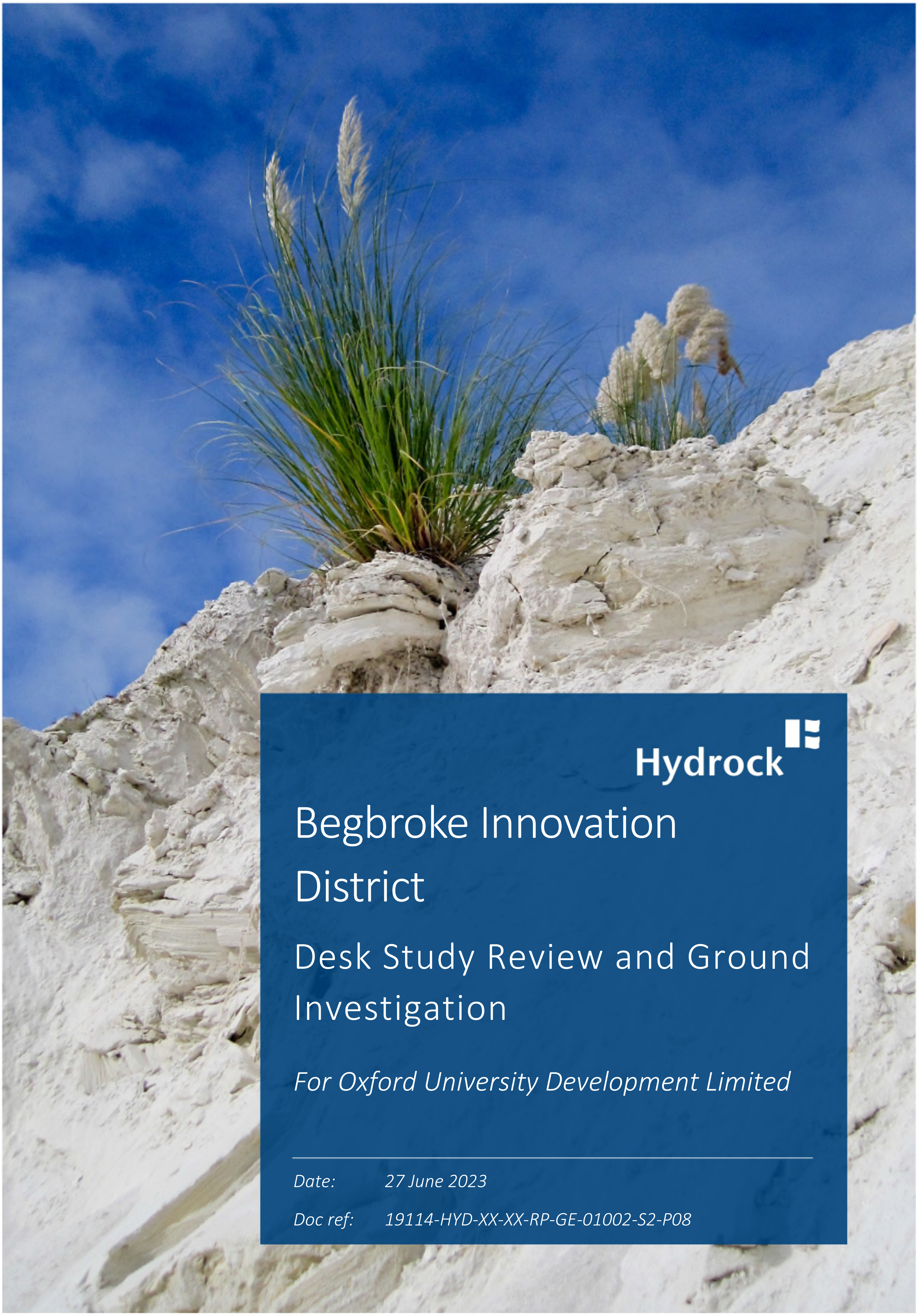
Appendix 15.1

DESK STUDY REVIEW AND GROUND INVESTIGATION



Hydrock

Begbroke Innovation District

Desk Study Review and Ground Investigation

For Oxford University Development Limited

Date: *27 June 2023*

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Executive Summary

SITE INFORMATION AND SETTING	
Objectives	The works have been commissioned to support to support the planning application, assist with clearing anticipated planning conditions and to assist the design of the development.
Client	Oxford University Development Limited.
Site name and location	Begbroke Innovation District. Located between Kidlington and the A44 Woodstock Road, approximately 8km to the west-north-west of Oxford. A nearby postcode is OX5 1GZ with the centre of the site at an approximate grid reference of 447925, 213503.
Proposed development	The site development proposals are understood to comprise a mixed housing and non-residential development. The proposed layout of the site has not been confirmed at the time of issue of this report. However, it is understood that the built environment will occupy the centre, west and south of the site, with the northern and eastern boundaries and the area of the landfill in the central-south of the site remaining as open space. A proposed footbridge and cycleway is proposed in the centre of the site crossing the Didcot and Chester Railway Line and a further proposed bridge over the canal in the southeast.
Site description	The site currently mostly comprises agricultural fields, used for arable farming, with several fields in the south-west of the site in use for raising poultry and deer. A field in the west of the site is used as allotment gardens. There are several farm storage barns shown as Parkers Farm in the central-east of the site. The total site area is approximately 170ha with the widest dimensions of approximately 1.5km north to south, and 1.3km west to east. An historical landfill (filled with inert/industrial waste) is present in the central-south of the site with an area of approximately 5.20ha. Sandy Lane bisects the site in a west to east orientation, through the approximate centre of the site. A railway line trends north to south, bisecting (but outside of) the site, and separates seven fields in the east (an area of approximately 43 hectares) from the rest of the site area. The approximately 7.9ha Begbroke Science Park is in the central-northern area (although not included in the investigation area) and is accessed by a roadway (Begbroke Hill road) off the A44 to the west. A pedestrian access road joins Begbroke Science Park to Sandy Lane to the east. A number of public footpaths are present leading to Begbroke Science Park and in the surrounding fields. An underground sewer crosses the site in a north to south direction and is present to the west of Begbroke Science Park (joining a pumping station in the north), before splitting into two in the south with one spur crossing site to the south of the landfill area (trending east to west), and the other continuing south beyond the site. The site is bounded by the A44 to the west, to the east by the Oxford Canal, to the north by fields and the Rowel Brook and to the south by open land. A fuel station is present adjacent to the south-west corner of the site. There are residential areas to the east of the Oxford Canal (Kidlington), Yarnton to the south-west, and Begbroke to the north-west. The southern section of Rushy Meadows Site of Special Scientific Interest (SSSI) borders 450m of the northern site boundary.

DESK STUDY SUMMARY	
Topography	The topography of the site is characterised by a plateau forming a topographic high in the west and centre of the site at approximately 67m Ordnance Datum (OD), sloping away from it as follows: • to the north towards Rowel Brook at approximately 63m OD and rising again to the north of Rowel Brook, to approximately 67mOD. and • To the east and south to a low-lying area at approximately 61m OD. The landfill area in the central-south, is between approximately 68.5m OD in the north-west, and slopes gently down to the south-east to approximately 64.5m OD and is between 0.5m and 1.0m higher than the surrounding land.
Hydrology	Rowel Brook enters the site in the north-west and flows west to east through the north of the site towards the Oxford Canal. A small watercourse (understood to be Thrupp Ditch), runs through Rushy Meadows (located to the north of the site), flowing in a north-south direction and converging with Rowel Brook on the central-northern edge of the site. There is also a small stream/ditch in the south of the site. All the streams and ditches on and in the immediate vicinity of the site were dry at the time of the investigation works, after an extended period of dry weather. The Oxford Canal forms most of the eastern boundary of the site.
Site History	The site is predominantly fields from the earliest available mapping to the present day with Parkers Farm shown in the central-east of the site. The railway line and Sandy Lane have been present from the earliest available mapping. Allotment gardens are shown in the west of the site from 1970. Begbroke Hill Farm (excluded from the site area) is shown in the central-north of the site until 1971 when it is shown as a Weed Research Associated (now Begbroke Science Park). Begbroke Hill Road is shown constructed off Woodstock Road to enter Begbroke Science Park located in the central-north of the site (excluded from the site area) from 1999. A number of gravel pits are shown in the surrounding area beyond the north-western boundary (Fern Hill Pits) and within the central-southern part of the site to the south of Sandy Lane, known as Sandy Lane Pits. Following completion of the gravel extraction operations, these pits were used as landfill and were backfilled by the early 1980's. Subsequent residential development has taken place over Fern Hill Pits and the western (off site) of the two Sandy Lane Pits. The eastern most Sandy Lane Pit was shown as a refuse pit until 1978 and remains undeveloped and backfilled slightly above the surrounding ground level.
Published Geology	Superficial Geology: • River Terrace Deposits (Summertown-Radley Sand and Gravel Member) in the central / northern plateau area of the site at topographically high areas of the site. • Alluvium in the east of the site. • 1st River Terrace Deposits anticipated to underlie the Alluvium in the east of the site. Solid Geology: • Oxford Clay Formation; comprising a dark grey mudstone; over • Kellaways Sand Member comprising interbedded silty sand and mudstone; over • Kellaways Clay Member comprising grey mudstone; over • Cornbrash Formation comprising bluish grey limestone weathering to olive or yellowish brown. The solid strata dip gently towards the south (2° or less).

Hydrogeology	The superficial deposits of the River Terrace Deposits and Alluvium are classified as Secondary A Aquifers. The solid deposits of the Cornbrash Limestone Formation and Kellaways Sand Member are classified as Secondary A Aquifers with the overlying Kellaways Clay Member and the Oxford Clay Formation classified as unproductive strata. The site is not in a Source Protection Zone. One abstraction consent is located 960m to the north-east of the site (operated by Unigate Dairies at Langford Lane, Kidlington, for general use). In areas adjacent to Rowel Brook in the north, and land east of the railway, there are areas identified as either primarily Flood Zone 2 and Flood Zone 3. The remainder of the site is shown as Flood Zone 1.
UXO Risk	A non-specialist unexploded ordnance (UXO) assessment indicates a low UXO risk.
INITIAL CONCEPTUAL SITE MODEL BASED ON DESK STUDY	
Potential on-site contaminant sources	• Made Ground associated with general historical activity. • Made Ground in the central-south of the site associated with the historical landfill. • Possible diesel fuel / heating oil around Parkers Farm and around unspecified tanks. • Ground gases from organic materials in the Made Ground and Alluvium. • Ground gases from materials in the landfill on the site. • Radon from underlying geology; • Leachate in the landfill waste. • Asbestos from existing buildings. • Pesticides and herbicides in the agricultural soils. • Naturally occurring arsenic in the geological soils.
Potential off- site contaminant sources	• Ground gases from materials in the landfills off-site. • Hydrocarbon fuels from adjacent petrol station in the south-west; and • Made Ground associated with the railway line bisecting (but outside of) the site.
Potential contaminant receptors	• Humans - residential with home grown produce / non-residential users (POS, commercial, research and development etc.). • Controlled waters – surface water and groundwater. • Plants. • Ecology (including Rushy Meadows SSSI, off site to the north). • Buildings / property.
GROUND MODEL PROVEN BY INVESTIGATION	
Ground and groundwater conditions encountered by investigation	The ground conditions encountered in the ground investigation comprise: • A surface covering comprising: » Topsoil Made Ground – between 0.05m and 0.80m below ground level (bgl), comprising clay. Gravel of brick and concrete (and occasional glass, metal and fabric) were encountered in the topsoil above the former Sandy Lane landfill. » Landfill Made Ground – in the former Sandy Lane landfill, to between 0.05m and 3.90m bgl, comprising brown gravelly sand (predominantly ash) with abundant man-made putrescible waste and gravel sized fragments of concrete, slag, brick, glass bottles, plastic bottles, plastic wrapping, scrap metal, wires, batteries, bike frames, animal bones and newspaper (dated 1960's). » Localised Made Ground – to between 0.10m and 1.20m bgl, generally comprising sandy gravelly clay or clayey sand with gravel constituents of limestone, sandstone flint and brick.

- Agriculturally Disturbed Topsoil across most of the site to between 0.10m bgl to 0.80m (average thickness of 0.31m bgl), comprising a brown slightly gravelly clayey sand or dark brown slightly gravelly sandy clay.
- Superficial deposits, comprising:
  - Alluvium; encountered close to the streams in the north and south of the site and across the east of the site between the railway line and Oxford Canal, to depths of between 0.45m bgl and 3.15m bgl, comprising soft orangish and yellowish-brown sandy clay to slightly sandy slightly gravelly clay, and a sandy gravel with gravel constituents of flint and limestone. Locally, an organic odour and remnant rootlets were noted.
  - Head Deposits; identified locally over the River Terrace Deposits, to depths of between 0.50m bgl to 1.70m bgl comprising orangish brown sandy clay, locally slightly gravelly, of flint.
  - River Terrace Deposits encountered in the higher areas of the site (west, centre and north) to depths of between 0.80m bgl (where extending down slopes) and 5.90m bgl, comprising generally medium dense to dense (locally loose) slightly gravelly slightly clayey sand / sandy gravel with gravel constituents of flint, limestone and ironstone and underlying the Alluvium in the east and south of the site. Locally, clay was thinly interbedded between the granular layers with a cohesive band at between 62mOd to 59mOD to the east and south of the landfill. The River Terrace Deposits were mostly extracted in the Sandy Lane pits, but a thin band remains beneath the Landfill in the central-south of the site.
- Solid geology, comprising:
  - Oxford Clay Formation in the centre and south of the site (at topographic highs) and in the southeast of the site to depths of between >1.90m to >10.45m bgl comprising grey to bluish grey clay, occasionally thinly laminated with shell fragments, selenite crystals and sand pockets. In a number of locations, bluish grey slightly clayey sand and siltstone bands were encountered.
  - Kellaways Sand Member sub-cropping at the surface in the north of the site, south of the site and underlying the Oxford Clay Formation, comprising a soft grey or orangish brown sandy clayey silt, sand or sandy clay.
  - Kellaways Clay Member sub-cropping at the surface in the north of the site, consisting of stiff fissured grey, yellowish brown or greenish grey clay.
  - Cornbrash Limestone Formation comprising a light grey to yellowish brown limestone gravel or stiff yellowish brown sandy gravelly clay. Encountered sub cropping in the north of the site and below the Kellaway's Clay Formation (where penetrated), and considered to extend at depth under the entire site.
  - Forest Marble Formation outcropping in the northeast of the site and underlying the Cornbrash Limestone Formation (where penetrated) comprising an upper grey mudstone with interbeds of a strong grey limestone. Limestone band thickness increased with depth.
  - White Limestone Formation encountered underlying the Forest Marble Formation (at depth where fully penetrated) comprising a light grey strong limestone.
  - The solid geological strata dip gently (0.7° to the south).

Evidence of petroleum hydrocarbon contamination were noted in some soils, mainly those associated with the landfill. No evidence of hydrocarbon contamination was noted elsewhere including the area of Parkers Farm.

Groundwater was encountered at depths between 0.10m bgl and 4.00m bgl during the investigation. Groundwater levels recorded post-fieldwork ranged between 0.03m bgl and 5.05m bgl (57.92m OD to 68.08m OD). Monitoring is ongoing.

The shallow groundwater flow within the superficial deposits is from the west of the site, from the topographic high, to the east and south-east, although in the north of the site

	groundwater flow is locally towards Rowel Brook (from the north and the south). In the far east of the site (in the floodplain), groundwater flows are to the south and at a shallower hydraulic gradient, but potentially influenced by the Oxford Canal which borders the east of the site. Within the bedrock geology in the north of the site, groundwater flow is shown from west to east although this is likely due to a complicated bedrock outcropping and superficial deposits and temporal limits of the investigation. Groundwater flow is likely to be towards the south following the dip of the strata.
WATER AND RUSHY MEADOWS SSSI	
Water and Rushy Meadows SSSI	Based on the data to date, groundwater flow in the far north of the site (adjacent to Rushy Meadows) is to the south towards Rowel Brook. Consequently, it is unlikely that any impact from the proposed development will extend to the north, past Rowel Brook and be transmitted upgradient to the SSSI. It is also unlikely that any changes in water level associated with the proposed development will significantly change the water levels to the north of Rowel Brook (which is more susceptible to any changes to the north and east of Rushey Meadows, than to changes to the south of Rowel Brook). Potential adverse impacts on the Rushy Meadows SSSI based on the proposed development are considered negligible.
SUMMARY OF GEOTECHNICAL CONCLUSIONS – ASSUMING THE HISTORICAL LANDFILL AREA IS POS	
Groundworks	Local obstructions associated with former development, including foundations, floor slabs and services, should be anticipated in Parkers Farm, along with known underground services (e.g. rising sewer main). The presence of shallow rock in the north of the site may cause localised difficult excavation. Whilst the Cornbrash Formation can usually be excavated by large plant and toothed buckets, localised breaking out may be required for excavation of rock. Collapse / spalling of trial pit faces was noted during trial pit excavation in several locations within Alluvium and River Terrace Deposits. This was noted particularly in the coarse soils and was exacerbated where groundwater ingress occurred. In addition, the Oxford Clay can be fissured and whilst instability due to fissuring was not noted in the trial pit excavations, fissuring can cause instability of excavations open for longer periods or long lengths. Temporary trench support, or battering of excavation sides, is recommended for all excavations that are close to, or below the water table, or are to be left open for any length of time, and must be provided for entry by personnel. Where shallow groundwater has been observed, the rate of water ingress to the proposed excavations is likely to be significant through the River Terrace Deposits and Alluvium. In these circumstances, groundwater control by sump pumping may not be sufficient to deal with anticipated flows and significant high volume pumps (running for extended time) are likely to be required. If high volume pumps are not sufficient, alternative methods of dewatering, or use of impermeable cut-offs would be required.
Earthworks, slopes and retaining	Soils are generally suitable Class 1, Class 2 and Class 4. The earthworks will need to be undertaken under a Materials Management Plan and in accordance with a suitable design and Specification. The use of hydraulic binders is not recommended for Oxford Clay soils. Given the relatively gentle slopes across the site, it is assumed, that significant retaining walls will not be required. As a preliminary assessment, 1V:3H slopes using natural subsoils are likely to be stable (subject to detailed design).
Foundations	Preliminary foundation recommendations are as follows: • For houses up to 2½ storeys: strip/trench fill foundations across the centre, north and west of the site (deepening due to trees as required) to depths of between 1m and a

	maximum depth of 2.5m bgl, depending on site specific ground conditions and the locations of existing and proposed trees and hedges. • Pad foundations for commercial buildings with relatively light loads. • Ground improvement by vibro stone columns (VSC) with reinforced strip foundations or pads in areas underlain by loose sands and soft clays, located to the east and south of the landfill. • Piled foundations will be required in areas underlain by deep Made Ground, and soft compressible deposits such as Alluvium, or to the south and east of the landfill, due to risks of excessive settlement from anticipated structural loads. • Piled foundations for houses where foundation depths are greater than 2.50m, such as due to trees on shrinkable clays, or deep low strength / loose / compressible strata. • Pile foundations are likely to be required for bridge abutments. Subject to further parcel specific assessment. Allowable net bearing pressure of 100 - 125 kN/m² should be available for strip/trench fill foundations and 130 - 150 kN/m² for pad foundations depending on the underlying geology. Deepening of foundations/heave protection is likely to be required to allow for the effects of trees where foundations are in cohesive deposits with shrinkage potential. Suspended slabs recommended to the presence of medium/high shrinkage potential clay soils depending on underlying geology. However, subject to further investigation, detailed design and time of construction, ground bearing slabs may be possible for some parts of the site. For commercial/industrial units and bridges these are likely to fall within Category 2 structures and specific geotechnical design with be required.
Roads and pavements	For road / pavement design, a design CBR of 3% will generally be achievable over the majority of the site, and 5% where the sub-grade is granular.
Sustainable drainage	Assessment of the infiltration rate data the ground model concludes: • The Alluvium, proven along the northern and southern edges of the site (and expected to be present along the eastern edge), is considered unsuitable for infiltration drainage due to a combination of high clay content (low permeability) and the presence of groundwater. • The thicker River Terrace Deposits in the centre of the site (at a topographic high) are considered suitable (subject to further testing) for infiltration drainage where there is sufficient depth of gravel present above the water table. However, there will need to be sufficient thickness of permeable soil above the water table to allow soakaway design. • The thinner River Terrace Deposits in the north, south and east of the site, at the topographic lower points, are considered unsuitable for infiltration due to shallow groundwater levels resulting in limited storage capacity, generally due to a limited thickness of River Terrace Deposits, merging with the Alluvium and overlying the Oxford Clay. • The Kellaways Clay Member and Oxford Clay Member (sub-cropping around the periphery of the northern part of the site, and present at depth below the site), are considered unsuitable for infiltration drainage due to their low permeability (high clay content). • Infiltration drainage should not be installed in the historical landfill site, located in the central-south of the site. The civils designer and flood risk designer will need to take groundwater water levels into account when designing the attenuation ponds. The design options available are to either: • increase the base level of the pond, so it is above the groundwater table; or

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	• line the pond. It should be noted that if it is proposed to line the ponds, the potential hydrostatic uplift needs to be considered with the design and the liner will need to be placed at an over excavated depth and covered with soil to prevent the liner lifting. • Due to the potential effects of a variable groundwater table on the sides of the attenuation ponds, subject to detailed assessment and design, Hydrock believe the ponds may require reinforcement to prevent wash out and collapse of the pond sides.
Buried concrete	Design Sulphate Class - DS-1 and ACEC Class AC-1 applies to the entire site for buried concrete in most of the natural underlying superficial deposits. This is equivalent to Design Chemical Class DC-1 for a 50 year design life with regards to: Head Deposits; Alluvium; River Terrace Deposits Design Sulphate Class - DS-4 and ACEC Class AC-4. Equivalent to Design Chemical Class DC-4 for a 50 year design life with regards to the Oxford Clay Formation, Kellaways Sand Member, Kellaways Clay Member, Forest Marble Formation and White Limestone Formation. Design Sulphate Class - DS-3 and ACEC Class AC-3. Equivalent to Design Chemical Class DC-3 for a 50 year design life with regards to the Cornbrash Limestone Formation.
SUMMARY OF GEO-ENVIRONMENTAL ASSESSMENT	
Human Health	The following are considered as potential contamination risks which will need to be given consideration to discharge likely planning conditions depending on the details of the development layout used for the application: Landfill Area – assuming public open space (POS) end use • Beryllium and dibenz(a,h)anthracene in the Topsoil Made Ground. • Arsenic, beryllium, lead, benzo(b)fluoranthene and dibenz(a,h)anthracene in the Landfill Made Ground. • Asbestos fibres and ACM in the landfill Made Ground. Wider Site (depending on final proposed residential or non-residential end use) • ACM within buildings around Parkers Farm to be demolished; • Asbestos fibres within soils around Parkers Farm (none encountered during the investigation, but needs confirmation after completion of demolition works).
Phytotoxicity	The following are considered as potential residual contamination risks to plant life: • Copper, nickel and zinc in the Topsoil – Made Ground over the historical Landfill • Boron, copper, nickel and zinc in the Landfill – Made Ground.
Controlled waters	Tests on groundwater samples exceed the EQS for cadmium, cobalt, chromium (III), copper, manganese, nickel, ammonium, ammoniacal nitrogen, nitrite and sulphate. However, based on risk evaluation and subject to regulatory approval it is considered these do not present a significant risk to controlled waters.
Radon	Basic to full protection measures are required in any buildings constructed north of Rowel Brook.
Potable water supply pipes	Standard potable water supply pipework is envisaged for most of the site outside of the former landfill area. However, confirmation should be sought from the water supply company. Within the landfill area barrier pipe is recommended. However, confirmation should be sought from the water supply company at the earliest opportunity.
Ground gases or vapours:	The risk from ground gases is low to moderate for most of the site (subject to additional and on-going monitoring) and CS1 conditions apply across the wider site. CS2 conditions apply within the landfill area.

ENABLING WORKS	
Proposed mitigation measures	With regards to the areas of the site outside of the former landfill area, the mitigation measures proposed to remove unacceptable contamination risks are: • Removal of asbestos from buildings to be demolished by specialist Contractors in accordance with the asbestos survey and relevant legislation). • Supplementary testing of Made Ground to confirm absence of asbestos fibres in soils and its removal where necessary. Assuming the landfill is proposed for POS use, the mitigation measures proposed to remove unacceptable risks from the identified contamination in the landfill for Open Space end use include: • The installation of a 450mm engineered cover, comprising a bonded geogrid break layer (to deter burrowing animals), subsoil beneath a topsoil thickness of between 150mm and 300mm. • Importation and placement of subsoil/topsoil in line with a Materials Management Plan. To assist with land forming, it is recommended the landfill is compacted using a High Energy Impact Compactor, to densify the existing landfill soils, reduce site levels and allow the cover system to be placed, whilst minimising disposal. As part of the mitigation, Hydrock would recommend that a cover system is placed across the landfill, and extending outside the landfill boundary by a minimum of 3.0m (to allow embedment). Given the human health risks of burrowing wildlife such as badgers bringing potentially contaminated materials to surface, Hydrock recommend the relocation of the badger setts which are present on the edges of the site to selected locations under the control of suitably licensed ecologists. If these cannot be closed and artificial setts need to be provided on the landfill, design to prevent burrowing into the landfill will be required (steel mesh). In addition, to prevent disturbance of the landfill material such as by roots and tree collapse, Hydrock recommends removal of existing trees and hedges (and introducing controlled re-planting, as necessary). This will also allow the cover system to be firmly embedded beyond the edge of the landfill and to mitigate any potential human health risks from contact with the landfill soils.
Earthworks	If earthworks are proposed for the wider site, a geotechnical design and an Earthwork Specification will be required to allow reuse of materials where suitable, along with the production of a Materials Management Plan (MMP) and its approval by a Suitably Qualified Person (SQP). Verification reports by competent independent geotechnical specialists will be required following completion of any earthworks to ensure compliance with the Specification and MMP.
Waste management	Excavated soils to be disposed of as waste, are likely to be classed as non-hazardous waste with natural uncontaminated subsoils likely able to be disposed of at an 'inert' landfill. Within the former landfill area, the soils are likely to comprise a mix classifying as hazardous and non-hazardous waste. All works will need to be undertaken in accordance with a Materials Management Plan (MMP) and its approval by a Suitably Qualified Person (SQP). It should be noted that the landfill soils are currently a waste and will remain a waste until they are recovered. Recovery of soils is difficult in the current regulatory regime, and Hydrock recommend that any soils excavated from the landfill area cannot be re-used on the site and will need to be disposed of off-site as waste.

FUTURE CONSIDERATIONS	
Further work	Following the ground investigation works undertaken to date, the following further works will be required: • Additional investigation to the east and south of the landfill to further define the softer, looser soils. • Demolition / refurbishment asbestos survey of farm structures. • Completion and reporting of the ongoing gas monitoring, hence the conclusions in this report are provisional, subject to the completion of monitoring. The following works should be undertaken once more details of the development layout have been finalised; • supplementary detailed ground investigation to allow geotechnical design and parcel specific investigations; • discussion and agreement with utility providers regarding the materials suitable for pipework; • discussions with regulatory bodies and the warranty provider regarding the conclusions of this report; • assessment of tree influence on foundations and design of foundations; • discussions with Vibro-stone Column Contractors regarding the viability of, and potential improvement by, VSCs; • discussions with piling contractors regarding conclusions of this report and design of the piles where these are required; • provision of geotechnical design for any Geotechnical Category 2 structures (earthworks, retaining, floor slabs, large scale foundations etc.); • production of Remediation Strategies and Verification Plans as necessary (and agreement with the regulatory bodies and the warranty provider); • production of Materials Management Plans relating to reuse of soils at the site and importation of soils to the site; • management of remediation and mitigation works; and • verification of the earthworks, remediation and mitigation works. If the landfill area is proposed for residential or non-residential end use, other than POS, the recommendations in this report should be reviewed and it is likely that extensive further investigation for mitigation and geotechnical design would be necessary.

This Executive Summary forms part of Hydrock Consultants Limited report number 19114-HYD-XX-XX-RP-GE-01002-S2-P08 and should not be used as a separate document.

1. INTRODUCTION

1.1 Terms of reference

In July 2022, Hydrock Consultants Limited (Hydrock) was commissioned by Oxford University Development Limited (OUD, also known as the Client) to a undertake site investigation, comprising review of a Phase 1 desk study previously produced by others, and Phase 2 ground investigation at Begbroke, Oxfordshire. Supplementary ground investigation works were commissioned by OUD in January 2023.

The site is 170 hectares in area, located between Kidlington and the A44 Woodstock Road, approximately 8km to the west-north-west of Oxford. The nearest postcode is OX5 1GZ. Currently, the site is mostly open fields surrounding the existing Begbroke Science Park, which does not form part of the investigation area.

Hydrock understands that preliminary plans for the proposed development comprise a mixed housing and non-residential development. The proposed layout of the site has not been confirmed at the time of issue of this report. However, it is understood that the built environment will occupy the centre, west and south of the site, with the northern and eastern boundaries and the area of the landfill in central south of the site remaining as open space. In addition, it is understood a road bridge is required to cross the railway line in the eastern part of the site, and a noise / screening bund is required adjacent to the railway line.

The investigation works have been undertaken in accordance with Hydrock's proposals referenced 19114-GMNO/FP003 Rev A, with the subsequent Client's instructions to proceed (email from King Technical Consultancy (on behalf of OUD), dated 22nd July 2022) and 19114/GMNO/FP004/Rev002 and 19114/GMNO/FP/005 both dated 15th December 2022 with the subsequent Client's instruction to proceed (email from King Technical Consultancy (on behalf of OUD), dated 03rd January 2023).

Investigation works with regards to Begbroke Hill Road (Access to Begbroke Science Park) are reported in a separate report reference 19114-HYD-XX-XX-RP-GE-01003.

1.2 Objectives

The works have been commissioned to support the planning application, assist with clearing anticipated planning conditions and to assist the design of the development.

The objectives of the Phase 1 Desk Study review are to formulate a preliminary Ground Model and an initial Conceptual Site Model of the site to identify and make a preliminary assessment of any potential geo-environmental and geotechnical risks to the proposed development.

The objectives of the Phase 2 Ground Investigation are to:

- determine ground and groundwater conditions, and allow collection of samples for geotechnical testing and chemical analysis and installation of gas and groundwater monitoring wells;
- update the initial Conceptual Site Model in accordance with the principles of the Defra Land Contamination Risk Management procedure (LCRM);
- To identify potential geo-environmental mitigation requirements to enable development; and
- to provide outline geotechnical recommendations for design.

1.3 Scope

The site investigation includes the review of a Phase 1 Desk Study produced by others, and to undertake a Phase 2 Ground Investigation.

The Desk Study review comprises:

- Summary of the desk study including the preliminary Ground Model and Preliminary Risk Assessment.
- A field reconnaissance (walkover) to determine the nature of the site and its surroundings including current land uses, topography and hydrology.
- Commission and review of BGS Radon Risk Reports.
- Development of a preliminary Ground Model representing ground conditions at the site.
- Development of an initial Conceptual Site Model (iCSM), including identification of potential complete contaminant linkages.
- A qualitative assessment of any geo-environmental risks identified.
- Identification of any plausible geotechnical hazards.

The scope of the Phase 2 Ground Investigation comprises:

- A preliminary ground investigation including trial pitting, hand pits, soakaways, windowless sampling, rotary cored boreholes and cable percussive boring, to:
  - » obtain data on the ground and groundwater conditions of the site;
  - » allow collection of samples for geotechnical and chemical laboratory analysis;
  - » allow geotechnical field tests to be undertaken; and
  - » install gas and groundwater wells.
- Gas concentration and flow monitoring and groundwater level gauging.
- Groundwater sampling.
- Geotechnical and chemical laboratory analysis.
- Updating the preliminary Ground Model.
- Preparation of a geotechnical risk register.
- Presentation of initial geotechnical design recommendations.
- Formulation of an updated Conceptual Site Model (CSM), including identification of any plausible complete contaminant linkages.
- Completion of a generic quantitative risk assessment (GQRA) of any identified chemical contaminants to establish ‘suitability for use’ under the current planning regime.
- Discussion of any potential environmental liabilities associated with land contamination (soil, water and gas).
- Identification of outline mitigation requirements to ensure the site is ‘suitable for use’.

1.4 Available information

The following relevant information has been provided to Hydrock by OUD for use in the preparation of this report:

- A topographic survey plan (unreferenced);
- Jubb Consulting Engineers Limited. May 2018. 'Land at Begbroke, Begbroke. Phase 1 Desk Study Report', Ref: 18182-DTS-011, undertaken for Begbroke Tripartite, Oxfordshire;
- Jubb Consulting Engineers Limited. December 2019. 'Land at Begbroke, Begbroke. Ground Conditions Assessment Report', Ref: 18182-GCA-1 undertaken for Begbroke Tripartite, Oxfordshire; and
- Buro Happold. November 2022. 'Proposed Road Alignment and Surface, Option 3', Ref: 0052188 (Sketch Plan).

The Jubb Report (December 2019) included reference to a Factual Report as follows, although this has not been provided to Hydrock:

- Terra Firma (South) Limited. November 2019. 'Factual Ground Investigation Report – Begbroke, Oxfordshire', Ref: 6307.

Railway Bridge and Canal Bridge Design Details / Options:

- Buro Happold. March 2023. 'Begbroke Park, PR7B Site Connection Option 2 – Shared Path Plan & Longitudinal Section'. Ref BEG-BUR-XX-XX-SK-CE-0005 Rev P02.
- Buro Happold. March 2023. 'Begbroke Park, PR7B Site Connection Option 1 –Road and Shared Path Plan & Longitudinal Section'. Ref BEG-BUR-XX-XX-SK-CE-0004 Rev P02.
- Robert Bird Group. January 2023. 'Oxford Corridor Phase 2A Level Crossings. Sandy Lane Footbridge Location Plan'. Ref 5060-RBG-177052-SL-DR-CV-00001 Rev P01 (approval in principle).
- Robert Bird Group. January 2023. 'Oxford Phase 2A. Sandy Lane General Arrangements. Ref 5060-RBG-177052-SL-DR-CV-83101 Rev P01.
- Robert Bird Group. January 2023. 'Oxford Corridor Phase 2A Level Crossings. Sandy Lane Footbridge General Arrangements. Ref 5060-RBG-177052-SL-DR-ST-13001 Rev P01 (approval in principle).

Hydrock has previously undertaken and reported on the following works, which are incorporated into this report (and superseded by this report):

- Hydrock. October 2021. 'Begbroke, Oxfordshire. Soil Infiltration Rate Assessment', Ref: 19114-HYD-XX-XX-TN-GE-01002, undertaken for Oxford University Development Limited; and
- Hydrock. October 2021. 'Begbroke, Oxfordshire. Landfill Geo-Environmental Assessment', Ref: HYD-19114-XX-XX-RP-GE-01001, undertaken for Oxford University Development Limited.

It is understood that the Client either commissioned or has obtained assignment of the above documents and Hydrock has assumed full reliance can be placed upon their contents. Should this not be the case, Hydrock should be informed at the earliest opportunity.

In addition, Hydrock has downloaded the following report (used for information only) from the Cherwell District Council (CDC) website, in relation to Rushy Meadows SSSI, which is located to the north of the site:

- White Young Green Limited. February 2018. 'Rushy Meadows SSSI: Hydrogeological and Hydrogeological Desk Top Study (DTS)', Ref: A106710 undertaken for CDC.

1.5 Regulatory context and guidance

The investigation work has been carried out and reported in general compliance with recognised best practice, including (but not limited to) BS 5930:2015+A1:2020, and BS 10175:2011+A2:2017.

The geotechnical section of this report is prepared in general accordance with BS EN 1997-1+A1:2013, BS EN 1997-2:2007 and BS 8004:2015. This report constitutes a Ground Investigation Report (GIR) as described in Part 2 of Eurocode 7 (BS EN 1997-2) (EC7). However, it is not intended to fulfil the requirements of a Geotechnical Design Report (GDR) as specified in EC7.

Where relevant the relevant requirements of the 2023 NHBC Standards have also been applied.

The methods used follow a risk-based approach, the first stage of which is a Phase 1 desk study (or desk study review) and field reconnaissance, with any potential geo-environmental risks assessed qualitatively in the iCSM. This is done using the 'source-pathway-receptor contaminant linkage' concept to assess risk as introduced in the Environmental Protection Act 1990 (EPA, 1990). Any potential geotechnical risks are also assessed at the Phase 1 desk study and site reconnaissance stage.

Phase 2 comprises intrusive ground investigation work and testing. The factual information from the desk study and the ground investigation are used to develop the iCSM into the Conceptual Site Model (CSM). This CSM is based on the Ground Model of the site physical conditions and an exposure model of the possible complete contaminant linkages. The CSM forms the basis for GQRA in accordance with current guidelines (LCRM, 2022). This GQRA might lead to the requirement for more Detailed Quantitative Risk Assessment (DQRA). Professional judgement is then used to evaluate the findings of the risk assessments and to provide recommendations for the development.

The geo-environmental and geotechnical aspects are discussed in separate sections. Throughout the report the term 'geotechnical' is used to describe aspects relating to the physical nature of the site (such as foundation requirements). The term 'geo-environmental' is used to describe aspects relating to ground-related environmental issues (such as potential contamination). However, it should be appreciated that this is an integrated investigation, and these two main aspects are inter-related. Designers should take all aspects of the investigation into account.

Remaining uncertainties and recommendations for further work are listed in Section 10 and Section 11 respectively.

2. DESK STUDY REVIEW (AND FIELD RECONNAISSANCE)

2.1 Introduction

Hydrock has been provided with a Desk Study for the site prepared by others (as detailed in Section 1.4), which is provided in Appendix B. The following sections summarise the pertinent information presented in the Desk Study, supplemented by additional information as required.

It should be noted that a north-south railway bisects the site, but is not included within the site. In addition, the area east of the railway line was not included as part of the historical Desk Study Report but, where relevant the desk study summary presented below provides updated information for the eastern section of the site.

2.2 Site location

The site is located between Kidlington and the A44 Woodstock Road, approximately 8km to the west-north-west of Oxford. A nearby postcode is OX5 1GZ with the centre of the site at approximate National Grid Reference 447925, 213503.

The location of the site is shown in Figure 2.1.

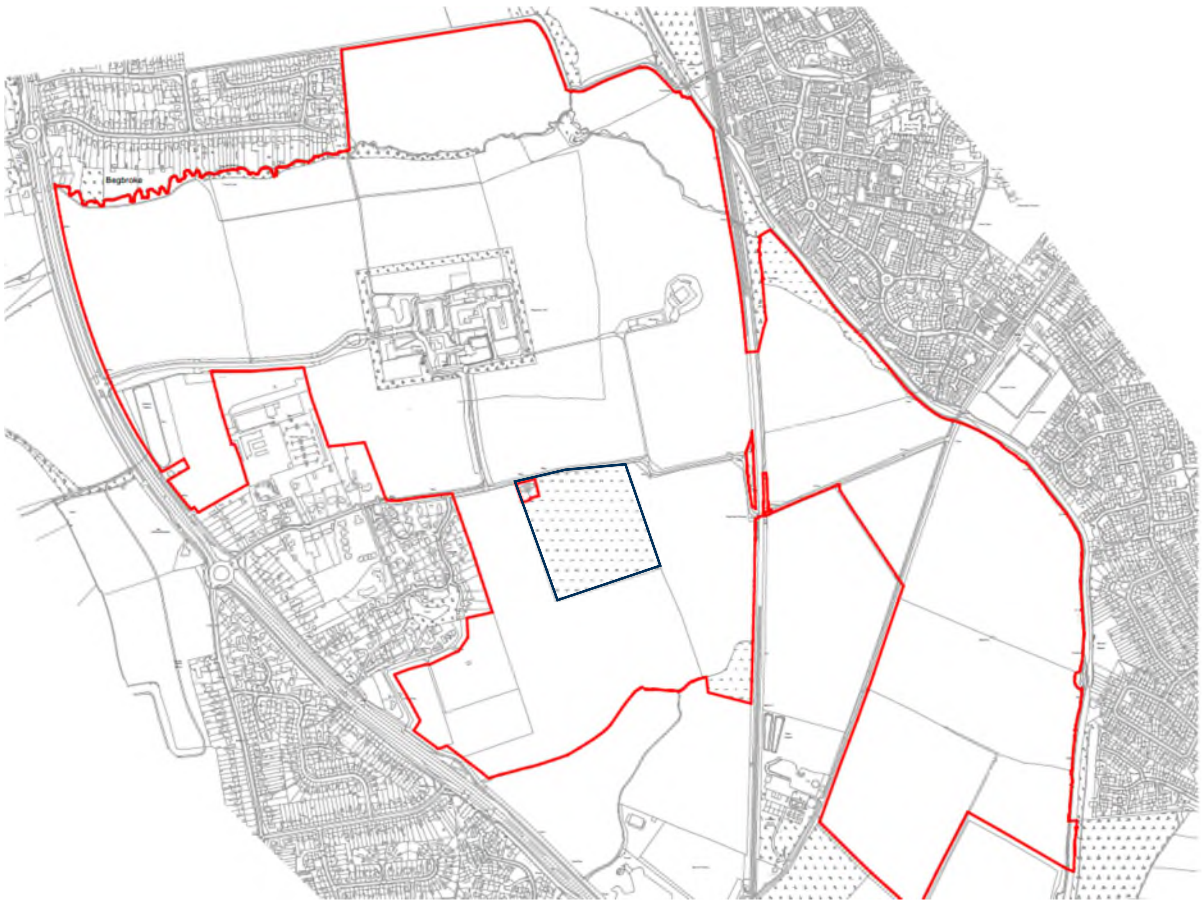

Figure 2.1: Site Boundary Plan

2.3 Site description

The site mainly comprises agricultural fields, used for arable farming. Several fields in the south-west of the site are in use for raising poultry and deer. A field in the west of the site is used as allotment gardens. A few farm buildings (storage barns) with asbestos cement roof sheeting are present in the central east of the site (Parkers Farm).

Begbroke Science Park in the central north of the site totals an approximate area of 7.9ha and is accessed along Begbroke Hill Road, off the A44 to the west. Although within the site boundary, this was not included within the investigation area.

A pedestrian access road joins Begbroke Science Park to Sandy Lane to the east.

A number of public footpaths are present leading to Begbroke Science Park and in the surrounding fields.

The blue outlined area in Figure 2.1 represents a former landfill of approximately 5.20ha in area. This comprises an undeveloped hummocky field of long grass, nettles and brambles with large trees and dense bushes along the field boundaries.

Sandy Lane bisects the site in a west-east orientation through the approximate centre of the site. The Great Western Railway line trends north-south, bisecting (but outside of) the site and splitting seven fields in the east (an area of approximately 43 hectares) from the remainder of the site area.

The total site area, including the land to the east of the railway line, is approximately 170ha. The longest north-south dimension measures approximately 1.5km and the west-east dimension is approximately 1.3km.

Rowel Brook runs along the northern boundary of the site in the north-west and part of the site and flows into the Oxford Canal to the north-east.

The site is bounded by the A44 to the west with residential areas (Yarnton) located in the centre of the western boundary either side of Sandy Lane; to the east by the Oxford Canal and residential properties beyond (Kidlington); to the north by open/fields in the centre including Rowel Brook and Rushy Meadows SSSI beyond; Rowel Brook and residential properties (Begbroke) beyond the north-east boundary; and to the south by open land.

The topography of the site is characterised by a plateau in the topographic highs of the site in the west and centre of the site at approximately 67m OD before sloping:

- to the north towards a stream at approximately 63m OD and rising again (on the northern side of Rowel Brook) to approximately 67m OD beyond.
- To the east and south to approximately 61m OD.

The landfill part of the site is at between approximately 68.5m OD in the north-west, sloping gently down to the south-east to approximately 64.5m OD and is between 0.50m and 1.00m higher than the surrounding land.

2.4 Detailed Site description

Jubb Consulting (2018) subdivided the site into 19 individual areas west of the railway line (east of the railway line was beyond the scope of their report) (see Appendix B) which are summarised below, along with Hydrock's observations during later walkover surveys and investigation works. Field numbering is as indicated in Figure 2.2, which corresponds with Jubb (2018) and, in order to retain consistency, Hydrock have continued the numbering sequence to cover the remaining fields (Fields 20 to 26). Individual field descriptions are presented in Table 2.1 and Table 2.2.

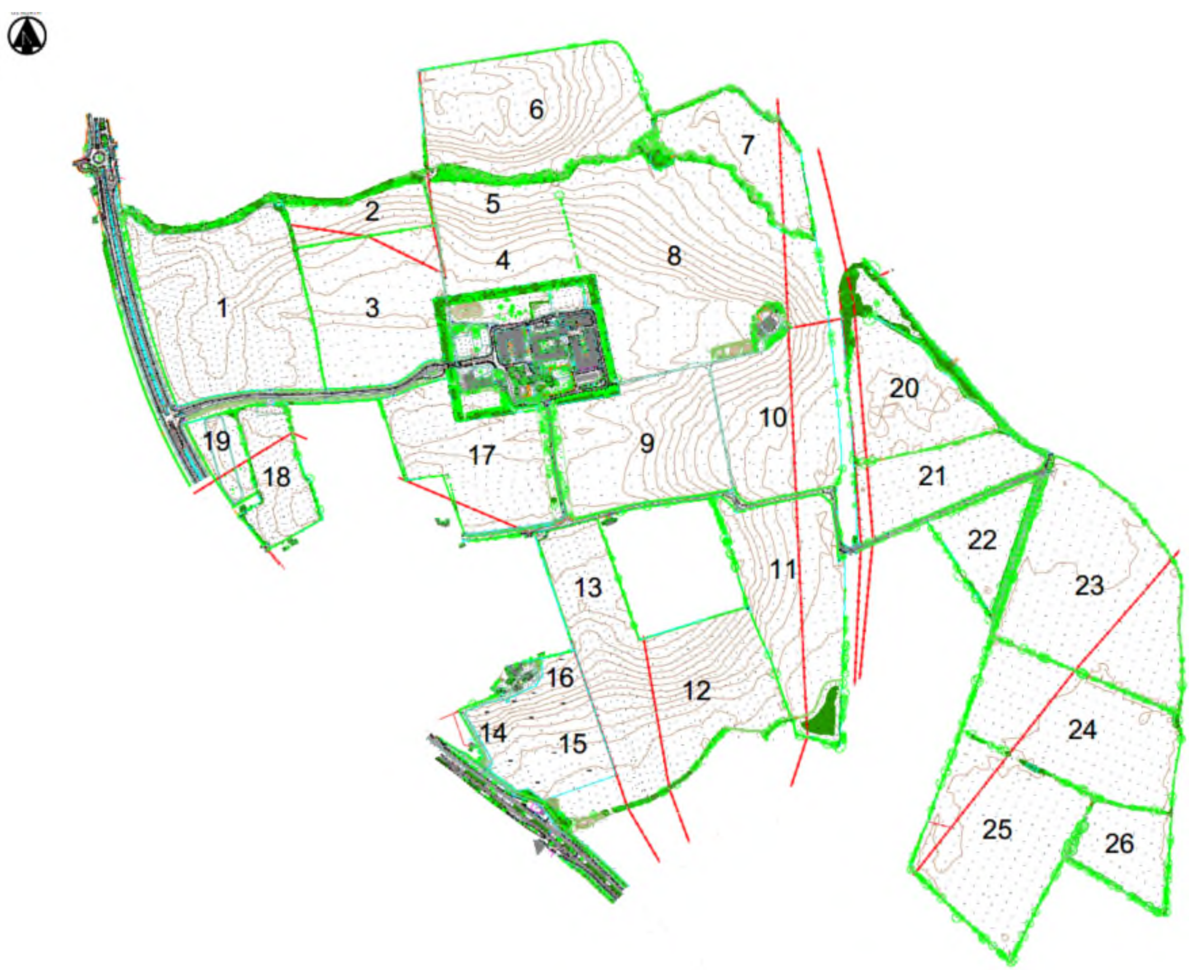

Figure 2.2: Field Numbering Plan

Table 2.1: Field Description Table 1 of 2 (2018 Jubb Walkover)

Field Reference	Approximate Area (ha)	Field Description
Field 1	10.6	Agricultural land with a topographic fall to the north, towards Rowel Brook in the north, with Rowel Brook, present along the northern boundary, flowing west to east. A footpath is present along a trackway leading to a Thames Water sewage pumping station in north-east corner of the field. Hedgerows surround field boundaries with trees located in the north adjacent to Rowel Brook.

Field Reference	Approximate Area (ha)	Field Description
Field 2	2.0	Agricultural field with a topographic fall to the north and rising slightly to the east. High Voltage (HV) overhead electricity cables trend north-west to south-east in the central-south of the field. A second overhead HV cable along eastern field boundary trends north to south. Raised manhole covers are present along the northern field boundary associated with a sewer. A public footpath follows southern field boundary. Rowel Brook forms the northern boundary. Hedgerows form the remainder of field boundaries.
Field 3	7.0	Agricultural field with a slight topographic fall to the north. HV cables follow the eastern boundary of the field, trending north to south with a second HV cable trending north-west to south-east, from the south-east corner of the site towards the centre of Field 2. Northern, western, and southern boundaries are formed by hedgerows with the eastern boundary open to a concrete trackway with Field 4 beyond. Manholes are present along the western boundary, associated with a sewer line.
Fields 4 & 5	5.2	Agricultural land with a topographic fall to the north. A public footpath crosses the field east to west, which is noted as the subdivision between Field 4 & 5. Rowel Brook forms the northern field boundary. Hedgerows are present along the eastern and southern boundaries, with Begbroke Science Park beyond to the south and trees are present adjacent to Rowel Brook. A concrete surfaced track forms the western boundary.
Field 6	9.1	Agricultural land with a topographic fall from the crest of the slope in the north to the south and east into the south-eastern corner. An overhead HV cable is present along the western boundary of the site, along with a sewer and public footpath, which trends north to south. Residential properties form the western boundary, with hedgerows to the north, Rowel Brook and mature trees to the south, and hedgerows and mature trees to the east with Rushy Meadows SSSI beyond.
Field 7	4.6	Open land, which is relatively flat and at the lowest point of the site. Identified as waterlogged during the walkover, Field 7 is adjacent to Rowel Brook which forms the southern boundary of the site. A public footpath crosses the field trending east-west with overhead HV cables present in the east of the field, trending north-south. Hedgerows and mature trees form the eastern boundary, with Oxford Canal beyond to the north-east and the railway line to the east. Hedgerows and mature trees form the northern boundary, with Rowel Brook and Rushy Meadows SSSI beyond.
Field 8	15.3	Agricultural land which slopes down to the north and east from the west where it borders Begbroke Science Park. Overhead HV cables cross the east of Field 8, trending north-south. A number of stockpiles are present in south of Field 8 comprising topsoil and wood chippings with barn structures and areas of hardstanding located in the south-west.

Field Reference	Approximate Area (ha)	Field Description
		Probable asbestos cement fragments are visible on the surface in the north and farm buildings with probable asbestos cement sheet roofing present on the barns in the south-west. The southern boundary is formed by a concrete access track to the farm buildings, with the northern boundary former by Rowel Brook and mature trees. The eastern boundary is formed by a railway line, which is located on an approximate 2m high embankment compared to the surrounding land.
Field 9 & 10	13.8	Agricultural land sloping towards the east, with a concrete track (trending north-south), subdividing Fields 9 & 10. An overhead HV cable continues through the east of Field 10, trending north-south from Field 8. Begbroke Science Park forms part of the northern boundary, with a concrete surfaced track to Field 8, and the barns in the north-east. The eastern boundary is formed by the railway line on an embankment with the western boundary formed by a concrete surfaced track for pedestrian access to Begbroke Science Park. Hedgerows form the southern boundary with Sandy Lane beyond.
Field 11	7.0	Agricultural land sloping towards the east and south from the north-western corner. An overhead HV cable is present in the centre, trending north-south. The field is bounded to the south by a former landfill area with mature trees and hedgerows and agricultural land. Hedgerows with Sandy Lane beyond define the northern boundary, while a ditch and marshy land define the southern boundary and the railway line on an embankment defines the eastern boundary trending north-south.
Field 12	9.7	Agricultural land sloping from the north to the south, towards an open ditch. Two overhead cables are present with one following the western boundary trending north-south and a second in the south (central) trending north-south to the south-western corner of the landfill located to the north. A manhole cover is located in the north-east, associated with an underground sewer. The northern boundary is half agricultural land (Field 13) and half former landfill, which is surrounded by hedgerows and mature trees. A mound of wood chipping is present in the south-west corner. The western boundary is formed by chain-link fencing to livestock areas, and mature trees and hedgerow to a Shell Fuel Station to the south-west. Field 12 is bound to the south by the open ditch, hedgerows and mature trees and to the east by hedgerows.
Field 13	3.1	Agricultural land gently sloping slope with a continuation into Field 12. An overhead HV cable is present in the west, trending north-south. Field 13 is bounded by the former landfill and mature trees in the east, a residential property in the north-east, hedgerow and Sandy Lane to the north and hedgerow and residential properties beyond to the west.
Field 14, 15 & 16	4.9	Livestock fields containing deer, poultry and goats separated by mesh fencing. A gravel track is present along the western boundary leading to farm cottages north of the livestock fields. Bordered by agricultural fields to the east and south (Field 12), farm buildings to the north and trackway, residential properties and the A44 to the west.

Field Reference	Approximate Area (ha)	Field Description
Field 17	6.2	Agricultural fields, relatively flat at the crest of sloping ground to the north and south. An overhead HV cable crosses the field trending north-west to south-east in the south-west corner of the field. A grass strip with sporadic trees is in the east of the field, adjacent to Begbroke pedestrian access roadway. Bounded by hedgerows to the south, west and north with sporadic mature trees along the north, west and eastern boundary. Begbroke Science Park and access road are located to the north, Sandy Lane to the south, residential properties and Yarnton Garden Centre to the west as well as Begbroke Pedestrian access to the west.
Field 18	2.6	Agricultural fields, relatively level with a gravel area in the north. An overhead HV cable crosses site trending south-west to north-east in the approximate centre of the field. Bounded by hedgerows with the allotments beyond to the west, access road to Begbroke Science Park to the north, residential properties to the south and hedgerows with sporadic matures trees to the east with Yarnton Garden Centre beyond.
Field 19	1.4	Allotments bounded by hedgerows and the A44 to the west, hedgerows with access road to Begbroke Science Park beyond to the north, hedgerows and sporadic mature trees with agricultural land to the west (Field 18) and a hedgerow with a residential property beyond to the south.

Additional fields to the east of the railway line and the landfill in the central-south, as indicated on the wider plan, total a further seven fields (Fields 20 to 26). Field descriptions at the time of the Hydrock Ground Investigation for the land east of the railway line, and the former landfill area are provided in Table 2.2.

Table 2.2: Field Description Table 2 of 2 (2022 Hydrock Investigation)

Field Reference	Approximate Area (ha)	Field Description
Field 20	5.3	Overgrown and relatively level. Overhead HV cables are present in the west of the field, trending north-south. Bounded by a railway line on an embankment to the west, hedgerows and sporadic trees to the north, west and south, with Oxford Canal located beyond the east, a grassed field (Field 21) to the south and open land to the north.
Field 21	4.2	Grassed field relatively level. Two overhead HV cables are located in the west, trending north-south. Hedgerows and sporadic trees are located along the field boundaries with overgrown land (Field 20) to the north, Oxford Canal to the east, Sandy Lane to the south and a residential property with the railway line on a raised embankment to the west.
Field 22	2.4	Grassed triangular shaped field and relatively level. Located to the south of Sandy Lane and west of Kidlington Lane. Agricultural land is located to the south. Field boundaries are formed by hedgerows with sporadic mature trees.

Field Reference	Approximate Area (ha)	Field Description
Field 23	11.4	Agricultural field and relatively level. An overhead HV cable crosses the field entering in the central south of the field trending north-east to south-west. A raised manhole cover is present in the north-west of the field associated with sewer infrastructure. A public footpath follows the western border of the site. Field boundaries are predominantly formed by hedgerows and mature trees as well as by the Oxford Canal to the north and east with residential properties beyond, agricultural fields to the south (Field 24) and Kidlington Lane to the west.
Field 24	8.4	Agricultural field and relatively level. An overhead HV cable crosses the field entering in the central south of the field trending north-east to south-west. A public footpath follows the western border of the field. Field boundaries are predominantly formed by hedgerows and mature trees as well as by the Oxford Canal to the east with residential properties beyond, agricultural fields to the south (Fields 25 & 26) and north (Field 23) and Kidlington Lane to the west.
Field 25	8.6	Agricultural field and relatively level. An overhead HV cable enters the field in the south-west trending north-east to south-west. A public footpath follows the western border. An area in the central north of the field is overgrown. Field boundaries are predominantly formed by hedgerows and mature trees as well as by agricultural land (Field 26) and a solar panel farm to the east, agricultural fields / open land to the south, agricultural land to the north (Field 25) and Kidlington Lane to the west with a disused sewage works beyond.
Field 26	2.9	Agricultural field and relatively level. Field boundaries are predominantly formed by hedgerows and mature trees and the field is bounded by Oxford Canal to the east, a solar panel farm to the south and agricultural fields to the north (Field 24) and west (Field 25).
Former Landfill	5.2	Hummocky land generally between 0.50m and 1.00m above the surrounding ground levels, with a gentle slope towards the south-west from 68.50m OD to 64.50m OD. The vegetation on the area predominantly consists of long grass, nettles and brambles, with large trees and dense bushes along the field boundaries. Field boundaries are formed by mature trees and hedgerows.

2.5 Site History

The site comprises fields from the earliest mapping (1876) until the present day with a field in the west (Field 19) shown as allotment gardens from the 1970's.

Parkers Farm is shown in the central-east of the site (currently two farm sheds) from the earliest available mapping with tanks (unknown above or below ground) shown around Parkers Farm from 1981 to 1983.

Begbroke Hill Farm (excluded from the site area) is shown in the central-north of the site until 1971, when it is shown as Weed Research Associates (now Begbroke Science Park). Begbroke Hill Road is shown as constructed off Woodstock Road and entering Begbroke Science Park located in the central-north of the site from 1999.

A railway line (Great Western Railway) is present, bisecting (but outside of) the site, from the earliest available mapping to the present day. The railway line separates the site into two areas and Sandy Lane trending east-west is shown through the centre of the site.

A number of 'small' buildings are shown in the central-north of Field 25 until 1981, when they are no longer shown.

A number of gravel pits are shown in the surrounding area located beyond the north-western boundary (Fern Hill Pits) and to the east and west of the central part of the site (south of Sandy Lane and known as Sandy Lane Pits). All pits were backfilled by the early 1980's with subsequent development over Fern Hill and the western of the two Sandy Lane Pits (located off-site). The Sandy Lane Pit in the east was shown as a refuse pit until 1978 and remains undeveloped and backfilled to ground level.

A petrol filling station is shown adjacent to the southern field (Field 12) from the 1920s to the present day.

Surrounding development has been continuous, with the villages of Yarnton, Begbroke and Kidlington expanding throughout the available mapping period to the current layout. Begbroke Science Park is shown from 1971 and shown as Weed Research Associates with various phases of development and expansion to the current day layout.

2.6 Geology

The published geology of the site is shown in Figure 2.3.

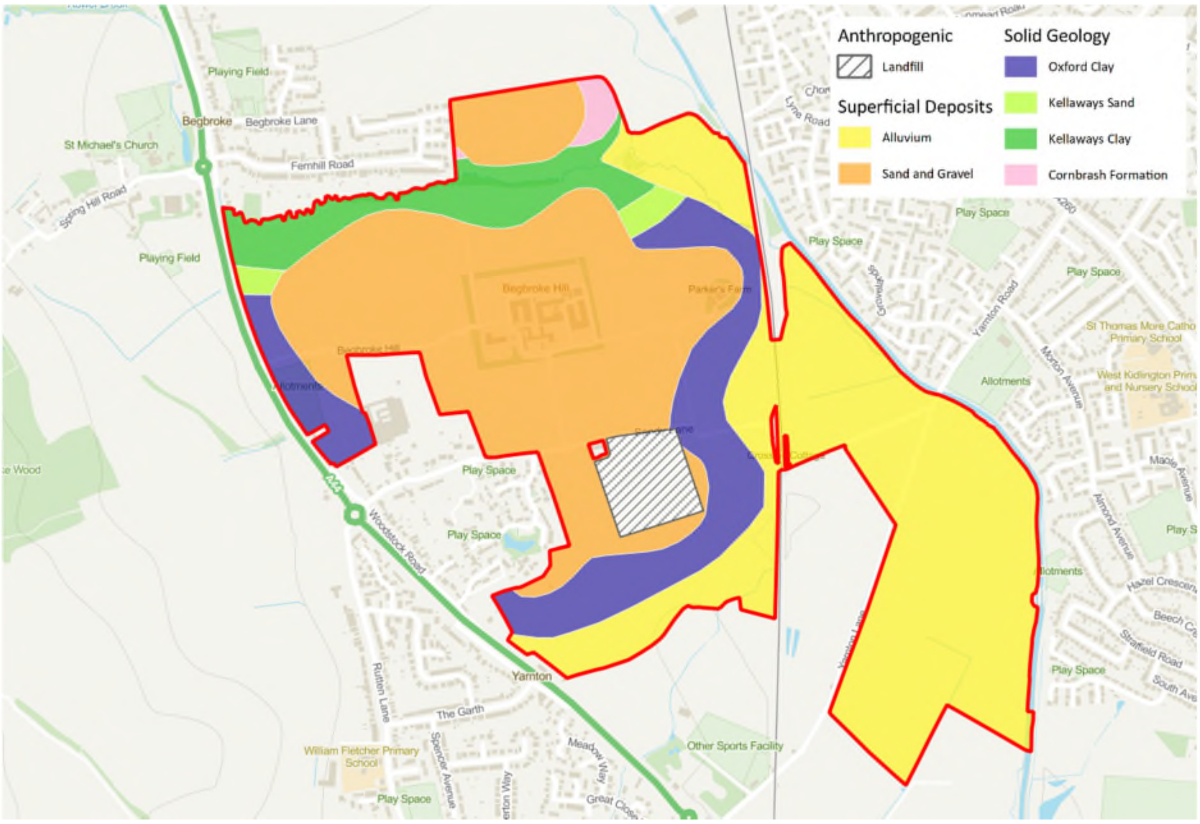

Figure 2.3: Geological map summary

The superficial geology comprises:

- Summertown-Radley Sand and Gravel Member (orange on Figure 2.3), located on the topographical highs of the site (2nd River Terrace Deposit).
- Alluvium (yellow on Figure 2.3), shown towards the topographical lows of the site in the east and south, and extending east beyond the railway line.
- 1st River Terrace Deposits, not shown on Figure 2.3. However, anticipated to underlie the Alluvium.

The solid geology comprises:

- Oxford Clay Formation, comprising a dark grey mudstone; over
- Kellaways Sand Member, comprising an interbedded silty sand and mudstone; over
- Kellaways Clay Member, comprising a grey mudstone; over
- Cornbrash Limestone Formation, comprising a bluish grey limestone weathering to olive or yellowish brown.

The solid geology dips gently towards the south at a gradient of approximately 1(v):40(h) (less than 2°).

A historical BGS borehole (SP41 SE6), located close to the western boundary of the Science Park, encountered 1.40m of brown silty clay over 3.10m of sand and gravel, over dark grey Oxford Clay at 4.50m below ground level (bgl). Groundwater was encountered approximately 3.00m bgl, within the sand and gravel deposits.

A second historical BGS borehole (SP41 SE10) near the southern boundary of the site, encountered 0.70m of alluvial clay, over 4.10m of sandy gravel, over Oxford Clay. Groundwater was recorded at less than 1.00m bgl.

2.7 Hydrogeology

The superficial deposits of the Summertown-Radley Sand and Gravel Member and Alluvium are classified as a Secondary A Aquifer.

The solid deposits of the Cornbrash Limestone Formation and Kellaways Sand Member are also classified as Secondary A Aquifers, with the Kellaways Clay Member and the Oxford Clay Formation as a unproductive strata.

The site is not in a groundwater Source Protection Zone. There is one groundwater abstraction consent located 960m north-east of the site (operated by Unigate Dairies at Langford Lane, Kidlington, for general use), which is considered unlikely to be affected or have an effect on the site.

The environmental data report indicates a potential for groundwater flooding to occur at surface across most of the site. However, this is more likely to be a risk in the lower lying areas around the perimeter of the site.

2.8 Hydrology

2.8.1 General

The nearest surface water feature is Rowel Brook which enters site in the north-west and flows west to east through the north of the site towards the Oxford Canal.

A small watercourse (understood to be Thrupp Ditch), runs through Rushy Meadows (located to the north of the site), flowing in a north to south direction and converging with Rowel Brook on the central-northern edge of the site.

There is also a small stream/ditch in the south of the site and a number of small, open ditches throughout the site. The Oxford Canal forms most of the eastern boundary of the site.

Reference to the Environment Agency website shows the site is located within the catchment of the Thames River Basin District, with the specific river water body being the Thames (Evenlode to Thame) Water Body. The current (2019 cycle 2) overall status under the Water Framework Directive is ‘moderate’.

2.8.2 Rushy Meadows Site of Special Scientific Interest (SSSI)

Rushy Meadows SSSI is located to the north of the site, is approximately rectangular in shape and comprises an area of 8.74ha.

Natural England (https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1001685), describes Rushy Meadows as comprising “*unimproved alluvial grassland alongside the Oxford Canal, in which low intensity, traditional management has produced rich meadows with fen communities containing several uncommon species. Meadow habitats of this type are now both rare and under threat in Britain. Rushy Meadows represents one of the few surviving sites in a district where such grasslands have declined in an area following agricultural improvement and urban development.*

The meadows are situated on terrace alluvium and gravels which have weathered to produce loamy soils….”

A small watercourse (thought to be Thrupp Ditch) runs through Rushy Meadows, flowing in a north-south direction and converges with Rowel Brook to the south of the SSSI boundary (north of the site).

White Young Green (2018) on behalf of CDC have historically undertaken a hydrological and hydrogeological desk study with regard to the impact the landfill part of the site (noted as PR8 in the Cherwell Local Plan) may have on the Rushy Meadows SSSI.

The WYG (2018) report notes

“Flow gradient of shallow groundwater within superficial deposits is expected to be towards local surface watercourses. Groundwater flow in Rushy Meadows is likely to be to the south towards Rowel Brook. Consequently, any impact from the proposed development site is unlikely to extend to the north past Rowel Brook and be transmitted upgradient to the SSSI.”

”Rushy Meadows SSSI would be more susceptible to impact from changes in water level and quality which occurred to the north of the SSSI. Significant changes in surface water or groundwater level within the proposed PR8 development site to the south could potentially impact Rushy Meadows SSSI, but such an event is considered to have a low probability of occurrence. Quality changes, to either surface water or groundwater are unlikely to impact upon Rushy Meadows SSSI.”

“Groundwater flow up-gradient beyond Rowel Brook into Rushy Meadows SSSI is not feasible, and consequently the superficial alluvium do not provide a viable hydrogeological connection between the proposed development site and Rushy Meadows.”

Potential adverse impacts on the Rushy Meadows SSSI based on the proposed development are considered negligible and the risk assessment summary (Table 12) of the WYG (2018) report is reproduced as Figure 2.4.

Table 12: Risk Assessment Summary

Development Stage	Receptors	Potential Impact	Preliminary Risk Level
Hydrogeology: Construction Phase	• Superficial Deposits (Alluvium, Sands and Gravels) • Secondary A Bedrock Aquifer (Cornbrash Formation)	• Accidental spillages • Historical ground contamination • General site works & excavations	**Negligible**
Hydrogeology: Operational Phase		• Decreased groundwater recharge • Diffuse pollution	**Negligible**
Hydrology: Construction Phase	• Surface Watercourses (Thrupp Ditch and Rowel Brook)	• Accidental spillages • Historical ground contamination • General site works & excavations • Increased surface runoff	**Negligible**
Hydrology: Operational Phase		• Increased surface runoff • Discharges to surface watercourses	**Negligible**

Figure 2.4: White Young Green, Rushy Meadows Hydrological and Hydrogeological Risk Assessment Summary

However, it is noted that due to a lack of site-specific data a quantitative assessment of potential risk could not be undertaken, and a number of uncertainties and data gaps were identified as part of the desk study. These included:

- site specific qualitative groundwater data (level and water quality);
- lateral extent, thickness, and hydrogeological characteristics of underlying superficial deposits;
- site specific water quality and generalised flow data at targeted locations; and
- specific construction details for individual elements of the development.

Whilst assessed as a negligible risk, the historical and recent investigations should to provide the majority of the data to more accurately assess risks to Rushy Meadows SSSI.

2.9 Flood risk

The desk study information indicates the proposed development is primarily within Flood Zone 1 (less than 0.1% chance of flooding in any year). However, in areas adjacent to Rowel Brook and land east of the railway, areas are identified as either Flood Zone 2 (0.1% - 1% chance of flooding) or Flood Zone 3 (>1% chance of flooding).

No further consideration of flood risk is undertaken in this report. Specialist flood risk advice should be sought with regard to drainage and flooding.

2.10 Mining or mineral extraction

A former sand and gravel extraction pit is present in the central-south of the site and several historical sand and gravel pits are shown in the surrounding area, all of which are shown to have ceased and subsequently been backfilled or used as landfills.

Two historical gravel pits have been identified in the immediate vicinity of the site, identified as Fern Hill Gravel Pit / Willow Way landfill, located 168m north; and Sandy Lane West gravel pit and landfill, located to the immediate west of the site. The former gravel pit and landfill area in the central part of the site was Sandy Lane East gravel pit. All locations appear to have been situated within the geological outcrop of the Summertown-Radley Sand and Gravel Member. The locations of the former gravel pits are shown in Figure 2.5.

Residential properties are now shown to have been constructed over the Fern Hill Gravel Pit and Western Sandy Lane Gravel Pit.

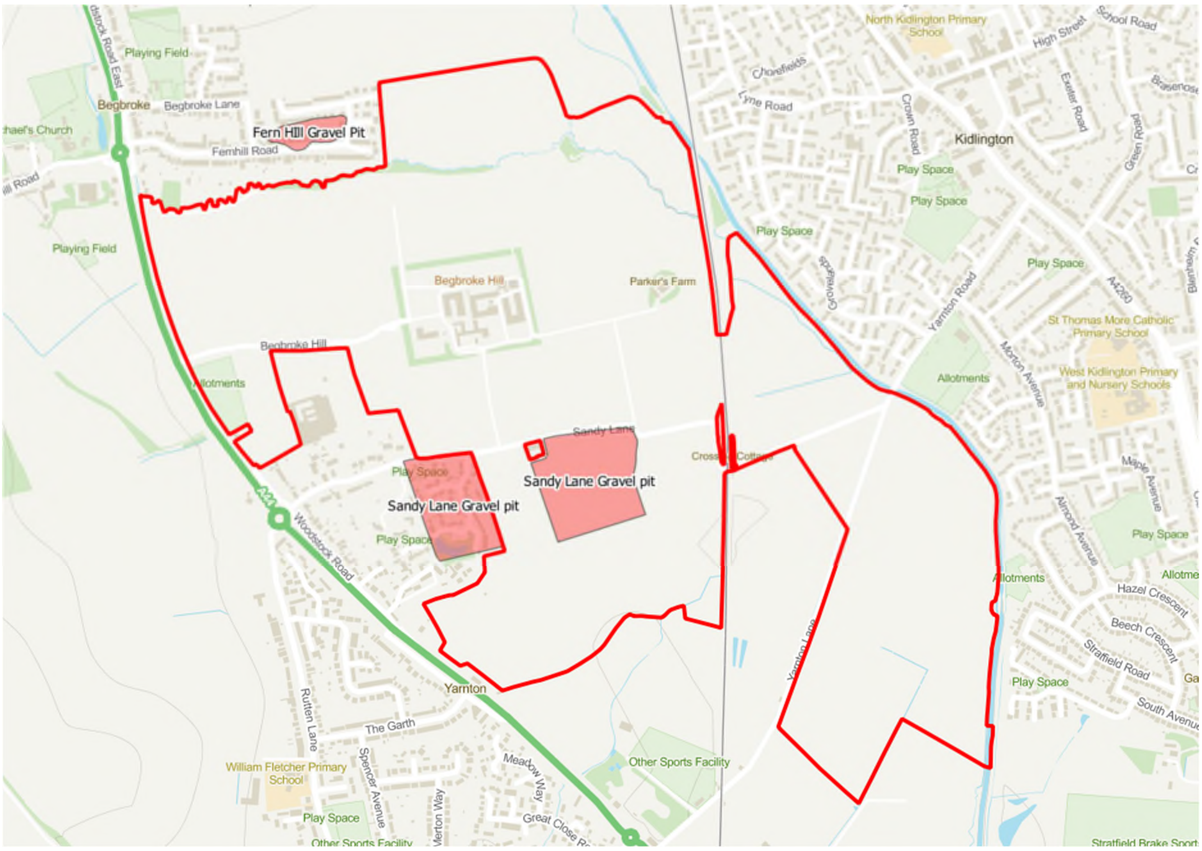

Figure 2.5: Former gravel pit / landfill location plan

2.11 Waste management

Three historical landfill sites are shown within 250m of the site relating to the backfilling of the historical sand and gravel pits:

- Willow Way located 168m north (formerly the Fern Hill Gravel Pits) accepted inert, industrial, commercial and household waste. Residential development now covers this area.
- Sandy Lane West accepted inert waste. Residential development now covers this area.
- Sandy Lane East accepted inert and industrial waste from unrecorded sources over an unspecified timeframe, but generally in the late 1960s and 1970s. Remains as undeveloped open land, approximately 0.50m to 1.00m above the surrounding ground levels.

2.12 Natural soil chemistry

The previous desk study did not identify any significantly elevated naturally occurring elements that may present a risk to future site users.

2.13 Radon and ground gas

Jubb (2018) indicates that the site is in a Radon Affected Area where recorded radon levels in 1-3% of homes are above the action level. However, since issue the UK Radon Maps have been updated (December 2022).

A full Radon report was obtained by Hydrock in March 2023 (see Appendix B), which indicates that the far northern part of the site (Radon Report ID BGS_331991/43780), north of Rowel Brook, is in a Radon affected area of between 3-5% and 10-30% where either basic or full protection measures are required in any buildings constructed in this area of the site.

The remainder of the site (Radon Report ID: BGS_331991/43779) is not considered to be in a Radon affected area (<3%) and no radon protection measures are required.

2.14 Unexploded ordnance (UXO)

The previous desk study did not address UXO risk. As such, in general accordance with CIRIA Report C681 (Stone et al 2009), Hydrock has undertaken a non-specialist UXO screening exercise for the purposes of ground investigation and this is presented in Table 2.3.

Table 2.3: Non-specialist UXO screening (for the purposes of ground investigation)

Data	Comment	Further Assessment Required
Site History	There is no indication of former military use from the desk study.	No
Post War Development	No evidence of potential damage or development on historical maps.	No
Geology Type	The ground conditions are highly variable but comprise Alluvium over River Terrace Deposits in the east. There is the potential that UXO, if present, would remain undetected in these areas. However, the softer superficial soils are underlain by hard soils (stiff clay or rock) from relatively shallow depth.	Yes, discounted on further assessment
Surface Cover during WWI	The surface cover during WWII comprised open fields. There is the potential that UXO, if present, would remain undetected. However, when assessed against the risk of UXO being present, the overall risk is considered low.	Yes, discounted on further assessment
Indicator of Aerial Delivered UXO	Screening against the regional bomb risk map (Northamptonshire) Appendix B indicates the site to be in an area where the bomb risk is low	No

The non-specialist UXO screening exercise has indicated that whilst there is the potential for UXO to remain undetected due to the presence of open fields at the site during WWII and Alluvium in the east, no further assessment is required with regard to UXO in relation to ground investigation.

2.15 Historical Ground Investigations

2.15.1 Jubb Consulting Engineers Limited. December 2019. Ref: 18182-GCA-1

A ground investigation was undertaken by Terra Firma (South) Limited after being scoped by Jubb with the factual report reference of 6307 dated November 2019. The factual report has not been made available to Hydrock. However, a summary of the ground conditions encountered is included within the Jubb (2019) report and are summarised below.

The works comprised a total of eight cable percussion boreholes located to the north, east, south and west of the Sandy Lane Landfill, which at the time was not included as part of the site. Whilst the logs are not available to review the individual locations, the geology encountered is understood to have comprised:

- Topsoil to between 0.20m bgl and 0.90m bgl, comprising dark brown slightly gravelly slightly silty clay; over
- Summertown/Radley Gravel Member (River Terrace Deposits) comprising a brown slightly clayey to clayey sandy flint gravel and locally, stiff orange brown slightly gravelly slightly sandy clay; over
- Oxford Clay Formation to depths exceeding 10.0m bgl, comprising stiff grey slightly sandy to sandy clay.

In situ tests undertaken in the River Terrace Deposits recorded SPT 'N' values between <10 and 50 with a median of 32. SPT 'N' values of between 4 and 16 were achieved in the cohesive strata. SPT 'N' values in the Oxford Clay were recorded between 8 and 50, generally increasing with depth.

Particle size distributions within the River Terrace Deposits indicated slightly silty/clayey sandy gravel.

Atterberg tests within the Oxford Clay indicated the soils to be of high plasticity with a moderate volume change potential as defined by NHBC Standards.

Groundwater was encountered in some of the boreholes between 5.20m bgl and 7.20m bgl during the investigation works with subsequent groundwater monitoring recording ground levels between 2.70m bgl and 6.40m bgl.

Elevated levels of arsenic were recorded within 13 out of 22 samples tested, with a maximum concentration of 79mg/kg in the natural soils. PBET testing was not undertaken as part of the works.

Naphthalene was encountered above the GAC in one location at 2.2mg/kg compared to a GAC of 1.5mg/kg. However, this was discounted as an outlier.

In summary, with regards to land contamination the Jubb report stated that *'it is likely that any potential landfill material has not had an adverse effect on the surrounding area'.*

Maximum concentrations of 7.0% carbon dioxide (CO_2) and 0% methane (CH_4)were recorded with a maximum gas screening value (GSV) of 0.014l/hr calculated, according with Characteristic Situation 1 (CS1). However, CS2 was recommended due to a value of 7% carbon dioxide which is above the 5% value for consideration to increase the CS.

Groundwater samples had exceedances for copper and zinc above the water quality targets (WQT). However, it was considered that these were not representative of landfill leachate and therefore were not considered to present a significant risk to the site.

2.15.2 Hydrock Consultants Limited October 2021. Ref: HYD-19114-XX-XX-RP-GE-01001

Comprising a Phase 1 Desk Study Review and Phase 2 Ground Investigation within the former Sandy Lane Landfill.

The site investigation works comprised:

- 3 Cable Percussion Boreholes to a maximum depth of 10.00m bgl with gas and groundwater wells installed below the base of the landfill;
- 10 Dynamic Sampling Boreholes to a maximum depth of 5.00m bgl with gas and groundwater monitoring wells installed within the landfill; and
- 7 Trial Pits to a maximum depth of 3.50m bgl.

Six gas and groundwater monitoring rounds were undertaken as part of the works.

The ground conditions underlying the site at the time of the investigation comprised and were interpreted as:

- Made Ground - Topsoil to between 0.05m bgl to 0.80m bgl comprising a dark brown to orangish brown silty gravelly sand with high root content with gravel constituents of brick and concrete with occasional glass, metal, and fabric fragments.
- Made Ground - Landfill to between 2.10m bgl to 3.90m bgl (approximately 64m OD) comprising highly variable material but generally consisted of greyish, orangish brown gravelly sand (predominantly ash) with abundant man-made putrescible waste and gravel sized fragments of concrete, slag, brick and fragments of glass, plastic, metal, batteries, paper, and animal bones. Local cobbles and boulders of concrete were encountered. Towards the base of the landfill the colour changes to dark grey and black. A putrid odour was noted in all locations and a strong hydrocarbon odour in TP02. No lining was encountered at the base of the landfill and no capping was identified.
- Made Ground – General, encountered in two locations (WS07 to BH01) to depths of up to 0.60m bgl comprising a firm yellowish greyish brown slightly sandy occasionally slightly gravelly clay. It was interpreted that these materials are separate to the landfill materials due to absence of man-made constituents.
- Residual sand and gravel (approximately 1m thickness) of the Summertown Radley Sand and Gravel Member (River Terrace Deposits) left during the quarrying operations (between the 1930's and 1970's) was encountered underlying the Landfill – Made Ground and underlying the topsoil in one location in the north-west corner. It comprised yellowish to greyish brown slightly sandy gravel or sand and gravel, with gravel of flint and sandstone. In the north-west corner these were noted to be sandy clay to 5.00m bgl.
- The Oxford Clay Formation was encountered underlying the Summertown Radley Sand and Gravel Formation to depths >10.00m bgl comprising a stiff (locally soft) thinly laminated grey sandy clay with rare lithorelicts of mudstone.

  Groundwater was encountered at between 2.40m bgl and 3.40m bgl during the investigation and in subsequent monitoring at between 1.88m bgl and 3.98m bgl (62.15m OD to 65.09m OD).

  A copy of the geological model across the former landfill (Reference Hydrock Drawing 19114-HYD-XX-ZZ-SK-GE-01006) is presented in Figure 2.6.

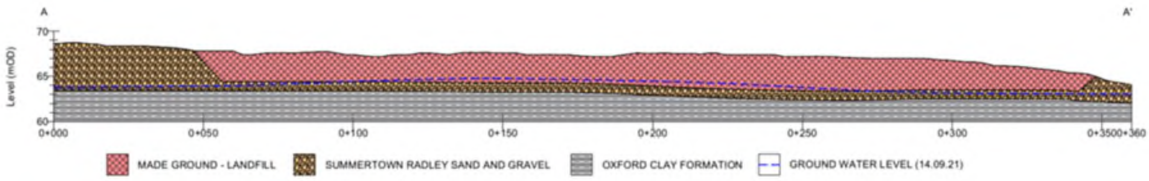

*Figure 2.6: Hydrock Consulting Limited Landfill Geological Model) * Since updated March 2023*

Since the landfill investigation works were undertaken and based on further works the above geological model has been updated (including nomenclature) and included within the dataset as well as the geo-environmental assessment.

The investigation identified a number of contamination risks associated with the former landfill for site end users:

- Human Health (POS);
  - Asbestos Containing Materials (ACM), Asbestos fibres and benzo(a)pyrene in the Landfill – Made Ground
  - PAH in the Topsoil Made Ground; and
  - Arsenic in the natural soils.
- Human Health (Residential);
  - Asbestos, arsenic, lead and benzo(a)pyrene in the Landfill Made Ground
  - Arsenic, lead, and benzo(a)pyrene in the Topsoil Made Ground; and
  - Arsenic in the natural soils
- Plant Growth;
  - Pervasive boron, copper, nickel and zinc.
- Controlled Waters;
  - Exceedances with regards to ammoniacal nitrogen, chromium (III), cobalt, chromium, copper, nickel, sulphate, and manganese as an indicator of groundwater risk.
- Moderate risk from ground gases and CS2 conditions apply for the area of the landfill.

Proposed mitigation measures with regards to a public open space (POS) use comprised:

- Installation of a 450mm engineered cover, comprising a bonded geogrid break layer and subsoil with a topsoil thickness of between 150mm and 300mm.
- Import of subsoil and topsoil in line with a MMP.

It was recommended that a cover system is placed over the landfill to break the pathway to the identified receptors, and that the landfill material is first compacted prior to placement of the cover system, which should extend a minimum of 3.0m beyond the edge of the landfill boundary to ensure adequate cover is provided.

The data from the investigation above has been included within the geological model and geo-environmental assessment as part of these works.

3. INITIAL CONCEPTUAL SITE MODEL

3.1 Introduction

The iCSM incorporates evidence from the site walkover, the Desk Study and previous investigations carried out at the site. The formulation of an iCSM is a key component of the LCRM methodology. The iCSM incorporates a Ground Model of the site physical conditions and an exposure model of the possible contaminant linkages; it forms the basis for GQRA in accordance with current guidelines.

The following section provides a discussion of the iCSM for the entire site currently under consideration, including the former landfill area and areas proposed for retention as open space.

3.2 Ground model

The geology presented in Section 2.6 provides an understanding of the ground conditions and is the basis for preparing the preliminary geotechnical hazard assessment (Section 3.3) and the preliminary geo-environmental exposure model (Section 3.4).

3.3 Geotechnical hazard identification

3.3.1 Context

A preliminary geotechnical hazard identification has been undertaken in general accordance with the ICE/DETR Document 'Managing Geotechnical Risk' and the Highways England documents HE-DMRB-G CS 641 and HE-DMRB-G CD 622 Revision 1.

The following section sets out the identified geotechnical hazards and the development elements potentially affected (see Table H.1 in Appendix H for further information).

3.3.2 Plausible geotechnical hazards

Plausible geotechnical hazards identified at the site are:

- Uncontrolled general Made Ground (variable strength and compressibility).
- Soft / loose compressible ground (low strength and high settlement potential) – e.g. landfill materials, Head Deposits, and Alluvium.
- Shrinkage / swelling of the clay fraction of soils under changes in moisture content from seasonal effects and the influence of trees, hedges and vegetation.
- Variable lateral and vertical changes in ground conditions.
- Attack of buried concrete by aggressive ground conditions.
- Obstructions – man made construction and natural buried resistant materials.
- Existing below ground structures which are to remain (e.g. mains sewers).
- Shallow groundwater.
- Changing groundwater conditions.
- Risk from flooding and erosion.
- Running sands and / or loose Made Ground, leading to difficulty with excavation and collapse of side walls.

- Slope stability issues – general slopes and retaining walls.
- Earthworks – risk of settlement of new fill.
- Earthworks – poor bearing capacity of new fill.
- Earthworks – suitability of site won material to be reused as fill.
- Effects of sand / gravel extraction.
- Solifluction.
- Problematic soils.

3.3.3 Potential development elements affected

Development elements potentially affected by geotechnical hazards are:

- Buildings – foundations and floor slabs.
- Roads and pavements.
- Infrastructure structures (bridges).
- Buried services.
- General slopes.
- Retaining walls.
- Gardens.
- Construction staff, vehicles and plant operators.
- Concrete below ground.
- Earthworks control, inability to place and compact fill.
- Insufficient volumes of suitable site-won fill to complete earthworks.

Health and safety risks to site contractors and maintenance workers have not been assessed during these works and will need to be considered separately during design.

The above plausible geotechnical hazards and development elements affected have been carried forward for investigation and assessment. The investigation is presented in Sections 4 and 5 and the assessment is presented in Section 6.

3.4 Geo-environmental exposure model

3.4.1 Context

The preliminary exposure model is used to identify geo-environmental hazards and to establish potential contaminant linkages, based on the source-pathway-receptor (SPR) approach. A viable contaminant linkage requires all the components of an SPR to be present. If only one or two are present, there is no linkage and no further assessment is required.

3.4.2 Potential contaminants

For the purpose of this assessment the potential contaminants have been separated according to whether they are likely to have originated from an on-site or off-site source.

3.4.2.1 Potential on-site sources of contamination

- Made Ground, associated with historical construction activities, possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials (ACM), polycyclic aromatic hydrocarbons (PAHs) and petroleum hydrocarbons (S1).
- Landfilled waste, possibly including: elevated concentrations of metals, metalloids, asbestos fibres, ACM, PAHs and petroleum hydrocarbons (S2).
- Hydrocarbon fuels, lubricants, and solvents from the operation around Parkers Farm, together with uncontrolled disposal and spillage from waste receptacles (S3) (no tanks have been observed during the walkover).
- Ground gases (carbon dioxide and methane) from organic materials in the Made Ground, Landfill and Alluvium (S4).
- Naturally occurring elevated concentrations of arsenic within soils (S5).
- Asbestos within existing buildings, with the potential to be incorporated into the ground from demolition activities (S6).
- Pesticides and herbicides from agricultural land use (S7).
- Leachate from landfilled waste including commercial and industrial, located on the northern boundary (Fern Hill (now residential housing)) and Sandy Lane Pits in the centre and west of the site (S8).

3.4.2.2 Potential off-site sources of contamination

- Hydrocarbon fuels from adjacent petrol station to the south-west of the site (S9).
- Made Ground, associated with historical construction activities, possibly including elevated concentrations of metals, metalloids, asbestos fibres, ACM, PAHs and petroleum hydrocarbons from Railway line (bisecting but outside of the site) (S10).
- Ground gases (carbon dioxide and methane) from organic materials in the landfills located off-site (S11).

Leakage from chemical stores from Begbroke Science Park are mentioned in the historical desk study (Jubb, 2018). However, Hydrock do not believe this is a plausible contaminant source, due to the controlled conditions of storage.

3.4.3 Potential receptors

The following potential receptors in relation to the proposed land use have been identified.

- People (site end users, and neighbours) (R1).
- Development end use (buildings, utilities and landscaping) (R2).
- Groundwater: Secondary A aquifer status of the Superficial Summertown Radley Sand and Gravel and Alluvium and Bedrock Cornbrash Limestone Formation and Kellaways Sand Formation (R3).
- Surface water: on-site stream (Rowel Brook) in the north of the site, Oxford Canal along the eastern boundary (R4) and stream in the south the site, along with any existing ditches, and ponds.
- Ecology: Rushy Meadows SSSI located adjacent to the north-east of the site (R5).

3.4.4 Potential pathways

The following potential pathways have been identified.

- Ingestion, skin (dermal) contact, inhalation of dust (P1).
- Migration and accumulation of ground gases via permeable soils and/or construction gaps into enclosed spaces (P2).
- VOC and petroleum hydrocarbon vapour ingress to buildings and outdoor air via permeable soils and/or construction gaps (P3).
- Root uptake by plants (P4).
- Migration of contaminants from landfill deposits (leachate) through the unsaturated zone in the River Terrace Deposits and laterally along the boundary with the Oxford Clay Formation (P5).
- Surface water via overland flow (P6).
- Surface water, via drainage discharge (P7).
- Surface water, via base flow from groundwater (P8).

Migration of leachate from the landfill, down to the underlying permeable geology (Kellaways Sand Formation and Cornbrash Formation) is not considered a viable pathway as the impermeable Oxford Clay Formation is present below the landfill, which will act as an aquitard.

Health and safety risks to site development contractors and maintenance workers have not been assessed as part of this study and will need to be considered separately.

The above sources, pathways and receptors have been included in the Preliminary Risk Assessment in accordance with LCRM (2022), and are considered to be plausible in the context of this site and therefore have been carried forward for investigation and assessment.

The investigation is described in Section 5 and the assessment is presented in Section 7.

An assessment of the SPR linkages is undertaken following the assessment (Section 7) and is presented in Appendix I (Table I.2).

4. GROUND INVESTIGATIONS

4.1 Site works

4.1.1 Rationale

The ground investigation works, including the rationale which was based on the findings of the preliminary risk assessment is summarised in Table 4.1. Works have been undertaken in several stages and comprise: landfill investigation; preliminary soil infiltration investigation; site wide preliminary investigation; Sandy Lane railway bridge and canal bridge investigation; and groundwater levels investigation.

Table 4.1: Investigation rationale

Location	Purpose – Preliminary Investigation.
Landfill investigation	
BH01 - BH03	Cable percussion boreholes to investigate the thickness of the landfill. To allow collection of samples for contamination testing. Installation of gas and groundwater monitoring and sampling wells in the Oxford Clay Formation.
WS01, WS02, WS09 & WS10	Dynamic sampled boreholes to investigate the extent of the landfill. To allow collection of samples for contamination testing. Installation of gas and leachate/groundwater monitoring and sampling wells in the landfill.
WS03-WS08	Dynamic sampled boreholes to assess shallow ground conditions within the known location of the landfill. To allow collection of samples for contamination testing. Installation of gas and leachate/groundwater monitoring and sampling wells in the landfill.
TP01-TP07	Machine dug trial pits to assess the shallow ground conditions To allow collection of samples for contamination testing.
Preliminary soil infiltration investigation	
SA01 – SA09	Machine dug trial pits to investigate the shallow geology on a very wide spacing across the site. To allow for soil infiltration rate testing. (The locations of tests were designed to provide an indication of infiltration potential at areas identified as potential attenuation pond locations in the north (SA03, SA04 and SA05) and south (SA08 and SA09) and also across the central part of the site (SA01, SA02, SA06 and SA07), where gravels were expected to be thicker.
Site wide preliminary investigation	
BH201 – BH205	Cable percussion boreholes to investigate the thickness of the underlying deeper geology. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical testing and in-situ geotechnical testing. Installation of gas and groundwater monitoring and sampling wells external to the landfill within the River Terrace Deposits.
WS201 – WS252	Dynamic sampled boreholes to investigate the thickness of the superficial deposits across the site. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical testing and in-situ geotechnical testing.

Location	Purpose – Preliminary Investigation.
	Installation of gas and groundwater monitoring and sampling wells within the River Terrace Deposits.
TP201 – TP234	Machine dug trial pits to investigate the thickness of the shallow geology across the site. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical testing and in situ geotechnical testing. Installation of gas and groundwater monitoring and sampling wells within the River Terrace Deposits.
HP201 – HP206	Hand dug pits to assess shallow conditions in the allotments in the west of the site. To allow collection of samples for contamination testing.
HP207 – HP210	Hand dug pits to assess shallow conditions around Parkers Farm in the central-east of the site. To allow collection of samples for contamination testing.
Sandy Lane railway bridge and canal bridge investigation	
RO301 – RO305	Rotary cored boreholes to assess the deeper underlying geology for the construction of a Railway and Canal bridge. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical testing and in situ geotechnical testing. Installation of gas and groundwater monitoring and sampling wells in either the River Terrace Deposits or Cornbrash Limestone Formation
TP301 – TP313, TP315 – TP317	Machine dug trial pits to investigate shallow ground conditions. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical testing and in situ geotechnical testing.
Groundwater levels investigation	
RO306 – RO321	Rotary open hole and rotary cored boreholes to confirm the underlying geology. To allow for installations of groundwater monitoring and sampling wells in the River Terrace Deposits and Cornbrash Limestone Formation.
CP301 – CP305	Cable percussion boreholes to investigate thickness of the deeper underlying geology. To allow for installation of groundwater monitoring and sampling wells into the River Terrace Deposits.
SA301 – SA302	Machine dug trial pits to investigate the shallow geology in the west of the site. To allow for soil infiltration rate testing.
HDP301 – HDP350	Hand dug pits to allow the collection of samples for organic analysis at 100mm intervals up to 300mm.

The fieldworks took place betweenThe fieldworks took place between:

- 17th and 20th August 2021 for the landfill investigation.
- 27th September and 1st October 2021 for the preliminary soil infiltration testing.
- 22nd August 2022 and 14th September 2022 for the site wide preliminary investigation.
- 23rd January 2023 and 14th February 2023 for the Sandy Lane Railway bridge and canal bridge investigation and groundwater levels investigation.

The ground investigation locations were surveyed in using a Total Station GPS survey instrument and are shown on the Exploratory Hole Location Plan (Hydrock Drawing 19114-HYD-XX-ZZ-DR-GE-01001) in Appendix A.

The logs, including details of ground conditions, soil sampling, in situ testing and any installations, are presented in Appendix C. A summary of the site works is presented in **Error! Reference source not found.**.

The weather conditions during the:

- Landfill site fieldwork and for the previous week were dry and sunny.
- Preliminary soil infiltration testing and for the previous week were scattered showers.
- Site wide fieldwork and for the previous week were dry and sunny generally with occasional periods of light rain, following an extended period of dry weather. The network of open ditches around site, along with Rowel Brook in the north and a small stream/ditch in the south were dry at the time of the investigation works.
- Railway and canal bridge crossing and supplementary groundwater investigations and the previous week were scattered showers and overcast.

Table 4.2: Summary of site works

Activity	Method	No.	Name	Maximum Depth Range (m bgl)	In situ tests	Rationale
Landfill investigation						
Boreholes	Cable percussive	3	BH01 – BH03	10.00	SPT	50mm HDPE wells with gas taps in 3 holes
	Windowless sampler	10	WS01 – WS10	5.00	SPT	50mm HDPE wells with gas taps in 10 holes
Trial pits	Machine (JCB 3CX)	7	TP01 – TP07	3.50	Hand shear vane (HSV)	
Preliminary soil infiltration investigation						
Infiltration tests	Machine (JCB 3CX)	10	SA01 – SA09	1.00 – 2.10m	BRE365 Soakaway Testing	Infiltration tests (not undertaken in SA06 due to damage to installation).
Site wide preliminary investigation						
Boreholes	Cable percussive	5	BH201 – BH205	5.20 – 10.45	SPT U100	63mm HDPE wells with gas taps in all holes
	Windowless sampler	52	WS201 – WS252	1.00 – 5.45	SPT	63mm HDPE wells with gas taps in all holes
Trial pits	Machine (JCB 3CX)	35	TP201 – TP234	0.70 – 3.60	HSV	
	Hand-excavated	10	HP201 – HP210	0.55 – 1.20	-	
Sandy Lane railway bridge and canal bridge investigation						

Activity	Method	No.	Name	Maximum Depth Range (m bgl)	In situ tests	Rationale
Boreholes	Rotary Cored	5	RO301 – RO305	20.00 – 21.00	SPT U100	63mm HDPE wells with gas taps in all holes
Trial pits	Machine (JCB 3CX)	16	TP301 – TP317	1.40 – 2.70	HSV	
Supplementary groundwater investigation						
Boreholes	Rotary Cored	16	RO306 – RO321	4.50 – 12.70	-	63mm HDPE wells with gas taps in all holes
	Rotary Open Hole	7	RO307A, RO309A, RO312A, RO313A, RO316A, RO318A & RO321A	0.90 – 4.50	-	63mm HDPE wells with gas taps in all holes
	Cable Percussive	5	CP301 – CP305	4.80 – 5.60	-	63mm HDPE wells with gas taps in all holes
Trial pits	Machine (JCB 3CX)	3	SA301 – SA302	2.00 – 2.50	HSV BRE365 Soakaway Testing	Infiltration tests
	Hand-excavated	50	HDP300 – HDP350	0.30	-	

4.1.2 Constraints

During investigation of the landfill site:

- Exploratory locations were constrained by the presence of badger setts along parts of the southern and western boundaries (locate by BSG Ecology who were present on the first day of site works) with a minimum of 15m excavation exclusion zone employed as indicated by BSG Ecology, where encountered.
- Works were also constrained by the presence of overhead HV cables along the eastern boundary with a 9m standoff zone employed. As such exploratory holes were not able to be undertaken to prove the lateral extents of the landfill in these locations.

During soil infiltration rate investigation:

- Infiltration tests were not able to be undertaken within SA06 as a result of damage to the infiltration test location as a result of ploughing shortly after construction.
- Excavation for soakaway tests in SA03a, SA04 and SA09 were stopped short of the target depth of 2.00m due to pit collapse and water ingress.
- Excavation for tests SA05 and SA08 were stopped short of the target depth due to water ingress.

During site wide preliminary investigation:

- Investigation works were limited in the area around the chicken and deer farm with exploratory holes undertaken external to the fenced livestock areas.
- A 15m exclusion zone around the badger setts was in use during the works, in consultation with the appointed ecologist.
- Several services were present on site including overhead HV cables, an underground sewage main and adjacent to the railway line. Appropriate exclusion zones were employed during the duration of the works.

During supplementary Investigation:

- Several services were present on site including overhead HV cables and an underground sewage main. Appropriate exclusion zones were employed during the duration of the works.
- Where appropriate, exclusion zones were employed around infrastructure elements of the railway line and canal after discussions with asset owners.

4.1.3 Monitoring installations

Wells for monitoring groundwater levels and ground gas concentrations, and to facilitate the sampling of groundwater were installed as part of several of the investigations. A summary of the monitoring well installations is presented in Table 4.3.

Table 4.3: Summary of monitoring installations

Location	Ground level (m OD)	Standpipe diameter (mm)	Screen top and base depth (m bgl)	Screen top and base elevation (m OD)	Strata targeted
Landfill investigation					
BH01	67.66	50	4.00 – 10.00	63.66 – 57.66	OCF / KSM /KCM
BH02	66.47	50	4.00 – 10.00	62.47 – 56.47	OCF / KSM /KCM
BH03	67.09	50	5.00 – 10.00	62.09 – 57.09	OCF / KSM /KCM
WS01	67.54	50	1.00 – 3.00	66.54 – 64.54	Landfill
WS02	65.62	50	1.00 – 4.00	64.62 – 61.62	RTD
WS03	67.71	50	0.70 – 2.70	67.01 – 65.01	Landfill
WS04	66.74	50	1.00 – 3.00	65.74 – 63.74	Landfill
WS05	67.39	50	1.00 – 3.00	66.39 – 64.39	Landfill
WS06	66.97	50	1.00 – 2.00	65.97 – 64.97	Landfill
WS07	67.14	50	0.50 – 2.50	66.64 – 64.64	Landfill
WS08	67.02	50	0.80 – 3.80	66.22 – 63.22	Landfill
WS09	66.71	50	1.00 – 3.00	65.71 – 63.71	Landfill
WS10	66.71	50	1.00 – 3.00	65.71 – 63.71	Landfill
Site wide preliminary investigation					
BH201	68.06	50	1.00 – 5.00	67.06 – 63.06	RTD
BH202	63.67	50	1.00 – 5.00	62.67 – 58.67	RTD
BH203	63.35	50	1.00 – 5.00	62.35 – 58.35	RTD
BH204	62.31	50	1.00 – 5.00	61.31 – 57.31	RTD
BH205	60.78	50	1.00 – 4.00	59.78 – 56.78	RTD / KSM
WS201	67.36	50	1.00 – 2.00	66.36 – 65.36	KCM
WS202	65.92	50	1.00 – 2.00	64.92 – 63.92	MG / RTD
WS203	68.32	50	1.00 – 2.00	67.32 – 66.32	RTD
WS204	64.19	50	0.70 – 1.00	63.49 – 63.19	RTD / CLF
WS205	64.23	50	1.00 – 3.00	63.23 – 61.23	RTD
WS206	64.72	50	1.00 – 4.20	63.72 – 60.52	RTD / KCM / CLF
WS207	62.87	50	1.00 – 2.00	61.87 – 60.87	RTD
WS208	62.33	50	0.80 – 2.00	61.53 – 60.33	RTD
WS209	64.34	50	1.00 – 3.00	63.34 – 61.34	RTD
WS210	62.37	50	1.00 – 2.50	60.87 – 59.87	ALV
WS211	68.29	50	2.80 – 3.50	65.49 – 64.79	RTD
WS213	68.30	50	1.00 – 3.70	67.30 – 64.60	RTD
WS214	68.15	50	0.70 – 1.20	67.45 – 66.95	RTD
WS215	62.11	50	1.00 – 2.70	61.11 – 59.41	RTD
WS216	67.87	50	1.00 – 4.00	66.87 – 63.87	RTD
WS217	68.52	50	1.00 – 2.00	67.52 – 66.52	RTD
WS218	68.42	50	1.00 – 1.80	67.42 – 66.62	RTD

Location	Ground level (m OD)	Standpipe diameter (mm)	Screen top and base depth (m bgl)	Screen top and base elevation (m OD)	Strata targeted
WS219	65.68	50	1.00 – 5.00	64.68 – 60.68	KSM / KCM
WS220	62.56	50	1.00 – 3.00	61.56 – 59.56	ALV / RTD
WS221	67.84	50	1.00 – 2.00	66.84 – 65.84	RTD
WS222	68.14	50	0.80 – 2.60	67.34 – 65.54	RTD
WS223	67.12	50	1.00 – 2.00	66.12 – 65.12	RTD
WS224	61.94	50	1.00 – 1.30	60.94 – 60.64	ALV
WS225	67.49	50	1.00 – 2.00	66.49 – 65.49	RTD
WS226	67.70	50	0.70 – 1.00	67.00 – 66.70	RTD
WS227	68.21	50	1.00 – 2.70	67.21 – 65.51	RTD
WS228	67.66	50	0.80 – 1.00	66.86 – 66.66	RTD
WS229	68.16	50	1.00 – 2.00	67.16 – 66.16	RTD
WS230	66.91	50	1.00 – 1.20	65.91 – 65.71	RTD
WS231	64.77	50	1.00 – 5.00	63.77 – 59.77	H / RTD
WS232	61.66	50	1.00 – 3.00	60.66 – 58.66	RTD
WS233	61.48	50	1.30 – 2.50	60.18 – 58.98	ALV / RTD
WS234	61.32	50	1.00 – 1.70	60.32 – 59.62	RTD
WS235	64.31	50	1.00 – 5.00	63.31 – 59.31	RTD / OCF / KSM
WS236	66.24	50	1.00 – 2.00	65.24 – 64.24	RTD
WS237	67.40	50	0.50 – 1.00	66.90 – 66.40	RTD
WS238	65.12	50	2.00 – 5.00	63.12 – 60.12	OCF
WS239	61.33	50	1.30 – 2.50	60.03 – 58.83	ALV / RTD
WS240	61.26	50	0.90 – 1.20	60.36 – 60.06	ALV / RTD
WS241	61.59	50	1.00 – 2.00	60.59 – 59.59	ALV / RTD
WS242	61.92	50	0.60 – 3.60	61.32 – 58.32	RTD
WS243	66.85	50	0.50 – 1.00	66.35 – 65.85	RTD
WS244	61.21	50	0.50 – 1.00	60.71 – 60.21	RTD
WS245	60.66	50	1.00 – 2.70	59.66 – 57.96	ALV / RTD
WS246	61.02	50	1.00 – 4.40	60.02 – 56.62	ALV / RTD
WS247	60.57	50	0.50 – 1.00	60.07 – 59.57	RTD
WS248	61.01	50	1.00 – 1.70	60.01 – 59.31	RTD
WS249	60.82	50	0.80 – 1.00	60.02 – 59.82	RTD
WS250	60.81	50	0.80 – 1.00	60.01 – 59.81	RTD
WS251	60.53	50	1.00 – 2.00	59.53 – 58.53	RTD
WS252	60.40	50	1.00 – 5.00	59.40 – 55.40	ALV / OCF
Sandy Lane railway bridge and canal bridge investigation					
RO301	61.81	50	5.50 – 7.60	56.31 – 54.21	CLF
RO302	61.57	50	1.00 – 3.15	60.57 – 58.42	RTD

Location	Ground level (m OD)	Standpipe diameter (mm)	Screen top and base depth (m bgl)	Screen top and base elevation (m OD)	Strata targeted
RO303	61.47	50	2.00 – 4.00	59.47 – 57.47	RTD
RO304	61.47	50	6.00 – 8.35	55.47 – 53.12	CLF
RO305	60.12	50	1.00 – 2.50	59.12 – 57.62	RTD
Supplementary groundwater investigation					
RO306	65.63	50	3.50 – 4.50	62.13 – 61.13	CLF
RO307	66.09	50	3.50 – 5.00	62.59 – 61.09	CLF
RO307A	66.09	50	1.00 – 2.00	65.09 – 64.09	RTD
RO309	68.22	50	4.50 – 5.50	63.72 – 62.72	CLF
RO309A	68.22	50	2.00 – 3.50	66.22 – 64.72	RTD
RO310	67.04	50	3.50 – 6.00	63.54 – 61.04	CLF
RO311	64.41	50	3.00 – 5.00	61.41 – 59.41	CLF
RO312	67.28	50	6.00 – 9.00	61.28 – 58.28	CLF
RO312A	67.28	50	1.00 – 2.00	66.28 – 65.28	RTD
RO313	65.84	50	2.00 – 4.50	63.84 – 61.34	CLF
RO313A	65.84	50	0.50 – 0.80	65.34 – 65.04	RTD
RO314	63.98	50	4.00 – 4.50	59.98 – 59.48	CLF / FMF
RO315	63.32	50	4.50 – 5.50	58.82 – 57.82	FMF
RO316	65.50	50	3.50 – 5.50	62.00 – 60.00	CLF
RO316A	65.50	50	2.00 – 3.50	63.50 – 62.00	RTD
RO317	62.75	50	6.70 – 7.30	56.05 – 55.45	FMF
RO318	62.13	50	5.50 – 6.00	56.63 – 56.13	FMF
RO318A	62.13	50	1.00 – 4.50	61.13 – 57.63	RTD
RO319	62.21	50	3.50 – 5.50	58.71 – 56.71	RTD / CLF
RO320	62.18	50	3.50 – 5.00	58.68 – 57.18	CLF
RO321	62.55	50	3.00 – 4.00	59.55 – 58.55	CLF
RO321A	62.55	50	1.00 – 2.00	61.55 – 60.55	RTD
CP301	67.69	50	1.60 – 4.60	66.09 – 63.09	RTD
CP302	66.74	50	1.50 – 4.00	65.24 – 62.74	RTD
CP303	68.15	50	1.00 – 4.00	67.15 – 64.15	RTD
CP304	68.02	50	1.00 – 4.00	67.02 – 64.02	RTD
CP305	67.78	50	1.60 – 4.60	66.18 – 63.18	RTD
ALV – Alluvium CLF – Cornbrash Limestone Formation FMF – Forest Marble Formation H – Head Deposits KCM – Kellaways Clay Member KSM – Kellaways Sand Member MG – Made Ground OCF – Oxford Clay Formation RTD – River Terrace Deposits					

4.2 Geo-environmental testing

4.2.1 Sampling strategy and protocols

Exploratory hole positions were determined by reference to the site conditions and uncertainties identified in the iCSM.

No specific sampling statistics or grid were utilised in this instance.

Samples were taken, stored and transported in general accordance with BS 10175:2011+A2:2017.

4.2.2 Geo-environmental monitoring

Six ground gas monitoring rounds were completed at the landfill site between August and October 2021.

The site wide preliminary investigation gas monitoring boreholes have been monitored on 14 occasions, and a further three monthly visits are scheduled to be undertaken (completion anticipated September2023).

The ground gas and groundwater monitoring results are presented in Appendix E.

4.2.3 Geo-environmental laboratory analyses

The chemical test certificates for testing undertaken as part of Hydrock's investigations are provided in Appendix F and are summarised in Table 4.4 (soils) and Table 4.5 (waters). Wherever possible, UKAS and MCERTS accredited procedures have been used.

Table 4.4: Geo-environmental analyses of soils

Determinand Suite	Made Ground	Landfill Made Ground	Agriculturally Disturbed Topsoil	Natural Soils
Landfill investigation				
Hydrock minimum suite of determinands for solids*	4	17	-	4
Speciated aliphatic and aromatic banding Total Petroleum Hydrocarbons (TPH) (Hydrock Tier 2 TPH Suite)	-	14	-	1
Volatile organic compounds (VOCs)	-	9	-	1
Semi-volatile organic compounds (SVOCs)	-	9	-	1
Site wide preliminary investigation				
Hydrock minimum suite of determinands for solids*	5	-	74	21
Hydrock Tier 2 TPH Suite	4	-	10	2
Benzene, toluene, ethylbenzene and xylene (BTEX)	4	-	10	2
MTBE (Methyl Tertiary Butyl Ether)	4	-	10	2
VOCs	2	-	4	-
SVOCs	2	-	4	-

Determinand Suite	Made Ground	Landfill Made Ground	Agriculturally Disturbed Topsoil	Natural Soils
BS 3882 Topsoil Suite + Interpretation	-	-	5	-
Pesticide / Herbicide screen	-	-	15	-
WAC Full Solid Suite	2	-	2	1
Sandy Lane railway bridge and canal bridge investigation				
Hydrock minimum suite of determinands for solids*	-	-	4	4
Hydrock Tier 2 TPH Suite	-	-	4	-
*Hydrock minimum soil suite comprises: As, B (water soluble), Be, Cd, Cr (total), Cr (VI), Cu, Hg, Ni, Pb, S (elemental), Se, V, Zn, cyanide (total), sulphide, pH, asbestos fibres, speciated PAHs (USEPA Priority 16), total phenols and fraction of organic carbon (FOC)				

The soils chemical test data are interpreted and assessed in Sections 7.3 and 7.4.

Table 4.5: Geo-environmental analyses of waters

Determinand Suite	Groundwater
Landfill investigation	
Hydrock minimum suite of determinands for waters*	6
Hydrock Tier 2 TPH Suite	6
VOCs	6
SVOCs	6
Site wide preliminary investigation	
Hydrock minimum suite of determinands for waters*	31
Hydrock Tier 2 TPH Suite	9
BTEX	9
VOCs	6
SVOCs	6
* Hydrock minimum waters suite comprises: Ag, Al, As, B, Ba, Cd, Co, Cr (III), Cr(VI), Cu, Fe, Hg, Mn, Mo, Na, Ni, Pb, Sb, Se, Sn, Zn, V, cyanide (total), phenols (total), ammonium, bromate, chloride, fluoride, nitrate, nitrite, sulphate, PAH (speciated), pH, EC and hardness;	

The groundwater chemical test data are interpreted and assessed in Section 7.5.

4.3 Geotechnical testing

4.3.1 Geotechnical laboratory testing

The geotechnical tests undertaken are summarised in Table 4.6 and the test certificates are provided in Appendix D. Wherever possible, UKAS accredited procedures have been used.

No geotechnical testing was undertaken as part of the landfill investigation.

The geotechnical test data are summarised in Section 5.6 and interpreted in Section 6.

Table 4.6: Summary of sample numbers for geotechnical tests

Test	Agriculturally Disturbed Topsoil	Alluvium	Head Deposits	River Terrace Deposits	Glacial Washout Till?	Oxford Clay Formation	Kellaways Sand Member	Kellaways Clay Member	Cornbrash Limestone Formation	Forest Marble Formation	White Limestone Formation
Natural moisture content	-	29	4	26	1	5	6	12	1	3	-
Atterberg limits	-	21	3	14	1	2	7	5	-	2	-
Particle size distribution (sieve/sedimentation)	-	8	1	10	-	-	1	-	-	-	-
Sulphate and aggressive chemical environment classification for buried concrete classification (full BRE SD1 suite)	-	8	2	15	1	2	5	5	2	4	1
Optimum Moisture Content / Maximum Dry Density Relationship (4.5kg rammer), with hand shear vane at each compaction point	-	-	1	3	-	-	-	1	-	-	-
Remoulded California Bearing Ratio at natural moisture content (soaked)	-	5	-	5	-	-	-	-	-	-	-
Remoulded California Bearing Ratio Remoulded at OMC (soaked)	-	-	1	3	-	-	-	1	-	-	-
Remoulded undrained triaxial shear strength at Optimum Moisture Content		-	1	3		-	-	1	-	-	-
Undrained Triaxial	-	-	-	-	-	-	-	1	-	-	-
Odometer	-	-	-	1	-	-	-	1	-	-	-
Particle density	-	-	1	3	-	-	-	1	-	-	-
Organic Matter	150	4	1	3		-	1	1	-		
Rock Tests – Point Load	-	-	-	-	-	-	-	-	4	4	3
Rock Tests – Uniaxial Compressive Strength	-	-	-	-	-	-	-	-	2	1	1

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5. GROUND INVESTIGATION RECORDS AND DATA

5.1 Physical ground conditions

5.1.1 Summary of strata encountered

The following presents a summary of the properties of the ground and groundwater conditions encountered, based on field observations, interpretation of the field data and laboratory test results, taking into account drilling, excavation and sampling methods, transport, handling and specimen preparation.

Details of the results of the Hydrock ground investigation works are provided in the logs in Appendix C, a summary of the strata encountered forming the Ground Model is presented in Table 5.1 and the individual strata are described in the sections below. Relevant geological cross-sections are presented in Appendix A.

Table 5.1 supersedes the previous geological conditions (Issue P01) due to deeper boreholes penetrating the Cornbrash Limestone Formation allowing a more accurate site-specific dip of strata to be determined and correlated across the site as well as an understanding of deeper geological units.

Table 5.1: Strata encountered

Stratum	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m) (range)	Thickness (m) (average)
Topsoil Made Ground - Landfill	0.00	0.05 – 0.80	0.05 – 0.80	0.24
Landfill - General Made Ground	0.25 – 0.30	0.50 – 0.60	0.25 – 0.30	0.28
Landfill – Made Ground (restricted to the landfill only)	0.05 – 0.80	2.10 – 3.90	1.80 – 3.75	2.86
'General' Made Ground	0.00 – 0.30	0.10 – 1.20	0.10 – 1.10	0.54
Agriculturally Disturbed Topsoil	0.00	0.15 – 0.80	0.15 – 0.80	0.31
Alluvium	0.18 – 0.80	0.45 – 3.15	0.20 – 2.85	0.93
Head Deposits	0.20 – 0.40	0.40 – 1.70	0.10 – 1.40	0.62
River Terrace Deposits	0.10 – 3.90	0.80 – 5.90	0.22 – 5.55	2.37
Glacial Washout Till	1.20	1.80	0.60	0.60
Oxford Clay Formation	1.50 – 4.90	3.30 – 11.30*	0.70 – 8.60*	-
Kellaways Sand Member	1.00 – 11.30	1.90 – 14.40*	0.40 – 3.14*	-
Kellaways Clay Member	1.00 – 14.44	1.80 – 17.30*	0.20 – 3.50*	-
Cornbrash Limestone Formation	0.30 – 17.30	4.00 – 9.10*	0.29 – 3.70*	-
Forest Marble Formation	3.00 – 9.10	16.84 – 18.00*	8.75 – 10.40*	-
White Limestone Formation	16.84 – 18.0	>21.00	Not Proven	-
* Where proven				

5.1.2 Topsoil Made Ground – Landfill

Topsoil Made Ground – Landfill, was encountered in all locations within the landfill, to a maximum depth of 0.80m (with an average of 0.24m). However, it should be noted that in some areas, namely TP03, TP04, TP05, WS07, WS08 and WS09, the topsoil cover was minimal, with the surface cover comprising grass surfacing straight onto landfill.

The Topsoil Made Ground generally consisted of dark brown to orangish brown silty gravelly sand with high root content. Gravels consist of angular to sub-rounded, fine to coarse, of flint and sandstone with gravel sized fragments of angular fine to coarse brick and concrete and occasional glass, metal and fabric.

5.1.3 General Made Ground (Landfill)

No obvious capping of the landfill was identified, although locally in two locations (WS03 and BH01) to depths of up to 0.60m bgl, a firm yellowish greyish brown slightly sandy occasionally slightly gravelly clay was encountered, which appeared different to the underlying landfill Made Ground.

No plastic, metal, etc. objects were identified in this material, but were present in the underlying Landfill Made Ground. Whilst the locations where General Made Ground was encountered were within the apparent landfill boundary, the absence of obvious and significant man-made material suggests potential differences in material deposited and therefore, it has been interpretated that the materials in the areas of these observations are separate from the main landfill deposits.

5.1.4 Landfill – Made Ground

Landfill Made Ground was encountered across the area of the former landfill site to depths of up to 3.90m bgl. The depth and level to the base of the landfill are shown on Hydrock Drawings 19114-HYD-XX-ZZ-SK-GE-01003 and 19114-HYD-XX-ZZ-SK-GE-01004, provided in Appendix A.

The Landfill Made Ground was highly variable. However, it generally consisted of a mixture of greyish, orangish brown, gravelly sand (predominantly ash) with abundant man-made putrescible waste (as below) and gravel sized fragments of fine to coarse, angular to sub-rounded concrete, slag and brick, glass bottles (containing unknown liquid), plastic bottles, plastic wrapping, scrap metal, wires, batteries, bike frames, animal bones and newspaper (dated 1960's). Locally cobbles and boulders of concrete were encountered. Towards the base of the landfill the colour notably changed to dark grey and black.

During the investigation it was noted that the Landfill Made Ground had a putrid odour in all locations that increased with depth and in one location (TP02) a strong hydrocarbon odour was noted between 1.40m and 3.20m bgl. No low permeability lining was encountered at the base of the landfill and no capping was identified.

The lateral extents of the landfill were unable to be determined due to the presence of badger setts. However, investigation in the fields beyond have identified natural strata in all locations and as such the lateral extents of the landfill are interpreted as the hedgerows around the site.

5.1.5 Made Ground

Made Ground was encountered around the farm buildings in the central-east of the site (Parkers Farm) in HP207 – HP210, WS202 adjacent to a track in the north of the site to the pumping station, around the farm track, WS224 located in the north-east of the site and WS235 & WS236 associated with a track and farmyard area associate with the poultry and deer farm in the south-west of the site.

Around Parkers Farm, the Made Ground comprised mixed materials with a 0.10 – 0.15m concrete surfacing in 2 locations, with Made Ground up to 1.10m bgl comprising a gravelly slightly clayey sand and limestone gravel/cobbles. A slight PAH odour was noted in HP208 and black staining.

WS202 undertaken adjacent to the track in the north recorded Made Ground to 1.20m bgl with a firm orangish brown slightly gravelly sandy clay with sandstone and flint gravel with a soft band with occasional fragments of brick between 1.00m bgl to 1.20m bgl.

WS235 & WS236 encountered in the south-west recorded a brown slightly sandy gravelly clay with gravel constituents of flint, quartz, chalk and brick.

5.1.6 Agriculturally Disturbed Topsoil

Agriculturally Disturbed Topsoil was encountered across the majority of the site (excluding around the farm buildings, tracks and the area of the landfill). The topsoil present in the allotments is also included in the Agriculturally Disturbed Topsoil designation for completeness.

Topsoil was between 0.15m and 0.80m thick, with an average thickness of 0.31m. The topsoil comprised a brown slightly gravelly clayey sand and stiff (site work followed a prolonged period of dry hot weather) dark brown slightly gravelly sandy clay. Gravel constituents comprised flint and limestone.

For the purposes of this report, topsoil is defined as the upper layer of an in-situ soil profile, usually darker in colour and more fertile than the layer below (subsoil) which is a product of natural chemical, physical, biological and environmental processes.

Five composite samples of the topsoil were tested for compliance with BS 3882:2015. These were found to be complaint when compared to multi-purpose topsoil on the basis of the grading (clay content). However, they were found to be non-compliant when compared to multi-purpose topsoil on the basis of the pH, available plant nutrients, extractable phosphate, potassium and magnesium and Mass Loss on Ignition in one sample. This does not preclude the use of the topsoil as a growing medium as long as it is recognised the topsoil will require regular application of general-purpose fertiliser. Subject to noting the above comments, and subject to approval by the Client, the landscape architect or landscape contractors, the Agriculturally Disturbed Topsoil is considered likely to be suitable for reuse as general topsoil in the proposed development.

5.1.7 Alluvium

Alluvium was encountered underlying the Agriculturally Disturbed Topsoil in the vicinity of the stream in the north of the site, the southern boundary of the site and in the east of the site between the railway line and Oxford Canal, to depths of between 0.45m bgl and 3.15m bgl.

The Alluvium generally consisted of soft to firm orangish and yellowish-brown, locally grey, sandy clay to slightly sandy slightly gravelly clay interbedded with bands of yellow brown clayey sand to gravely sand with gravel constituents of flint and limestone. Locally an organic odour, or remnant rootlets were present.

The depth to the base of the Alluvium is presented on Hydrock Drawings 19114-HYD-XX-ZZ-DR-GE-01018 (m OD) and 19114-HYD-XX-ZZ-DR-GE-01019 (m bgl) in Appendix A.

Instability of excavation faces was noted in a number of locations within the Alluvium and was exacerbated by groundwater ingress.

5.1.8 Head Deposits

Head Deposits were encountered underlying the Agriculturally Disturbed Topsoil sporadically across the site and are interpretated as a cohesive band overlying the River Terrace Deposits, formed under periglacial conditions after their deposition. These were recorded to depths of between 0.40m bgl and 1.70m bgl with an average thickness of 0.62m.

The Head Deposits generally consist of stiff orangish brown sandy clay to slightly gravelly sandy clay with gravel constituents of predominantly flint.

5.1.9 River Terrace Deposits

River Terrace Deposits were encountered in the centre of the site, in the topographically higher areas, to depths between 0.80m bgl (where extending down slopes) to 5.90m bgl in the centre of the site. The depths to the base of the River Terrace Deposits are shown on Hydrock Drawings 19114-HYD-XX-ZZ-DR-GE-01020 (m OD) 19114-HYD-XX-ZZ-DR-GE-01021 (m bgl) in Appendix A.

These deposits generally consisted of medium dense to dense (but locally loose) slightly gravelly slightly clayey sand to a sandy gravel, with the gravel constituents of flint, limestone and ironstone. Local cohesive deposits were identified between granular layers.

Review of the data distribution indicates that the River Terrace Deposits are more cohesive, generally to the east and south of the landfill, with a soft cohesive band and occasionally a loose granular band of soils present at between approximately 62m OD and 59m OD.

Collapse within the River Terrace Deposits was recorded in the centre and south of the site, generally associated with groundwater ingress from depths of between 1.10m bgl and 1.40m bgl in the south (SA09, TP225, TP228 & TP229). Collapse of excavations within the trial pits was also noted in a number of locations between 1.20m bgl and 2.0m bgl in the east of the site and also generally associated with groundwater ingress.

Beneath the landfill, remnant River Terrace Deposits were present and consisted of yellowish to greyish brown slightly sandy gravel or sand and gravel.

The gravel consists of angular to rounded, fine to coarse flint and sandstone and limestone from 0.50m bgl to 3.90m bgl but >5.00m where the thickness was not proven. Within WS02 in the north-west corner these were noted to be a sandy clay to 5.0m bgl.

5.1.10 Glacial Washout Till

Strata interpreted as Glacial Washout Till was encountered in TP308 at a depth of between 1.20m bgl and 1.80m bgl and was described as a firm to stiff light brown and mottled grey slightly sandy slightly gravelly clay with gravel constituents of mudstone, sandstone and quartz.

5.1.11 Oxford Clay Formation

The Oxford Clay Formation was encountered underlying the superficial deposits in the centre of the site at topographic highs and underneath River Terrace Deposits beneath the landfill with the thickness of the unit generally unproven to depths of between 3.30m bgl and >11.30m bgl.

These deposits generally comprised a stiff grey to bluish grey clay occasionally thinly laminated and presence of shell fragments, selenite crystals and sand pockets.

Previous interpretation in the south of the site (Issue P01) has been updated to be reflective of the Kellaways Formation based on the local dip of the strata identified during additional works.

5.1.12 Kellaways Sand Member

The Kellaways Sand Member was encountered underlying the superficial deposits in the north of the site where it outcrops at surface and in RO305 in the southeast of the site. It was generally encountered as banded soft grey and orangish brown sandy clayey silt, grey sand or sandy clay and locally weathered near surface.

In the north of the site where encountered, the full thickness was not observed likely due to the deposition and erosion during deposition of the River Terrace Deposits where at outcrop.

5.1.13 Kellaways Clay Member

The Kellaways Clay Member was encountered directly underlying the superficial deposits in the north of the site and beneath the Kellaways Sand Member and overlying the Cornbrash Formation where proven in the deeper rotary boreholes in the north, centre and south of the site. In the north of the site where encountered, the full thickness was not observed likely due to the deposition and erosion during deposition of the River Terrace Deposits where at outcrop.

These deposits generally consisted of a stiff fissured grey, yellowish brown or greenish grey clay and were encountered near surface in the north overlying the Cornbrash Limestone Formation. Oyster shells were encountered in a number of locations which is consistent with the basal unit of this member and within TP215 for correlation.

5.1.14 Cornbrash Limestone Formation

The Cornbrash Limestone Formation was encountered underlying the superficial deposits, Kellaways Clay Member or immediately beneath the Topsoil in the north of the site where it outcrops at surface. These deposits generally consisted of light grey to yellowish brown very weak limestone or stiff yellowish brown sandy gravelly clay where weathered. The limestone was fractured and encountered as a gravel in the near surface highly weathered zones. Where deepening in the centre and south of the site the Cornbrash Limestone was generally un-weathered and comprised a strong grey limestone.

The Cornbrash Limestone Formation is anticipated to underlie the entire site beneath the Kellaways Clay Member, becoming deeper towards the south due to the dip of the strata and encountered at 17.30m bgl in the far southeast of the site.

In the vicinity of the landfill in the central-south of the site the Oxford Clay Formation, Kellaways Sand Member and Kellaways Clay Member are present above the older solid geology including the Cornbrash Limestone Formation.

The depth to the top of the Cornbrash Formation is shown on Hydrock drawing 19114-HYD-XX-ZZ-DR-GE-01022 (m OD) 19114-HYD-XX-ZZ-DR-GE-01023 (m bgl) in Appendix A.

5.1.15 Forest Marble Formation

The Forest Marble Formation was encountered underlying the Cornbrash Limestone Formation across the site (where fully penetrated) and underlying superficial deposits in the far northeast of the site. These deposits generally consisted of a grey very weak mudstone in the upper elements of the unit and a grey limestone in the base of the unit with a maximum thickness (where proven) of 10.40m.

The Forest Marble Formation is anticipated to underlie the entire site beneath the Cornbrash Limestone Formation, becoming deeper towards the south due to the dip of the strata.

5.1.16 White Limestone Formation

The White Limestone was encountered underlying the Forest Marble Formation in RO301 to RO304 at depths between 16.84m bgl to 18.00m bgl and comprised a strong light grey limestone. The base of the unit was unproven during the investigation.

5.1.17 Geological Cross Sections

Geological cross sections of the site based on the Hydrock Ground Investigations are presented on Hydrock Drawing 19114-HYD-XX-ZZ-DR-GE-01007 in Appendix A.

A dip of 0.7^{o} (a gradient of approximately 1(v) in 82(h)) has been assumed in the ground model based on the wider geology and assessment of strata horizons in boreholes RO301 to RO305 and RO308.

Individual cross sections relating to the proposed railway bridge and the proposed footbridge are presented in Cross Section lines E-E' and F-F'.

5.2 Obstructions

To date, obstructions encountered during the investigation have been limited to the landfill as summarised in Table 5.2.

Table 5.2: Obstructions encountered

Stratum	Location	Depth (m bgl)	Description
Landfill – Made Ground	TP06	0.90	Blocks of concrete and cemented bricks

Obstructions associated with existing buildings and with excavation in rock (in the north of the site) will also be present.

5.3 Visual and olfactory evidence of contamination (soil)

In addition to the more common man-made constituents (ash, slag, plastic, etc), described above in Section 5.1, visual and olfactory evidence of contamination was noted in a number of locations within the landfill, which are summarised in Table 5.3.

Table 5.3: Visual and olfactory evidence of contamination - soils

Stratum	Location	Depth (m bgl)	Description
Landfill – Made Ground	BH02	0.40 – 3.00	Putrid odour
Landfill – Made Ground	BH02	3.00 – 3.10	Strong putrid odour
Landfill – Made Ground	BH03	0.50 – 3.90	Putrid odour
Landfill – Made Ground	TP02	140 – 3.20	Hydrocarbon odour

Stratum	Location	Depth (m bgl)	Description
Landfill – Made Ground	TP03	1.50 – 2.50	Putrid odour
Landfill – Made Ground	TP05	1.40 – 2.80	Strong putrid odour
Landfill – Made Ground	WS05	2.80 – 3.60	Strong putrid odour
Landfill – Made Ground	WS06	1.40 – 2.10	Strong putrid odour
Landfill – Made Ground	WS09	2.90 – 3.10	Strong putrid odour

5.4 Groundwater

5.4.1 Groundwater observations and levels

Groundwater encountered during the investigation is provided on the logs in Appendix C.

Where groundwater was encountered, little rise in groundwater level was noted after 20 minutes. However, where observation was undertaken over a longer period, and shallow groundwater had been encountered during investigation, groundwater levels rose between 500mm and 750mm.

Groundwater levels recorded during post-fieldwork monitoring are provided in Appendix E.

Anecdotal evidence suggests the potential for springs to be present at the site. Following review of the geology encountered at the site during investigation works, the only location for potential springs is in the north-east of the site, to the north of Rowel Brook where a spring has been noted during a site visit/walkover by others.

5.4.2 Groundwater summary

In general, groundwater was encountered within the River Terrace Deposits towards the base of the stratum with the groundwater encountered shallower in the topographic lows of the site.

Groundwater levels are shown as hydraulic gradients in Figure 5.1 and Figure 5.2, reproduced from Hydrock Drawings 19114-HYD-XX-ZZ-DR-GE-01008 (m OD) and 19114-HYD-XX-ZZ-DR-GE-01009 (m bgl) in Appendix A.

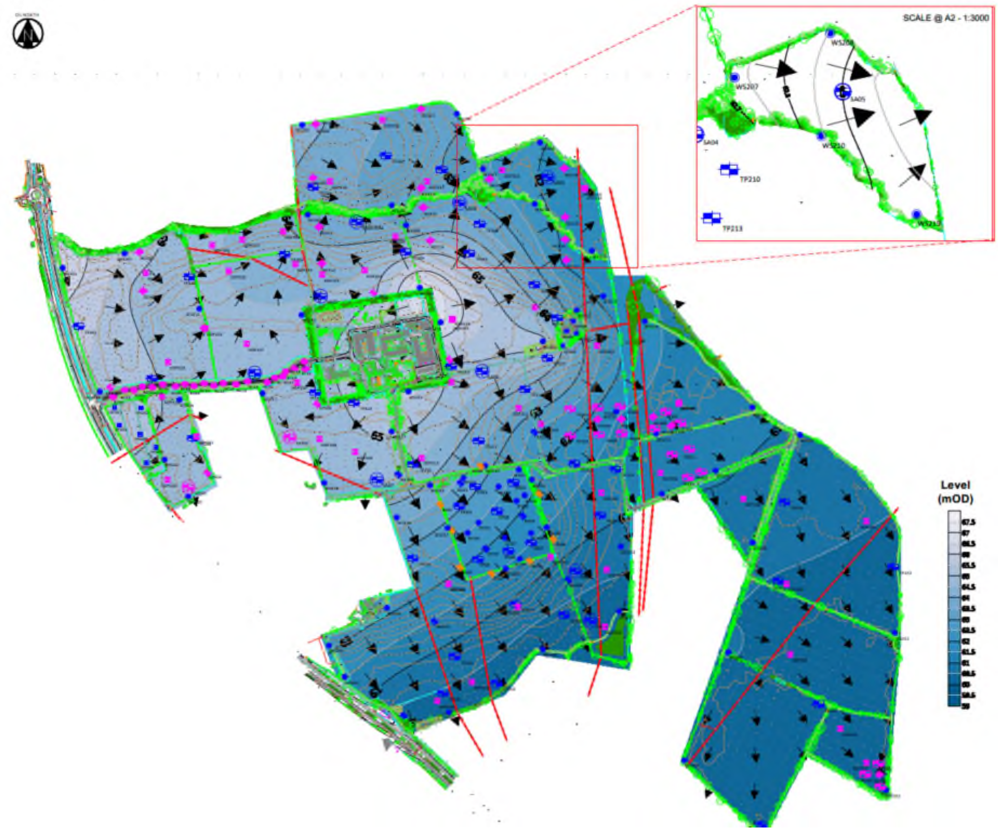


Figure 5.1: Groundwater levels (m OD)

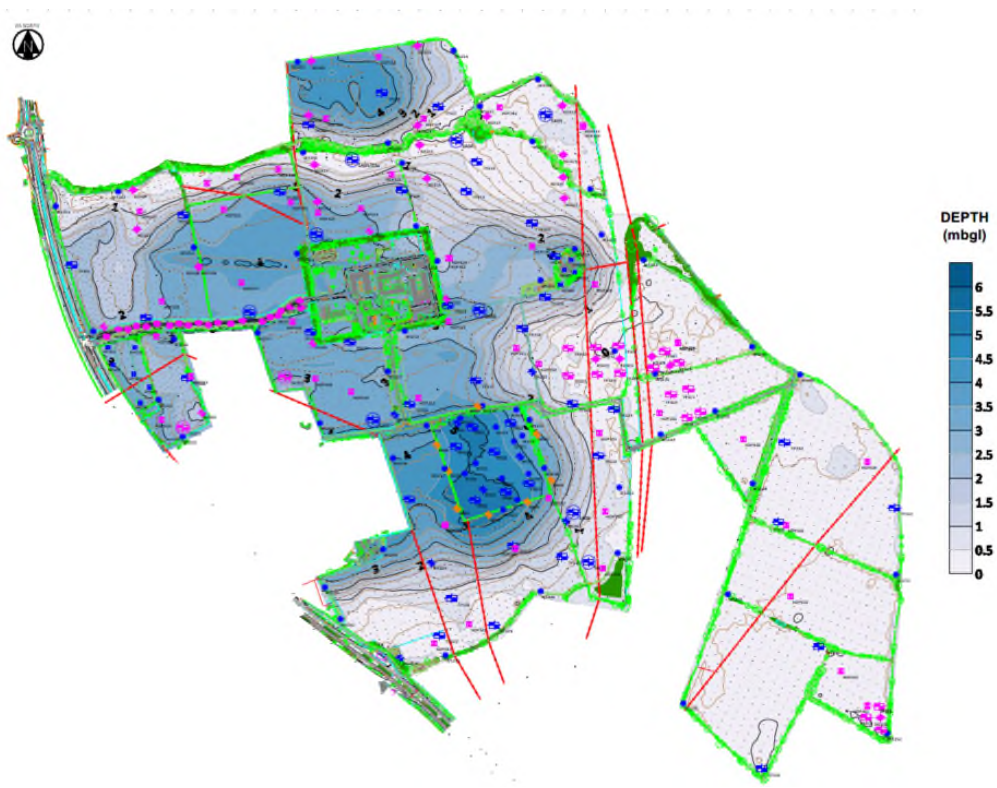


Figure 5.2: Groundwater depths (m bgl)

Based on the hydraulic gradient, within superficial deposits, the shallow groundwater flow is from the west of the site, from the topographic high, to the east and south-east, although in the north of the site groundwater flow is locally towards Rowel Brook (from the north and the south). In the far east of the site (in the floodplain), groundwater flows are to the south and at a shallower hydraulic gradient, but potentially influenced by the Oxford Canal which borders the east of the site.

Groundwater flow within the Cornbrash Limestone Formation and Forest Marble Formation is shown in the north of the site to flow towards the east as shown on Hydrock Drawing 19114-HYD-XX-ZZ-DR-GE-01024 (Appendix A). However, whilst based on the contour profiles from monitoring, the variable geology outcropping and overlying superficial deposits leads to a complicated groundwater regime and is likely to mask groundwater flow direction in this area. Groundwater flow is likely to be towards the south-west following the geological dip of the strata. It is unlikely that any impact from the proposed development will extend to the north, past Rowel Brook and be transmitted upgradient to the SSSI.

It is also unlikely that any changes in water level associated with the proposed development will significantly change the water levels to the north of Rowel Brook (which is more susceptible to any changes to the north and east of Rushy Meadows, than to changes to the south of Rowel Brook).

Potential adverse impacts on the Rushy Meadows SSSI based on the proposed development and the risk assessment summary (Table 12) of the WYG (2018) report are considered negligible.

Groundwater was encountered within the Landfill Made Ground in a few locations, likely to be at a similar level and in continuity with the groundwater in the surrounding remaining sand and gravel deposits, although monitoring indicates groundwater within the Summertown Radley Sand and Gravel is limited.

5.4.3 *Infiltration tests*

The results of the infiltration testing undertaken are summarised in Table 5.4. The results sheets are presented in Appendix C. Testing was carried out in general accordance with BRE Digest 365 (BRE DG365) (2016).

Table 5.4: Infiltration test results

Stratum	Location	Depth to base of pit (m bgl)	Infiltration rate (m/s)		
			Run 1	Run 2	Run 3
River Terrace Deposits	SA01	1.20 – 2.00	1.67×10^{-4}	1.91×10^{-4}	1.40×10^{-4}
	SA02	1.00 – 2.00	6.05×10^{-5}	3.47×10^{-5}	4.05×10^{-5}
	SA06	-	Destroyed by ploughing between installation and test.		
	SA07	1.30 – 2.10	1.92×10^{-4}	1.81×10^{-4}	1.35×10^{-4}
	SA301	1.00 – 1.60	7.13×10^{-5}	8.13×10^{-5}	8.09×10^{-5}
	SA302	1.40 – 2.50	2.25×10^{-4}	1.44×10^{-4}	1.40×10^{-4}
Alluvium	SA04	0.70 – 1.40	No water added due to standing groundwater level of 0.70m bgl decreasing to 0.75m bgl over 3 days.		
	SA03a	0.46 – 1.00	Infiltration rate too slow to calculate.		
	SA09	0.50 – 1.10	Infiltration rate too slow to calculate.		
Kellaways Clay Member	SA05	0.50 – 1.40	No water added due to standing groundwater level of 0.50m bgl decreasing to 0.61m bgl over 3 days.		

Stratum	Location	Depth to base of pit (m bgl)	Infiltration rate (m/s)		
			Run 1	Run 2	Run 3
	SA08	1.00 – 2.00	Infiltration rate too slow to calculate.		

5.5 Ground gases (carbon dioxide and methane)

Records from the gas monitoring boreholes are presented in Appendix E.

Six monitoring visits were undertaken as part of the previous landfill investigation works.

Fourteen monitoring visits have been undertaken to date as part of the site wide preliminary and additional investigations, with monitoring continuing on a monthly interval for a further three visits. The data are assessed in Section 7.6.

5.6 Geotechnical data

5.6.1 Introduction

Geotechnical laboratory test results are contained in Appendix D with *in situ* test results shown on the relevant exploratory hole log or datasheet in Appendix C. The following sections summarise the main findings and provide interpretation where appropriate.

5.6.2 Plasticity

The volume change potentials in terms of NHBC Standard (Chapter 4.2) with respect to building near trees have been determined from the results of plasticity index tests on samples of soil. These are summarised in Table 5.5.

Table 5.5: Volume change potential

Stratum	No. of tests	Plasticity Index (%)			Modified Plasticity Index (%)			Plasticity designation	Modified Volume Change Potential
		Min.	Max.	Av.	Min.	Max.	Av.		
Head Deposits	3	13	21	7	3	9	6	Low	Low
Alluvium	21	NP	44	20	NP	56	19	Medium to very high	Medium to high
River Terrace Deposits	14	NP	26	17	NP	17	7	Low	Non-Plastic to low
Glacial Washout Till	1	17	17	17	14	14	14	Medium	Low
Oxford Clay Formation	2	17	35	26	17	35	26	Medium to high	Medium to high
Kellaways Sand Member	6	8	17	14	8	17	13	Low	Low
Kellaway's Clay Member	6	34	45	39	34	45	39	High to very high	High
Forest Marble Formation	2	13	14	14	13	14	14	Low to Medium	Low

5.6.3 Particle size distribution

Particle Size Distribution test (PSDs) results are summarised in Table 5.6 and summary descriptions and PSD plots of the material analysed are presented in Appendix D.

Table 5.6: PSD results summary

Stratum	No. of tests	Fines %		Sand %	Gravel %	General description
		Clay	Silt			
Head Deposits	1	12	9	41	38	Slightly clayey gravelly SAND.
Alluvium	5	10 - 27	6 - 34	29 - 69	3 - 44	Slightly gravelly slightly sandy, slightly clayey SILT to gravelly sand.
River Terrace Deposits	9	13	17	17 - 66	27 - 53	Slightly clayey slightly silty sandy GRAVEL to gravelly SAND.

Stratum	No. of tests	Fines %		Sand %	Gravel %	General description
		Clay	Silt			
Kellaway's Sand Member	1	0 - 13	0 - 17	17 - 66	32 - 53	Slightly silty, slightly clayey SAND to sandy GRAVEL.

5.6.4 Soil strength

Table 5.7 summarises information pertaining to the shear strength of the soils according to geological stratum.

Factual results are summarised for laboratory tests, field tests (e.g. hand shear vane) and uncorrected Standard Penetration Tests (SPT). Where the SPT is used to infer shear strength by published correlation, this is also tabulated.

A shear strength versus depth profile is summarised in Figure 5.3 and presented in Appendix D.

Table 5.7: Soil strength results and derived values (Cohesive Soils)

Stratum	No. of tests	SPT (N 60-value) (range)	c_u (kPa) N60	Method
Head Deposits	2	24 – 28	205 – 240**	SPT – windowless sampler boreholes
	1	-	320	Laboratory Remoulded at OMC triaxial test
Alluvium	8	6 – 22	30 – 115**	SPT – windowless sampler boreholes
	1	8	40	SPT – rotary percussive
	22	-	11 – 73	Hand shear vane
Glacial Washout Till	1	-	90	Hand shear vane
River Terrace Deposits (Cohesive)	9	3 – 12	32 – 107**	SPT – cable percussion
	6*	3 – 18	32 – 169**	SPT – windowless sampler boreholes
	3	-	23 – 47	Hand shear vane
	3	-	250 – 540	Laboratory Remoulded at OMC triaxial test
Oxford Clay Formation	11	8 – 32	40 – >150**	SPT – windowless sampler boreholes
	6	25 – 50	120 – >250**	SPT – rotary percussive
	15	-	59 – 140	Hand shear vane
Kellaways Sand Member (Cohesive)	2***	18 – 19	120 – 125**	SPT – windowless sampler boreholes
	2	-	45 – 57	Hand shear vane
Kellaways Clay Member	12	9 – 50	40 – >250**	SPT – windowless sampler boreholes
	3	17	70	SPT – rotary percussive
	14	-	45 – 140	Hand shear vane
	1	-	610	Laboratory Remoulded at OMC triaxial test
	1	-	60	Undrained Triaxial
Forest Marble Formation	6	50	250**	SPT – rotary percussive

* three SPT values of N Value 50 removed due to refusal of borehole on likely granular material.

**Correlation with Stroud (1975) based on 'average' plasticity

*** Cohesive unit within this strata

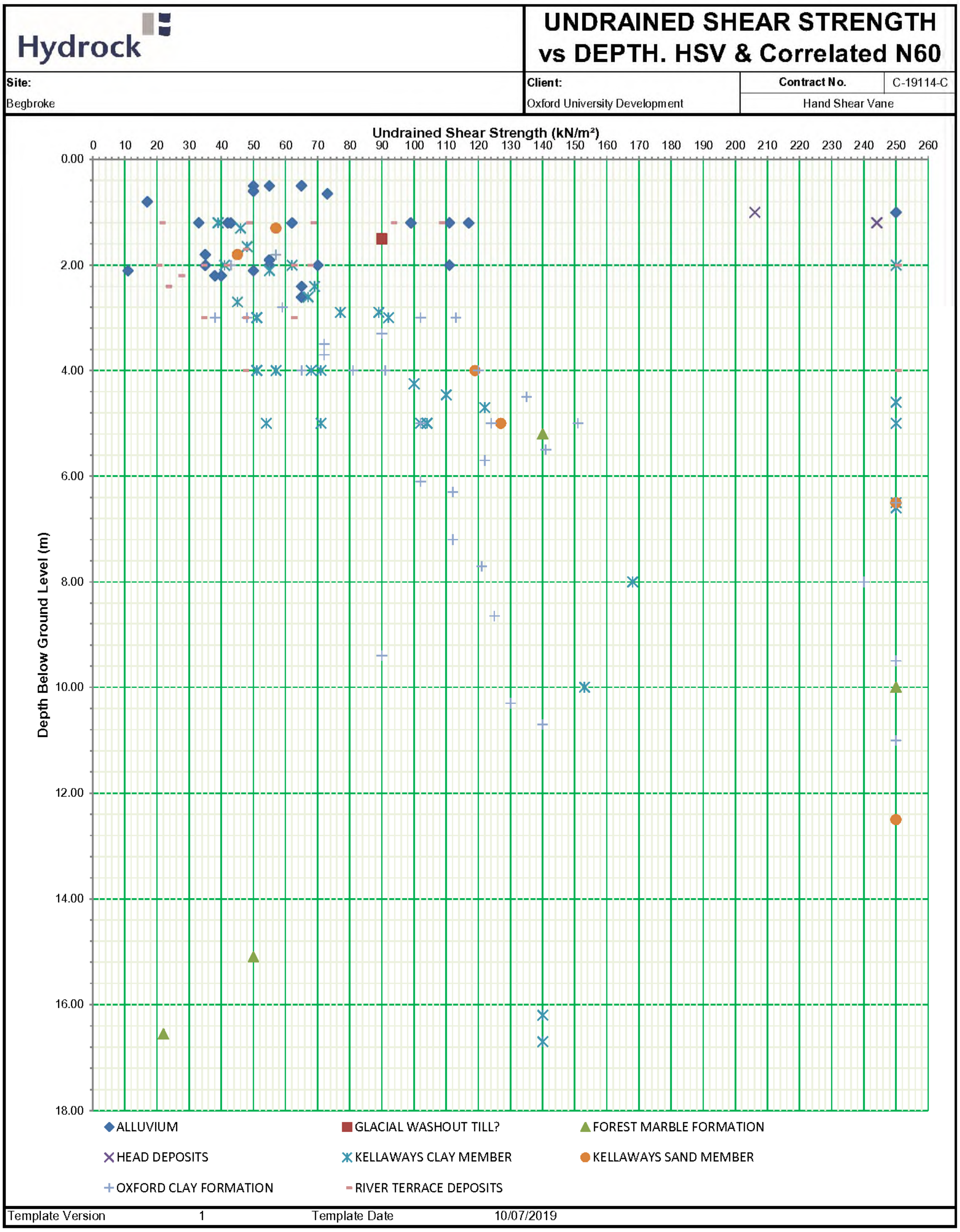


Figure 5.3: Undrained shear strength versus depth summary

As shown by Figure 5.3:

- The strength profile of the Alluvium indicates consistent, relatively low strength (<50kN/m^2). Although is highly variable.
- Head deposits are shown to be of high strength; however, it is noted that the soils were dry at the time of the investigation due to a prolonged period of hot and dry weather, and it is likely affected by some degree of desiccation near surface, which may be seasonal.

- Cohesive units within the River Terrace Deposits are shown to be generally of low to medium strength (25kN/m^2 to 80kN/m^2). However, based on a review of the data distribution, the cohesive soils of the River Terrace Deposits are generally located to the east and south of the landfill at a level of between 62m OD to 59m OD.
- The underlying solid geology of the Kellaways Clay Member and Kellaways Sand Member (Cohesive units) shows predominantly medium strength to 3.00m depth and then an increasing strength with depth profile.
- The Oxford Clay Formation shows medium strength to approximately 5.00m bgl and then has an increasing strength profile with depth.

5.6.5 *Relative density*

Table 5.8 summarises information pertaining to the relative density of the granular soils according to geological stratum.

Factual results are summarised for laboratory tests, field tests (e.g. SPT, CPT, dynamic probe correlation). A SPT 'N60' value versus depth profile is summarised in Figure 5.4. Plots are presented in Appendix D.

Table 5.8: Relative density results and derived values

Stratum	No. of tests	Method	SPT (N-value) (Range) N60	phi' (°)
Alluvium	2	SPT – windowless sampler boreholes (Peck et. al. (1967).	4 – 9	30 – 35
	1	SPT – rotary percussive (Peck et. al. (1967).	8	
River Terrace Deposits	12	SPT – cable percussion (Peck et. al. (1967).	4 – 50	30 – 52
	89	SPT – windowless sampler boreholes (Peck et. al. (1967).	3 – 50	28 – 52
	11	SPT – rotary percussive (Peck et. al. (1967).	4 – 40	-
Kellaways Sand Member	2	SPT – windowless sampler boreholes (Peck et. al. (1967).	22 – 24	42 – 56
	2	SPT – rotary percussive (Peck et. al. (1967).	23 – 50	

As shown on Figure 5.4:

- Gravel units as part of the Alluvium are recorded as loose.
- Within the River Terrace Deposits on the topographic high, SPT N_{60} values are generally indicative of medium dense soils or better (N_{60} >10) although locally loose to very loose soils are recorded with a general area of 62m OD to 59m OD recorded loose around the east and south of the landfill based on the data distribution.
- The Kellaways Sand Member is generally medium dense.

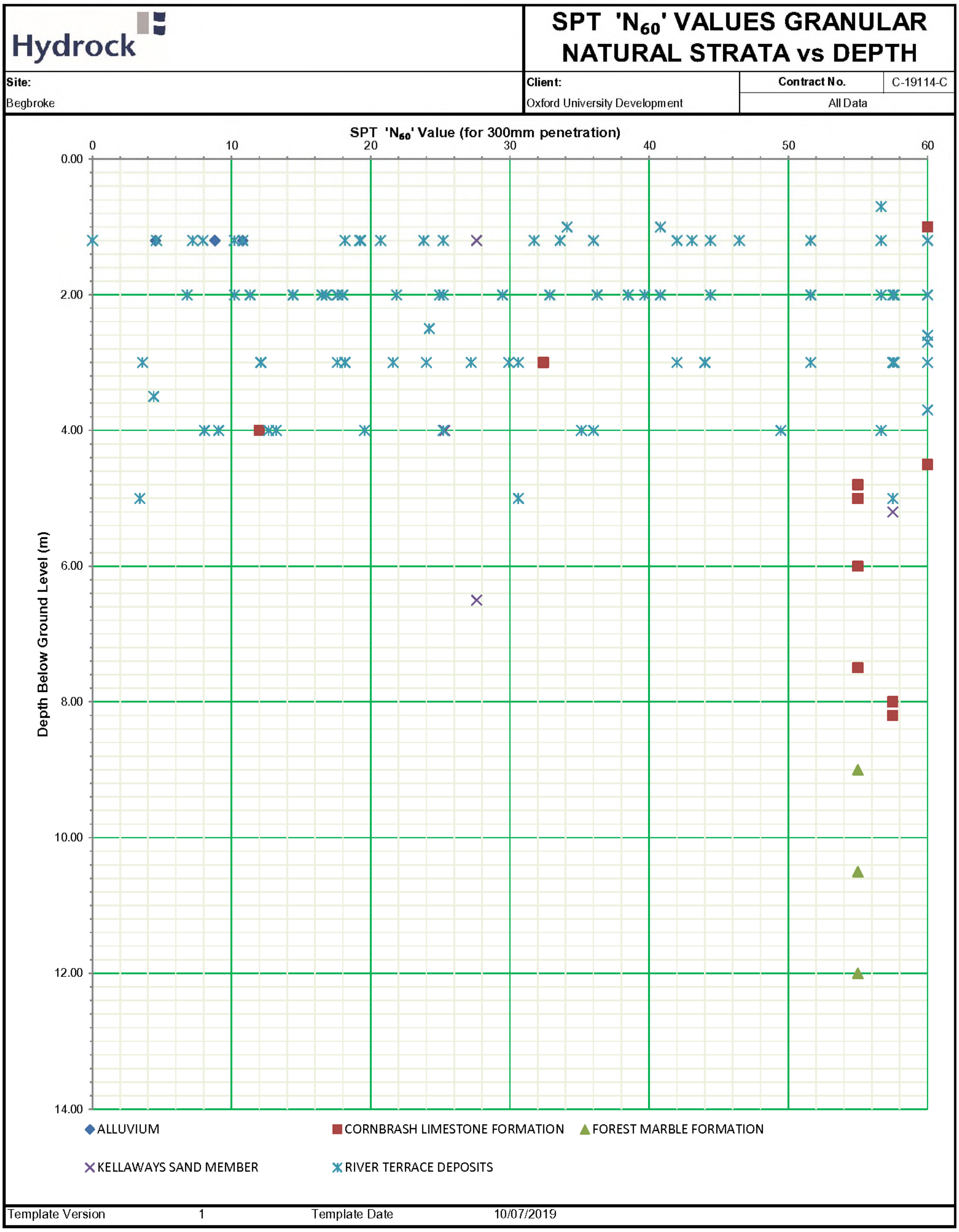


Figure 5.4: SPT 'N' Value versus depth summary

5.6.6 Compressibility

Table 5.9 presents a summary of the derived parameters for coefficient of consolidation and compressibility. The data indicates that the material is generally of medium to high compressibility over the pressure ranges tested.

Table 5.9: Summary of compressibility

Stratum	No. of tests / results	Method	Pressure Range (kN/m^2	Derived coefficient of volume compressibility (m_v) (m²/MN)
Head Deposits	2	Correlation with SPT [1]	-	0.04 – 0.05
Alluvium	9	Correlation with SPT [2]	-	0.02 – 0.29
River Terrace Deposits (Cohesive)	15	Correlation with SPT [3]	-	0.01 – 0.48
River Terrace Deposits (Granular on description)	1	One Dimensional Oedometer	40	0.097 (re-load 0.00042)
Oxford Clay Formation	17	Correlation with SPT [4]	-	0.02 – 0.26
Kellaways Sand Member	2	Correlation with SPT [5]	-	0.01 – 0.08
Kellaways Clay Member	15	Correlation with SPT [6]	-	0.18 – 0.25
	1	One Dimensional Oedometer	80	0.089 (re-load 0.041)

[1] An f_2 value of 0.88 has been used based on a plasticity index of 6. (Tomlinson (2001), after Stroud)).
[2] An f_2 value of 0.57 has been used based on a plasticity index of 6. (Tomlinson (2001), after Stroud)).
[3] An f_2 value of 0.62 has been used based on a plasticity index of 6. (Tomlinson (2001), after Stroud)).
[4] An f_2 value of 0.49 has been used based on a plasticity index of 6. (Tomlinson (2001), after Stroud)).
[5] An f_2 value of 0.68 has been used based on a plasticity index of 6. (Tomlinson (2001), after Stroud)).
[6] An f_2 value of 0.45 has been used based on a plasticity index of 6. (Tomlinson (2001), after Stroud)).

5.6.7 Compaction and moisture content

Table 5.10 presents a summary of the moisture content tests and compaction studies undertaken at the site. It should be noted that the samples tested were collected during an exceptionally long and significant dry period.

Table 5.10: Compaction study results

Stratum	No. tests	Method	Natural moisture content (%) (range)	Optimum moisture content (%) (range)	Particle density (Mg/m³) (range)	Maximum dry density (Mg/m³) (range)
River Terrace Deposits	3	4.5kg Rammer	8.9 – 13	9.2 – 11	2.74 – 2.92	2.03 – 2.22
Head Deposits	1		6.7	12	2.92	2.06
Kellaways Clay Member	1		27	19	2.72	1.74

5.6.8 *Subgrade stiffness*

The subgrade stiffness (CBR and Modulus of Subgrade Reaction) results are summarised in Table 5.11.

Table 5.11: CBR results and derived values

Stratum	No. tests	Method	Modulus of Subgrade Reaction k (MN/m²/m) (Range)	CBR (%) (Range)
Alluvium	5	Laboratory remoulded sample at Natural Moisture Content (NMC)	11 - 113	0.6 - 35
	21	Correlation in accordance with CD 255 based on plasticity and thin construction	22 – 27	2 – 3
Head Deposits	1	Laboratory remoulded sample at Optimum Moisture Content (OMC)	42.5	6.4
	3	Correlation in accordance with CD 255 based on plasticity and thin construction	27 - 32	3 - 4
River Terrace Deposits	5	Laboratory remoulded sample at Natural Moisture Content (NMC)	61 - 108	12 - 32
	3	Laboratory remoulded sample at OMC	49 - 136	8.3 - 48
	14	Correlation in accordance with CD 255 based on plasticity and thin construction	87 25 (cohesive)	20 2.5 (cohesive)
Oxford Clay Formation	2	Laboratory remoulded sample at OMC	27 - 32	3 - 4
Kellaways Sand Member	6	Correlation in accordance with CD 255 based on plasticity and thin construction	77	18
Kellaways Clay Member	1	Laboratory remoulded sample at OMC	31	3.7 (Top)
	6	Correlation in accordance with CD 255 based on plasticity and thin construction	22 - 25	2 – 2.5
Where using the IAN method, ‘k’ has been back calculated from the Equivalent CBR.				

5.6.9 Sulphate content

In accordance with BRE (Special Digest 1), the Design Sulphate (DS) classification and the Aggressive Chemical Environment for Concrete (ACEC) classification are presented in Table 5.12. The assessment summary sheets are presented in Appendix D.

Table 5.12: Aggressive chemical environment concrete classification

Stratum	No. tests	DS	ACEC
Head Deposits	2	DS-1	AC-1
Alluvium	8	DS-1	AC-1
River Terrace Deposits	15	DS-1	AC-1
Glacial Washout Till	1	DS-1	AC-1
Oxford Clay Formation	2	DS-4	AC-4
Kellaways Sand Member	5	DS-4	AC-4
Kellaways Clay Member	5	DS-4	AC-4
Cornbrash Limestone Formation	2	DS-2	AC-2
Forest Marble Formation	4	DS-4	AC-4
White Limestone Formation	1	DS-4	AC-4
GW around proposed Railway Bridge	5	DS-3	AC-3

5.6.10 Organic Matter Tests

The results of the Organic Matter Tests are presented in Table 5.13.

Table 5.13: Organic Matter

Stratum	No. tests	Organic Matter (%)
Agriculturally Disturbed Topsoil 0 - 100mm	50	2.0 – 8.4 (Average 3.9)
Agriculturally Disturbed Topsoil 100 - 200mm	50	1.3 – 6.8 (Average 3.5)
Agriculturally Disturbed Topsoil 200 - 300mm	50	0.9 – 4.4 (Average 2.5)
Alluvium	3	1.60 – 2.20
Head Deposits	1	0.60
River Terrace Deposits	3	0.20 – 0.40
Kellaways Sand Member	1	0.30
Kellaways Clay Member	1	0.60

5.6.11 Intact material strength – rock

Table 5.14 summarises information pertaining to the strength of the intact rock material according to geological stratum and, if applicable, weathering zones or other variations within particular strata. Results are summarised for laboratory and field tests. Where point load index tests are used to infer unconfined compressive strength (UCS), this is also tabulated. Rock strength terms follow the method of BS EN ISO 14689-1:2003.

Care should be exercised in using these assumed rock strength parameters for any purpose beyond the scope of this report because it may be that additional sampling and testing is required for certain purposes. The reader should refer to the original test results in Appendix D.

Note also that rock mass properties, in addition to intact rock material properties, should be taken into account for rock slope stability analysis and design purposes.

Table 5.14: Intact rock strength results and derived values

Stratum	No. of tests	Point load index (Range)		UCS (MPa) (range)	Method
		Is	$Is_{(50)}$		
Cornbrash Limestone Formation	4	0.68 – 3.46	0.82 – 4.17	19.68 – 101.1	Axial point load [derived from 24x Is_{50}]
	2	-	-	35.2 – 42.4	UCS test
Forest Marble Formation	4	0.54 – 1.63	0.69 – 2.10	16.56 – 50.4	Axial point load [derived from 24x Is_{50}]
	1	-	-	24.4	UCS test
White Limestone Formation	3	0.66 – 1.43	0.80 – 1.81	19.2 – 43.4	Axial point load [derived from 24x Is_{50}]
	1	-	-	27.2	UCS test

6. GEOTECHNICAL ASSESSMENT

6.1 Geotechnical categorization of the proposed development

The following geotechnical assessment is based on the preliminary Ground Model and understanding of the site. Further detailed investigation will be required to finalise foundation recommendations across the site.

Eurocode 7, Section 2 (EC7) advocates the use of geotechnical categorisation of the proposed structures to establish the design requirements.

Whilst the design of the development is not finalised to date, it is understood that the development will be mixed residential and non-residential uses with a number of greenspaces in the east and north of the site,.. Final site levels and cut/fill requirements are not available at this stage.

A proposed cycleway and footbridge is proposed across the Didcot and Chester Rail Line with up to approximately 9m of fill adjacent to bridge abutments and retaining walls. Whilst outside the scope of this report consideration should be undertaken with regards to settlement of fill and abutments, groundwater levels and ground deflection both vertically and laterally. Current plans approved in principle indicate a proposed piled foundation solution with up to 1.20m of existing ground level excavated and replaced beneath raised areas.

A second bridge is proposed to cross the canal in the south west with two options under consideration. second proposed bridge in the southeast of the site crossing Oxford Canal comprising either a roadway and path totalling 8.2m width or 4m shared path. Both designs include approximately 5m of fill either side of the bridge abutments. No further details are known. As above, consideration should be undertaken with regards to settlement of fill and abutments, groundwater levels and ground deflection both vertically and laterally

For a preliminary assessment, it has been assumed that all the proposed structures will be classified as Geotechnical Category 1 in accordance with EC7. However, based on the outline design it is likely that once confirmed a number of areas of the site will be classified as Geotechnical Category 2 including proposed bridges (understood to be undertaken by others).

The Geotechnical Category should be re-assessed at the design stage.

For Category 2 or 3 structures, specific geotechnical design is required together with Geotechnical Design Reports and Feedback Reports.

Following ground investigation and as part of the assessment provided in the following section, the preliminary geotechnical hazard identification undertaken in Section 3.3 has been updated.

A preliminary Geotechnical Risk Register following investigation is provided in Appendix H (Table H.3). This will need to be updated during future design works.

6.2 Characteristic design values

For design of Category 1 structures in accordance with BS EN ISO 1997-1 (EC 7), the geotechnical parameters given in Table 6.1 can be used for preliminary design, with additional investigation required to allow design for construction.

These values have been determined from laboratory testing, *in situ* testing and by professional judgement using published data together with knowledge and experience of the ground conditions. Care should be exercised in using these assumed soil strength parameters for any purpose beyond the scope of this report because it may be that additional sampling and testing is required for certain purposes. The reader should refer to the original test results summarised in Section 5 and provided in Appendix C and Appendix D.

Table 6.1: Geotechnical parameters recommended for design of Geotechnical Category 1 Structures (EC7)

Parameter / Stratum	Bulk unit weight kN/m³	Effective angle of internal friction °	Undrained shear strength kN/m²	Coefficient of compressibility m²/MN	Modulus of subgrade reaction (IAN73/06) MN/m²/m
	γ [a]	ϕ' [b c]	c_u [d]	m_v [e]	k [f]
Head Deposits	15 – 17	27	75	0.04 – 0.05	30
River Terrace Deposits	15 – 18	30 – 52	30 – 75 (Cohesive unit)	0.01 – 0.48	60 25 (Cohesive)
Oxford Clay Formation	16 – 20	24	50kPa at 3.0m + 15 z* (depending on depths and levels) Increasing with depth	0.02 – 0.26	30
Kellaways Sand Member	15 – 18	42 – 52	50	0.01 – 0.08	30
Kellaways Clay Member	15 – 19	23	50kPa at 3.0m + 15 z* (depending on depths and levels) Increasing with depth	0.18 – 0.25	25

All design values should be selected based on specific conditions. This table is for general guidance only.

[a] Estimated based on the recommendations of BS 8004-2015.

[b] Internal friction (ϕ') values for the granular in situ material derived from SPT data following the recommendations of Peck et al., (1967).

[c] Internal friction (ϕ') values for the cohesive in-situ material derived from BS 8004-2015, where ϕcv' is derived from plasticity index. The use of ϕcv' in the analysis is considered to provide a conservative estimate of ϕ'.

[d, e] Site measurements and laboratory data.

[f] Based upon the equilibrium long term CBR from DMRB IAN 73/06 Rev 1 Table 5.1.

* Generally increased linearly with depth. z represents depth.

6.3 Groundwork

6.3.1 Site preparation

No significant buried obstructions were encountered by this investigation and are unlikely to be present outside of the landfill and areas of historical construction, and for most of the site the possibility of buried obstructions being encountered is low. However, the redevelopment will involve demolition of some existing buildings (at Parkers Farm and part of the Science Park. It is highly likely that buried obstructions will be encountered in areas of previous development. It is therefore recommended that allowance be made for breaking out obstructions, for example provision of pneumatic breakers for site plant. If underground structures cannot be removed, they could be surveyed in three dimensions and the new structures designed to accommodate them.

The presence of the shallow Cornbrash Limestone Formation (rock) in the north of the site may cause localised difficult excavation. Whilst the Cornbrash Limestone Formation can usually be excavated by large plant and toothed buckets, localised breaking out may be required for excavation of rock.

Several services cross the site, including overhead HV cables and a below ground rising sewage main, which will require either moving or consideration as part of the detailed design.

Topsoil should be removed from beneath all building and hardstanding areas, this will create significant volumes of soil, which will need to be managed as part of the development.

6.3.2 Groundworks

Noting the above comments regards excavation through buried construction, or intact rock, excavation of shallow soils should be generally feasible using conventional plant and equipment.

Collapse / spalling of trial pit faces was noted during trial pit excavation in several locations within Alluvium and River Terrace Deposits. This was noted particularly in the coarse soils and was exacerbated where groundwater ingress occurred.

In addition, the Oxford Clay can be fissured and whilst instability due to fissuring was not noted in the trial pit excavations, fissuring can cause instability of excavations open for longer periods or long lengths.

Shallow (1.00m deep) excavations should generally be stable for short periods of time, but random and sudden falls should be anticipated from the faces of near vertically sided deeper excavations put down at the site.

Temporary trench support, or battering of excavation sides, is recommended for all excavations that are close to, or below the water table, or are to be left open for any length of time, and must be provided for entry by personnel. Particular attention should be paid to excavation at, or close to, site boundaries and adjoining existing roads, railway (and embankment features), structures and buildings, where collapse of excavation faces could result in damage to property or risks to safety and accessibility.

A risk assessment of the stability of any open excavation should be undertaken by a competent person and appropriate measures adopted to ensure safe working practise in and around open excavations. Further guidance on responsibilities and requirements for working near, and in, excavations can be obtained from the Construction Design and Management Regulations (2015), Construction Information Sheet 47: Inspections and Reports (2005) and HSG47: Avoiding Danger from Underground Services.

To ensure no loads are imposed on the sides of the excavation, spoil should not be placed immediately adjacent to the excavation. Spoil should be placed a suitable distance from the side of the excavation (as assessed by a competent person).

Based on site observations, the rate of water ingress to the proposed excavations is likely to be significant through the River Terrace Deposits and Alluvium. Variable groundwater depths were encountered across the site, generally controlled by topography but as shallow as 1.30m bgl in the south and east as shown on Hydrock Drawing 19114-HYD-XX-ZZ-DR-GE-01009 (Appendix A). In these circumstances, groundwater control by sump pumping may not be sufficient to deal with anticipated flows and significant high volume pumps (running for extended time) are likely to be required. If high volume pumps are not sufficient, alternative methods of dewatering, or use of impermeable cut-offs would be required.

However, it should be recognised that groundwater levels may vary from those at the time of the investigation, for example in response to seasonal fluctuations and the timing of construction may dictate the extent of groundwater control required.

Any water pumped from excavations may need to be passed via silt controls (to reduce suspended solids) before being discharged (under license or consent as required).

6.3.3 Earthworks/reuse of site-won materials

At this stage, Hydrock is not aware of specific earthworks proposals. However, it is understood that general cut to fill will be required, along with the construction of bridge abutments, and a noise / visual screening bund along the railway. Given the relatively gentle slopes across the site, it is assumed (at this stage), that significant retaining walls will not be required (although this is subject to detailed design of site levels).

Supplementary earthworks testing and an Earthworks Specification will be necessary to ensure the appropriate design and specification of earthworks.

Significant earthworks, such as the construction of bridge abutments, and a noise / visual screening bund along the railway will be Category 2 in accordance with BS EN ISO 1997-1 (EC 7) and further geotechnical design may be necessary. Once site proposals have been further defined, more specific consideration will need to be given to the reuse of materials and reference should be made back to this office.

The classification of materials depends on both the proposed end use and whether the material will meet the performance requirements of that end use. Based on Hydrock's understanding of the proposed development, the following assessment (Table 6.2) is based on the preliminary geotechnical classification data (see Section 5.6 and Appendix D) and the assumption that fill is placed as General Fill.

Table 6.2: Preliminary earthworks assessment

Stratum^	Proposed end use	Preliminary classification (SHW Series 600)	Comment	Suitability for improvement by the inclusion of binders
Topsoil	Open Space	Class 4 (Landscape Fill)	Unsuitable for General Fill due to high organic content. Can only be used in areas which are not sensitive to settlement. Could be used for landscape bunding if designed appropriately.	-
Alluvium	External Areas	Class 2C Class 4 Class 1	Areas predominantly outside development areas and unlikely to be significant excavation. Generally more suitable to Class 4 use, but some pockets may be suitable for Class 2. Granular layers class 1.	-
Head Deposits*	External Areas	Class 2C	Dry of optimum moisture conditioning e.g. wetting down by bowser and rotavator potentially to be required.	Likely to be suitable

Stratum^	Proposed end use	Preliminary classification (SHW Series 600)	Comment	Suitability for improvement by the inclusion of binders
River Terrace Deposits*	External Areas	Class 1 – granular Class 2C – cohesive pockets	Near optimum.	Likely to be suitable
Kellaway's Clay Member	External Areas	Class 2A/2B	No earthworks testing undertaken.	Unlikely to be suitable
Kellaway's Sand Member	External Areas	Class 2C	No earthworks testing undertaken.	Unlikely to be suitable
Oxford Clay Formation	External Areas	Likely Class 2	No earthworks testing undertaken due to depth of unit beneath RTD	Unlikely to be suitable due to the high sulphate concentrations

^ Cornbrash Formation soils are generally poor with regards to earthworks due to a mix of weathered platy rock, clay and unweathered rock. This may be suitable for Class 4 fill, but may need running through a crusher to homogenise the excavated materials.

* It should be noted that sampling was during a significant and extended dry period, and natural moisture contents may be lower than normally present.

The earthworks will need to be undertaken under a Materials Management Plan (see Section 9.3).

This report is written on the understanding that the landfill is to remain open space, with any excavated landfill soils, to be disposed of off-site.

Before the use of hydraulic binders is approved, comprehensive testing will need to be completed by a specialist Contractor to satisfy both themselves and the Engineer of the suitability of the soils for treatment and to confirm that the requisite end-performance of the material is achievable. In all instances where improvement by the inclusion of binders is considered, a mix design is required and as part of this design, samples should be checked for swelling, even where very low sulphate values are recorded.

Where it is proposed to reuse site won materials as an engineered fill it will be necessary to understand the proposed levels and structures, undertake additional investigation and develop an appropriate geotechnical design, and site-specific Earthworks Specification. The basis for the Specification should be BS 6031:2009 and the latest version of the SHW, Series 600 Earthworks. Once site proposals have been further defined more specific consideration will need to be given to the reuse of materials and reference should be made back to Hydrock.

6.4 Slope stability

There are no significant existing slopes on the site. Therefore, Hydrock considers the existing slopes will not present significant constraints to the development.

However, the above preliminary conclusions should be reviewed as part of the separate geotechnical design once final levels are known, and in the light of proposed engineered changes in levels where slopes or retaining walls may be required.

As a preliminary assessment, 1V:3H slopes using natural subsoils are likely to be stable (subject to detailed design).

6.5 Foundation recommendations

This section provides recommendations for the foundations for Characteristic Design Situation 1 (low rise 1 to 2 story developments) founding in natural ground. The foundation recommendations should be reviewed once the final design and further detailed investigation works are known. It is considered that the majority of structures will be within the west, central and south of the site based on a preliminary understanding of the proposed site layout.

The recommendations in this report include recommendations in the current NHBC Standards (2023).

Preliminary foundation recommendations for the related buildings in this section are based on the geotechnical parameters provided in Section 6.2 and are subject to further assessment following detailed investigation.

The safe bearing pressures for foundations quoted for Category 1 structures in this report take into consideration traditional factors of safety against the risk of shear failure of the ground and should prevent undue or excessive total and differential settlement from the anticipated structural loadings.

A separate geotechnical design will be required at the design stage (subject to further detailed investigation) once the development proposals are finalised with regards to Geotechnical Category 2 assessment to take into account the risk of shear failure of the ground (ultimate limit state). Serviceability limit state assessment will need to be undertaken as part of the separate geotechnical design.

6.5.1 Foundation types

Based on the ground conditions indicated from the current investigation, the preliminary recommendations are as follows:

- For houses up to 2½ storeys: strip/trench fill foundations across the centre, north and west of the site (deepening due to trees as required) to depths of between 1m and a maximum depth of 2.5m bgl, depending on site specific ground conditions and the locations of existing and proposed trees and hedges. Groundwater ingress and stability is likely to be a limiting factor with regards to strip/trench fill.
- Pad foundations for commercial buildings with relatively light loads.
- Ground improvement by vibro stone columns (VSC) with reinforced strip foundations or pads in areas underlain by loose sands and soft clays, located to the east and south of the landfill.
- Piled foundations will be required in areas underlain by deep Made Ground, and soft compressible deposits such as Alluvium, or to the south and east of the landfill, due to risks of excessive settlement from anticipated structural loads.
- Piled foundations for houses where foundation depths are greater than 2.50m, such as due to trees on shrinkable clays, or deep low strength / loose / compressible strata.
- Pile foundations are likely to be required for bridge abutments.

A foundation zonation plan is presented in Hydrock Drawing 19114-HYD-XX-ZZ-DR-GE-01026 (Appendix A).

6.5.2 Strip / trench fill and pad foundations

Strip / trench fill foundations are considered suitable for houses up to 2.5 storeys in height across the centre, north and west of the site, where they can be restricted to 2.5m depth.

Pad foundations are likely considered suitable to support columns for commercial structures, where soil strengths or relative densities are adequate (across the centre, north and west of the site) and where excessive settlement can be mitigated. However, this will be dependent on the structural loads and limits of acceptability for settlement, which are unknown at this stage.

All foundations should be founded at least 300mm into the medium dense or better River Terrace Deposits and firm or better clay of the Head Deposits, Oxford Clay Formation or Kellaways Clay Member or the Cornbrash Limestone Formation if encountered. The Alluvium, landfill, and areas of deeper General Made Ground, and loose or soft natural deposits are unlikely to be suitable founding stratum.

Appropriate preliminary safe net bearing pressures are presented in Table 6.3. As Alluvium is not a suitable stratum for founding this is not included.

Table 6.3: Preliminary Safe Net Bearing Pressures, subject to site specific assessment and design

Stratum	Safe net bearing pressure (Strip) (kN/m^2)	Safe net Bearing Pressure (Pad 1.0 x 1.0m) (kN/m^2)	Minimum Founding Depth (m)
Head Deposits	100	170	0.75
River Terrace Deposits	130	190	0.75
Weathered Oxford Clay Formation	100	130	1.00
Kellaways Sand Member	100	130	0.75
Kellaways Clay Member	100	130	1.00
Cornbrash Limestone Formation	150 (assumed on rockhead)	150 (assumed on rockhead)	0.75

If enlarging the foundations is considered (for example because loads are such that the quoted bearing pressure is inadequate) this could lead to increased settlements and the above recommendations should be reviewed.

Based on the NHBC volume change potential (medium to high in cohesive soils), the minimum founding depth for pad, strip or trench fill foundations is variable across the site. Within cohesive units foundations should be a minimum of 1.00m below final ground level (bfgl), and within granular soils it is recommended that a minimum depth of 0.75m bfgl is allowed for.

Foundations should extend through the base of any Made Ground and below the soft cohesive soils, and loose granular deposits whichever is deeper, and at least 300mm into underlying competent material.

In addition, foundations may need to be deepened to below the depth of influence of trees from desiccation effects and roots.

Where foundation depths are stepped, for instance, in trench fill and strip foundations to match changes in depths due to trees or ground conditions, the steps should be designed in accordance with NHBC Standards.

If trees are to be removed, the roots should be grubbed out and foundations extended to below the zone of disturbance created by this activity and to below any remaining root hairs.

Deepening of foundations in accordance with NHBC Standards will be required where foundations are within the zone of influence of existing, removed or proposed trees and proposed shrub planting. A tree survey should be undertaken by an arboriculturist in accordance with BS 5873:2012 to identify the type, and height of existing trees on the site and including any off-site trees, which could have an effect on foundation design.

Where trench fill foundations are within the zone of potential desiccation from trees and are deeper than 1.50m bgl, a suitable compressible material or void former will be required on the inside faces of foundations to external walls and beneath ground bearing floor slabs.

Excavation of strip / trench fill and pad foundations in excess of 2.50m bgl (in some places, significantly shallower) is unlikely to be economical and may be impracticable to undertake due to loose granular soils (from generally 1.80m bgl but as low as 1.30m bgl in the south) and water bearing sands which could result in trench collapse. However, if trench fill foundations in excess of 2.50m depth are proposed, they should be designed by a Structural Engineer in accordance with the requirements of the NHBC Standards (Chapter 4.2.8) and NHBC Technical Requirement R5. In addition, Hydrock recommends that the design of foundations deeper than 2.50m should take into account soil desiccation risk from plot specific testing if within the influencing distance of trees.

Foundation formations should be inspected by a suitably competent person to ensure the founding conditions are suitable and as indicated in this report. Any formation materials deemed as unsuitable should be excavated and replaced with lean mix concrete or deepened to suitable strata. If this is not possible, alternative solutions (such as piling) should be undertaken.

As the ground conditions at formation level are likely to be of variable type and stiffness, for the strip/trench fill foundations, it is recommended that foundation concrete should be reinforced with mesh reinforcement (designed by others) across the zone of variable soil conditions.

Foundation excavations should be protected from rainfall, inflow of surface water, frost and freezing conditions. They should also be protected from drying out in hot dry weather.

Groundwater monitoring indicates a shallow groundwater table in topographic lows of the site within the River Terrace Deposits and excavations may be difficult to undertake. Alternative methods of groundwater control may be required as fast groundwater ingress is anticipated, which could result unstable excavations.

The Oxford Clay Formation is an over consolidated clay, which can swell and soften in contact with water. Therefore, care will be required to ensure that foundation excavations are kept as free of water as practicable. Foundation concrete should be poured as soon as practicable after excavation.

6.5.3 Piled foundations

Piled foundations are recommended, to deepen foundations to below the influence of trees (in the vicinity of cohesive soils), where foundation depths are greater than 2.50m and where loose granular deposits are encountered, and where foundation trenches are prone to collapse.

Depending on column loads and layouts, piles should extend to a suitable depth into the underlying solid geology. The choice of piling system should be undertaken by a specialist piling Contractor and the design of piles is beyond the scope of this report. However, the decision on pile type and design should take into account the following factors relevant to the site:

- Obstructions in the ground are expected from rock bands which could cause piles to stop shallower than the design depths, or to deviate from the vertical, thereby reducing their capacity. In some circumstances, obstructions can lead to pile breakage.
- Pile installation can create preferential pathways for the migration of contaminants to the groundwater.
- Boring of piles through coarse soils can result in loosening of the material, with resultant risk of shaft collapse prior to concreting and reduced shaft friction.
- Groundwater levels are variable across the site and temporary casing is likely to be required for bored piles. If CFA piles are used, concrete is placed as the auger is withdrawn, which can balance the water pressure if the operation is undertaken carefully.
- Piles should extend a minimum of five pile diameters into the bearing stratum to mobilise sufficient shaft friction and end-bearing resistance to carry the required loads without unacceptable settlement.
- Piles should also be designed to cater for the potential down-drag effects of negative skin friction on piles from the secondary consolidation / creep.
- Collapse of the pile shaft can be caused by 'necking' of the pile in running sand conditions, leading to pile failure.
- Where foundations are constructed on clay soils within the influencing distance of trees design should include for the upper section of the pile to be sleeved or additional length allowed for to resist stresses from clay swelling or shrinkage. In addition, heave protection may be required on the inside faces and underside of the ground beams.

6.5.4 Vibro-replacement stone columns (VSC)

VSC may be suitable where excavations through loose granular deposits are prone to collapse to reach a suitable stratum subject to further investigation, or in areas of loose / soft deposits (generally east and south of the landfill).

Treatment by VSC at suitable spacing should lead to significant improvement of the soils by the creation of stone columns, but also by the densification of the existing essentially granular soil. Soils with a high silt content or organic soils are typically unsuitable for VSC improvement. The depth and spacing of the VSC treatment should be determined by a specialist contractor.

Following treatment, a safe net bearing pressure of 125 kN/m² is typically available for design of spread foundations. Confirmation of the allowable net bearing pressure should be confirmed by *in situ,* maintained plate load testing.

Shrinkable soil reinforced with stone columns is still susceptible to volume change and foundations should be designed accordingly, particularly where they are in the zone of influence of existing or proposed trees.

Different VSC Contractors use different methods of emplacing the stone columns and an initial assessment by Hydrock indicates that there is no restriction on the type of emplacement method (top feed, bottom feed, wet mix, dry mix etc.) due to the ground conditions. However, due to the presence of groundwater and / or weak soils (with the potential for collapse), it is recommended that bottom feed VSC is used.

The VSCs should be designed by a specialist in accordance with Chapter 4.5 of the NHBC Standards. In addition, Hydrock recommend a Specification for the use of VSCs is written in accordance with BRE 391 to assist with NHBC approvals and sign off.

6.5.5 *Foundation works risk assessment*

A foundation risk assessment may be required to determine if the proposed piling and the installation of VSCs will result in a significant increase in risk of pollution to Controlled Waters, particularly if undertaken in close proximity to the landfill.

The foundation works risk assessment should be undertaken in accordance with the risk assessment flowchart from National Groundwater & Contaminated Land Centre Report NC/99/73 (Figure 6.1) and will need to identify what additional risks to the environment piling / VSC installation may introduce and, if necessary, identify mitigation measures that will need to be put in place to remove any significant adverse environmental impacts.

6.5.6 *Working platform*

A working platform will be required prior to the arrival on site of tracked piling and VSC installation plant. This should be designed and installed in accordance with BR470 (BRE 2004) based on data on the specific plant in accordance with an FPS certificate for the rig loadings.

6.6 Ground floor slabs

6.6.1 *Residential dwellings*

In accordance with the NHBC standards, as clay soils of medium to high volume change potential are present at the site, it is recommended that suspended floor slabs with a void be adopted in areas of cohesive soils where outcropping at surface.

However, a significant part of the site (central and central -western areas) has granular deposits near surface (non-plastic or low heave potential) and slabs without a void (ground bearing or suspended cast *in situ* onto the ground) may be used if all of the following criteria are satisfied:

- the foundation depth (such as due to the influence of trees) is less than 1.50m;
- any fill is suitable, well-compacted granular material and less than 600mm thick;
- it is demonstrated that the soils are not desiccated and are at their equilibrium moisture content; and
- ground floor construction is not undertaken when the surface soils are seasonally desiccated (i.e. during summer and autumn), unless NHBC is satisfied the soil is not desiccated.

Ground floor slabs should be designed to incorporate any gas mitigation measures that may be required, as discussed later within this report.

6.6.2 *Commercial properties*

For small scale commercial buildings, suspended floor slabs are proposed.

For large scale commercial buildings, ground bearing floor slabs will likely be possible.

6.7 Roads and pavements

Based on the test results and subject to *in situ* testing during construction, it is considered likely an equilibrium CBR of 3% should generally be achievable over the majority of the site, and 5% where the sub-grade is granular. Where earthworks are undertaken to a suitable Specification, as 3% equilibrium CBR of 3% should assumed.

Proof rolling of the formation level will be required, and any loose or soft spots should be removed and replaced with an engineered fill, in accordance with a suitable Specification. The formation level will also need to be protected during inclement weather from deterioration; all slopes should be trimmed to falls to shed rainwater and the surface sealed to limit infiltration.

Prior to the placement of the founding materials and the construction of the road pavement, the sub-formation and formation will need to be inspected and checked in accordance with a suitable Specification to ensure the ground conditions are as expected. All testing should be carried out in accordance with DMRB IAN 73/06 to confirm that the ground conditions at time of construction are consistent with the previous design parameters.

6.8 Drainage

Infiltration rate tests are presented in Section 5.4.3 and are included in Appendix C for reference.

Assessment of the infiltration rate data the ground model concludes:

- The Alluvium, proven along the northern and southern edges of the site (and expected to be present along the eastern edge), is considered unsuitable for infiltration drainage due to a combination of high clay content (low permeability) and the presence of groundwater.
- The thicker River Terrace Deposits in the centre of the site (at a topographic high) are considered suitable (subject to further testing) for infiltration drainage where there is sufficient depth of gravel present above the water table. However, there will need to be sufficient thickness of permeable soil above the water table to allow soakaway design.
- The thinner River Terrace Deposits in the north, south and east of the site, at the topographic lower points, are considered unsuitable for infiltration due to shallow groundwater levels resulting in limited storage capacity, generally due to a limited thickness of River Terrace Deposits, merging with the Alluvium and overlying the Oxford Clay.
- The Kellaways Clay Member (sub-cropping around the periphery of the northern part of the site, and present at depth below the site), are considered unsuitable for infiltration drainage due to their low permeability (high clay content).
- Infiltration drainage should not be installed in the historical landfill site, located in the central-south of the site.

It should be noted that the ground slopes to the north, east and south and the presence of underlying relatively impermeable soils at shallow depth (Kellaways Clay Member and Oxford Clay Member) will need to be considered, as groundwater will track along the interface of these impermeable units and the overlying River Terrace Deposits. During the design process, the designer will need to consider the effects soil infiltration drainage and groundwater levels would have on the proposed development.

The works to date indicate that shallow groundwater is present in the north and south (and likely present in the east) of the site. If attenuation ponds are proposed in these parts of the site, subject to groundwater monitoring, groundwater levels and the proposed base of pond levels, groundwater level may be above the base of the proposed ponds with a corresponding potential reduction in surface water volume attenuation (due to loss of storage). As such, the civils designer and flood risk designer will need to take groundwater water levels into account when designing the attenuation ponds.

The design options available are to either:

- increase the base level of the pond, so it is above the groundwater table; or
- line the pond. It should be noted that if it is proposed to line the ponds, the potential hydrostatic uplift needs to be considered with the design and the liner will need to be placed at an over excavated depth and covered with soil to prevent the liner lifting.

Due to the potential effects of a variable groundwater table on the sides of the attenuation ponds, subject to detailed assessment and design, Hydrock believe the ponds may require reinforcement to prevent wash out and collapse of the pond sides.

6.9 Buried concrete

Based on guidelines provided in BRE Special Digest 1 (BRE 2005) and the information presented in Section 5.6.9 (Table 5.12):

- The superficial soils (Head, Alluvium, Glacial Washout Till and River Terrace Deposits) can be classified as Design Sulphate Class DS-1 and ACEC Class AC-1.
- The Cornbrash Limestone Formation is classified as Design Sulphate Class DS-2 and ACEC Class AC-2.
- The Oxford Clay formation, White Limestone Formation, Forest Marble Formation, Kellaways Sand Member and Kellaways Clay Member can be classified as Design Sulphate Class DS-4 and ACEC Class AC-4 for strip / trench fill / pad foundations.

These equate to Design Chemical Classes[1] of:

- DC-1 for the Head, Alluvium, Glacial Washout Till and River Terrace Deposits;
- DC-1 for the Cornbrash Limestone Formation; and
- DC-4 for the Oxford Clay formation, White Limestone Formation, Forest Marble Formation, Kellaways Sand Member and Kellaways Clay Member.

Further sulphate testing is required as part of detailed investigation and design.

The designer should check and confirm the classification of concrete using the information presented in Appendix C and Appendix D during the design.

[1] The calculated ACEC class can be used in accordance with BS 8500-1+A2 (2019), Table A.9 to select the Designated Concrete (DC) class for an intended working life of 50 years. However, the designer is referred to BS 8500-1+A2 (2019), for full details and notes to Table A.9, including any Additional Protective Measures (APMs).

7. GEO-ENVIRONMENTAL ASSESSMENT

7.1 Updated conceptual model

7.1.1 Updated ground model

The iCSM developed from the Desk Study review and field reconnaissance survey in Section 3 has been updated using the findings of the ground investigations presented in Sections 4 and 5

7.1.2 Updated exposure model

Following the ground investigation, the plausible contaminant sources, receptors and pathways identified in the preliminary geo-environmental exposure model Section 3 have been updated or confirmed as follows.

7.1.2.1 Sources

No potential sources have been removed from, or added to, the exposure model.

7.1.2.2 Receptors

No potential receptors have been removed from, or added to, the exposure model.

7.1.2.3 Pathways

No potential pathways have been removed, or added, to the exposure model. However, the landfill investigation proved the absence of any capping layer or lining of the landfill, and therefore the potential pathways highlighted in the preliminary geo-environmental exposure model (Section 3) are plausible.

Using the updated Ground Model and updated exposure model, GQRA is undertaken as presented below.

7.2 Risk assessment approach

A Tier 2 GQRA for identified receptors, based on all media sampled, has been undertaken in accordance with the principles of LCRM.

Firstly, the risks associated with the identified potential contaminant linkages have been estimated using standardised methods (typically involving comparison of site data with published ‘screening values’). Secondly, where screening values are exceeded, the result has been evaluated in an authoritative review of the findings with other pertinent information to determine whether or not the exceedance is or is not acceptable in the site-specific circumstances.

The data sets used in the assessment comprise the analytical results obtained by Hydrock as listed in Section 4.

In cases where potentially unacceptable risks are indicated and/or the land is potentially unsuitable for its intended use, actions such as more advanced stages of risk assessment (Tier 3, detailed quantitative risk assessment (DQRA)) or remediation are proposed in Section 11.

7.3 Human health risk assessment

7.3.1 *Soils Assessment*

7.3.1.1 *Generic Assessment Criteria*

The soil screening values used are generic assessment criteria (GAC) derived in accordance with EA CLEA guidance (2009) using the updated exposure model detailed in Defra SP1010 (2014), with the exception of published C4SLs. The term 'GAC' used in this report is inclusive of all generic soil screening values.

Based on the proposed development, and at this stage for completeness across the site, GAC based on a default residential with homegrown produce, CLEA land use scenario have been adopted for the wider site, and POS (residential) (POSresi) for the landfill area.

GAC are selected based on the following hierarchy:

- Category 4 Screening Levels (C4SL), where available.
- SoBRA Acute GAC for free cyanide, as acute dose toxicity is the primary risk driver.
- Hydrock GAC, derived by Hydrock as detailed in Appendix F.

The results of the assessment are presented in Appendix F.

It is noted that since the initial issue (P01) of this report, including the contamination assessment, Hydrock have updated the in-house assessment methodology including GAC and therefore the assessment undertaken previously has been updated as part of this report and is therefore superseded by this assessment.

7.3.1.2 *Data sets*

The data set(s) used in this report is based on the CSM and the proposed development, and is split into:

- the wider site Made Ground, Topsoil and natural soils;
- the Landfill Area, with the data separated into:
  - » Landfill - Made Ground;
  - » Topsoil – Made Ground;
  - » Natural soils.

GAC are conservatively based on a soil organic matter (SOM) of 1%. Assessment sheets are presented in Appendix F.

7.3.2 *Assessment Results – Wider Site excluding Landfill area*

Based on individual test results that exceed the GAC, the chemicals of potential concern (CoPC) which require further assessment are summarised in Table 7.1 for the wider site.

Table 7.1: CoPC in soils which require further assessment (human health) – Wider Site

CoPC	GAC (mg/kg)	GAC Source	No. samples	Min. (mg/kg)	Max. (mg/kg)	No. samples >GAC
Made Ground						
Arsenic	37	C4SL CL:AIRE 2014	6	25	73	3
Topsoil						
Arsenic	37	C4SL CL:AIRE 2014	78	13	71	29
Beryllium	1.7	Hydrock Derived	78	0.64	1.90	3
Dibenz(a,h)anthracene	0.25	Hydrock Derived	78	0.05	0.38	1
Natural Soils						
Arsenic	37	C4SL CL:AIRE 2014	25	16	93	16
Beryllium	1.7	Hydrock Derived	25	0.81	2.5	5

All samples submitted for analysis of petroleum hydrocarbons (PHCs), SVOCs, and VOCs reported concentrations below the GAC and/or laboratory limit of detection.

The individual analytical results have been compared with the relevant GAC in the summary table with individual assessment sheets presented in Appendix F. From this, the CoPC are

- Made Ground:
  - arsenic (3 out of 6 samples);
- Topsoil:
  - arsenic (29 out of 78 samples);
  - beryllium (3 out of 78 samples), and
  - dibenz(a,h)anthracene (1 out of 78) samples.
- Natural Soils:
  - arsenic (16 out of 29 samples); and
  - beryllium (5 out of 29 samples).

The presence of arsenic in the Made Ground, arsenic, beryllium and dibenz(a,h)anthracene in the Topsoil and arsenic and beryllium in the natural soils at concentrations above the GAC requires further consideration.

The phrase 'further assessment required' is used to denote soil concentrations that exceed a GAC. This does not necessarily mean that the soil is 'contaminated' or not otherwise suitable for use. The assessment and any mitigation required are to ensure the site does not pose an 'unacceptable risk' as defined under Planning and Part 2A of EPA 1990.

Pesticides and Herbicides

No pesticides and herbicides were identified within the samples submitted for chemical testing.

Asbestos

No visual evidence of ACM was visible within the exploratory holes undertaken by Hydrock.

However, suspected asbestos cement fragments were observed on the surface in the vicinity of Parkers Farm in the central-east of the site as well as asbestos sheet roofing as part of the two barn structures.

The presence of ACM requires further consideration.

Groundwater (dissolved phase) assessment

The risks to human health arising from vapours in dissolved phase groundwater have been assessed in accordance with the SoBRA GW GAC guidance (2017). This is a preliminary approach whereby GAC have been developed using the CLEA v1.071 model for indoor air and outdoor inhalation pathways only, assuming a residential or commercial end-use.

A review of the groundwater screening values, indicate a low risk with regard to dissolved phase VOC in groundwater. As such, dissolved phase VOC in groundwater does not require further consideration.

7.3.3 Risk evaluation – Wider Site excluding Landfill area

The screening exercise has identified arsenic in the Made Ground, arsenic, beryllium and dibenz(a,h)anthracene in the Topsoil and arsenic and beryllium in the natural soils at concentrations above the GAC. These are considered further here to assess if the exceedance may be acceptable with respect to the proposed development.

Arsenic and Beryllium in Natural Soils and Arsenic in Made Ground

There is no evidence of a man-made source of arsenic on the site and whilst the units underlying the site are not generally known to contain naturally high levels of arsenic, the superficial soils are to the south of an area shown to be high in naturally occurring arsenic according to the Advanced Geochemical Atlas of England and Wales (Rawlins et al 2012). As such it is considered likely that the superficial soils are derived from soils containing higher concentrations of arsenic (as indicated by presence of ironstone in some locations).

Consequently, these exceedances are not considered a significant risk to human health in line with the current Contaminated Land Statutory Guidance, which accepts that there may be natural background levels of substances as a result of the geology, but it is recommended that further assessment be undertaken using bio accessibility testing, in consultation with the regulatory authorities.

Concentrations of beryllium were identified in the natural soils and topsoil at concentrations of up to 2.50mg/kg compared to a GAC of 1.70mg/kg. These are considered marginal exceedances and are considered not to represent an unacceptable risk to end users. Hydrock believes mitigation measures with regards to beryllium are not required.

PAH in Topsoil

Dibenz(a,h)anthracene is recorded in one location (HP202) within the Topsoil at 0.38 mg/kg compared to a GAC of 0.25mg/kg. It is likely that the exceedance is associated with activities as part of the allotment uses (ash spreading as fertilizer for soil and/or burning of waste products).

As the exceedance is marginal, it is not considered to pose a significant risk to human health and no further consideration is required.

Asbestos

No ACM have been noted in exploratory holes with fragments of suspected asbestos cement visible on the surface around the two farm outhouses in the central-east of the site as well as in use as sheet roofing.

Risk factors applicable to the site, based on potential for inhalation of airborne fibres, are considered below:

- No visible evidence of asbestos materials was noted in the exploratory holes, suggesting that asbestos materials are present on the surface; and
- No asbestos was detected in the soils on site including around the farm buildings.

Subject to regulatory and warranty provider approval, whilst Hydrock consider it plausible for asbestos to be present in any of the Made Ground soils, overall, the risk associated with the identified presence of asbestos is considered to be low. However, mitigation will be required to ensure risks to site users and adjacent off-site receptors remains negligible.

7.3.4 Assessment Results – Landfill

Based on individual test results that exceed the GAC, the CoPC which require further assessment are summarised in Table 7.2 for the landfill area.

Table 7.2: CoPC in soils which require further assessment (human health) – Landfill

CoPC	GAC (mg/kg)	GAC Source	No. samples	Min. (mg/kg)	Max. (mg/kg)	No. samples >GAC
POS						
Topsoil Made Ground						
Beryllium	2.2	Hydrock Derived	4	<0.06	8.2	1
Dibenz(a,h)anthracene	0.57	Hydrock Derived	4	<0.05	1.4	1
Landfill Made Ground						
Arsenic	79	C4SL CL:AIRE 2014	17	25	85	2
Beryllium	2.2	Hydrock Derived	4	<0.06	8.2	6
Lead	630	C4SL CL:AIRE 2014	17	45	830	2
Benzo(b)fluoranthene	7.2	Hydrock Derived	17	0.05	9.70	1
Dibenz(a,h)anthracene	0.57	Hydrock Derived	17	0.05	1.60	1
Natural						
Arsenic	79	C4SL CL:AIRE 2014	4	25	84	1
Dibenz(a,h)anthracene	0.57	Hydrock Derived	4	0.05	0.60	1

With regards to POS land Use, the presence of a number of metals and metalloids in the Topsoil, landfill and natural soils, and PAH in the landfill and natural soils require further consideration.

If the area of the landfill is proposed for residential use the above assessment will need to be updated.

Asbestos

No evidence of ACM was observed on within the Landfill area. However, the presence of ACM cannot be discounted.

In addition, asbestos was identified by laboratory screening and testing of soil samples within the Landfill-Made Ground as summarised in Table 7.3.

Table 7.3: Asbestos in soil samples (laboratory testing)

Location	Depth (m bgl)	% Asbestos (w/w)	Comment
BH03	1.00	0.323	Chrysotile - Rope (ACM)
WS09	3.00	<0.001	Amosite - Loose Fibres
WS10	0.60	<0.001	Chrysotile – Loose Fibres

The presence of ACM and asbestos fibres in soil requires further consideration.

7.3.5 Risk Evaluation – Landfill (as proposed POS)

The screening exercise has identified elevated concentrations of the following which require further consideration:

- beryllium and dibenz(a,h)anthracene in the Topsoil Made Ground;
- ACM, arsenic, beryllium, lead, benzo(b)fluoranthene and dibenz(a,h)anthracene in the Landfill – Made Ground; and
- arsenic and dibenz(a,h)anthracene in the natural soils.

These are considered further here to assess if the exceedances may be acceptable with respect to the proposed development. The phrase 'further assessment' does not necessarily mean that the soil is 'contaminated' or not fit for use.

Topsoil Made Ground

Elevated beryllium up to 8.2mg/kg compared to a GAC of 2.2mg/kg was identified in one location and dibenz(a,h)anthracene of 1.4mg/kg compared to a GAC of 0.57mg/kg.

Whilst the exceedance is slight for dibenz(a,h)anthracene and less than 4x the GAC for beryllium in only one of four samples for both CoPC and not considered a significant risk, given the nature of the site and the presence of PAH and other contaminants (ACM and asbestos fibres) in the underlying Landfill Made Ground, Hydrock consider the presence of beryllium and dibenz(a,h)anthracene) in the Topsoil Made Ground to be an unacceptable risk, which requires mitigation for end use as POS

Landfill Made Ground

Asbestos

There was one exploratory hole location (BH03) where ACM were present. In addition, low concentrations of asbestos fibres (<0.001%v/v) of chrysotile and amosite have been detected in two additional samples of the Landfill Made Ground.

Hydrock considers it plausible for asbestos to be present in any of the Landfill Made Ground soils and asbestos, (even at low concentrations), represents an unacceptable risk with regard to the potential

POS use and mitigation measures would be required in this area of the site in the form of an engineered cover system.

Arsenic, Beryllium and Lead

Arsenic is present in the landfill at up to 85mg/kg compared to a GAC of 79mg/kg (2 exceedances above the GAC), beryllium within the landfill at up to 8.20mg/kg compared to a GAC of 2.2mg/kg (6 exceedances) and lead up to 830mg/kg compared to a GAC of 630mg/kg (2 exceedances).

Whilst the exceedances are slight, given the nature of the site and the presence of other contaminants (ACM and asbestos fibres), Hydrock consider the presence of arsenic, beryllium and lead in the Landfill Made Ground to be an unacceptable risk, which requires mitigation for end use as POS.

PAH in Landfill Made Ground

Benzo(b)fluoranthene was identified in 1 sample at 9.70mg/kg above the GAC of 7.20mg/kg and dibenz(a,h)anthracene of 1.4mg/kg compared to a GAC of 0.57mg/kg in one sample. Whilst the exceedance of both is slight, given the nature of the site and the presence of other contaminants (ACM and asbestos fibres), Hydrock consider the presence of benzo(b)fluoranthene and dibenz(a,h)anthracene in the Landfill Made Ground to be an unacceptable risk, which requires mitigation for end use as POS.

Natural Soils (River Terrace Deposits)

Concentrations of arsenic were identified in the natural soils with of 84mg/kg compared to a GAC of 79mg/kg in one of four samples. This is considered a marginal exceedance and is considered not to represent an unacceptable risk to end users. Hydrock believes mitigation measures with regards to arsenic are not necessary for end use as POS.

Dibenz(a,h)anthracene was identified in one sample at 1.4mg/kg compared to the GAC of 0.29mg/kg. This exceedance is considered to have originated from the overlying Landfill Made Ground rather that the River Terrace Deposits (due to no exceedance across the rest of the site) and is therefore not considered to be representative of these soils.

Hydrock do not believe any further consideration is required with regards to natural soils below the landfill.

7.4 Phytotoxicity risk assessment

7.4.1 Risk estimation

Priority phytotoxic chemical concentrations have been screened against published values to determine the likely risk to plant growth (phytotoxic GAC). Phytotoxic GAC based on a pH of 7% have been adopted for all soils based on laboratory results.

As with human health, individual sample test results are compared directly with the phytotoxic GAC.

Based on individual test results that exceed the GAC, the CoPC which require further assessment with regards to phytotoxicity within the landfill area are presented in Table 7.4.

Table 7.4: Chemicals of potential concern for which further assessment is required (risk to plants)

Chemical of potential concern	Generic criterion (mg/kg)	Basis for generic criterion	No. samples	Min. (mg/kg)	Max. (mg/kg)	No. samples exceeding generic criterion
General Made Ground						
No exceedances						
Site Wide Topsoil						
No exceedances						
Natural soils						
No exceedances						
Topsoil - Made Ground						
Copper	135	BS 3882 2015	4	1	780	1
Nickel	75	BS 3882 2015	4	19	88	1
Zinc	300	BS 3882 2015	4	1	570	1
Landfill Made Ground						
Boron	5	Nable, et al.1997	17	0.9	17	9
Copper	135	BS 3882 2015	17	21	1000	8
Nickel	75	BS 3882 2015	17	24	150	4
Zinc	300	BS 3882 2015	17	110	6500	9
Natural						
Boron	5	Nable, et al.1997	4	0.90	5.70	1

For the wider site, there are no exceedances, and no further consideration is required.

Within the landfill, the Topsoil Made Ground and the Landfill Made Ground, indicate copper, nickel and zinc exceed the GACs. In addition, in the Landfill Made Ground and natural soils boron exceeds the GAC. Whilst the exceedances in the Topsoil Made Ground and natural soils are marginal, the exceedances in the Landfill Made Ground are significant.

Detriment to plant life is difficult to quantify and many of the GAC are based on agricultural crop yields rather than harm to particular plant species. However, the significant exceedance of the GAC (especially for the Landfill Made Ground, indicates the probability of an unacceptable risk to plant life and mitigation should be undertaken.

Notwithstanding the concentrations of contamination identified, there is little to no suitable subsoil or topsoil growing medium on the site and this will require import.

The requirement for mitigation of risk to human health will also serve (in part) to mitigate risks to plant life.

7.5 Pollution of controlled waters risk assessment

7.5.1 Risk estimation

The risks to groundwater and surface water from contaminants on site have been assessed in accordance with the Environment Agency (2006) Remedial Targets Methodology (RTM).

Site contaminant loadings are compared with relevant screening values WQTs, which are linked to the CSM.

Acceptable WQT are defined for protection of human health (based on Drinking Water Standards (DWS)) and for protection of aquatic ecosystems (Environmental Quality Standards (EQS)).

As related specifically to this site, the data are compared with criteria selected in accordance with the methodology presented in Appendix F. This methodology involves selecting which of several alternative risk scenarios apply in this case. The assessment is presented in Table 7.5 below, with the justification for the scenarios selected explained in the following text:

- The River Terrace Deposits and Alluvium are classified as a Secondary A Aquifer;
- The solid geology of the Cornbrash Limestone Formation and Kellaways Sand Member are classified as a Secondary A Aquifer.
- The thickness of the Cornbrash Limestone Formation and the Secondary A Aquifers is unlikely to provided sufficient flow for extraction on strategic scale and therefore groundwater abstraction has been discounted as a secondary receptor at this stage. The thickness of the Oxford Clay Formation across the majority of the site and Kellaways Clay, and Blisworth Clay at depth will restrict groundwater migration into the deeper geology.
- Groundwater levels are relatively shallow in the north, east and south of the site and may provide base flow to the stream in the north.
- Hydrock do not consider groundwater at the site to be in hydraulic continuity with the Oxford Canal, as it is assumed that the canal is lined. As discussed in Section 2.8.2, Rushy Meadows SSSI is up gradient of the site and it is therefore not feasible for this to be impacted by the site. Shallow groundwater within the sands and gravels, and the landfill, may be in hydraulic continuity with Rowel Brook and other surface water features in the immediate area.

Table 7.5: Summary of water quality risk assessment protocol

Hydrock scenario	Water body receptors	Secondary receptors	Example contaminant linkages	RTM level and data used	Water quality targets
B	Groundwater Surface water.	Aquatic ecosystem.	Contaminants from site leach or seep into a groundwater body that feeds inland surface water by base flow. The surface water is an aquatic ecosystem.	RTM Level 2 - Groundwater.	EQS (inland)
Notes: Some EQS are water hardness dependent. This is measured either in the receiving surface water or in groundwater (if it is part of the pathway), or is estimated from national maps. Inland waters EQS applicable to freshwater, 'other' waters EQS applicable to coastal or transitional waters. This table and the results of the assessment are considered as a first screening for potential risks of pollution of Controlled Waters. More specific requirements may be stipulated by the relevant Agency.					

The results of the screening assessment are presented in Appendix F and are summarised in Table 7.6.

There are no WQT for petroleum hydrocarbon fractions in water. However, because of the sensitivity of the water environment to petroleum hydrocarbons, an initial screening exercise is also included in Table 7.6 irrespective of the assessment scenario(s) stated in Table 7.5.

In some instances, the reporting limit (or detection limit) quoted by the laboratory may be greater than the WQT that it is being assessed against. As the current exercise is an initial screening assessment, further assessment of these elements has not been undertaken.

Table 7.6: CoPC which require further assessment (controlled waters)

CoPC	WQT (µg/l)	Basis for WQT	No. samples	No. samples above LoD	Min. (µg/l)	Max. (µg/l)	No. samples exceeding WQT and above LoD
Shallow groundwater in the River Terrace Deposits External to and near the Landfill							
Cadmium	0.08	EQS	31	9	<0.02	0.1	2
Cobalt	3	EQS	31	18	<0.2	11	2
Chromium(III)	4.7	EQS	31	2	<5	7.9	2
Copper	1	EQS bio†	31	28	<0.5	3.6	15
Manganese	123	EQS bio†	31	31	0.05	940	7
Nickel	4	EQS bio†	31	27	<0.5	13	10
Ammoniacal Nitrogen	300	EQS	13	13	<15	7300	3
Sulphate (SO_4^-)	400000	EQS	31	31	31600	606000	1
Shallow groundwater within the Landfill area							
Cobalt	3	EQS	6	4	1.5	19	4
Chromium (III)	4.7	EQS	6	6	5.3	9.2	6
Copper	1	EQS bio†	6	6	1.5	8.5	6
Manganese	123	EQS bio†	6	6	230	2500	6
Nickel	4	EQS bio†	6	6	5.6	16	6
Ammoniacal Nitrogen	300	EQS	6	4	69	18000	4
Sulphate	400000	EQS	6	4	127000	645000	4
Note: the maximum recorded value is compared with the water quality target.							

7.5.2 Risk evaluation

The data indicates that the EQS for cadmium, cobalt, chromium (III), copper, manganese, nickel, ammoniacal nitrogen and sulphate, in groundwater are exceeded external to the landfill and the EQS for chromium (III), copper, manganese, nickel ammoniacal nitrogen and sulphate within groundwater samples taken within the landfill site area. These require further consideration.

There are no recorded concentrations of VOCs, SVOCs, PAH or petroleum hydrocarbons in the groundwater.

Cadmium, cobalt, chromium (III) copper, manganese and nickel exceedances are relatively slight across the site. Furthermore, the inland waters EQSs for copper, manganese and nickel are based on the bioavailable fraction and because bioavailability has not been calculated for these metals the assessment is conservative as it assumes 100% bioavailability.

Sulphate is considered to be a naturally occurring chemical and is due to the elevated sulphate concentrations which are usually present within the Oxford Clay Formation. As such, sulphate is not considered a risk to Controlled Waters.

Ammoniacal Nitrogen concentrations have been observed with the landfill materials in excess of the Environmental Agency's physio-chemical 'Good' standard for rivers, of 0.3mg/l with concentrations of ammoniacal nitrogen within the landfill recorded up-to 18mg/l. Ammoniacal nitrogen is a typical contaminant associated with biodegradation of organic materials in historical landfills. The concentrations that have been observed in the landfill soils are, in Hydrock's experience' towards the lower end of typical concentrations in historical landfills. As part of the further works Ammoniacal Nitrogen is exceeded in 3 locations as part of the monitoring with exceedances in WS252 at 1.2mg/l (located in the south-east of the site) BH01 (Jubb) at 7.2mg/l and BH07 (Jubb) at 0.31mg/l compared to a EQS of 0.3mg/l and moving south and east in BH202, H203, BH204 and WS246 at a maximum concentration of 0.003mg/l indicating attenuation (via dispersion, dilution and degradation) is occurring externally to the landfill and as such, is not considered a significant risk to Controlled Waters. In the remainder of the locations Ammoniacal Nitrogen was recorded below the limit of detection.

It is also noted that WS252 is located in the far south-east of the site, likely as a result of farming activities impacting groundwater as a source rather than the landfill solely.

7.6 Ground gases risk assessment

7.6.1 Data

It is judged from the available evidence that the gas generation potential at the site is high (due to Alluvium present on site, along with the landfill present in the central-south of the site and that the sensitivity of the development is high (due to a mixed end use (including residential) across most of the site). Consequently, and in accordance with CIRIA C665 (Table 5.5a and 5.5b), an appropriate minimum monitoring regime is 24 readings over 12 months, provided other monitoring requirements are also met, such as prevailing atmospheric pressure conditions (for example, BS 8485:2015+A1:2019 suggests monitoring should include a period of falling atmospheric pressure).

Hydrock has undertaken six readings within the landfill and 14 readings in the areas beyond the landfill (including during periods of falling and low atmospheric pressure), with further visits being undertaken in 2023. As such, the conclusions presented below are considered to approximate to worst-case conditions and are interim, pending ongoing ground gas monitoring.

7.6.2 Assessment

The risks associated with the ground gases methane (CH_4) and carbon dioxide (CO_2) have been assessed using BS 8485:2015 +A1:2019, which cites the guidelines published by CIRIA (C655, 2007).

The assessment guidelines set out in Table 2 of BS 8485 are based on interpretation of the gas concentrations and the gas flow rates. The quantitative assessment has been carried out by comparing the individual gas concentrations and gas screening values (GSV[2]) in Appendix E with the published CS thresholds (BS 8485 Table 2), in addition to a worst-case GSV assessment in accordance with section 6.3.7 of BS 8485. The assessment is summarised in Table 7.7 and Table 7.8 and the full assessment is presented in Appendix E.

Table 7.7: Ground gas risk assessment – Wider Site (excluding flooded wells)

	Min	Max	Typical	Comment
Steady Flow Rate (l/hr)	-4.5	2.1	<1	-
Methane (%)	0.1		<1	The typical methane concentration is <1% and the typical carbon dioxide concentration is less than 5%.
Carbon Dioxide (%)	0.1	4.2	<5	Whilst it is considered that there is a potential source related to the landfill in the central-south of the site (although not included within the site) the GSV is indicated as CS1 conditions.
Carbon Monoxide (ppm)	0	4	0	-
Hydrogen Sulphide (ppm)	0	5	0	-
Oxygen (%)	11.6	21.9		-
Carbon Dioxide GSV Maximum flow and Concentration Per Visit (l/hr)	<0.07	0.087	<0.07	Generally, CS1. CS2 conditions relating to GSV indicated in WS242
Methane GSV Maximum Concentration Per Visit (l/hr)	<0.07	<0.07	<0.07	CS1

The majority of the gas readings are indicative of CS1 conditions when compared against worst case flow and worst gas carbon dioxide concentrations per borehole. Boreholes where GSVs are indicative of CS2 conditions on a borehole basis are:

- WS242 at a GSV of 0.08 combining a flow of 3.8l/hr to a carbon dioxide concentration of 2.3%. The flow rate was recorded as a negative flow and therefore this GSV is not considered to be representative of conditions. It is also noted that there was minimal headspace within the borehole and it subsequently became flooded from the next reading onwards and therefore it is considered to be unreliable.

Table 7.8: Ground gas risk assessment – Landfill (excluding flooded wells)

	Min	Max	Typical	Comment
Steady Flow Rate (l/hr)	0.1	0.3	<1	There is generally low flow rate, with no discernible change in flow rate, or ground gas

[2] Note: GSV is synonymous with 'site characteristic hazardous gas flow rate' (Q_{hgs}) of BS 8485:2015 +A1:2019 Table.

	Min	Max	Typical	Comment
				concentrations with changes in atmospheric pressure.
Methane (%)	0.1	0.3	<1	The typical methane concentration is less than 1% and the typical carbon dioxide concentration is greater than 10%. Given that there is a potential source (landfill), Hydrock considers that as a precautionary measure the Characteristic Situation indicated by the GSV requires raising by one level.
Carbon Dioxide (%)	0.4	16.3	<15	Assessment of the data on a ternary plot of ground gas ratios ($O_2 + N_2$, CO_2 and CH_4), in accordance with guidance by Wilson et. al. (2018), indicates the ground gas present is likely to represent microbial respiration of organic material in soil. Whilst the site is a former landfill, the source soils are predominantly ash, with little organic material.
Oxygen (%)	1.1	20.3	-	-
Carbon Dioxide GSV (l/hr)	<0.07	<0.07	<0.07	CS1
Methane GSV (l/hr)	<0.07	<0.07	<0.07	CS1

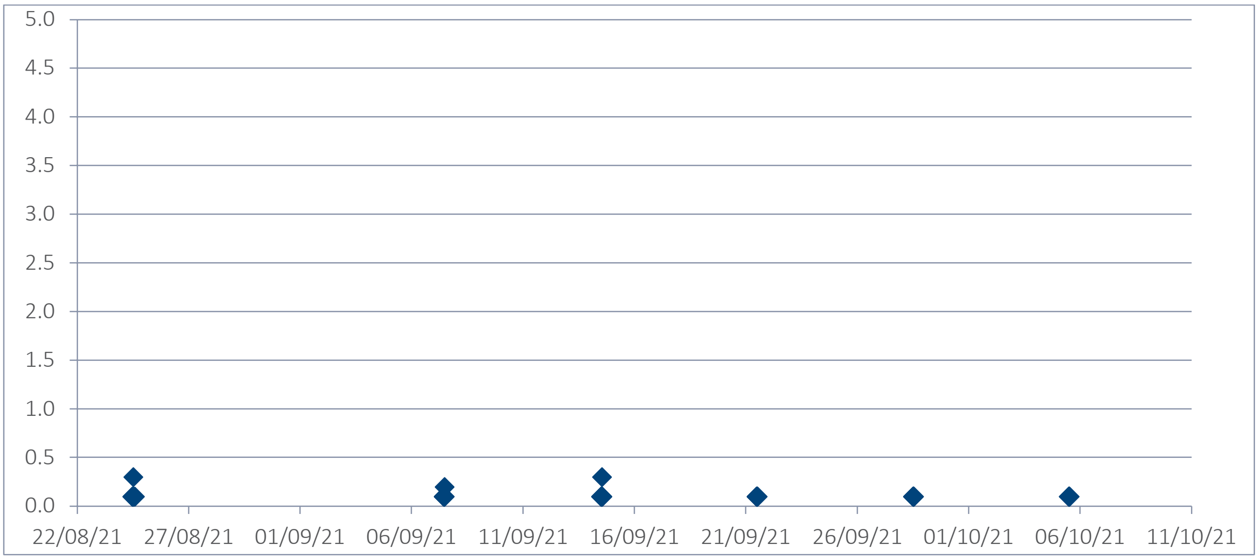


Figure 7.1: Methane Concentrations within the landfill

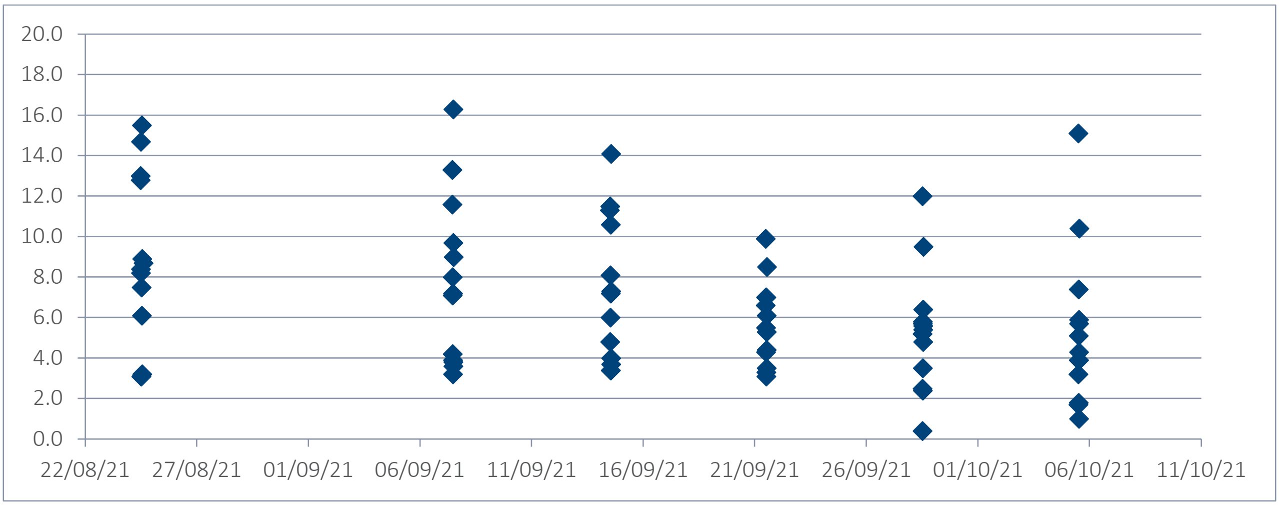


Figure 7.2: Carbon dioxide Concentrations within the landfill

As indicated in Table 7.7, Table 7.8 and, Figure 7.1 and Figure 7.2:

Within the landfill

- There is no recognisable difference between the gas concentrations in the landfill and the underlying Oxford Clay, indicating fissuring is present in the Oxford Clay.
- Recorded concentrations of carbon dioxide are as high as 16.3%, but generally less than 15%.
- In non-flooded wells, the gas flow readings are generally low (<1.0 l/hr).
- The computed GSVs would generally accord with CS1 conditions. However, given the number of carbon dioxide values that are in excess of 10%. Hydrock would recommend the classification is raised by one value to CS2 for the landfill itself.
- In conclusion, if the landfill site is proposed for residential land use, on the basis of the low gas flows, the consistently high carbon dioxide concentrations, Hydrock considers that a CS2 classification is appropriate for the site, subject to agreement by Local Planning Authority (LPA) and warranty provider.
- If proposed for residential land use, significant further monitoring will be required to confirm the assessment presented above.
- If proposed for POS land use, no mitigation is required on site. However, detailed monitoring would be required on the adjacent areas of the wider site to fully assess risks to adjacent receptors.

Wider Site

- Gas flow readings are generally low (<1.0l/hr) which is not considered significant. It is noted that readings of up to 2.1l/hr.
- The computed GSVs would generally accord with CS1 conditions. Where CS2 conditions are recorded this is likely the results of water levels being above the response zone and confined within minimal head space.
- There is no indication of significant gas migration from the landfill to boreholes in vicinity to the landfill is noted.

- As indicated in Table 7.7, the computed GSV for carbon dioxide and methane indicates CS1 conditions and methane and carbon dioxide at concentrations are 'typically' below 1% and 5% respectively.
- Whilst historical gas monitoring inside the landfill indicated CS2 conditions, no evidence of ground gas migration within the River Terrace Deposits have been recorded around the site or in close proximity to the landfill.
- As such, the site is provisionally classified as Characteristic Situation 1. Based on the data to date no mitigation measures are required externally to the Landfill.

The areas requiring gas protection measures are presented in Hydrock drawing 19114-HYD-XX-ZZ-DR-GE-01027.

7.6.3 *Off-site risks from carbon dioxide and methane*

The National Planning Policy Framework requires that a developed site should be incapable of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990. This position includes a consideration of the potential for off-site migration of ground gases that may impact on adjacent properties.

The risk to receptors (dwellings and commercial properties) constructed in close proximity to the landfill, is considered to be low.

7.6.4 *Radon*

A full radon report was obtained by Hydrock in March 2023 (see Appendix B), which indicates that the far northern part of the site (Radon Report ID BGS_331991/43780), north of Rowel Brook, is in a Radon affected area of between 3-5% and 10-30%, where either basic or full protection measures are required. It is understood that there are no proposed residential buildings within this area as part of the development, but buildings associated with the proposed community farm may be present.

The remainder of the site (Radon Report ID: BGS_331991/43779) is not considered to be in a Radon affected area (<3%) and no radon protection measures are required.

7.7 Construction materials risk assessment

7.7.1 *Water pipelines*

A formal water pipe investigation and risk assessment is beyond the scope of this report. However, the findings of this investigation have been compared to the threshold values in Water UK HBF (2014), Table 1 as far as is practicable.

The majority of the site is previously undeveloped, and the preliminary risk assessment and investigation has indicated no plausible contaminant sources. It is envisaged that standard pipework will be suitable for delivery of potable water to the site. However, confirmation should be sought from the water supply company at the earliest opportunity.

Within the landfill organic contamination (PAH) has been identified in exceedance of the threshold values and if potable water pipes are installed across the landfill areas, Hydrock considers barrier pipe should be used. However, confirmation should be sought from the water supply company at the earliest opportunity.

In addition, over-excavation of service runs, and replacement with clean soils would be required. Where pipes cross the landfill.

7.7.2 *Other construction materials*

Plastic pipes for drains and sewers are manufactured from unplasticized poly(vinyl chloride) (PVC-U), polypropylene (PP) or polyethylene (PE). These materials may be affected by the presence of organic compounds in the soil.

In accordance with the British Plastics Federation Guidance (August 2018), as the concentrations of PAH, and BTEX are below 100mg/kg and the concentrations of petroleum hydrocarbons (TPH) are below 200 mg/kg, PVC-U, PP or PE pipework is considered suitable.

Within the landfill local concentrations of TPH above 100mg/kg were recovered. Discussions with regards to pipework should be undertaken with regards to suppliers. Regardless of the type of pipework installed, over-excavation of service runs, and replacement with clean soils would be required.

The implications for buried concrete are discussed in Section 6.9.

7.8 Contamination risks to ground workers

7.8.1 Introduction

Whilst risks to construction workers are not discussed in detail, the following section discusses potential risks that should be considered.

Information presented in this document is provided to assist in managing the risk associated with contamination in soil and groundwater at the site but is not definitive. The Contractors are responsible for undertaking their own assessments and assessing what risks are present and what control measures are required.

Task specific risk assessments and method statements should be in place, and risks and required mitigation measures communicated to all relevant personnel prior to the works commencing. Appropriate PPE and, if required, RPE should be provided and utilised.

7.8.2 Metals and metalloids

The soils contain metals and metalloids recorded as pervasive concentrations throughout the Made Ground.

7.8.3 Ground Gas

It is noted that concentrations of carbon dioxide (an asphyxiant) in the soil exceed HSE Workplace Exposure Limits for personnel in the working environment of 1.5% for short term (15 minutes) exposure and / or 0.5% for long term exposure. Furthermore, soil concentrations of oxygen are below the HSE recommendations of 18%.

Soil gas concentrations are not necessarily reflected by those in the breathing zone, as such, all Contractors and maintenance workers should be made aware of the possible presence of carbon dioxide and should take all necessary health and safety precautions when working in trenches or confined spaces.

7.8.4 Asbestos

Visible fragments of suspected asbestos cement sheeting have been identified on the surface around Parkers Farm during the ground investigation and visible on the barn roofs and are likely present at the landfill. In addition, asbestos fibres (<0.001%) and rope loose fibrous debris are present in the soils in the landfill was identified in laboratory testing.

All site staff should be made aware that there is a likelihood of encountering further ACM and at any stage of the development. It is advised that the Contractor should supply suitable and sufficient ‘Asbestos Awareness’ training (specific to asbestos in soils) to all site staff who could foreseeably encounter asbestos containing materials during the course of their work.

The Contractor for each stage of works must undertake a suitable and sufficient Risk Assessment in accordance the Regulation 6 of the Control of Asbestos Regulations 2012 (CAR2012). The results of the assessment should be used to compile a methodology in accordance with Regulation 7 of CAR2012, which limits potential exposure and spread of asbestos fibre. Appropriate training should be provided to all site staff identified within the risk assessment as having the potential to be exposed or encounter asbestos during their work in accordance with Regulation 10 of CAR2012.

It is the responsibility of the Contractor to ensure that mitigation measures are suitable and sufficient to prevent exposure to airborne asbestos so far as is reasonably practicable in accordance with Regulation 11 of CAR2012.

It is recommended that any asbestos cement sheeting encountered is handpicked under controlled conditions in accordance with HSG210 'Asbestos Essentials' Hand picking needs to be undertaken by suitably qualified Contractors in accordance with HSE guidance and an Environmental Permit. All ACM must be suitably packaged, placed in a dedicated, covered and lockable skip pending off-site disposal to a suitably licensed waste facility.

7.9 Findings of the generic contamination risk assessments

The potential sources, pathways and receptors identified in the desk study (Section 3 have been investigated (Sections 4 and 5) and assessed (Sections 7.2 to 7.7). A SPR linkage assessment has been undertaken and is presented in Appendix I (Table I.2).

A summary of the SPR contaminant linkages for which the risks may be unacceptable and require mitigation (those that are moderate or higher) are discussed in:

- Table 7.9 for POS end use within the landfill area; and
- Table 7.10 for residential end use with plant uptake (Wider Site).

Table 7.9 and Table 7.10assume the following SPR linkages which have been discounted (subject to agreement) as not requiring further consideration (mitigation). If these assumptions are not agreed during regulatory discussions, the conclusions as noted in Table 7.9 and Table 7.10 will need to be updated:

- Elevated concentration of naturally occurring arsenic and beryllium.
- Slightly elevated dibenz(a,h)anthracene in one location (HP202) in Topsoil in the allotment areas.
- Slightly elevated concentrations of cadmium, cobalt, chromium (III), copper, manganese, nickel, ammoniacal nitrogen and sulphate within the groundwater beneath the site.
- Ground gases outside the landfill.

*Table 7.9: Residual risks following risk evaluation (POS) within the landfill area**

Contaminant Linkage	Sources	Pathways	Receptors	Comments
CL 1.	CoPC identified in soils.	Ingestion, inhalation or dermal contact with soils and soil-derived dust.	Site end users.	Exceedance of the GAC. Mitigation required in the form of an engineered cover system.
		Inhalation and ingestion of soil-derived dust.	Site end users. Neighbours.	
		Root uptake	Plant life.	Exceedance of the GAC. Imported growing material will be required to form the engineered cover system.
CL 2.	Asbestos fibres and ACM in Landfill Made Ground.	Inhalation of fibres.	Site end users. Neighbours.	Chrysotile and amosite fibres (<0.001% w/w) and chrysotile rope (0.323%w/w) detected in Landfill Made Ground. Mitigation required in the form of an engineered cover system.

Table 7.10: Residual risks following risk evaluation – Wider Site

Pollutant Linkage	Sources	Pathways	Receptors	Comments
CL 3.	Asbestos fibres from ACM at the site surface and in existing building materials.	Inhalation of fibres.	Site end users. Neighbours.	Asbestos sheet roofs were noted in farm structures and sporadic fragments were noted on the site surface in the vicinity if the farm structures. Although not noted in soils, the potential for fibres remains. Surface ACM and suspected ACM should be removed by a licenced specialist. Any suspected ACM encountered during earthworks will need to be handpicked and removed from site. If ACM encountered in the remaining building on site, removal under controlled conditions will be required. Removal of ACM under controlled conditions should limit off-site emissions. Shallow Made Ground around the farm structures should be removed and the removal documented.
CL 4.	Asbestos fibres in soils around Parkers Farm.	Inhalation of fibres.	Site end users. Neighbours.	
CL 5.	Radon	Migration through soils and accumulation in indoor air.	End users of new buildings.	The area north of Rowel Brook is in a Radon affected area and basic or full radon protection measures in buildings in this area.

Pollutant Linkage	Sources	Pathways	Receptors	Comments
				To be installed by competent installer, validated and verified.

7.10 Conclusions and recommendations for development (Landfill area)

The site investigation works have proven the presence of the historical landfill identified within the Desk Study as well as confirming the surrounding geological model for the site although further works will be required at a later date to allow design.

The landfill is predominantly ash, with significant man-made materials present throughout. An odour is present during excavation of the landfill and some areas of hydrocarbon odour have been noted.

Groundwater is generally encountered at the base of the River Terrace Deposits and at shallow depths in the south and east of the site. It is assumed the gravel workings undertaken prior to landfilling operated as a dry operation, which stopped on encountering the summer groundwater level (which will be lower than the winter / spring groundwater level).

Chemical testing of soils has confirmed there are elevated CoPC within the soils which require mitigation within the landfill. The remainder of the site has no elevated CoPC.

Chemical testing of groundwater has confirmed there are elevated CoPC within the groundwater. However, subject to the Environment Agency agreement, this is not considered to be a significant risk to Controlled Waters.

Given the findings to date, whilst mitigation measures could be proposed to allow development of the landfill site for residential use, the risks and costs (principally associated with excavation and disposal, and ground gas mitigation) are likely to be significantly higher than those for a proposed POS land use. This is coupled with waste regulation issues and the inability to re-use any Landfill excavated soils under a Materials Management Plan. Given the size of the development, and the need to create suitable POS areas as part of the development, Hydrock would recommend that the landfill site is not included in the area allocated for residential or non-residential use, but is allocated as an area of POS with minimal excavation of the landfill undertake.

8. MITIGATION MEASURES & OUTLINE REMEDIATION STRATEGY

8.1 Introduction

The outline remediation strategy presented below is provided for guidance only, and does not represent a 'Remediation Options Appraisal', or a 'Remediation Strategy', prepared in accordance with LCRM (2022).

As shown in Table 7.10 and Table 7.9 (and subject to regulatory and warranty provider agreement), Hydrock consider the following mitigation is required to ensure the site is suitable for use for the proposed end use. The mitigation measures are shown on Hydrock Drawings 19114-HYD-XX-ZZ-DR-GE-01027 (Gas Zonation Plan) and 19114-HYD-XX-ZZ-DR-GE-01028 (Remediation Zonation Plan) included in Appendix A.

8.2 POS proposed end use within the Landfill Area as per Table 7.9

Based on a proposed POS land use (with the assumption that no services are proposed to cross the landfill area), outline mitigation measures are proposed below. If the proposed land use changes, additional significant mitigation measures would be required.

Subject to regulatory (and NHBC) agreement), Hydrock consider the following mitigation is required to ensure the landfill area is suitable for use for the proposed end use. The mitigation measures include:

- The installation of a 450mm engineered cover, comprising a bonded geogrid break layer (to deter burrowing animals), subsoil beneath a topsoil thickness of between 150mm and 300mm (CL1-CL2).
- Import of subsoil/topsoil in line with the Materials Management Plan (PL6).

To assist with land forming, it is recommended the landfill is compacted using a High Energy Impact Compactor, utilising specialist compaction equipment fitted with Surface Covering Dynamic Compaction Control (SCDCC) or similar to provide a continuous measurement of the ground response. Typical compaction plant which is suitable for this operation and can be fitted with SCDCC is the Bomag BW 226 and BW 332). These works would be undertaken to densify the existing landfill soils, reduce site levels and allow the cover system to be placed, whilst minimising disposal.

As part of the mitigation, Hydrock would recommend that the cover system is placed across the landfill, and extending outside the landfill boundary by a minimum of 3.00m (to allow embedment).

Given the potential human health risks of burrowing animals such as badgers bringing potentially contaminated materials to surface, Hydrock recommend the closure of the badger setts which are present on the edges of the site (and associated re-location of the badgers under the supervision of suitably qualified ecologists). If these cannot be closed and artificial setts need to be provided on the landfill, design to prevent burrowing into the landfill will be required (steel mesh).

In addition, to prevent disturbance of the landfill material by roots and potential tree collapse, subject to ecological and arboricultural agreement, Hydrock recommend removal of existing trees and hedges (and re-planting, as necessary). This will also allow the cover system to be firmly embedded beyond the edge of the landfill and to mitigate any potential human health risks from contact with the landfill soils.

8.3 Wider Site (excluding the landfill area) as per Table 7.10

Subject to regulatory (and NHBC) agreement, Hydrock consider the following mitigation is required to ensure the wider site is suitable for use for the proposed end use. The mitigation measures include:

- Removal of asbestos by specialist Contractors in accordance with the asbestos survey and relevant legislation) (CL3).
- Removal of Made Ground around Parkers Farm and supplementary testing to confirm absence of asbestos fibres in soils (CL4).
- Installation of basic/full radon protection measures in buildings north of Rowel Brook (CL5).

8.4 Future documentation

The methodology for the remediation should be set out in a Remediation Strategy (which will include the 'Implementation Plan', the 'Verification Plan' and the 'Long Term Monitoring and Maintenance Plan'), which will need to be submitted to the warranty provider and the regulatory authorities for approval.

In addition, the production of a Materials Management Plan and its approval by a Qualified Person will be required to allow reuse of suitable material at the site (as part of the cover system) in accordance with waste regulations. The landfill material would not be able to be re-used (unless an Environmental Permit was obtained) and would need to be disposed.

Verification reports by a competent independent geo-environmental specialist will be required following completion of any remedial works.

9. WASTE AND MATERIALS MANAGEMENT

9.1 Introduction

The Waste Framework Directive (WFD) (2009/98/EC) defines waste as '*any substance which the holder discards or intends to discard.*' In a geo-environmental context, the waste is most often 'soil' and the two main scenarios are offsite disposal of the material as a waste and/or reuse of the material on site. For cost and sustainability reasons, reuse is preferred to off-site disposal.

Section 9.2 below describes the key issues relating to off-site disposal to landfill and Section 9.3 considers requirements relating to reuse of soils and materials management.

9.2 Waste disposal

9.2.1 Principles

Based on the WFD, any material excavated on site may be classified as waste and it is the responsibility of the producer of a material to determine whether or not it is waste. Where off-site disposal is undertaken, the following guidance applies.

Classification is a staged process:

- Hazardous waste is defined under the WFD as one which possesses one or more of fifteen defined hazardous properties. If a waste is not defined as hazardous, then it must be considered as non-hazardous.
- Where the materials are soil, it is then be assigned using the 'List of Waste Codes', which classifies the material as either:
  - hazardous (17-05-03), which is defined as "*soil and stones containing hazardous substances*"; or
  - non-hazardous (17-05-04), which is defined as "*soil and stones other than those mentioned in 17-05-03*".
  - Hydrock utilise the proprietary assessment tool, HazWasteOnline™ to undertake this assessment.
- Waste Acceptance Criteria (WAC) testing is then undertaken if required, and are only applicable following classification of the waste, and only where the waste is destined for disposal to landfill. The WAC are both qualitative and quantitative. The WAC and the associated laboratory analyses (leaching tests) are not suitable for use in the determination of whether a waste is hazardous or non-hazardous.

It should be noted that some non-hazardous wastes may be suitable for disposal at an inert landfill as non-hazardous waste, subject to meeting the appropriate waste acceptance criteria.

It should be noted that classification must be undertaken on the waste produced, by the waste producer. Necessary sampling frequency to adequately characterise a soil population is defined within WM3.

9.2.2 Preliminary waste disposal options

The majority of the site is greenfield (as proven by the desk study assessment and a visual assessment of the soils). However, WAC testing and the HazWasteOnline™ assessment have been undertaken. As long as no unexpected contamination is encountered and if suitable segregation of different types of natural waste streams is put in place, for soils to be disposed of, it is considered that:

- The topsoil generally has a low organic content (as proven by the Loss on Ignition and Total Organic Carbon tests) and is likely to be classified as non-hazardous waste for disposal at a non-hazardous landfill.
- The Made Ground (Topsoil Made Ground and Landfill Made Ground) within the landfill likely to comprise a mix of hazardous and non-hazardous waste, with the hazardous elements due to elevated TPH and zinc.
- The natural uncontaminated subsoils are likely to be classified as non-hazardous waste and based on the WAC testing should be able to be disposed of at an inert landfill.
- The wider site Made Ground is likely to be classified as non-hazardous waste.
- In addition, asbestos is identified in one of the samples (0.323%) and any soils containing > 0.1% asbestos or visible asbestos containing materials would be considered as hazardous.

9.2.3 General waste comments

It should be noted that:

- It is the waste producer's responsibility to segregate the waste at source and waste producers must not mix waste materials/streams or dilute hazardous components, for example by mixing with less or non-hazardous waste on site to meet WAC limit values.
- The above preliminary assessment has been made on the basis of the soils tested as part of the ground investigation, using WAC testing and the HazWasteOnline™ assessment. However, the formal classification of waste can only be undertaken on the material to be disposed of, and by the waste producer and the receiving landfill as license conditions vary from landfill to landfill.
- Basic Characterisation should be undertaken in accordance with Environment Agency guidance by the waste producer. Hydrock can assist if required and this report will assist the characterisation. However, Basic Characterisation does not form part of the current commission and would require further assessment and testing on the wastes actually to be disposed.
- Once the waste producer has undertaken an initial Basic Characterisation on each waste stream, they can manage the soils as part of the on-site processing programme (for example, stockpiling, treatment, screening and separation). The waste producer and landfill operator will then need to agree the suite of compliance testing for regularly generated waste to demonstrate compliance with the initial Basic Characterisation prior to disposal.
- At the time of disposal, additional testing on the excavated soils to be disposed of, will likely be necessary.
- Non-hazardous and hazardous soils require pre-treatment (separation, sorting and screening) prior to disposal.
- The costs for disposal of non-hazardous and hazardous soils are significant compared to disposal of inert material.

- In addition to disposal costs, landfill tax will be applicable. Non-hazardous and hazardous waste will generally be subject to the Standard Rate Landfill Tax. Inert or inactive waste will generally be subject to the Lower Rate Landfill Tax. The landfill tax value changes each April and can be found at https://www.gov.uk/government/publications/rates-and-allowances-landfill-tax/landfill-tax-rates-from-1-april-2013.
- Before a waste producer can move waste to a landfill site for disposal, they need to check the landfill site has the appropriate permit and must have completed the following[3]:
  - » Duty of care transfer note / Hazardous Waste consignment note, including comment as to if pre-treatment has been undertaken; and
  - » Basic Characterisation of the waste, to include: description of the waste; waste code (using list of wastes); composition of the waste (by testing, if necessary) and; WAC testing (if required).

9.3 Landfill Site Materials management

It should be noted that the landfill soils are currently a waste and will remain a waste until they are recovered.

A materials management plan for the Landfill area of the site would not apply to the excavation and management of soils from the landfill. Soils would need to be re-used under a Waste Recovery Plan (and associated Deposit for Recovery Permit).

Given the difficulties in obtaining a Deposit for Recovery Permit at the current time, Hydrock recommend excavation of the landfill is kept to a minimum, as any excavated soils will need to be disposed of off-site as waste.

9.4 Wider Site Materials management

9.4.1 Introduction

Soils that are to remain on site, should be managed and reused in accordance with a Materials Management Plan (MMP), prepared in accordance with 'The Definition of Waste: Development Industry Code of Practice', Version 2 (CL:AIRE), known as the DoWCoP. Where all aspects of the DoWCoP are followed the soils are considered not to be waste, because they were never discarded in the first place.

Version 2 of the DoWCoP clearly sets out the principles and an outline of the requirements of a MMP. The following compliance criteria must be seen to apply to the MMP for the site:

- Factor 1: Protection of human health and protection of the environment.
- Factor 2: Suitability for use, without further treatment.
- Factor 3: Certainty of Use.
- Factor 4: Fixed Quantity of Material.

The reuse of soils at sites should be considered during the planning and development design process so that compliance with issues such as fixed quantity and certainty of use clearly relate to agreed site levels. Suitability of Use is normally evident from the remediation strategy or the design statement,

[3] ENVIRONMENT AGENCY. November 2010. Guidance on waste acceptance procedures and criteria. Waste acceptance at landfills. The Environment Agency.

which form an integral part of a MMP. However, some soils may need to be tested post-excavation to prove they are suitable for use.

Once the MMP is finalised, it must be declared by a Qualified Person (QP). The Declaration is an on-line submission as part of which the QP is required to confirm that the declaration is being made before the relevant works have commenced (i.e. it is not a retrospective application).

Once all material movements have been completed in accordance with the MMP a verification report must be produced, kept for 2 years and provided to the EA on request.

It should be noted that failure to comply with the requirements of the DoWCoP when re-using materials has potentially significant consequences for the waste holder. The risk is that the reused materials are still regarded as a waste that has been illegally deposited. From 1 April 2018, the scope of Landfill Tax has been extended to sites operating without the appropriate environmental disposal permit, and operators of illegal waste sites will now be liable for Landfill Tax. Further information is available at: https://www.gov.uk/government/publications/landfill-tax-disposals-not-made-at-landfill-sites/landfill-tax-disposals-not-made-at-landfill-sites.

If soils are excavated and reused on sites (or moved to another site) without a MMP, exemption, or appropriate Permit in place, anyone who knowingly facilitates the disposal may be '*jointly and severally liable'* to any assessment of tax, fines or prosecution.

9.4.2 Materials management scenarios

The materials management scenarios present on site are discussed below.

It should be noted that more than one scenario may apply, dependent upon where the soils are proposed for reuse.

9.4.2.1 Clean, naturally occurring materials – reused on the site of origin

Where soils are naturally occurring, uncontaminated and are reused on the site they are excavated (i.e. greenfield site with documented site history, with no Made Ground), they will fall outside the Waste Framework Directive (WFD) (i.e. they will not be a waste when reused on the site of origin).

However, there needs to be certainty of that reuse, and evidence is necessary to support this strategy, for example through information provided during the planning process. The onus is on the developer to demonstrate that the materials are not a waste and will never become a waste. As such, a Materials Re-use Strategy is recommended to show certainty. Alternatively, if the volume of material is under 1,000 tonnes, then a U1 waste exemption may be applied for from the Environment Agency.

It may be noted that some 'clean naturally occurring materials' may still fail the 'suitable for use' test, for example, soils with a naturally high organic content may not be suitable for use because of their propensity to produce ground gases such as methane. Rules regarding other more unusual circumstances such as where natural soils contain an unacceptably high mineral content are described in the DoWCoP.

9.4.2.2 Clean, naturally occurring materials – transferred to other sites

Where soils are naturally occurring, uncontaminated and are transferred to other sites (i.e. direct transfer), they will not become waste as long as the transfer is undertaken in accordance with the

DoWCoP. A MMP must be prepared for the receiving site and the materials movement must be noted in the MMP of the Donor site. This movement must have been declared to CL:AIRE prior to the works commencing.

9.4.2.3 Geotechnical improvement requirements

Construction activities carried out on uncontaminated soils solely for the purpose of improving geotechnical properties e.g. lime / cement modification, are not generally regarded as waste treatment operations and do not require a permit.

However, should processing be needed (such as screening, treatment or improvement), that would constitute a waste activity and require a mobile treatment permit. This may be as simple as removing oversize material with an excavator bucket, to using a riddle bucket to remove hardcore to full mechanical screening.

10. UNCERTAINTIES AND LIMITATIONS

10.1 Site-specific comments

The investigation works were undertaken on a relatively wide spacing as part of pre-planning investigation works. Further detailed investigation works will be required to fully characterise the site to allow design at a later date.

Due to access constraints for ecological reasons, it was not possible to identify precisely the outer perimeter of the landfill area.

The scheduled ground gas monitoring is complete but is insufficient at this stage to fully characterise the site in accordance with CIRIA Report 665. Whilst the monitoring completed to date provides a preliminary indication of the gas regime, additional monitoring is required and the conclusions of this report will need to be updated following completion of the additional monitoring.

Groundwater monitoring is ongoing until September 2023.

10.2 General comments

Hydrock Consultants Limited (Hydrock) has prepared this report in accordance with the instructions of Oxford University Development Limited (the Client), under the terms of appointment for Hydrock, for the sole and specific use of the Client and parties commissioned by them to undertake work where reliance is placed on this report. Any third parties who use the information contained herein do so at their own risk. Hydrock shall not be responsible for any use of the report or its contents for any purpose other than that for which it was prepared or for use of the report by any parties not defined in Hydrock's appointment.

This report details the findings of work carried out in August to October 2021, September 2022 – November 2022 & January to March 2023. The report has been prepared by Hydrock on the basis of available information obtained during the study period. Although every reasonable effort has been made to gather all relevant information, not all potential environmental constraints or liabilities associated with the site may have been revealed.

Hydrock has used reasonable skill, care and diligence in the design of the investigation of the site and in its interpretation of the information obtained. The inherent variation of ground conditions allows only definition of the actual conditions at the locations and depths of trial pits and boreholes at the time of the investigation. At intermediate locations, conditions can only be inferred.

Groundwater data are only representative of the dates on which they were obtained and both levels and quality may vary.

Unless otherwise stated, the recommendations in this report assume that ground levels will remain as existing. If there is to be any re-profiling (e.g. to create development platforms or for flood alleviation) then the recommendations may not apply.

Information provided by third parties has been used in good faith and is taken at face value; however, Hydrock cannot guarantee its accuracy or completeness.

Where the existing report(s) prepared by others have been provided by the Client, it is assumed that these have been either commissioned by the Client, or can be assigned to the Client, and can be relied upon by Hydrock. Should this not be the case Hydrock should be informed immediately as additional work may be required. Hydrock is not responsible for any factual errors or omissions in the supplied data, or for the opinions and recommendations of others. It is possible that the conditions described may have since changed through natural processes or later activities.

The work has been carried out in general accordance with recognised best practice. Unless otherwise stated, no assessment has been made for the presence of radioactive substances or unexploded ordnance. Where the phrase 'suitable for use' is used in this report, it is in keeping with the terminology used in planning control and does not imply any specific warranty or guarantee offered by Hydrock.

The chemical analyses reported were scheduled for the purposes of risk assessment with respect to human health, plant life and controlled waters as discussed in the report. Whilst the results may be useful in applying the Hazardous Waste Assessment Methodology given in Environment Agency Technical Guidance WM3, they are not primarily intended for that purpose and additional analysis will be required at the time of disposal to fully classify waste. Discussion and comment with regards to waste classification are preliminary and do not form the requirements of 'Basic Characterisation' as required.

Unless otherwise stated, at the time of this investigation the future routes of water supply pipes had not been established. This investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling and chemical testing may be required at a later date once the routes 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.

Whilst the preliminary risk assessment process has identified potential risks to construction workers, consideration of occupational health and safety issues is beyond the scope of this report.

The non-specialist UXO screening has been undertaken for the purposes of ground investigation only (i.e. low risk activity in accordance with CIRIA Report C681). Further assessment should be undertaken with regards to other higher risk activities e.g. construction.

Please note that notwithstanding any site observations concerning the presence or otherwise of archaeological sites, asbestos-containing materials or invasive weeds, this report does not constitute a formal survey of these potential constraints and specialist advice should be sought.

Any site boundary line depicted on plans does not imply legal ownership of land.

11. RECOMMENDATIONS FOR FURTHER WORK

Following the ground investigation works undertaken to date, the following further works will be required for planning and high-level design:

- Additional investigation to the east and south of the landfill to further define the softer, looser soils.
- Demolition / refurbishment asbestos survey of farm structures.
- Completion and reporting of the ongoing gas monitoring, hence the conclusions in this report are provisional, subject to the completion of monitoring.

The following works should be undertaken once the development layout has been finalised;

- supplementary detailed ground investigation as required and on a development phase basis to allow design;
- discussion and agreement with utility providers regarding the materials suitable for pipework;
- discussions with regulatory bodies and the warranty provider regarding the conclusions of this report;
- assessment of tree influence on foundations and design of foundations;
- discussions with Vibro-stone Column Contractors regarding the viability of, and potential improvement by, VSCs;
- discussions with piling Contractors regarding conclusions of this report and design of the piles;
- provision of geotechnical design for the Category 2 (earthworks, retaining, floor slabs, foundations, bridge construction etc.);
- production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider);
- production of a Materials Management Plan relating to reuse of soils at the site;
- remediation and mitigation works; and
- verification of the earthworks, remediation and mitigation works.

If the landfill site is proposed for residential or non-residential land use (other than POS), the recommendations in this report will need to be reviewed and extensive mitigation and geotechnical investigation would be necessary.

12. REFERENCES

ASSOCIATION OF GROUND INVESTIGATION SPECIALISTS. 2006. Guidelines for Good Practice in Site Investigation. Issue 2. AGS, Beckenham.

ASSOCIATION OF GROUND INVESTIGATION SPECIALISTS. 2019. Waste Classification for Soils – A Practitioners' Guide. AGS, Beckenham.

BRE. 1999. The influence of trees on house foundations in clay soils. BRE Digest 298. Building Research Establishment, Garston.

BRE. 2016. Soakaway design. BRE DG 365. BRE, Garston.

BRE. 2000. Specifying Vibro Stone Columns. BR391. BRE, Garston.

BRE. 2004. Working platforms for tracked plant: good practice guide to the design, installation, maintenance and repair of ground-supported working platforms. BR470. BRE, Garston.

BRE. 2005. Concrete in aggressive ground. BRE Special Digest 1, 3rd Edition. BRE, Garston.

BRITISH PLASTIC FEDERATION. August 2018. 'Designing Drains and Sewers for Brownfield Sites. Guidance Notes'. BPF Pipes Group (https://www.bpfpipesgroup.com/media/29155/Designing-drains-and-sewers-for-brownfield-sites.pdf)

BRITISH STANDARDS INSTITUTION. 2015. Code of Practice for Foundations. BS 8004. BSI, London.

BRITISH STANDARDS INSTITUTION. 2015+A2 2019. Concrete – complementary British Standard to BS EN 206-1 – Part 1: Method of specifying and guidance to the specifier. BS 8500-1+A2 2019. BSI, London.

BRITISH STANDARDS INSTITUTION. 2007. Eurocode 7 – Geotechnical design - Part 2: Geotechnical investigation and testing. BS EN 1997-2. BSI, London.

BRITISH STANDARDS INSTITUTION. 2009. Code of practice for earthworks. BS 6031 Incorporating Corrigendum No.1:2010. BSI, London.

BRITISH STANDARDS INSTITUTION. 2011. Code of Practice for Investigation of Potentially Contaminated sites. BS 10175 Incorporating Amendment No. 2:2017. BSI, London.

BRITISH STANDARDS INSTITUTION. 2012. Trees in relation to design, demolition and construction – Recommendations. BS 5837. BSI, London.

BRITISH STANDARDS INSTITUTION. 2004+A1 2013. Eurocode 7 – Geotechnical design - Part 1: General rules. BS EN 1997-1+A1. Incorporating Corrigendum February 2009. BSI, London.

BRITISH STANDARDS INSTITUTION. 2015. Specification for topsoil. BS 3882. BSI, London.

BRITISH STANDARDS INSTITUTION. 2015. Code of practice for ground investigations. BS 5930. BSI, London.

CARD, G., WILSON, S. and MORTIMER, S. 2012. A pragmatic approach to ground gas risk assessment. CL:AIRE Research Bulletin RB17. CL:AIRE, London.

CARD, G., LUCAS, J., WILSON, S., 2019. Risk and reliability in gas protection design - 20 years on. Ground Engineering, August/September 2019.

CL:AIRE, 2017. A Pragmatic Approach to Ground Gas Risk Assessment. Research Bulletin 17, CL:AIRE, Buckinghamshire. ISSN 2047-6450.

CL:AIRE, 2020. Professional Guidance: Comparing Soil Contamination Data with a Critical Concentration. CL:AIRE, Buckinghamshire. ISBN 978-1-905046-35-5.

CL:AIRE, 2018. Ground gas monitoring and 'worst-case' conditions. Technical Bulletin 17, CL:AIRE, Buckinghamshire, August 2018.

CL:AIRE, 2021. Good practice for risk assessment for coal mine gas emissions. CL:AIRE, Buckinghamshire. ISBN 978-1-905046-39-3

CLAYTON, C. R. I. 2001. Managing Geotechnical Risk. Improving productivity in UK building and construction. Thomas Telford, London.

CL:AIRE. March 2011. The Definition of Waste: Development Industry Code of Practice, Version 2. Contaminated Land: Applications in the Real Environment (CL:AIRE), London.

CL:AIRE. March 2016. CAR-SOIL™ Control of Asbestos Regulations 2012 - Interpretation for Managing and Working with Asbestos in Soil and Construction and Demolition Materials: Industry guidance. Contaminated Land: Applications in the Real Environment (CL:AIRE), London.

CONCRETE SOCIETY, THE. 2013. Concrete industrial ground floors. A guide to design and construction. Technical Report 34 (4th Ed.). The Concrete Society, Camberley.

DEPARTMENT FOR ENVIRONMENT FOOD AND RURAL AFFAIRS (DEFRA). 2005. 'Landfill (England and Wales) (Amendment) Regulations', (with reference to previous iterations of the regulations).

DEFRA. March 2014. SP1010: Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination – Policy Companion Document. Defra, London.

ENVIRONMENT AGENCY. 2006. Remedial Targets Methodology. Hydrogeological Risk Assessment for Land Contamination. The Environment Agency, Bristol.

ENVIRONMENT AGENCY. November 2010. Guidance on waste acceptance procedures and criteria. Waste acceptance at landfills. The Environment Agency.

ENVIRONMENT AGENCY. November 2011. Treatment of waste for landfill. Report – GEHO1111BVDF-E-E 913_11, Version 2 The Environment Agency. http://publications.environment-agency.gov.uk/pdf/GEHO1111BVDF-E-E.pdf

ENVIRONMENT AGENCY. 2021. Waste classification. Guidance on the classification and assessment of waste (1st Edition v1.2.GB) Technical Guidance WM3. The Environment Agency.

ENVIRONMENT AGENCY. 2022. Land Contamination: Risk Management (LCRM). The Environment Agency.

HATANAKA, M, UCHIDA, A, KAKURAI, M, and AOKI, M. 1980. A consideration on the relationship between SPT N-value and internal friction angle of sandy soils. Journal of Structural and Construction Engineering (Transactions of AIJ). 63. 125-129. 10.3130/aijs.63.125_2.

HEALTH and SAFETY EXECUTIVE. December 2005. Construction Information Sheet 47: Inspections and Reports (CIS 47 (Rev 1)). HSE.

HEALTH and SAFETY EXECUTIVE. 2014. HSG47 - Avoiding danger from underground services (Third edition). HSE.

HIGHWAYS AGENCY. 2009. Design Guidance for Road Pavement Foundations (Draft HD25). Interim Advice Note 73/06. Rev 1. Highway Agency, London.

HIGHWAYS AGENCY. 2014. Manual of Contract Documents for Highway Works, Specification for Highway Works: Volume 1, Amendment August 2014. Highway Agency, London.

HIGHWAYS AGENCY. 2019. Design Manual for Roads and Bridges. Managing Geotechnical Risk. HE-DMRB-G-CD 622 Rev 1. Highway Agency, London.

HIGHWAYS AGENCY. 2020. Design Manual for Road and Bridges: Managing the maintenance of highway geotechnical assets. HE-DMRB-G CS 641.

HIGHWAYS AGENCY. 2020. Design Manual for Road and Bridges: Design for new pavement foundations. HE-DMRB-G CD 225.

MILES, J. C. H., APPLETON, J. D., REES, D. M., GREEN, B. M. R., ADLAM. K. A. M. and MYRES. A. H. 2007. Indicative Atlas of Radon in England and Wales. Health Protection Agency and British Geological Survey. Report HPA-RPD-033.

MINISTRY OF HOUSING, COMMUNITIES and LOCAL GOVERNMENT (MHCLG). Internet published Planning practice guidance https://www.gov.uk/government/collections/planning-practice-guidance. MHCLG. London

NHBC. 2022. NHBC Standards. NHBC, Milton Keynes. https://nhbc-standards.co.uk/

PECK, R.B., HANSON, W.E., AND THORNBURN, T.H., Foundation Engineering, 2nd Edn, John Wiley, New York, 1967, p.310.

RAWLINS, B. G., McGRATH, S. P., SCHEIB, A. J., CAVE, N., LISTER, T. R., INGHAM, M., GOWING, C. and CARTER, S. 2012 .The advanced geochemical atlas of England and Wales. British Geological Survey, Keyworth.

SCIVYER, C. 2023. Radon: Guidance on protective measures for new buildings. Building Research Establishment Report BR 211. BRE, Garston.

STONE, K., MURRAY, A., COOKE, S., FORAN, J. and GOODERHAM, L. 2009. Unexploded ordnance (UXO), a guide to the construction industry. CIRIA Report C681. Contaminated Land: Applications in Real Environments, London.

STROUD, M. A. 1975. The standard penetration test in insensitive clays and soft rocks. Proceedings of the European Symposium on penetration testing, 2, 367-375.

TOMLINSON. M.J. 2001. Foundation Design and Construction (6th Edition and 7th Edition). Prentice Hall Press

WASTE AND RESOURCES ACTION PROGRAMME (WRAP). October 2013. Quality Protocol. Aggregates from inert waste. End of waste criteria for the production of aggregates from inert waste.

WATER UK HBF. January 2014. Contaminated Land Assessment Guidance. Water UK and the Home Builders Federation.

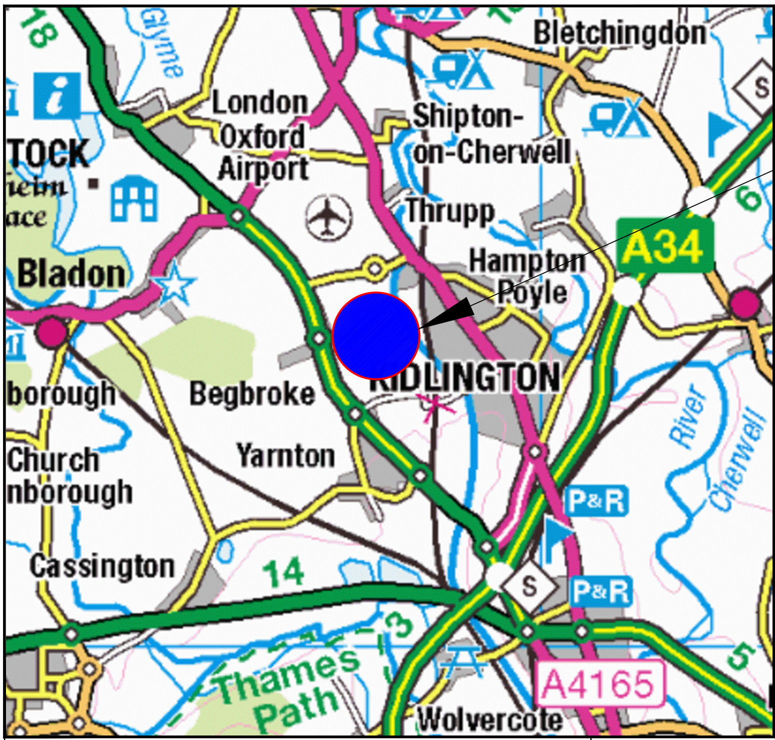
WFD-UKTAG. July 2014. UKTAG River and Lake Assessment Method, Specific Pollutants (Metals), Metal Bioavailability Assessment Tool (M-BAT). Water Framework Directive – United Kingdom Technical Advisory Group. Stirling.

WILSON, S., OLIVER, S., MALLETT, H., HUTCHINGS, H. and CARD, G. 2007. Assessing risks posed by hazardous ground gases to buildings. CIRIA Report C665. Contaminated Land: Applications in Real Environments, London.

Appendix A Drawings

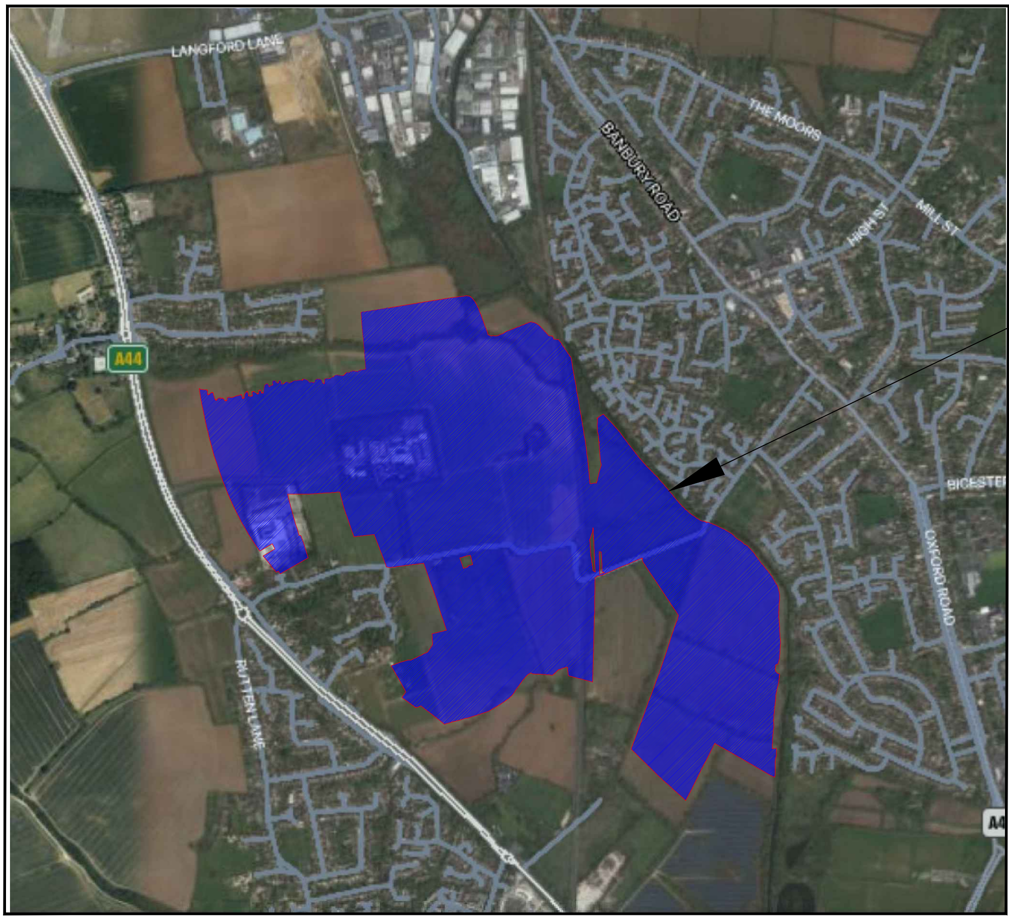
OS NORTH

THE SITE



0m 1000m 2000m 3000m 4000m 5000m Scale = 1:100,000

THE SITE



REV.	REVISION NOTES/COMMENTS					
	DRAWN BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
P03	FIRST ISSUE					
	SD	12/04/23	NT	12/04/23	CD	12/04/23
P02	FIRST ISSUE					
	SD	01/11/22	NT	01/11/22	AB	01/11/22
P01	FIRST ISSUE					
	SD	06/10/21	NT	06/10/21	AB	06/10/21

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CLIENT

Oxford University Development Ltd

PROJECT

Begbroke, Oxfordshire

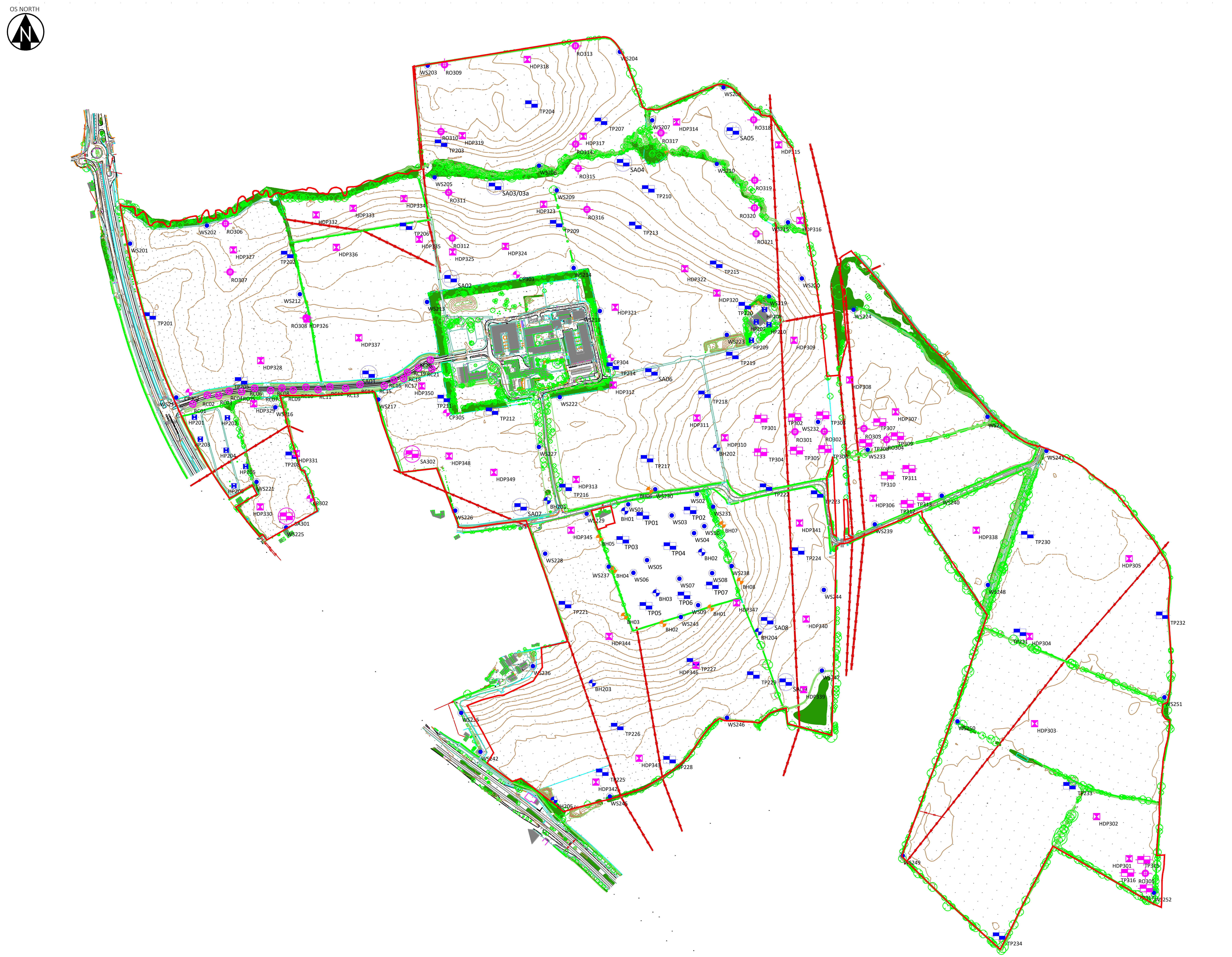
TITLE

SITE LOCATION PLAN

HYDROCK PROJECT NO.	SCALE @ A4
19114	See Drawing

PURPOSE OF ISSUE	STATUS
SUITABLE FOR INFORMATION	S2

DRAWING NO. (PROJECT - ORIGINATOR-VOLUME-LEVEL-TYPE-ROLE-NUMBER)	REVISION
19114-HYD-XX-ZZ-DR-GE-01000	P03



KEY

Hydrock January/February 2023

- CP3## Cable Percussion Borehole
- RO3## Rotary Borehole
- SA3## Soakaway Pit
- TP3## Trial Pit
- RC## Road Core Location
- HDP## Hand Dug Pit

Initial Site Investigation (September 2022)

- SAXXX Hydrock Soil Infiltration Rate Test Pit
- WSXX Hydrock Dynamic Sampler Borehole
- TPXX Hydrock Trial Pit
- BHXX Hydrock Borehole
- HPXX Hydrock Hand Dug Pit

JUBB Site Investigation (December 2019)

- BH07 Borehole

NOTES

1. All dimensions are to be checked on site before the commencement of works. Any discrepancies are to be reported to the Architect & Engineer for verification. Figured dimensions only are to be taken from this drawing.

2. This drawing is to be read in conjunction with all relevant Engineers' and Service Engineers' drawings and specifications.

3. This drawing has been based on the following drawings and information: Topographical Survey number:180133 by:Interlock Surveys dated:11/02/2019.

4. A minimum 9metre stand off zone has been applied to (and must be adhered to for all siteworks) all proposed SI positions in relation to Overhead power lines shown on the Survey.

LEGEND

Site Boundary

REV.	REVISION NOTES/COMMENTS					
	DRAWN BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
P07	SITE BOUNDARY ADDED					
	SD	12/04/23	NT	12/04/23	CD	12/04/23
P06	HAND PITS ADDED					
	SD	14/03/23	NT	14/03/23	AB	14/03/23
P05	UPDATED FOLLOWING FURTHER SITE INVESTIGATION					
	SD	21/02/23	NT	21/02/23	AB	21/02/23
P04	SURVEYED LOCATIONS FOLLOWING SITE INVESTIGATION					
	NS	27.10.22	NT	27.10.22	AB	27.10.22
P03	THIRD ISSUE - UPDATED LOCATIONS					
	SD	15/08/22	NT	16/08/22	AB	16/08/22
P02	SECOND ISSUE - PROPOSED LOCATIONS					
	NT	29/06/22	AB	29/06/22	AB	29/06/22
P01	FIRST ISSUE					
	SD	07/12/21	NT	07/12/21	AB	07/12/21

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CLIENT

Oxford University Development Ltd

PROJECT

Begbroke, Oxfordshire

TITLE

Exploratory Hole Location Plan

HYDROCK PROJECT NO.	SCALE @ A2
C-19114-C	1:5000

PURPOSE OF ISSUE	STATUS
SUITABLE FOR INFORMATION	S2

DRAWING NO. (PROJECT CODE-ORIGINATOR-ZONE-LEVEL-TYPE-ROLE-NUMBER)	REVISION
19114-HYD-XX-ZZ-DR-GE-01001	P07