
BH6	4.70–5.00	0.30

5.1.4 Mining

The preliminary mining risk assessment in section 3.10 highlighted the presence of historical mining between the late 1800s and 1986. The seams that were worked included the Barnsley and Low Haigh Moor (Netherton Thick) seams. A series of six boreholes (BH1 to BH6) have been completed to depths ranging from 9.1m to 31.0m and eight rotary probeholes (PH1 to PH8) have been completed to depths ranging from 9.0m to 30.0m to establish the presence of coal or workings underlying the site.

The probing investigation encountered evidence of shallow workings (broken ground or possible voids) across the site, as presented in Table 15.

Table 15: Summary of coal workings/voids encountered

Exploratory hole location	Depth (m)	Thickness (m)	Details and Assumed Coal Seam
PH2	3.00–7.50	4.50	Void – Barnsley Seam
PH3	10.00–14.50	4.50	Soft ground – Barnsley Seam
PH5	8.80–15.20	6.40	Soft ground – Barnsley Seam

Exploratory hole location	Depth (m)	Thickness (m)	Details and Assumed Coal Seam
PH6	2.00-8.00	6.00	Soft ground – Barnsley Seam
PH7	4.50-9.00	5.00	Soft ground – Barnsley Seam
BH4	17.00-19.00	2.00	Void – Barnsley Seam

To the south of the southeast-northwest trending fault lines the Barnsley Rider Coal has been confirmed to exist at shallow depth across the north eastern part of the site (as shallow as 0.70m) at BH4 with a thickness of 0.40m.

Underlying the Barnsley Rider, the crop of the Barnsley Seam across the north eastern area of the site is confirmed. The Barnsley Seam is encountered as an intact thickness of 3.80m at 12.00m to 15.80m in PH04. The seam however, is encountered as voids or soft ground as detailed in Table 15 above. These voids / soft ground horizons confirm the Barnsley Seam has been worked.

The unnamed seam that is shown to crop to the south west of the site is confirmed as an intact 0.5m thick coal seam at BH05 at depths of 6.70m to 7.20m. The Top Haigh Moor Coal Seam is encountered as a 0.10m thick intact coal seam at BH05 (between 9.00m to 9.10m bgl), at BH06 as a 0.30m thick intact seam (between 4.70m and 5.00m bgl) and at PH08 as an intact 0.20m thick coal seam (between 10.30m to 10.50m bgl).

To the north of the southeast-northwest trending fault line, the same sequence of seams is encountered, with similar thicknesses, but as intact seams suggesting the seams were not extensively worked north of the southeast-northwest trending fault line.

Figure 7 and Figure 8 show a representative cross-section of geological profile of the boreholes and probeholes that intersect the voids/working of the Barnsley Seam. The line of the cross-sections are shown on Figure 6.

In addition to the coal seam investigation, a series of trial trenches were excavated to attempt to locate the presence of the mine adits that are detailed in the Coal Authority report. A detailed Shaft Plan and Data Sheet was obtained from the Coal Authority to investigate further any records held by the Coal Authority, the report is included in Appendix F. The details are listed in Table 7 in section 3.10.

The trial trenching was able to identify one of the mine adits, as shown on Figure 10. Photographs are included in Appendix I.

5.1.5 Groundwater

Due to the nature of the drilling (rotary that uses added water for flush throughout drilling) significant groundwater strikes were not encountered during this investigation. Groundwater seepages were noted in four trial pits at various depths and in differing strata which suggests a localised perched groundwater table may be present across the site.

It should be noted that groundwater levels might fluctuate for a number of reasons including seasonal variations. Ongoing monitoring would be required to establish both the full range of conditions and any trends in groundwater levels.

The results of the subsequent groundwater monitoring and well surveying exercise are summarised in Table 16. The limited data available is unable to confirm the groundwater flow direction.

Table 16: Groundwater monitoring data (22.02.2016)

Monitoring well	Depth to water (mb TOC)
BH01	8.404
BH02	8.070
BH03A	3.735
BH04	1.880
BH05	Dry
BH06	Dry

5.1.6 Visual/olfactory evidence of soil and groundwater contamination

Generally, no significant visual or olfactory evidence of anthropogenic contamination was noted during the investigation and no further source areas were identified. Significant depths of made ground were noted in the northern central part of the site, however the made ground did not contain any notable evidence of contamination.

5.2 Ground gas regime

The results of the ground gas monitoring and testing carried out are given in Appendix J. The results are summarised in Table 17.

Table 17: Summary of ground gas monitoring results

Borehole	Response zone/strata	Probable source(s) of ground gas	Number of monitoring visits	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Flow rate (l/hr)	Water level (m b TOC)	Atmospheric pressure (mbar)
BH1	PMCM	Coal measures strata	2	<0.1	<0.1	20.8	2.5	8.404	996 - 1018
BH2			2	<0.1	1.9	18.7	0.1	8.070	997-

									1018
BH3A			2	<0.1	<0.1	21.1	0.2	3.735	996-1018
BH4			2	<0.1	1.4	20.3	0.0	1.48	995-1018
BH5			2	<0.1	0.3	21.4	0.2	0.882	997-1020
BH6			2	0.1	0.9	18.6	0.3	Dry	997-1021
Note: PMCM = Pennine Middle Coal Measures									

5.3 Refinement of the initial conceptual site model

The ground, groundwater and ground gas conditions confirmed by the intrusive investigation are generally in accordance with those considered in the PRA. Three areas of significant made ground were noted associated with the building next to Manor House Farm (Area 4), the northern portion of the Central Area (Area 2), and associated with the former school (Area 5). There are some other areas of made ground present in the south of the site and across the site, assumed to be from disturbance of the ground due to agricultural activities.

Firm to stiff clay believed to represent the residual upper surface of the Pennine Middle Coal Measures in its completely weathered state was encountered between ground level and a depth of 0.60m below ground level at a thickness varying between 0.40 and 2.70m. Mudstone and sandstone of the Pennine Middle Coal Measures were encountered at a depth of between 0.55 and 3.20m to the full depth of investigation. Bands of coal were encountered in four locations at shallow depth of between 0.65 and 2.70 m and at five locations slightly deeper between 4.70 and 9.10 m depth. Deeper bands of coal were encountered in three locations between 10.30 and 26.80 m depth.

This generally confirms the stratigraphical succession described in the initial conceptual model.

Shallow groundwater was encountered as seepages during the trial pit investigation at depths ranging between 0.60 and 2.55m in the made ground and underlying Pennine Middle Coal Measures. The standing water levels in monitoring wells installed in boreholes were between 1.880 and 8.404 mb TOC.

Shallow groundwater beneath the site is not expected to be in continuity with the underlying secondary A Aquifer, which is expected to be encountered at depth. The groundwater seepages encountered during the investigation are believed to be discrete pockets within the various strata. The groundwater is unlikely to be in continuity with the River Dearne located 177m west of the site, as discussed within the PRA.

Concentrations of ground gas were found to be low in the first two rounds of monitoring; however, it is considered that the monitoring carried out to date is insufficient to characterise the ground gas regime adequately.

The following potential pollutant linkages, which were identified in the PRA, are considered as still requiring assessment:

- 1) Direct contact of contaminated soils to future site users
- 2) Inhalation exposure of future site users to asbestos fibres
- 3) Plant uptake of contaminants within the soils, which may affect plant growth
- 4) Chemical attack on infrastructure including concrete and potable water supply pipes from contaminated soils
- 5) Inhalation and explosion of hazardous ground gases from build up within buildings

These linkages are assessed in Section 6.

5.3.1 Uncertainty

Close to the area of trial trench 4, a pile of broken suspected asbestos containing corrugated tiles were noted. This was not sampled due to specialist equipment not being available at the time of the excavation. A photograph was taken and was assessed by an RSK asbestos specialist who confirmed the material is highly likely to be ACM. The photograph has been provided in Appendix I.

6 QUANTITATIVE RISK ASSESSMENT

In line with CLR11 (EA, 2004a), there are two stages of quantitative risk assessment, generic and detailed. The GQRA comprises the comparison of soil, groundwater, soil gas and ground gas results with generic assessment criteria (GAC) that are appropriate to the linkage being assessed. The results of the soil laboratory testing are provided in Appendix K.

6.1 Linkages for assessment

Section 5.3 presents the refined conceptual model which identified the linkages that required assessment after the findings of the site investigation had been considered. These linkages together with the method of assessment are presented in Table 18.

Table 18: Linkages for generic quantitative risk assessment

Potentially relevant pollutant linkage	Assessment method
1. Direct contact with impacted soil by future residents	Human health GAC in Appendix L for a proposed residential end use with private gardens since proposed end use includes residential gardens.
2. Inhalation exposure of future residents to asbestos fibres	Qualitative assessment based on the asbestos minerals present, their form, concentration, location and the nature of the proposed development.
3. Uptake of contaminants by vegetation potentially impacting plant growth	Comparison of soil data to GAC in Appendix N.
4. Contaminants permeating potable water supply pipes	Comparison of soil data to GAC in Appendix O for plastic water supply pipes using UKWIR (2010) guidance.
5. Concentrations of methane and carbon dioxide in ground gas entering and accumulating in: depressions and excavations that could affect workers enclosed spaces or small rooms in new buildings, which could affect future residents. In the case of methane this could create a potentially explosive atmosphere, while death by asphyxiation could result from carbon dioxide.	Gas screening values (GSV) have been calculated using maximum methane and carbon dioxide concentrations with maximum flow rates recorded at the site. The GSV have been compared with the generic Traffic Lights, as presented within the NHBC ground gases guide (Boyle and Witherington, 2007) and the aforementioned CIRIA report C665, owing to the development comprising low-rise housing with suspended floors. In addition, the gas regime is considered within the context of a conceptual model as required by both aforementioned guidance documents and BS8576

6.2 Methodology and results

The methodology and results of the GQRA are presented for each relevant pollutant linkage in turn.

6.2.1 Direct contact with impacted soil by future residents

Both targeted and non-targeted soil samples were obtained during the site investigation, however, this investigation was aimed at providing an indicative assessment of the site and only a limited number of samples were tested from each area. The results of the laboratory testing have been evaluated in the following subsections depending on the site area. A comparison table of the soil laboratory results to the corresponding GAC is provided in Appendix M.

6.2.1.1 Area 1 – The Western Area

One sample of made ground and one sample of the underlying natural soils was tested for a suite of contaminants. The results were directly compared to the GACs for a residential end use. All of the results were below the GACs, which indicates that the made ground and underlying natural soils are suitable for the proposed end use.

6.2.1.2 Area 2 – The Central Area

Two samples of made ground or possible made ground were tested from the southern part of this area, and four samples were tested from the raised area of infilled ground in the north. All results were compared directly to the GACs and were below the GAC values for all contaminants except the following:

- TP13 at 0.00-0.25m, result of 47mg/kg for Arsenic, which is above the GAC of 37mg/kg
- TP13 at 0.30-0.50m, result of 45mg/kg for Arsenic, which is above the GAC of 37mg/kg
- TP16 at 1.10-1.40m, result of 382mg/kg for Lead, is above the GAC of 200mg/kg

These results indicate there may be some elevated concentrations of metals within the infilled ground in the northern part of Area 2.

6.2.1.3 Area 3 – The Eastern Area

Two samples of made ground and one sample of the topsoil was tested for a suite of contaminants. The results were directly compared to the GACs for a residential end use. All of the results were below the GACs, which indicates that the made ground and topsoil are suitable for the proposed end use.

6.2.1.4 Area 4 – Manor House Farm Area

Two samples of made ground was tested for a suite of contaminants. The results were directly compared to the GACs for a residential end use. All of the results were below the GACs, which indicate that the made ground is suitable for the proposed end use.

6.2.1.5 Area 5 – Former School Area

Two samples of made ground were tested from this area. All results were compared directly to the GACs and were below the GAC values for all contaminants except the following:

- TP21 at 0.00-0.50m, result of 42.1mg/kg for Benzo(a)anthracene, which is above the GAC of 11mg/kg
- TP21 at 0.00-0.50m, result of 35.6mg/kg for Benzo(a)pyrene, which is above the GAC of 5mg/kg
- TP21 at 0.00-0.50m, result of 40.8mg/kg for Benzo(b)fluoranthene, which is above the GAC of 3.3mg/kg
- TP21 at 0.00-0.50m, result of 50.6mg/kg for Chrysene, which is above the GAC of 22mg/kg
- TP21 at 0.00-0.50m, result of 3.81mg/kg for Dibenzo(ah)anthracene, which is above the GAC of 0.28mg/kg

These results indicate some elevated concentrations of PAH within one sample (TP21 at 0-0.5m). This is likely to be due to the presence of tarmac gravel within this material.

6.2.1.6 Summary

On the basis of the above assessment it is considered that there are potentially significant risks associated with the soil contamination and, as such, either additional risk assessment or remediation is required.

6.2.2 Inhalation exposure of future residents to asbestos fibres

The visual inspection at the laboratory identified no materials suspected of potentially containing asbestos and the scheduled laboratory screening for asbestos found no detectable asbestos fibres within the samples of made ground.

However, during the site works, broken piece of possible asbestos containing material in cement form were noted at ground level, close to the area of trial trench 4. The material was left in-situ in order to not disturb the area, as specialist sampling equipment was not available. A photograph was taken and has been assessed by an asbestos specialist, who confirmed it is highly likely to be ACM. The photograph is included in Appendix I.

6.2.3 Uptake of contaminants by vegetation potentially inhibiting plant growth

The results have been compared with the GAC presented in Appendix N for this linkage. The results indicate that a relevant pollutant linkage associated with phytotoxic effects is likely to exist. The results for zinc from TP12 at 0.00-0.60 m of 647 mg/kg (pH 7.66) and from TP16 at 1.10-1.40 m of 606 mg/kg (pH 7.33) are above the GAC of 300 mg/kg for both the appropriate pH bands.

However, the depth of an analysis for uptake of contaminants by vegetation is not required to be any deeper than 0.25 m depth, according to the guidance. Therefore, it is likely that the sample from TP16 at 0.80 m be discounted, depending on the proposed final ground levels.

In the area of TP12, a suitable thickness of capping material may be required, depending on the layout of the proposed development.

6.2.4 Impact of organic contaminants on potable water supply pipes

For initial assessment purposes, the results of the investigation have been compared with the GAC presented in Appendix O for this linkage, which are reproduced from *UKWIR Report 10/WM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites* (UKWIR, 2010).

The results indicate that a relevant linkage is unlikely to exist associated with organic contaminants across the majority of the site. Therefore pollutant polyethylene (PE) and/or polyvinyl chloride (PVC) water supply pipes are expected to be suitable for use on the majority of the development, except for within the vicinity of TP21, where elevated results for mineral oils were noted. Further assessment of this area should be completed once the proposed routes of the pipelines are known.

It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling/analytical strategy may be required at a later date once the route(s) of the supply pipes are known. In addition, it is recommended that the relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

6.2.5 Ground gas

The results have been assessed in accordance with the guidance provided in BS8576 and *CIRIA Report C665*. In the assessment of risks and selection of appropriate mitigation measures, both reports highlight the importance of the conceptual model.

CIRIA C665 identifies two types of development, termed Situation A (modified Wilson and Card method), appropriate to all development excluding traditional low-rise

construction, and Situation B (National House-Building Council, NHBC) only appropriate to traditional low-rise construction with ventilated sub-floor voids.

Both methods are based on calculations of the limiting borehole gas volume flow for methane and carbon dioxide, renamed as the gas screening value (GSV). The GSV (litres of gas per hour) is calculated by multiplying borehole flow rate (litres per hour) and gas concentration (percent by volume).

In both situations, it is important to note that the GSV thresholds are guideline values and not absolute. The GSV thresholds may be exceeded in certain circumstances, if the site conceptual model indicates it is safe to do so. Similarly, consideration of additional factors such as very high concentrations of methane, should lead to consideration of the need to adopt a higher risk classification than the GSV threshold indicates.

The site is to be redeveloped with low rise housing, however the foundation solutions have yet to be finalised and therefore both Situation A and B have been considered.

Situation A relates to all development types except low-rise housing and, by combining the qualitative assessment of risk (see refined conceptual model in Section 5.3) with the gas monitoring results, provides a semi-quantitative estimate of risk for a site. The method uses both gas concentrations and borehole flow rates to define a characteristic situation for a site based on the limiting borehole gas volume flows for methane and carbon dioxide. Having calculated the worst case GSVs for methane and carbon dioxide, the Characteristic Situation is then determined from Table 8.5 of CIRIA C665.

Situation B is a characterisation system developed by the NHBC (Boyle and Witherington, 2007), which relates only to low rise housing development constructed with a clear ventilated underfloor void. The system provides a risk-based approach that is designed to allow an identification of the required gas protection measures for low-rise housing by comparing the measured gas emission rates to generic “Traffic Lights”. The Traffic Lights include typical maximum concentrations that are provided for initial screening purposes and risk-based GSVs for situations where the typical maximum concentrations are exceeded. Based on the typical maximum gas concentrations and the GSVs, the appropriate Traffic Light, ranging from Green through Amber 1 and Amber 2 to Red, is determined from Table 8.7 of CIRIA C665.

The GSV calculations for each borehole are included in Appendix P. The gas monitoring data has identified a maximum methane concentration of <0.1% and a maximum concentration of carbon dioxide of 1.9%. A maximum gas flow rate of 2.4 l/hr has been recorded. Please note CIRIA C665 recommends using the highest gas concentration and highest flow rate recorded at the site even if recorded in different boreholes, unless the characterisation of the site has clearly indicated that the values are associated with different soil gas regimes, e.g. different sources of gas. The calculated GSV for methane is 0.00 l/hr and the GSV for carbon dioxide is 0.00 l/hr. Based on the GSVs the site has been characterised as Green or as Characteristic Situation 1.

For both types of development, CIRIA C665 provides details of the typical scope of protective measures to be adopted for the relevant site characterisation.

The gas monitoring programme carried out to-date provides some evidence for an initial assessment of redevelopment requirements. However, it is considered that the monitoring undertaken during this investigation has not established the 'worst-case' scenario and therefore further monitoring is required to characterise adequately the ground gas regime. Adequate monitoring should be carried out to enable the confident assessment of risk and subsequent design of an appropriate gas protection scheme(s) for the proposed development.

6.3 Environmental assessment conclusions

This investigation aimed to provide information on the ground conditions to provide an initial assessment of the geo-environmental liabilities associated with the development of the site. At the time of writing the layout of proposed development has not been finalised and only an indicative plan has been provided.

The potential pollutant linkages were looked at in turn. The following conclusions can be drawn from the findings:

The intrusive investigation indicated that a number of areas of made ground were present in discrete locations across the site. The results of the contamination testing indicate elevated levels of metals within the northern raised area and a single location with elevated levels of PAH in the south eastern corner of the site associated with the former school were present. The testing completed this far is intended to represent an exploratory level survey of chemical conditions, generally in accordance with BS10175:2001.

In line with BS10175 and CLR 11, further investigations may subsequently be required to achieve full characterisation of the site and development of a detailed conceptual site model to provide full site characterisation to a level that will enable the design of a remediation strategy for the site and / or the discharge of planning conditions relating to contamination.

Whilst asbestos containing materials were not identified during the laboratory analysis of the eight samples, significant depths of made ground, both historical and recent are noted at the site and therefore the risk from asbestos fibres should not be discounted completely.

Furthermore, a pile of suspected ACM was noted close to the location of trial trench 4. The ACM was broken corrugated tiles/cement. Analysis by an RSK asbestos specialist indicated that it is highly likely to be ACM. It is likely to be present due to localised fly tipping. The risk of inhalation exposure to future site users cannot be discounted.

The results from the laboratory analysis indicated an area around TP12 which would be unsuitable for the growth of plants due to the presence of zinc. The results provide an indication of the chemical constituents of the soils on site, although due to the presence of made ground across certain parts of the site, it is likely that further intensive sampling and testing will be required in the proposed garden areas to ensure the soils are suitable for the growth of plants.

The proposed routes of the potable water supply pipes are currently unknown. A targeted soil sampling and testing investigation should be completed in the route of the proposed pipes once they are known to fully assess the risk of chemical attack on the supply pipes from contaminated soils.

Two rounds of ground gas monitoring have been completed to date. The results indicate that ground gas protection measures will not be required in the construction of the new dwellings. However, it would be prudent to note that the site lies within an intermediate probability radon area, as between 3 and 5% of homes are above the action level as defined by the British Geological Survey, National Geoscience Information Service.

Therefore, the risk of significant ingress of radon into structures on-site is considered to be medium and basic radon protective measures are required within new dwellings at the site.

7 GEOTECHNICAL SITE ASSESSMENT

7.1 Engineering considerations

It is understood that the proposed development is to involve the construction of approximately 300 residential properties and associated infrastructure. At this stage no specific information relating to building loads has been provided and therefore a wall loading of 100kN/m has been considered. It has been assumed the ground-bearing floor slabs will not be required and that beam and block flooring will be utilised.

7.2 Geotechnical hazards

A summary of commonly occurring geotechnical hazards is given in Table 19 together with an assessment of whether the site may be affected by each of the stated hazards.

Table 19: Summary of main potential geotechnical hazards that may affect site

Hazard category (excluding contamination issues)	Hazard status based on investigation findings and proposed development			Engineering considerations if hazard affects site
	Found to be present on site	Could be present but not found	Unlikely to be present and/or affect site	
Sudden lateral changes in ground conditions		√	Two fault line shown to dissect the site may cause variable change in depth to bedrock	Likely to affect ground engineering and foundation design and construction
Shrinkable clay soils	√	Clays have been found to be low to medium plasticity and there are a number of established trees on the site which will affect the shrinkability of the soils		Design to NHBC Standards Chapter 4.2 or similar
Highly compressible and low bearing capacity soils, (including peat and soft clay)		√		Likely to affect ground engineering and foundation design and construction

Hazard category (excluding contamination issues)	Hazard status based on investigation findings and proposed development			Engineering considerations if hazard affects site
	Found to be present on site	Could be present but not found	Unlikely to be present and/or affect site	
Silt-rich soils susceptible to rapid loss of strength in wet conditions	√	Variable silt content in the weathered Middle Coal Measures		Likely to affect ground engineering and foundation design and construction
Running sand at and below water table			√	Likely to affect ground engineering and foundation design and construction
Ground subject to or at risk from landslides			√	Likely to require special stabilisation measures
Ground subject to or at risk from coastal or river erosion			√	Likely to require special protection/stabilisation measures
High groundwater table (including waterlogged ground)		√		May affect temporary and permanent works
Underground mining	√	Evidence of mine workings and mine adits present on site		Likely to require special stabilisation measures
Existing sub-structures (e.g. tunnels, foundations, basements, and adjacent sub-structures)	√	Evidence of basements noted in Area 5, former school area		Likely to affect ground engineering and foundation design and construction
Filled and made ground (including embankments, infilled ponds and quarries)	√	Areas of filled ground associated with former buildings and infilled raised area in north of Area 2.		Likely to affect ground engineering and foundation design and construction
Adverse ground chemistry (including expansive slags and weathering of sulphides to sulphates)		√ (See section 7.3.7)		May affect ground engineering and foundation design and construction
Note: Seismicity is not included in the above table as this is not normally a design consideration in the UK.				

7.3 Foundations

7.3.1 General suitability

Generally, firm to stiff clay is present at a relatively shallow depth across the site beneath the made ground, therefore it is considered that traditional shallow spread footings will be suitable for the majority of the proposed development.

Localised areas of deeper made ground and possible made ground were encountered as follows:

- Raised area in central northern part of site (TP13, at least 4.6m; TP14, 3.2m; TP15, 1.8m and TP16, 1.7m)
- BH05, 3.0m (possible made ground)
- TP21, 3.0m in the south eastern part of site

Where made ground is less than 2.5m deep in these areas, trench fill foundations are considered suitable.

Where made ground is over 2.5m deep, alternative foundations will be required. Alternative foundation options will depend on final ground levels and may include piled and/or raft foundations; production of a final foundation design layout is recommended.

For areas affected by shallow underground coal workings, spread foundations will need to be suitably reinforced.

7.3.2 Shallow spread foundations

The recommendations for the design and construction of spread foundations in relation to the ground conditions are set out in Table 20.

Table 20: Design and construction of spread foundations

Design/construction considerations	Design/construction recommendations
Founding stratum	Residual soils (Class E to Class C weathered Coal Measures)
Depth	Foundations should be taken to a minimum depth of 0.9m below finished ground level and at least 0.1m into the founding stratum below any overlying topsoil or made ground or to any greater depth required in respect of the special design considerations given below.
Special design considerations	Owing to the presence of low to medium shrinkable clay soils, foundations should be designed taking into account all the normal precautions, including minimum founding depths, to minimise the risk of future foundation movements in accordance with NHBC standards or similar.

Design/construction considerations	Design/construction recommendations
	Owing to the potential for significant lateral and vertical variability of the founding strata, consideration should be given to incorporating appropriate reinforcement into the strip foundations to minimise the risk of future differential foundation movements.
Bearing capacity	Spread foundations constructed on the weathered Coal Measures at a minimum depth of 0.90 m bgl can be designed using a net allowable bearing pressure of 120 kN/m². The allowable bearing capacity includes an overall factor of safety of 3 against bearing capacity failure with the total settlements associated with the bearing pressure estimated to be less than 25 mm.
Stability of excavations	Generally the trial pits remained stable during excavation which indicates that foundation excavations should also remain stable in the short term. In the event that excavations are to remain open for longer periods, consideration should be given to the use of trench support systems.
Dewatering	During ground investigation works, groundwater seepage was occasionally recorded in the trial pits. Subsequent groundwater monitoring indicated standing water at it's highest in BH4 and BH5 at depths ranging between 0.88m and 1.88m bgl, therefore allowance should be made for localised water control in these parts of the site (eastern area) during foundation excavation. The highest standing water level in the remaining monitoring wells was 3.6m bgl, indicating that dewatering may not be required in the western part of site.
Construction considerations	All foundation excavations should be inspected, and any made ground and soft, organic or otherwise unsuitable materials removed and replaced with mass concrete. The proposed founding stratum is a relatively silt-rich soil, hence susceptible to rapid softening once exposed. Hence all foundation excavations should immediately be blinded with concrete or the full foundation constructed.

7.3.3 Foundation works risk assessment

It is anticipated that a foundation works risk assessment report will not be required for the development because concentrations of chemicals of potential concern (COPC) within made ground and natural soils were typically below corresponding GAC. Where exceedances were noted, these were found to be marginal and of the same order of magnitude as the associated GAC. It may be prudent to further investigate the area of elevated PAH in the south east corner of the site, as a localised foundation works risk assessment may be required for this area.

7.3.4 Development risk from coal mining assessment

There are a number of lines of evidence that show the Barnsley Rider Coal and Barnsley Coal outcrop within the site boundary. Additionally, the unnamed seam and the Top Haigh Moor Coal Seam outcrop to the southwest of the site. Therefore, there are

significant areas of the site that are underlain by either intact or worked coal seams at relatively shallow depth.

It is recommended that the thickness of competent rock overlying an underlying coal / worked seam required to ensure ground stability at the surface is ten times that of the underlying coal / worked seam. On this basis there are substantial areas of the site that do not have the required 'ten times' seam thickness, and these areas will require stabilisation prior to development. These areas are shown on Figure 11.

In addition four mining adits have been identified from the Coal Authority records to be present close to the crop of the Barnsley Coal. The position of each of these adits should be identified and each of them stabilised to mitigate potential risk to the proposed development.

7.3.5 Floor slabs

It is assumed that during construction of the proposed housing development, a block and beam flooring system will be utilised and therefore floor slabs will be suspended across the whole development.

7.3.6 Roads, hardstanding and drainage

The near surface ground conditions consist of made ground over firm to stiff clay. Therefore, for preliminary purposes a California bearing ratio (CBR) value of 3% can be considered for pavement design. It is recommended that in situ CBR determination be carried out targeting areas of hardstanding prior to construction works, to confirm this value.

7.3.7 Chemical attack on buried concrete

This assessment of the potential for chemical attack on buried concrete is based on current BRE guidance. The desk study and site walkover indicate that, for the purposes of this assessment of the aggressive chemical environment, the site should be considered as a brownfield site.

The laboratory results indicate 2:1 water soil extract sulphate contents of up to 60mg/l with pH values varying between 6.62 and 7.70. Based on the results, an Aggressive Chemical Environment for Concrete classification of AC-1 with a Design Sulphate Class of DS-1 may be assumed for design purposes. This assumes nominally mobile groundwater conditions and that no significantly disturbed clay comes into contact with concrete foundations or structures.

8 REUSE OF MATERIALS AND WASTE

8.1 Reuse of suitable materials

Under the Waste Framework Directive naturally occurring soils are not considered waste if re-used on the site of origin for the purposes of development.

In accordance with the definition provided in the Waste Framework Directive, materials are only considered waste if 'they are discarded, intended to be discarded or required to be discarded, by the holder'. Thus, soils that are not of clean and natural origin, i.e. made ground (whether contaminated or not) and other materials such as recycled aggregate, do not become waste until the aforementioned criteria are met.

The Definition of Waste: Development Industry Code of Practice (CL:AIRE, 2011) (CoP) was developed in consultation with the Environment Agency and development industry to enable the re-use of materials under certain scenarios and subject to demonstrating that specific criteria are met. The current re-use scenarios covered by the CoP comprise:

- Re-use on the site of origin (with or without treatment)
- Direct transfer of clean and natural soils between sites
- Use in the development of land other than the site of origin following treatment at an authorised Hub site (including a fixed Soil Treatment Facility).

The importation of made ground soils (irrespective of contamination status) or crushed demolition materials is not currently permitted under the CoP and requires either a standard rules environmental permit or a U1 waste exemption (see below).

In the context of excavated materials used on sites undergoing development, four factors are considered to be of particular relevance in determining if the material is a waste or when it ceases to be waste:

- the aim of the Waste Framework Directive is not undermined, i.e. if the use of the material will create an unacceptable risk of pollution of the environment or harm to human health it is likely to be waste
- the material is certain to be used
- the material is suitable for use both chemically and geotechnically
- only the required quantity of material will be used.

The CoP requires the preparation of a materials management plan (MMP) that confirms the above factors will be met. This plan needs to be reviewed by a 'Qualified Person' (QP) who will then issue a declaration form to the EA. As the project progresses, data must be collated and on completion a verification report produced that shows the MMP was followed and describes any changes.

The MMP establishes whether specific materials are classified as waste and how excavated materials will be treated and/or re-used in line with the CoP. The MMP is likely to form part of the site waste management plan.

Although generally undeveloped, the site has had several phases of construction and demolition of buildings, industrial uses (the tramline) and an area of infilled ground and the investigation has confirmed the presence of made ground. Therefore, before any excavation works begin on-site, an MMP will need to be prepared, reviewed by a QP; and a Declaration lodged with the EA.

As noted above, under the Waste Framework Directive naturally occurring soils are not considered waste and therefore arisings of clean natural soils, e.g. from foundation and drainage excavations, may be re-used on the site. However, it is important that these soils should be stockpiled separately and not become cross-contaminated with made ground / contaminated soils or construction wastes.

If it is proposed to import clean and naturally occurring soils direct from another site, the receiving site's MMP would need to be updated in advance of importation.

8.2 Treatment to meet suitable-for-use criteria

Where materials do not meet the suitable for use criteria it may be possible to treat them under an environmental permit (mobile treatment licence) to enable them to be reused onsite.

To enable the treatment options to be determined, an options appraisal and a remediation strategy document will be necessary to support discussion of the issues with regulators and third parties.

8.3 Reuse of waste materials

If material is discarded as waste then its reuse on site may still be possible. Waste soils and recycled aggregate can be reused on site under a standard rules environmental permit or a U1 waste exemption from the Environmental Permitting (England and Wales) Regulations 2010 provided that they are suitable for the proposed use, i.e. not cause harm to human health or the environment. However, it should be noted that these have strict limits on the quantity of material that can be reused.

8.4 Wastes for landfill disposal

Wastes require pre-treatment prior to disposal at landfill. Pre-treatment must be a physical, thermal, chemical or biological process (including sorting) that changes the characteristics of the waste to reduce its volume, reduce its hazardous nature, facilitate its handling and enhance its recovery.

The latest, edition of the EA's 'Technical Guidance WM3' (2015) Guidance on the classification and assessment of waste, requires that within a mixed waste* the separately identifiable wastes are assessed separately. Mixing of different types of hazardous waste and hazardous waste with other waste substances is prohibited under the Waste Framework Directive. Wastes that have been mixed must be separated whenever possible.

It is best practice to provide your waste carrier (or the disposal site) with details of how the waste has been treated. Your waste carrier may provide a pre-treatment confirmation form or space on the waste transfer note to detail the pre-treatment.

The classification of waste soil is a two-stage process, the first being an assessment of whether the soil is considered hazardous or not following the guidance within Technical Guidance WM3. For off-site disposal to landfill the results of Waste Acceptance Criteria (WAC) testing must then be reviewed to establish if the soil is acceptable at the relevant class of landfill or requires pre-treatment to reduce specific hazardous properties.

8.4.1 Waste acceptance criteria

All inert, stable non-reactive hazardous and hazardous wastes have limit values (waste acceptance criteria) set out in legislation that must be met before that class of landfill can accept the waste. Currently, no WAC are in place for non-hazardous waste.

Soil and other materials that are found not to be hazardous may be classified as either non hazardous or inert. In order to determine whether they can be classed as inert the soil must be tested and found to be below the inert waste acceptance criteria.

8.4.2 Waste sampling plan

Technical Guidance WM3 sets out in Appendix D requirements for waste sampling. It is a legal requirement to correctly assess and classify waste. The level of sampling should be proportionate to the volume of waste and its heterogeneity. At this stage RSK consider that the level of soil sampling is/is not sufficient to robustly/fully categorise the material.

RSK recommends that a Sampling Plan be prepared to support any waste classifications and hazardous waste assessments, prior to development.

8.4.3 Preliminary waste assessment

Given the level of data obtained, scale of the development and heterogeneity of the site soils the following assessment should be considered indicative and further assessment should be undertaken following the preparation of a Waste Sampling Plan.

EnviroLab (an RSK company) has developed a waste soils characterisation assessment tool (HASWASTE), which follows the guidance within Technical Guidance WM3. The

analytical results have been assessed using this tool for potential off-site disposal of materials in the future. The results are presented in Table 21.

Table 21: Results of waste soils characterisation assessment (HASWASTE)

Sample ref/location	Waste classification
TP02, 0m	Not hazardous
TP05, 0.6m	Not hazardous
TP07, 0.3m	Not hazardous
TP07, 0.8m	Not hazardous
TP09, 0.2m	Not hazardous
TP12, 0m	Not hazardous
TP13, 0m	Not hazardous
TP13, 0.3m	Not hazardous
TP14, 1.5m	Not hazardous
TP16, 1.1m	Not hazardous
TP17, 0m	Not hazardous
TP18, 0m	Not hazardous
TP20, 0m	Not hazardous
TP21, 0m	Hazardous
TP23, 0m	Not hazardous

Made ground at one location (sample TP21 at ground level) was classified as hazardous waste, owing to the presence of tarmac gravel within the material and therefore must be disposed of at a suitably licensed hazardous waste landfill.

None of the other samples were classified as hazardous waste. Therefore to determine whether waste might be classified as inert or non hazardous WAC testing will need to be undertaken.

8.4.4 Asbestos within waste soils

The latest, edition of Technical Guidance WM3, requires that within a mixed waste the separately identifiable wastes be assessed separately.

For instance where waste soil contains identifiable pieces of asbestos (visible to the naked eye) the asbestos should, where feasible, be separated from the soil and classified separately.

No asbestos fibres were detected in soil samples analysed for asbestos, however suspected ACM was noted at one location (trial trench 4). Furthermore, asbestos is

often present in discrete areas and since localised made ground is present, asbestos may be found during more extensive ground works.

8.5 Landfill tax

Waste producers disposing of material to landfill are required to pay landfill tax by HM Revenue and Customs.

The tax is chargeable by weight (tonnage) and two rates apply, either standard or lower rate. The lower rate only applies to those less polluting wastes as set out in the Landfill Tax (Qualifying Material) Order 2011, which include naturally occurring rock and soil, concrete, some minerals, some furnace slags and ash, and some low-activity organic compounds. Evidence confirming that the waste qualifies for the lower rate will be required, and standard rate tax will apply for the whole waste load for any loads of mixed waste.

Currently (since April 2015), standard rate landfill tax is £82.60 per tonne and rising to £84.40 after the 1st April 2016.

The lower rate of landfill tax applicable to less polluting wastes (i.e. 'inert' wastes) remains at £2.60 per tonne.

Material disposed of at a soil treatment centre will not be subject to landfill tax.

8.6 Groundwater

When there is an intention to discard groundwater, chemical test results will indicate the appropriate disposal options. This could include disposal to treatment facility, via consent (issued by the water authority) to foul sewer or via consent (issued by the EA) to a watercourse or land.

8.7 Recommendations

RSK recommends that consideration as to how potentially waste soils will be dealt with as part of this development/remediation is given as early in the project planning process as possible. Such planning can lead to cost savings where potentially waste soils are viewed as a resource and retained on-site as part of the development. We also recommend, where off-site disposal is being considered, that appropriate facilities are identified and discussions initiated to confirm suitability of the facility to take the material. Potentially, these may include soil treatment facilities as well as landfills.

RSK can provide specialist advice to assist in this process, which can be complex and subject to regular regulatory change.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Environmental

On completion of the GQRA the following pollutant linkages that require further action are:

1. Direct contact of contaminated soils to future site users associated with localised contamination in made ground
2. Inhalation exposure of future site users to asbestos fibres
3. Plant uptake of contaminants within the soils, which may affect plant growth in certain areas of the site
4. Permeation of contaminants to water supply pipes in certain areas of the site
5. Inhalation and explosion of hazardous ground gases from build up within buildings

Localised made ground is present across the site. Three exceedances of the GAC for metals were identified in the area of raised ground (north of Area 2) and five exceedances of the GAC for PAH at a single location in Area 5 (former school area), due to the presence of tarmac gravel. This indicates potential risk associated with soil contamination in these areas of the site. The testing completed to date is intended to represent an exploratory level survey of chemical conditions. It is recommended that additional sampling and analysis of made ground is undertaken to further investigate this linkage and to delineate areas of contamination. It is recommended that a clean cover, with a minimum thickness of 600mm be placed within garden areas of affected plots.

Asbestos fibres were not detected in any of the samples analysed for this contaminant, however the presence of suspected ACM was encountered on site and as such this potential linkage and the potential for encountering further ACM at the site cannot be discounted. It is recommended that a watching brief is undertaken during ground works in areas where fly-tipping and made ground are present. ACM should be removed from site by a suitably licensed and qualified company.

Two exceedances of the GAC for zinc with respect to plant uptake were identified at a single location. It is unlikely that the soils will pose a risk to plant growth site-wide, however it would be prudent to undertake additional assessment of this linkage.

The proposed routes of the potable water supply pipes are currently unknown. A targeted soil sampling and testing investigation should be completed in the route of the proposed pipes once they are known to fully assess the risk of chemical attack on the supply pipes from contaminated soils.

In summary, further investigations may subsequently be required to achieve full characterisation of the site and development of a detailed conceptual site model to provide full site characterisation to a level that will enable the design of a remediation strategy for the site and / or the discharge of planning conditions relating to contamination.

Assessment of the ground gas regime is ongoing with a further four rounds to be completed. Currently the site is considered 'Green', however final determination of the requirement for gas protection measures should be reserved until the monitoring programme is completed. The ground gas risk assessment will be completed as an addendum report.

The site lies within an intermediate probability radon area, as between 3 and 5% of homes are above the action level as defined by the British Geological Survey, National Geoscience Information Service.

Therefore, the risk of significant ingress of radon into structures on-site is considered to be medium and basic radon protective measures are required within new dwellings at the site.

The presence of Japanese Knotweed in discrete locations within Area 2 has been highlighted. It is recommended that the site be re-surveyed during the growing season. A competent knotweed contractor should be employed manage and perform the treatment/ eradication works.

9.2 Reuse of materials and waste

The results of the waste soils and characterisation assessment (HASWASTE) indicates that all soil samples are classified as not hazardous, with the exception of shallow made ground at TP21, which contained tarmac gravel.

9.3 Geotechnical

The firm to stiff natural soils (weathered Coal Measures) would be considered suitable to support shallow spread foundations. Trench fill foundations are considered suitable in areas of deeper made ground (less than 2.5m deep) and alternative foundation options will be required in areas where made ground is deeper than 2.5m. Production of a final foundation design layout is recommended. For areas affected by shallow underground coal workings, spread foundations will be required to be reinforced.

The preliminary recommended sub-grade soil CBR value for road pavement design is 3% based on the ground conditions encountered. It is recommended that in-situ CBR determination be carried out targeting areas of hardstanding prior to construction works to confirm this value.

The Aggressive Chemical Environment for Concrete classification is indicated to be AC-1, with a Design Sulphate Class of DS-1 in accordance with current BRE guidance.

9.4 Mining

The Barnsley Rider Coal and Barnsley Coal are indicated to outcrop within the site boundary. Additionally, the unnamed seam and the Top Haigh Moor Coal Seam outcrop to the southwest of the site. Significant areas of the site that are underlain by either intact or worked coal seams at relatively shallow depth.

The probing investigation encountered evidence of shallow working (broken ground or possible voids) at six exploratory locations across the site.

It is recommended that the thickness of competent rock overlying a coal / worked seam required to ensure ground stability at the surface is ten times that of the underlying coal / worked seam. On this basis there are substantial areas of the site that do not have the required 'ten times' seam thickness, and these areas will require stabilisation prior to development. These areas are shown on Figure 11.

In addition, four mining adits have been identified from the Coal Authority records to be present close to the crop of the Barnsley Coal. Evidence of an adit was encountered at one location during the trial trenching exercise. The position of each of the adits should be identified and each of them stabilised to mitigate potential risk to the proposed development.

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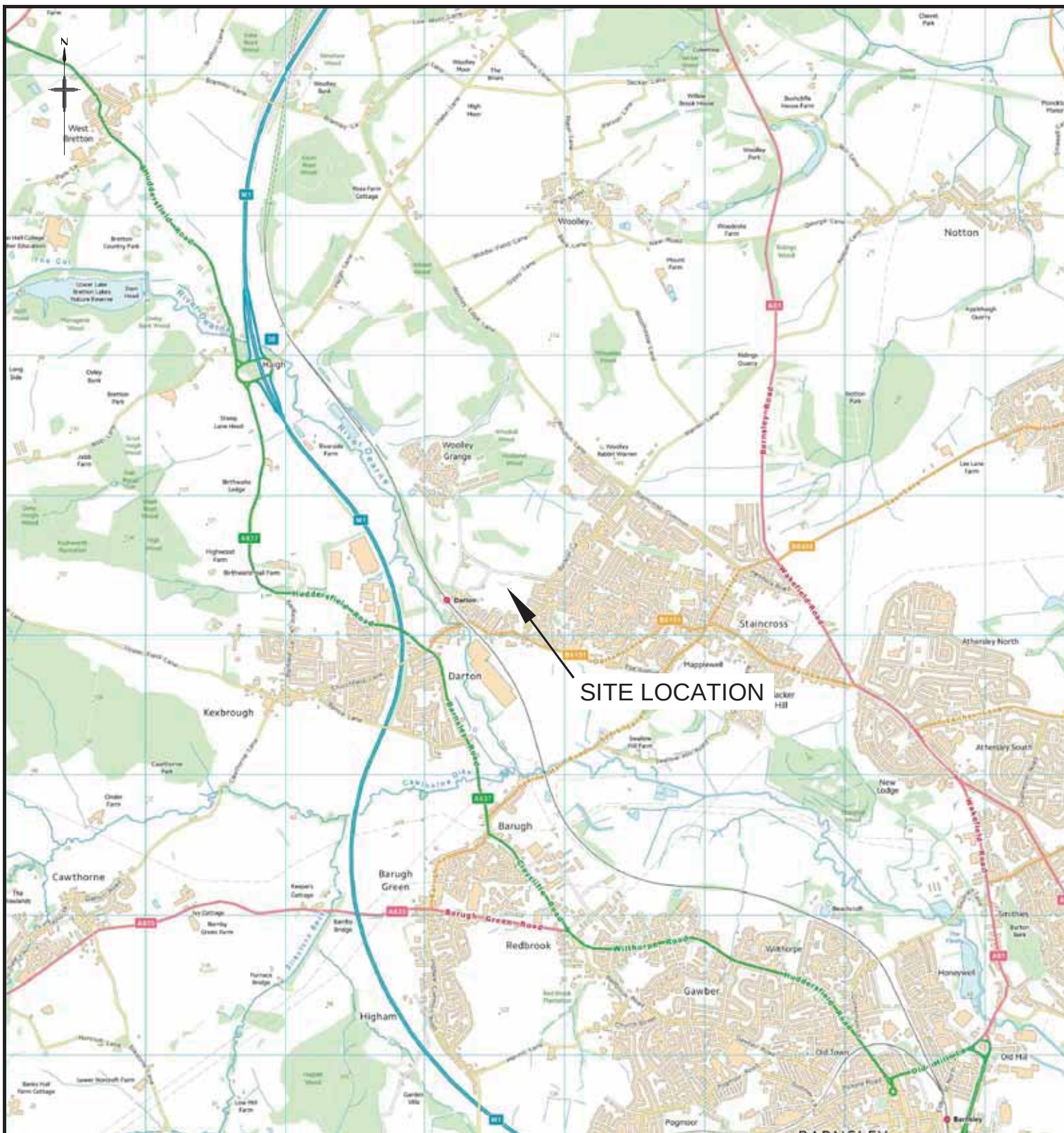
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FIGURES



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Client

JONES HOMES (YORKSHIRE) LIMITED

Project Title

LAND OFF BLOOMHOUSE LANE,
DARTON

Drawing Title

SITE LOCATION PLAN

Drawn

Date

HD

22.03.16

Checked

Date

JH

22.03.16

Approved

Date

JH

22.03.16

Project No.

301645

Drawing File

301645-R1(00)D001A

Scale
NTS

Orig Size
A4

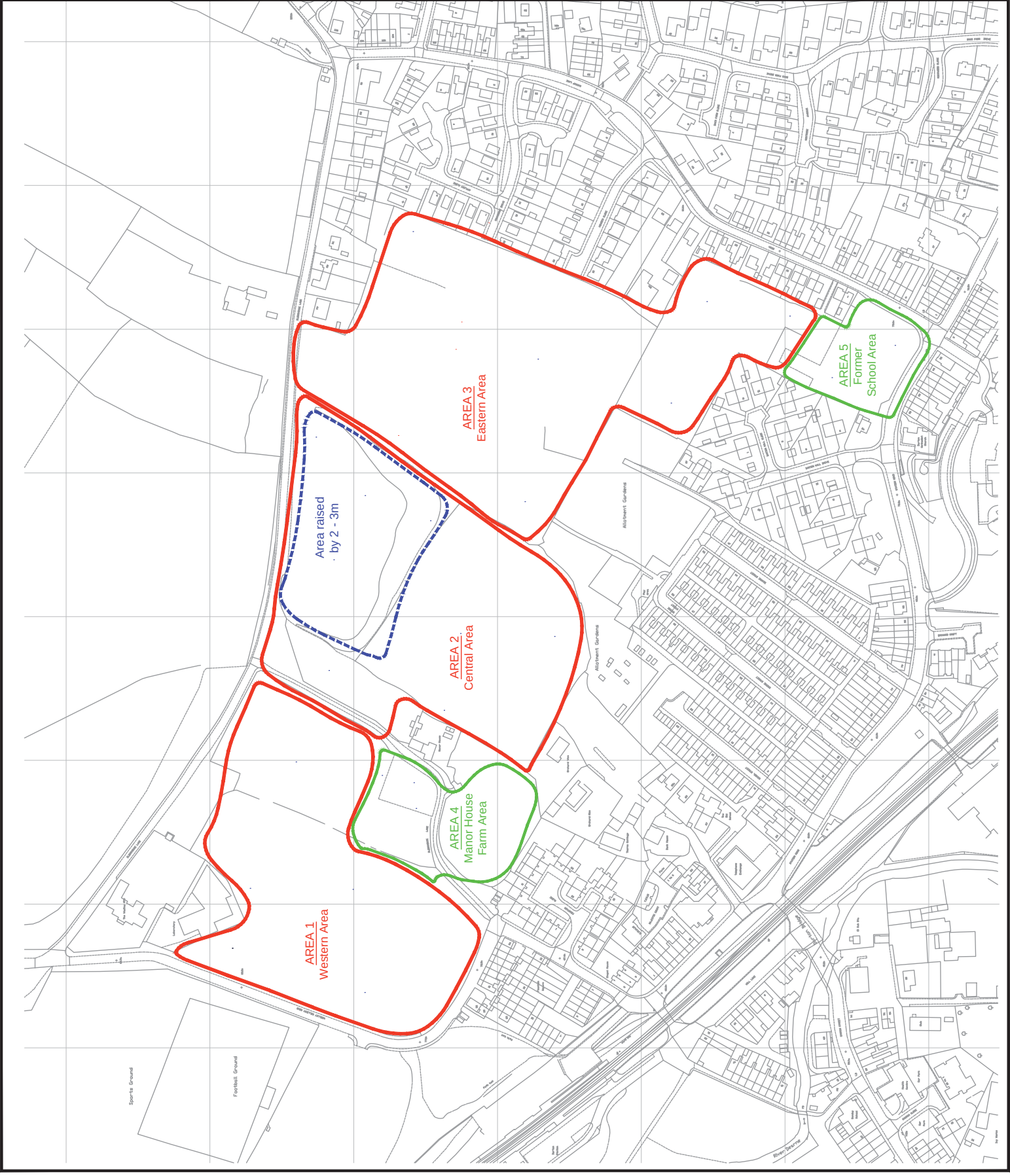
Dimensions
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Drawing No.

FIGURE 1

Rev.

A



LEGEND:

A	22.03.16	FIRST ISSUE	HD	JH	JH
REV	DATE	DESCRIPTION	BY	CHKD	APPR.
Dimensions		Projection	Scale	Orig. Size	
m		North Arrow	1:2,500	A3	



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CLIENT
JONES HOMES (YORKSHIRE) LIMITED

PROJECT
LAND OFF BLOOMHOUSE LANE, DARTON

TITLE
SITE FEATURES PLAN

JOB NO.:		DRAWING FILE:	
301645		301645-R1(00)D002A	
BY:	DATE:	CONTRACT NO.	REV:
HD	22.03.16		FIGURE 2 A

Scale 1 : 2,500

0 20 40 60 80 100m



LEGEND:

Base plan from Spawforths, Indicative Master Plan, Dwg No. 0100-0002, dated Feb 2015

A	22.03.16	FIRST ISSUE	HD	JH	JH
REV	DATE	DESCRIPTION	BY	CHKD	APPR
Dimensions		Projection	Scale	Orig Size	
m			1:2,500	A3	



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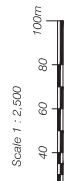
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JONES HOMES (YORKSHIRE) LIMITED

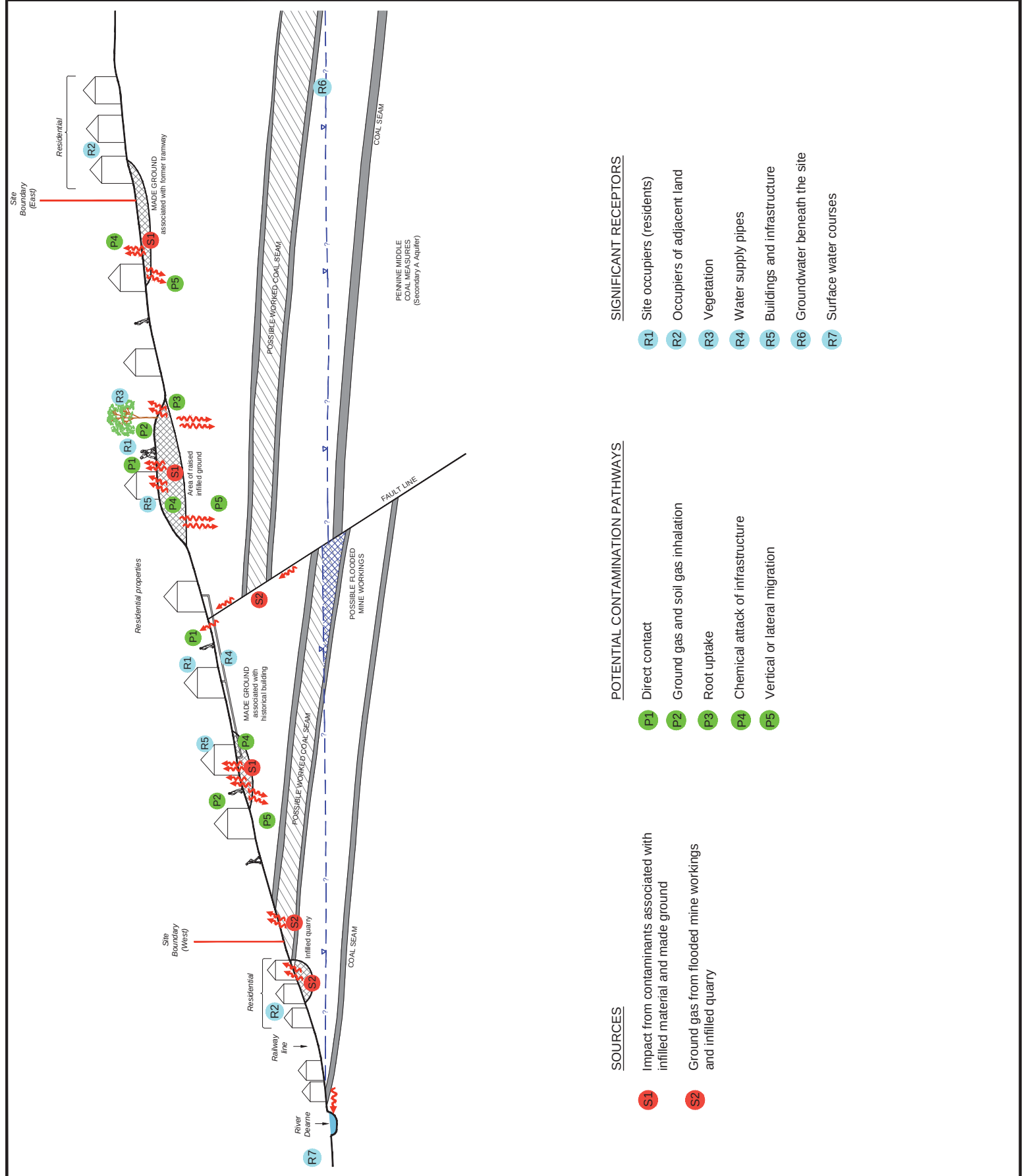
PROJECT
LAND OFF BLOOMHOUSE LANE, DARTON

TITLE
PROPOSED DEVELOPMENT PLAN

JOB No.:	DRAWING FILE:
301645	301645-R1(00)D003A

BY:	DATE:	CONTRACT NO.	REV:
HD	22.03.16		A
FIGURE 3			A





LEGEND:

S1

Sources

P1

Pathways

R1

Receptors

Potential Contamination pathways

REV	A	22.03.16	FIRST ISSUE	HD	JH	JH
Dimensions			Projection	Scale	Orig. Size	
				NTS	A3	

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LAND OFF BLOOMHOUSE LANE, DARTON

TITLE

INITIAL CONCEPTUAL SITE MODEL

JOB No.:

301645

DRAWING FILE:

301645-R1(00)D004A

BY:

DATE:

22.03.16

CONTRACT NO.

FIGURE 4

REV:

A

SOURCES

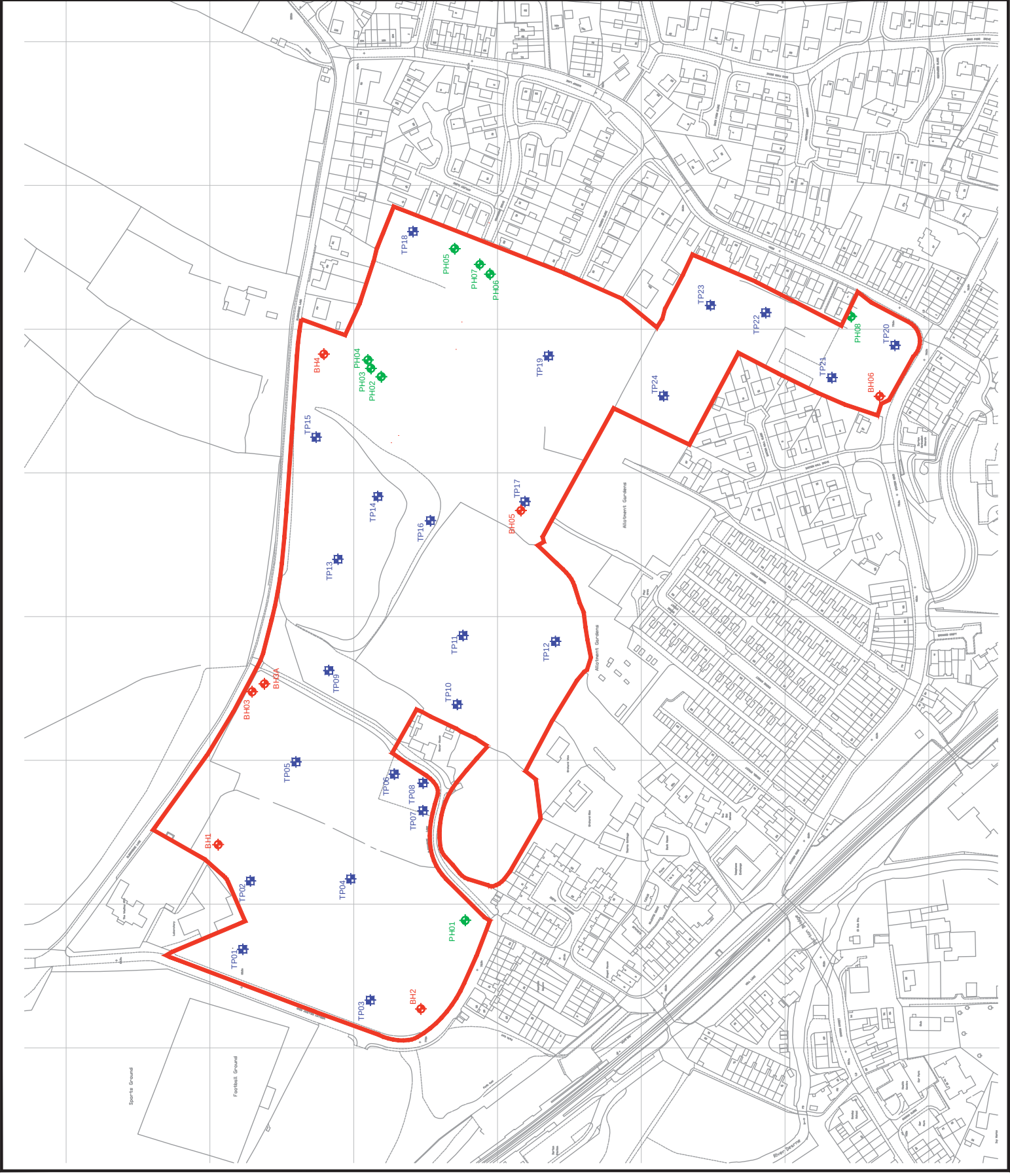
- S1 Impact from contaminants associated with infilled material and made ground
- S2 Ground gas from flooded mine workings and infilled quarry

POTENTIAL CONTAMINATION PATHWAYS

- P1 Direct contact
- P2 Ground gas and soil gas inhalation
- P3 Root uptake
- P4 Chemical attack of infrastructure
- P5 Vertical or lateral migration

SIGNIFICANT RECEPTORS

- R1 Site occupiers (residents)
- R2 Occupiers of adjacent land
- R3 Vegetation
- R4 Water supply pipes
- R5 Buildings and infrastructure
- R6 Groundwater beneath the site
- R7 Surface water courses



LEGEND:

- Site boundary
- RSK borehole
- RSK probe hole
- RSK trial pit

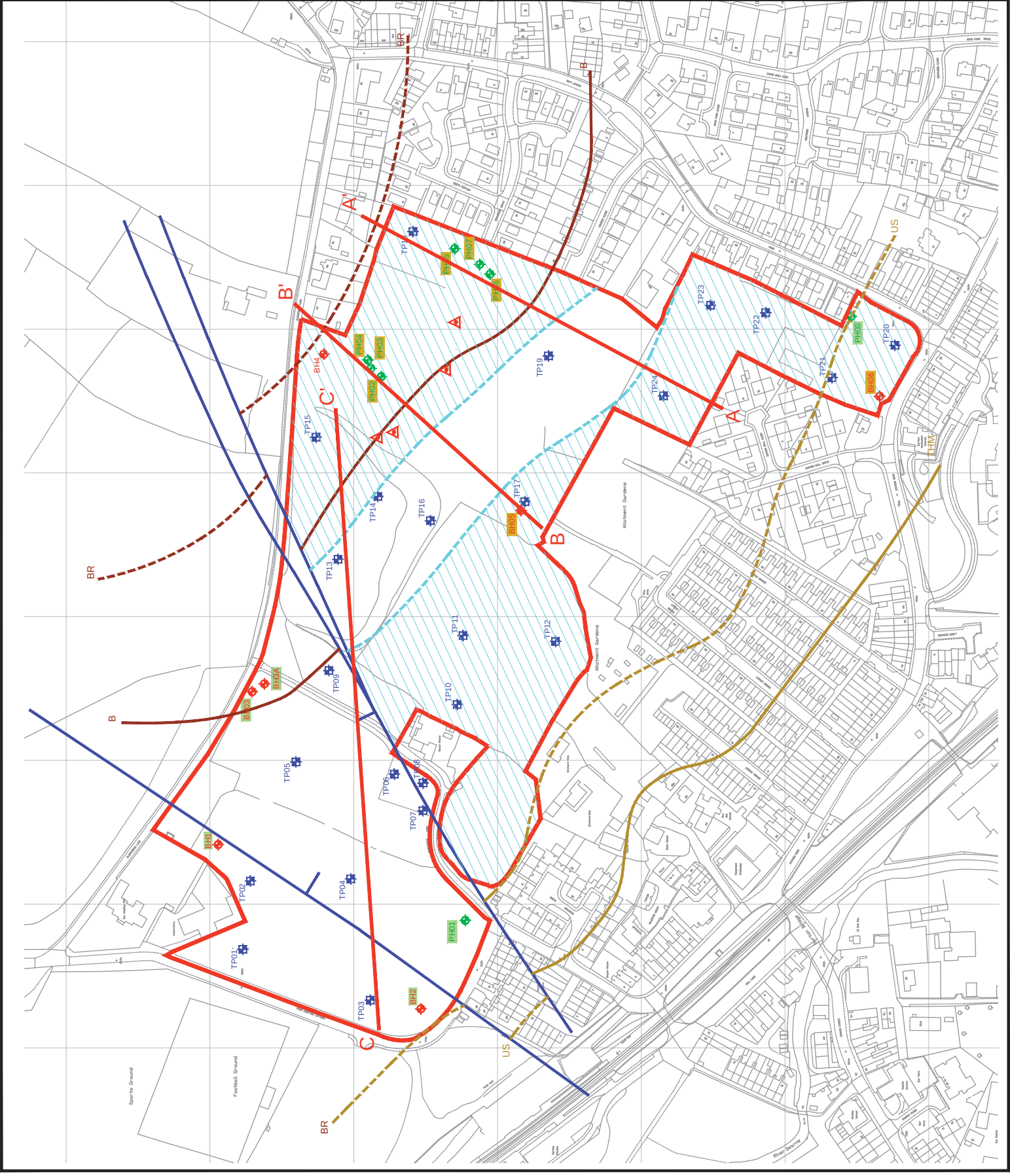


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REV	DATE	DESCRIPTION	BY	CHKD	APPR
Dimensions		Projection	Scale	Orig. Size	
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CLIENT		JONES HOMES (YORKSHIRE) LIMITED			
PROJECT		LAND OFF BLOOMHOUSE LANE, DARTON			
TITLE		EXPLORATORY HOLE LOCATION PLAN			
JOB No.:		DRAWING FILE:		301645-R1(00)D005A	
BY: DATE:		CONTRACT NO.		REV:	
HD 22.03.16		FIGURE 5		A	

Scale 1 : 2,500



LEGEND:

Site boundary

Fault

Barnsley Rider Coal (BR)

Barnsley Coal (R)

Unnamed seam (US)

Top High Moor Coal (THM)

Ten times seam thickness of competent rock demonstrated

Ten times seam thickness of competent rock not demonstrated

Area requiring mine work stabilisation

RSK borehole

RSK probe hole

RSK trial pit

Mine Adits

North Arrow

REV	A	23.03.16	FIRST ISSUE	HD	JH	JH
DESCRIPTION	BY CHD, APR					
Dimensions	m		Projection	Scale	1:2,500	
Origin	m		Scale	1:2,500		
Origin	m		Scale	1:2,500		

RSK

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JONES HOMES (YORKSHIRE) LIMITED

PROJECT

LAND OFF BLOOMHOUSE LANE, DARTON

TITLE

SECTION DIAGRAM PLAN

JOB NO.:

301645

DRAWING FILE:

301645-R1(00)D006A

BY:

DATE:

23.03.16

CONTRACT NO.

REV:

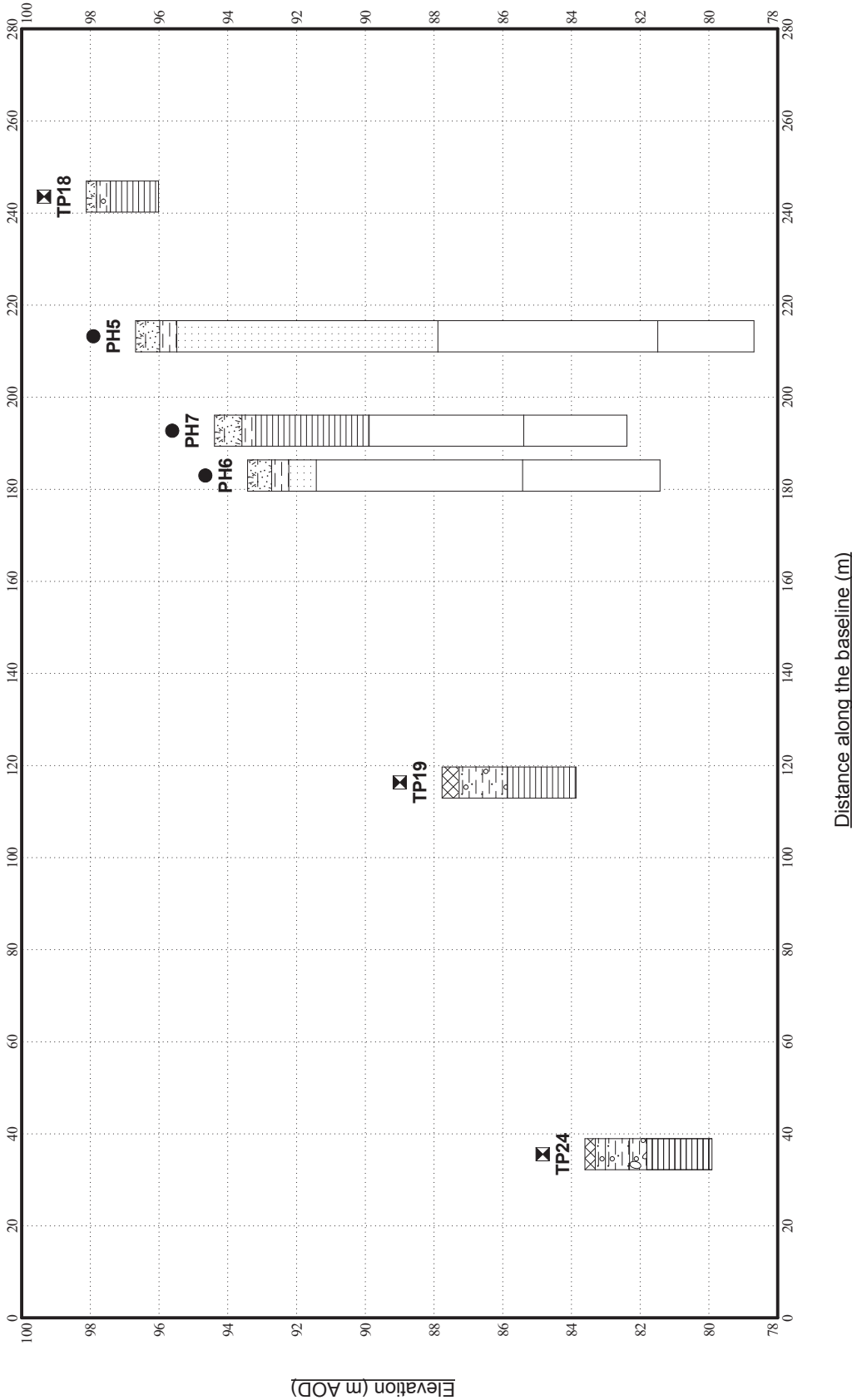
FIGURE 6

A

Scale 1 : 2,500

0 20 40 60 80 100m

SUBSURFACE SECTION DIAGRAM



HOLE TYPE MARKER LEGENDS:

- = Probeholes
- ☒ = Trial Pits

REV.	DATE	DESCRIPTION	BY	CHKD.	APR.
	22/03/2016		KF		
Scale					
m					
Scale X = 1:366 Scale Y = 1:129					
RSK Environment Ltd Fourways House 57 Hilton Street Piccadilly Manchester M1 2EJ					
CLIENT: Jones Homes (Yorkshire) Limited					
PROJECT: Bloomhouse Lane, Darton					
TITLE: Cross section A to A'					
CONTRACT REF: 301645					
DRAWING REF: 1 of 1					
DRAWING STATUS: FIGURE					
7					

DRAWING TRACK CODE: GINT LIBRARY: 18_06_GLB ST: STANDARD: A3:
LANDSCAPE: ELEV: 301645 DARTON GP: 22/3/16 17:26:16

SITEMAP AND SECTION BASELINE

MATERIAL LEGENDS



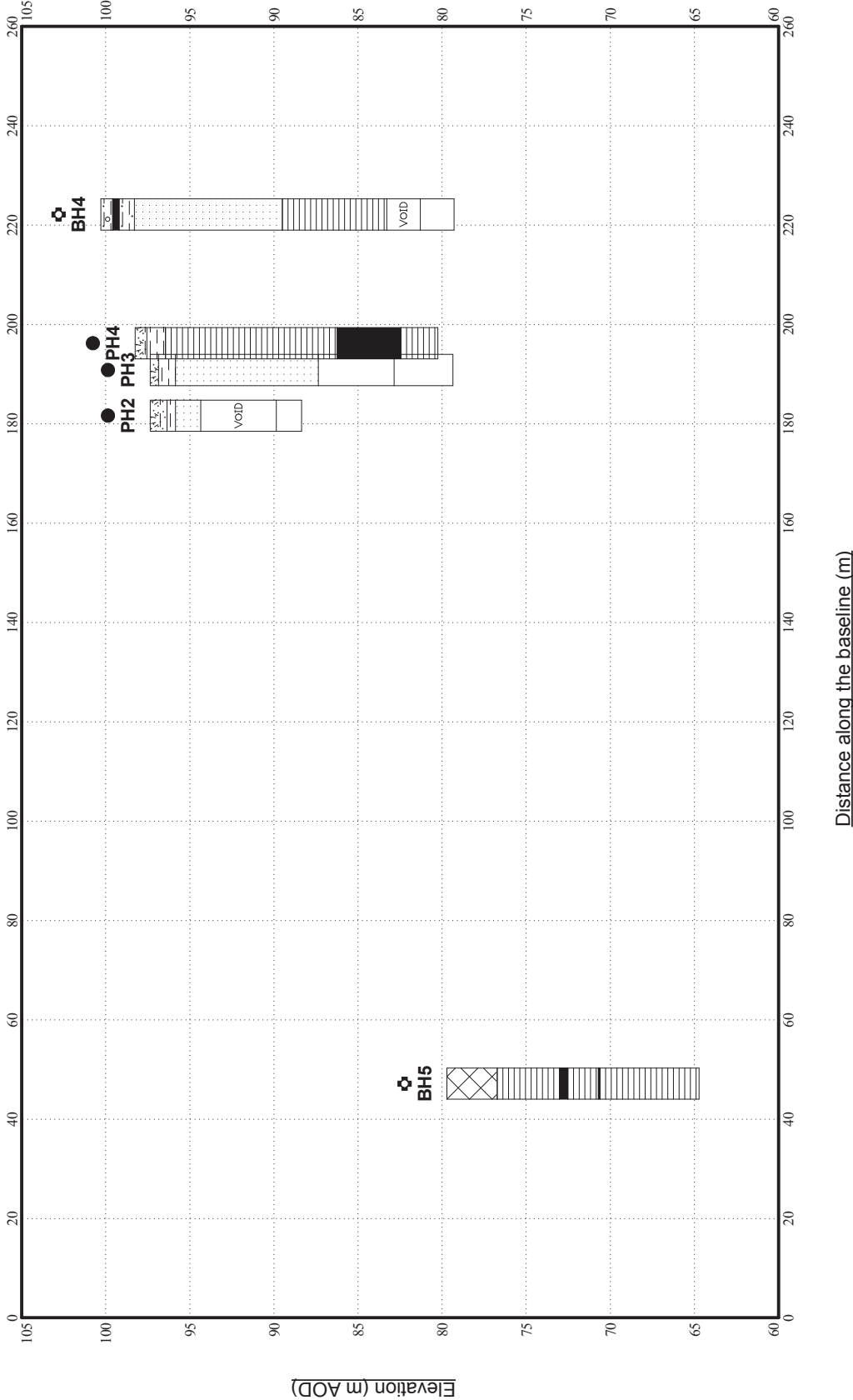
- CLAY
- Mudstone
- MUDSTONE

- Gravelly CLAY
- Sandstone

- Gravelly CLAY with COBBLES
- Sandy gravelly CLAY

- MADE GROUND
- Topsoil

SUBSURFACE SECTION DIAGRAM



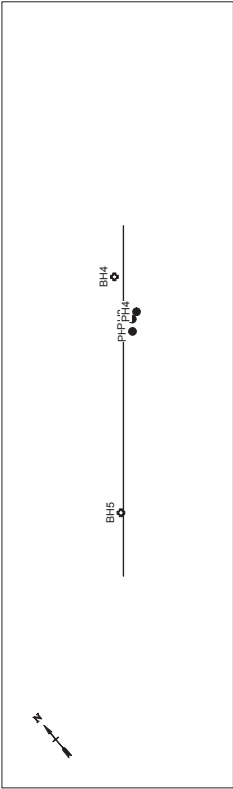
HOLE TYPE MARKER LEGENDS:

- = Boreholes
- = Probeholes

REV.	DATE	DESCRIPTION	BY	CHKD.	APR.
	22/03/2016		KF		
Scale					
m					
Scale X = 1:897 Scale Y = 1:265					
RSK Environment Ltd Fourways House 57 Hilton Street Piccadilly Manchester M1 2EJ					
CLIENT: Jones Homes (Yorkshire) Limited					
PROJECT: Bloomhouse Lane, Darton					
TITLE:					
Cross section B to B'					
CONTRACT REF:		DRAWING REF:			
301645		1 of 1			
DRAWING STATUS:					FIGURE
					8

DRAWING TRACK CODE: GINT LIBRARY: 18_06_GLB_STANDARD_A3:
LANDSCAPE: ELEV: 301645 DARTON GP: 22/3/16 17:52:16

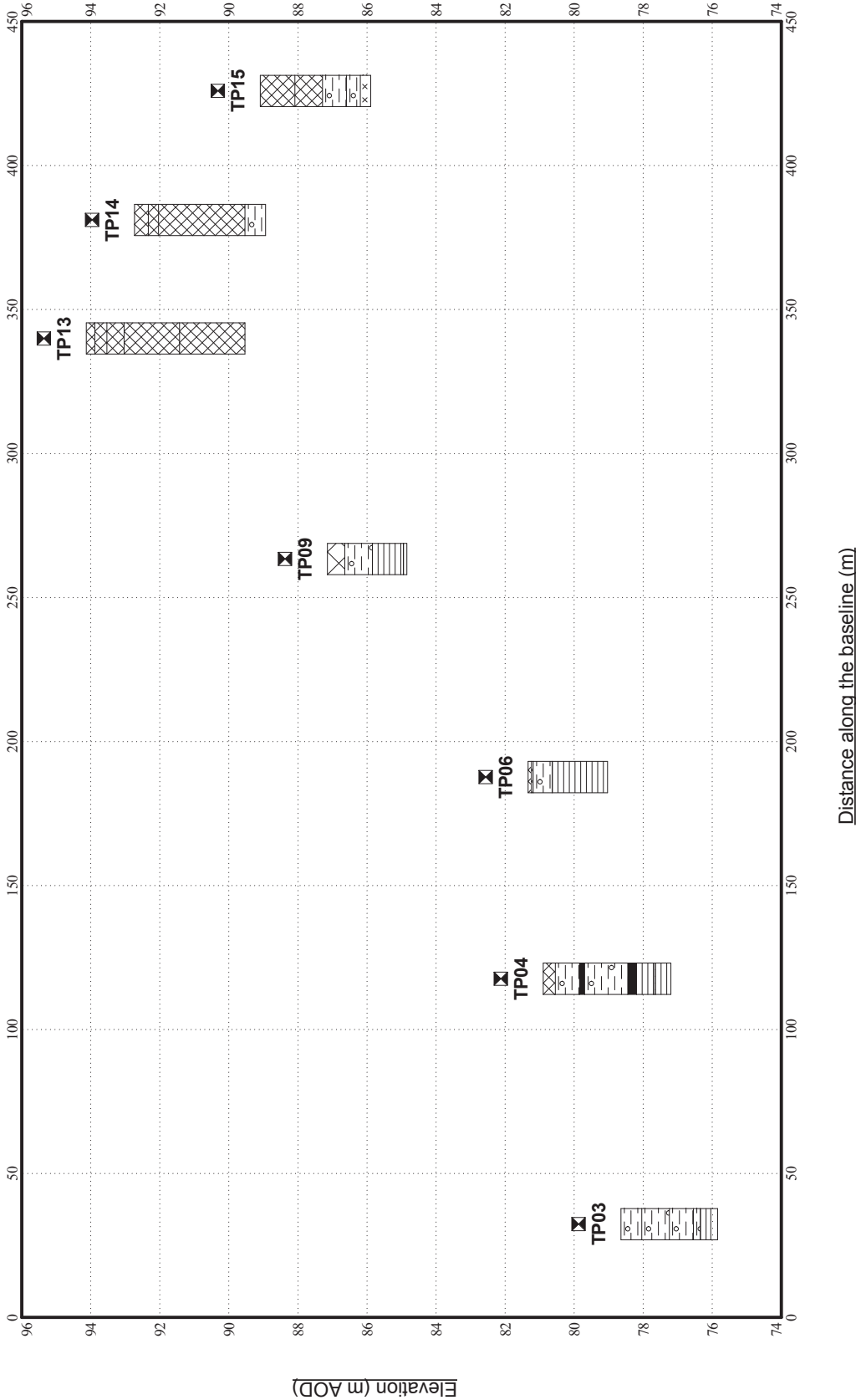
SITEMAP AND SECTION BASELINE



MATERIAL LEGENDS

- CLAY
- Sandstone
- Void
- Coal
- Sandy CLAY
- Mudstone
- Sandy gravelly CLAY
- Possible MADE GROUND
- Topsoil

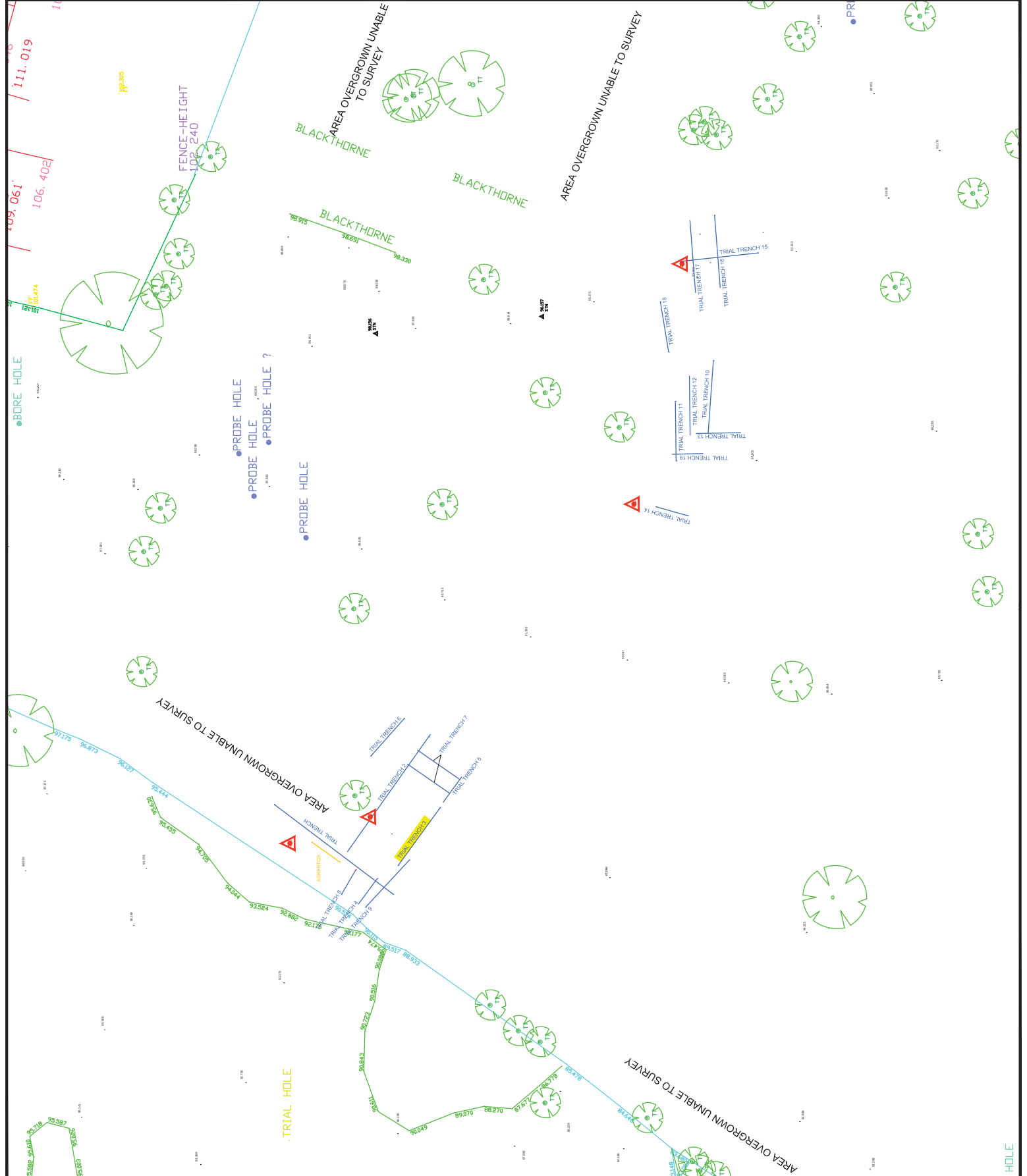
SUBSURFACE SECTION DIAGRAM



HOLE TYPE MARKER LEGENDS:
☒ = Trial Pits

REV.	DATE	DESCRIPTION	BY	CHKD.	APR.
	22/03/2016		KF		
m					
Scale X = 1:1552 Scale Y = 1:129					
RSK Environment Ltd Fourways House 57 Hilton Street Piccadilly Manchester M1 2EJ					
CLIENT: Jones Homes (Yorkshire) Limited					
PROJECT: Bloomhouse Lane, Darton					
TITLE: Cross section C to C'					
CONTRACT REF: 301645		DRAWING REF: 1 of 1			
DRAWING STATUS: FIGURE					9

DRAWING TRACK CODE: GINT LIBRARY V18 06/05/18 STANDARD: A3:
LANDSCAPE: ELEV: 301645 DARTON GP3: 22/03/16 17:50:16



LEGEND:

TRIAL TRENCH 6

TRIAL TRENCH 3

Trial trench location

Evidence of adit encountered

REV	A	22.03.16	FIRST ISSUE	HD	JH	JH
DESCRIPTION			BY CHD, APR			
Dimensions		m	Projection	Scale	Ordnance Survey	
				1:500	A3	

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PROJECT

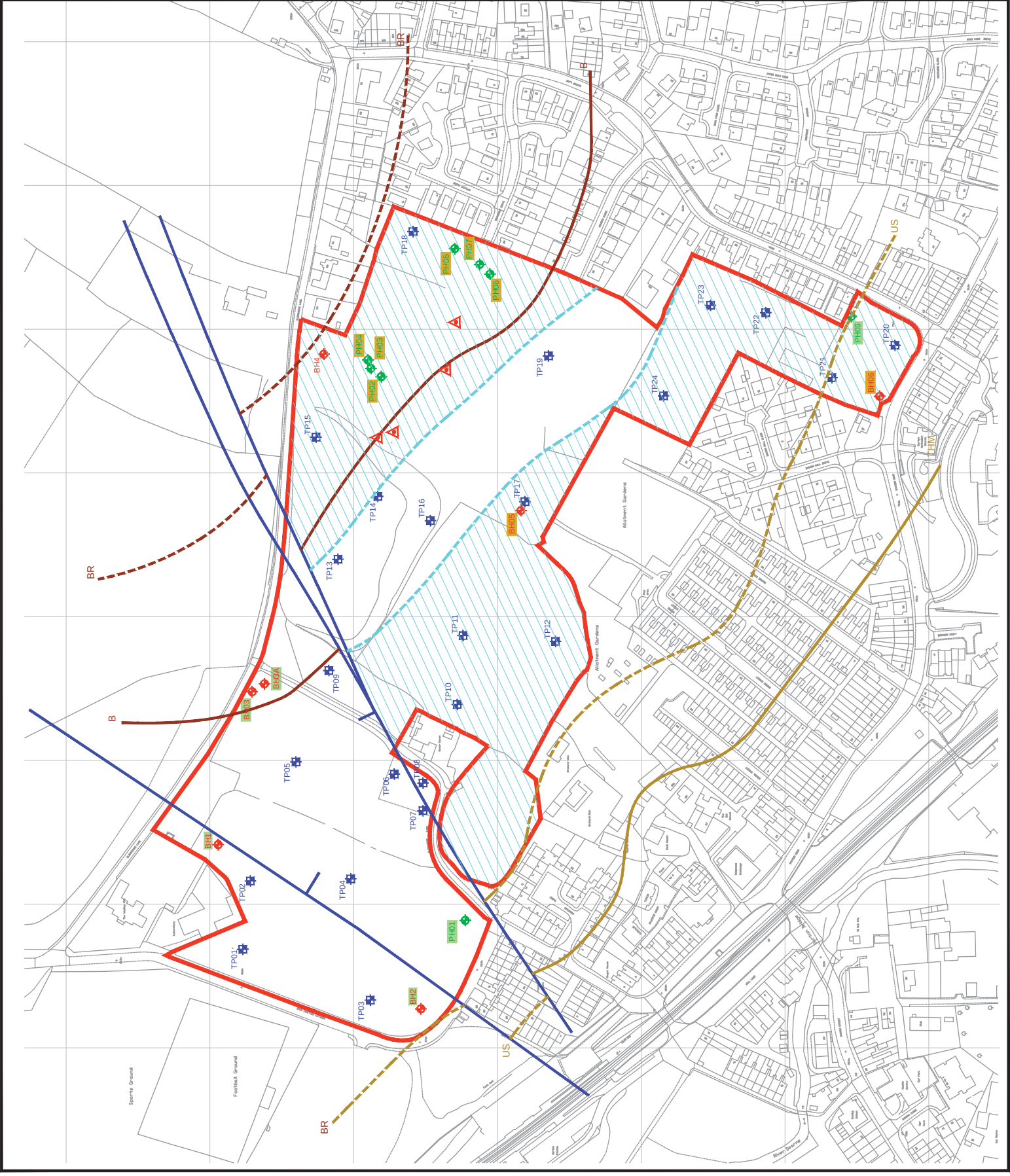
LAND OFF BLOOMHOUSE LANE, DARTON

TITLE

TRIAL TRENCH LOCATION PLAN

JOB NO.:	301645	DRAWING FILE:	301645-R1(00)D010A
BY:	DATE:	CONTRACT NO.	REV:
HD	22.03.16	FIGURE 10	A





LEGEND:

Site boundary

Fault

Barnsley Rider Coal (BR)

Barnsley Coal (R)

Unnamed seam (US)

Top High Moor Coal (THM)

Ten times seam thickness of competent rock demonstrated

Ten times seam thickness of competent rock not demonstrated

Area requiring mine work stabilisation

RSK borehole

RSK probe hole

RSK trial pit

Mine Adits

North Arrow

Scale

1:2,500

0 20 40 60 80 100m

RSK

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PROJECT

LAND OFF BLOOMHOUSE LANE, DARTON

TITLE

MINING CONSTRAINTS PLAN

JOB No.:

301645

DRAWING FILE:

301645-R1(00)D011A

BY:

DATE:

22.03.16

CONTRACT NO.

FIGURE 11

REV:

A

REV

A

22.03.16

FIRST ISSUE

BY

CHD, APR

JH

JH

Dimensions

m

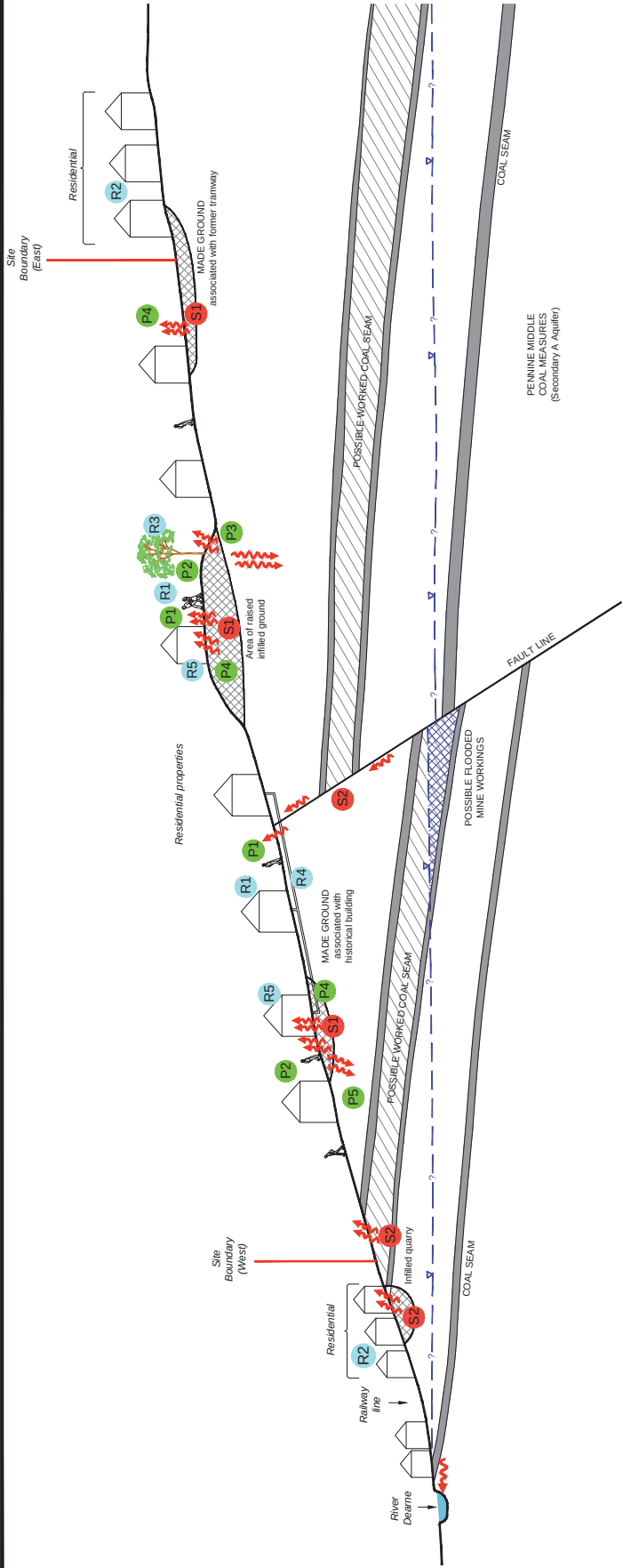
Projection

Scale

1:2,500

Grid Size

A3



SOURCES

- S1 Impact from contaminants associated with infilled material and made ground
- S2 Ground gas from flooded mine workings and infilled quarry

POTENTIAL CONTAMINATION PATHWAYS

- P1 Direct contact
- P2 Ground gas and soil gas inhalation
- P3 Root uptake
- P4 Chemical attack of infrastructure

SIGNIFICANT RECEPTORS

- R1 Site occupiers (residents)
- R2 Occupiers of adjacent land
- R3 Vegetation
- R4 Water supply pipes
- R5 Buildings and infrastructure

LEGEND:

S1

Sources

P1

Pathways

R1

Receptors

Potential Contamination pathways

REV	A	23.03.16	FIRST ISSUE	HD	JH	JH
Dimensions			Projection	Scale	Orig. Size	
				NTS	A3	

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CLIENT
JONES HOMES (YORKSHIRE) LIMITED

PROJECT
LAND OFF BLOOMHOUSE LANE, DARTON

TITLE
REFINED CONCEPTUAL
SITE MODEL

JOB No.:
301645
DRAWING FILE:
301645-R1(00)D012A

BY: DATE: 23.03.16 CONTRACT NO. FIGURE 12

REV: A