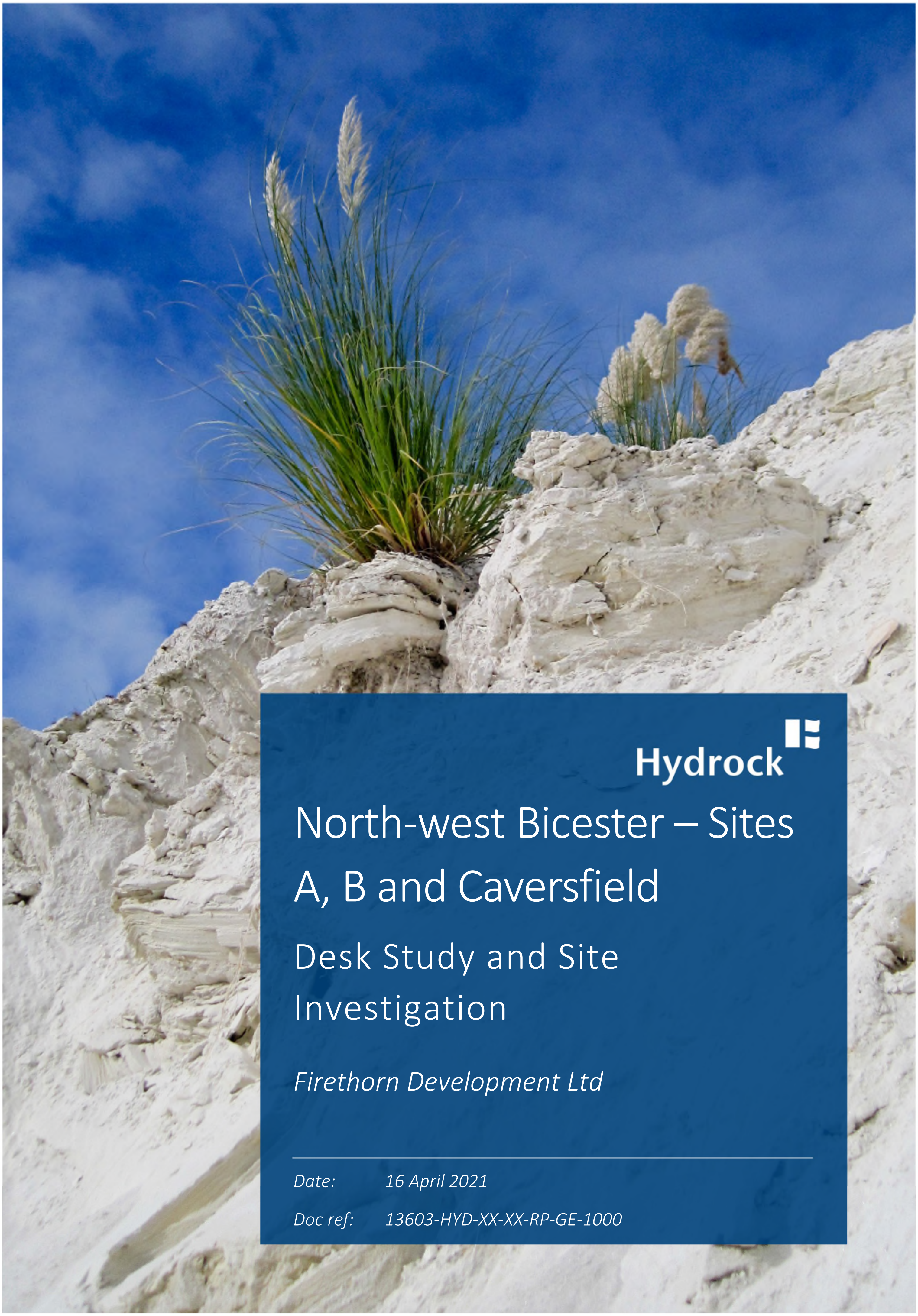

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North-west Bicester – Sites A, B and Caversfield

Desk Study and Site Investigation

Firethorn Development Ltd

Date: *16 April 2021*

Doc ref: *13603-HYD-XX-XX-RP-GE-1000*

DOCUMENT CONTROL SHEET

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EXECUTIVE SUMMARY

SITE INFORMATION AND SETTING	
Objectives	The works have been commissioned to support the planning application and to assist with the design of the development.
Client	Firethorn Developments Ltd
Site name and location	North-west Bicester Eco Development – Sites A, B and Caversfield. The site is located to the south of the B4100, approximately 1.8 miles to the north-west of Bicester and approximately 1 mile east of the village of Caversfield, Oxfordshire. The National Grid Reference of the approximate centre of the site is 457701E, 225165N.
Proposed development	Hydrock understands that the proposed development is to comprise residential properties (approximately 500 homes) with public open space and associated infrastructure.
GROUND MODEL	
Desk study summary	The site currently comprises open agricultural land, comprising from three land parcels. Site A (in the site centre) is formed of four fields with a wooded area in the south-west. Site B is to the west and is formed of the eastern end of an agricultural field with a wooded area present in the south-east. The area of the site known as 'Caversfield' is the eastern most land parcel and is formed of three fields. The whole site has an area of approximately 22 ha. There are streams on the southern and eastern boundaries and an existing residential development is present between Site A and Caversfield. The site slopes down towards the south and south east from 94m above Ordnance Datum (OD) in the north-west, to 83m OD in the south-east. The site slopes more steeply in the southern sections of Sites A and B towards the stream immediately to the south. The south-east of Caversfield also slopes steeply towards the stream immediately to the east, with a reduction in level from approximately 90m OD to 83.5m OD. Review of historical Ordnance Survey mapping indicates: • The site remained predominantly open land made up of several land parcels since 1881 to present day. There is a small quarry approximately 75m east of Caversfield from 1881 to 1922. • Bicester Aerodrome formally RAF Bicester, located approximately 1km to the south-east, appears on maps from 1952; however, is recorded dating back to 1916. • In the 1920s a filter bed is shown on Caversfield's south-east boundary and several quarries are shown approximately 500m east of the site; • Satellite imagery from 2017 shows construction of residential housing in the adjacent fields north and south; Charlotte Avenue and an attenuation pond are shown between Site A and Caversfield. A non-specialist UXO assessment indicates a low UXO risk. The geology at the site is shown to comprise Cornbrash Formation at higher levels overlying the Forest Marble Formation. The deeper geology comprises the White Limestone Formation. Alluvium is shown associated with streams in lower parts of the site. Otherwise, no superficial deposits are shown. The superficial deposits, Cornbrash Formation and Forest Marble Formation are all Secondary A aquifers and the deeper laying White Limestone Formation is a Principal Aquifer. The site is not within a Source Protection Zone, but there are two groundwater abstractions within 1km of it.
Ground and groundwater conditions encountered by investigation	The ground conditions as proven by the investigation undertaken at the site comprise: • Topsoil across most of the site from surface to between 0.20m to 0.60m bgl, comprising brown locally orangish brown organic variably sandy gravelly clay with frequent rootlets. • Made Ground, encountered locally in the south-east of Site A and north-east of Caversfield, from the surface to 0.30m below ground level (bgl), to depths of between 0.25m to 1.60m bgl. The Made Ground comprised:

	- 'General' Made Ground comprising soft brown locally blackish brown variably sandy gravelly clay with fragments of brick, concrete and plastic; or - 'Reworked' Made Ground, in TP81 only, comprising soft brown slightly gravelly sandy clay and soft blackish brown slightly gravelly sandy clay. • Alluvium in the south of Site B (TP11 only) encountered between 0.30m bgl and 0.80m bgl comprising soft orangish brown slightly gravelly slightly sandy clay. • Head Deposits were identified across most of the site from between 0.25m bgl and 0.80m bgl, to depths of between 0.50m bgl and 2.40m bgl, comprising soft (locally firm) orangish brown variably sandy gravelly clay with cobbles and boulders; orangish brown, reddish brown and cream variably sandy clayey gravel with cobbles and boulders; and reddish brown variously gravelly clayey sand. • Cornbrash Formation across the majority of the higher parts in the central and western sections of the site, but not at the lower topographic levels in the central south and the far east. This was recorded from 0.20m bgl to 2.00m bgl to depths of 1.00m bgl to 3.73m bgl. The Cornbrash Formation comprised firm to stiff orangish brown, light brown, yellowish brown and grey variously sandy gravelly clay, locally with shell fragments and calcareous nodules; and very weak to moderately weak locally fractured orangish brown, light grey and yellowish-brown limestone, locally with shells fragments. • Forest Marble Formation encountered beneath the Cornbrash Formation and locally sub-cropping below the superficial deposits in the central south-east and east. This was recorded from 0.60m bgl to 3.73m bgl to a maximum depth of 5.00m bgl (base not proven). The Forest Marble Formation comprised firm to very stiff bluish grey, greenish grey, light yellowish grey and orangish brown variably sandy gravelly silty clay; very weak to moderately weak light grey, dark grey, light yellowish brown and locally stained orangish brown limestone, locally with fossil and shell fragments; and extremely weak light grey and dark grey mudstone. Groundwater was encountered at depths between 0.8m bgl and 3.2m bgl during the investigation. Water levels recorded post-fieldwork ranged from 0.51m bgl to 4.37m bgl (91.65m OD to 83.50m OD). Shallow groundwater was encountered towards the base of the Cornbrash Formation, with local variations probably associated with varied permeability due to the alternating beds of clay and limestone recorded. There is also a deeper groundwater body in the Forest Marble Formation, notably identified in the south-east of the site (in Caversfield), where this stratum sub-crops. No visual or olfactory evidence of contamination was recorded.
GEOTECHNICAL CONCLUSIONS	
Conclusions of geotechnical assessment	Man-made obstructions are unlikely to be encountered. Topsoil should be removed from beneath all building and hardstanding areas. Shallow excavation should generally be achievable with standard excavation plant. Heavy duty excavation plant/breaking equipment will likely be required to excavate the limestone of the Cornbrash Formation and the Forest Marble Formation, especially with depth. Excavations during investigation were generally stable, although slight spalling should be expected from the Made Ground and overbreak should be expected where limestone bands are excavated through. Water seepages into excavations are likely to be controllable by sump pumping. However, in periods of high rainfall, high-capacity pumps will likely be required. Strip/trench fill foundations are recommended for the majority of foundations. Deepening of foundations/heave protection is likely to be required to allow for the effects of trees. Piles may be required where in close proximity to trees. A permissible net bearing pressure of 125kN/m² should be available for strip/trench fill foundations up to 1.0m wide. Suspended ground floor slabs are recommended because of the depth of Made Ground (locally) and the presence of medium shrinkage potential clay soils. A design CBR 2.5% is recommended for design for most of the site, with <2.5% recommended in areas of Made Ground and Alluvium.

	Subject to further works, infiltration of surface water into the ground is possible for parts of the site. However, shallow groundwater was recorded and as such any infiltration drainage will be shallow and subject to design by a specialist. Design Sulfate Class - DS-1 and ACEC Class AC-1. Equivalent to Design Chemical Class DC-2 for a 50-year design life.
GEO-ENVIRONMENTAL CONCLUSIONS	
Conclusions of contamination Generic risk assessment	Human health and plant growth: • Low risks. No mitigation required. Ground gases or vapours: • Low risk from ground gases (subject to additional and on-going monitoring) and CS1 conditions apply and no mitigation required. Radon: • The is in a Radon Affected Area where recorded radon levels in 3-10% of homes are above the action level and basic radon protection measures are required. Water supply pipes: • Standard pipework is envisaged. However, confirmation should be sought from the water supply company at the earliest opportunity.
Waste management	Excavated soils which are to be disposed of as waste, are likely to be classed as: • Topsoil - non-hazardous waste (subject to organic content); • Made Ground - non-hazardous waste that is likely able to be disposed of at an inert landfill; and • Natural soils - non-hazardous waste that is likely able to be disposed of at an inert landfill.
FUTURE CONSIDERATIONS	
Further work	Following the ground investigation works undertaken to date, the following further works will be required: • completion and reporting of the ongoing gas monitoring, hence the conclusions in this report are provisional, subject to the completion of monitoring; • discussions with regulatory bodies and the warranty provider regarding the conclusions of this report; • geotechnical design; • production of a Materials Management Plan relating to reuse of soils at the site; and • verification of the earthworks and MMP works.

This Executive Summary forms part of Hydrock Consultants Limited report number 13603-HYD-XX-XX-RP-GE-1000 and should not be used as a separate document.

1. INTRODUCTION

1.1 Terms of reference

In August 2020, Hydrock Consultants Limited (Hydrock) was commissioned by Review Partners (the Client's agent) on behalf of Firethorn Development Ltd (the Client) to undertake a site investigation, comprising a desk study and ground investigation at North-west Bicester – 'Site A', 'Site B' and 'Caversfield', confirmed via contract document dated 24th August 2020.

The site is located approximately 1.8 miles to the north-west of Bicester and approximately 1 mile east of the village of Caversfield, Oxfordshire. It is currently undeveloped fields, split into three parcels of land:

- Site A is in the centre of the development and comprises four fields with a woodland area in the south-west.
- Site B comprises open agricultural land with a small woodland area in the south-east and an open boundary to the west, formed by the remainder of the agricultural field.
- Caversfield comprises three fields, bounded by hedgerows and trees.

All three parcels of land are bounded by hedgerows and trees. An existing residential development is present between Site A and Caversfield and to the north of Site A and west of Caversfield.

Hydrock understands that the proposed development is to comprise residential properties (approximately 500 homes) with public open space and associated infrastructure. At the time of commission and the site works, the proposed drainage strategy for Sites A and B comprised permeable paving and / or discharge (and possible attenuation in oversize pipework) to the existing drainage system in the adjacent development; or discharge to the brook to the south. It is understood that the drainage strategy for the Caversfield site will include attenuation in a surface water pond located to the east of the residential dwellings, in an area of Public Open Space.

A proposed development layout (David Lock Associate Drawings RPC001-016 Rev A and ZMK363/006), are presented in Appendix A.

A supplementary ground investigation was carried out in January 2021 to assist in the design of the site. These works targeted the proposed attenuation pond in the south east of Site A and the shallow drainage of the permeable paving. This report has been updated to include all the data obtained from the supplementary investigation.

1.2 Objectives

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

The objective of the Phase 1 Desk Study is to formulate a preliminary Ground Model and an Initial Conceptual Model of the site to identify and make a preliminary assessment of key geo-environmental and geotechnical risks to the proposed development.

The objective of the Phase 2 Ground Investigation is:

- to resolve uncertainties identified in the Phase 1 Desk Study by refining and updating the preliminary Ground Model, determining geo-environmental and geotechnical site conditions and identifying key contamination risks by updating and finalising the Conceptual Model in accordance with the principles of LCRM;
- to identify geo-environmental mitigation requirements to enable development; and
- to provide preliminary geotechnical recommendations for design.

1.3 Scope

The site investigation includes a Phase 1 Desk Study and a Phase 2 Ground Investigation.

The scope of the Phase 1 Desk Study comprises:

- a field reconnaissance (walkover) to determine the nature of the site and its surroundings including current and former land uses, topography and hydrology;
- acquisition and review of:
  - historical Ordnance Survey maps, to identify former potentially contaminative uses shown at the site and immediately surrounding it, and an assessment of the associated contamination risks;
  - a third-party environmental report to identify flooding warning areas, local landfills, pollution incidents, abstractions, environmental permits etc. which may have had the potential to have environmental impact on the site;
  - topographical, geological and hydrogeological maps;
  - British Geological Survey (BGS) archive records;
  - regional UXB risk maps;
- a review of previous investigations carried out at the site;
- development of a preliminary Ground Model representing ground conditions at the site;
- development of an outline Conceptual Model (oCM), including identification of potential pollution linkages;
- a qualitative assessment of any geo-environmental risks identified; and
- identification of plausible geotechnical hazards.

The scope of the Phase 2 Ground Investigation comprises:

- a ground investigation including trial pitting, rotary drilling 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;
  - install gas and groundwater wells;
- gas concentration and groundwater level monitoring;
- geotechnical and chemical laboratory analysis;
- updating of the preliminary Ground Model;

- preparation of a geotechnical risk register;
- presentation of an initial geotechnical design recommendations;
- formulation of an updated Conceptual Site Model (CM), including identification of plausible pollution linkages;
- completion of a generic quantitative risk assessment of potential chemical contaminants to establish 'suitability for use' under the current planning regime;
- discussion of potential environmental liabilities associated with land contamination (soil, water and gas); and
- identification of outline mitigation requirements to ensure the site is 'suitable for use'.

The scope of the Supplementary Phase 2 Ground Investigation comprises:

- 10 shallow machine excavated trial pits to a maximum depth of 0.90m below ground level (bgl) with soil infiltration rate testing;
- 2 deeper machine excavated trial pits to a maximum depth of 3.00m with soil infiltration rate testing;
- 3 rotary boreholes to a maximum depth of 5.00m bgl;
- ongoing gas concentration and groundwater level monitoring.

1.4 Available information

The following documents, reports etc have been provided to Hydrock by Review Partners for use in the preparation of this report:

- Hyder. November 2010. 'P3 Eco (Bicester) Lts & A2 Dominion Group Ltd NW Bicester Eco Development Geotechnical Desk Study - Masterplan Site'. Ref: 2501-UA001881-UP33R-01.
- Hyder. February 2011. 'P3 Eco (Bicester) Lts & A2 Dominion Group Ltd NW Bicester Eco Development Geotechnical Interpretative Report - Masterplan Site'. Ref: 2507-UA001881-UP33R-01.
- David Lock Associates. 27th February 2018. 'Caversfield, Bicester. Illustrative Master Plan'. Ref: RPC001-016 Rev A.
- Barton Willmore. 28th August 2019. 'Bicester North. Location Plan'. Ref: 1300 LN-P-01.
- David Lock Associates. October 2019. 'Illustrative Master Plan, North-west, Bicester', Ref: ZMK363/006 (showing Site A and Site B).

Hydrock understand that the Client has commissioned or obtained assignment of the above documents and Hydrock and Hydrock is entitled to full reliance upon their contents.

1.5 Regulatory context and guidance

The investigation work has been carried out in general compliance with recognised best practice, including (but not limited to) BS 5930:2015, BS 10175:2011+A2:2017 and the AGS (2006) 'Good Practice Guidelines for Site Investigations'.

The geo-environmental section of this report is written in broad accordance with BS 10175:2011+ A2:2017, 'Land Contamination: Risk Management' (LCRM, 2020) and the AGS (2006) 'Good Practice Guidelines for Site Investigations'.

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

Phase 2 comprises intrusive ground investigation work and testing. The factual information from Phase 1 and Phase 2 are used to develop the Conceptual Model (CM). This CM is based on a ground model of the site physical conditions and an exposure model of the possible contaminant linkages. The CM forms the basis for Generic Quantitative Risk Assessment (GQRA) in accordance with current guidelines. This GQRA might lead to 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 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 NHBC Standards (2020), have also been applied.

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) and 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 09 and Section 10.

2. PHASE 1 STUDY (DESK STUDY AND FIELD RECONNAISSANCE)

2.1 Data

A number of desk study sources have been used to assemble the following information. These are presented in Appendix D and include:

- Third-party environmental report (Envirocheck report, reference NW Bicester Combined);
- Historical Ordnance Survey mapping;
- BGS Archive Records; and
- Zetica UXB Risk Maps (https://zeticauxo.com/downloads-and-resources/risk-maps/).

As part of the desk study information, a number of previous ground investigations undertaken at the site and immediate surrounding area have been reviewed (see Section 1.4). Where suitable (see Section 2.17), the data from the previously referenced reports is included within this Phase 1 study. Previous information includes:

- Hyder. November 2010, Ref: 2501-UA001881-UP33R-01, a desk study, including a summary review of historical, geological and hydrogeological mapping and review of a third-party environmental report;
- Hyder. February 2011, Ref: 2507-UA001881-UP33R-01, a ground investigation, comprising:
  - eleven trial pits to a maximum depth of 2.85m bgl;
  - five rotary boreholes to a maximum depth of 9.00m bgl;
  - five in-situ soakaway tests;
  - three in-situ permeability tests;
  - chemical analysis of soils and water;
  - installation of gas monitoring standpipes to depths of up to 10 metres within boreholes 1, 3, 5, 10 and 11; and
  - ground gas concentration and groundwater level monitoring (3 visits, over a 2-month period).

2.2 Site referencing

The site is referenced in Table 2.1 and the location is indicated in Figure 2.1 and Figure 2.2.

Table 2.1: Site referencing information

Item	Brief Description
Site name	Site A, Site B and Caversfield, North-west Bicester Eco Development
Site address	North of the wider North-west Bicester development site. The nearest postcode to the site is OX27 8BH.
Site location and grid reference	The site is located to the south of the B4100, approximately 1.8 miles to the north-west of Bicester and approximately 1 mile east of Caversfield. The National Grid Reference of the approximate centre of the site is 457701E, 225165N.

Figure 2.1: Site location
(Reproduced from Google Earth© Imagery 2020)

Figure 2.2: Extract from the Ordnance Survey Map.
(OS licence 100023353).

A site location plan (Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1000) and a site zonation plan (Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1002), denoting the land parcel Site A, Site B and Caversfield, are presented in Appendix A.

2.3 Site description and field reconnaissance survey

A field reconnaissance survey was undertaken on 26th August 2020 to visually assess potential geotechnical hazards, contaminant sources and receptors. The weather during the field reconnaissance survey was sunny.

A basic site description is presented in Table 2.2 and selected photographs are presented in Figure 2.3 to Figure 2.6. Additional photographs are presented in Appendix B.

Table 2.2: Site description

Item	Brief Description
Site access	Site A and Caversfield are both accessed via Charlotte Avenue, with an additional access point for Caversfield from the B4100 to the north. Site B is accessed via Bainton Road to the west with pedestrian access from Site A to the east.
Site area	The site is formed from three land parcels. Site A (in the site centre) is formed of four fields with a wooden area in the south-west. Site B is to the west and is formed of the eastern end of an agricultural field, with a wooded area in the south-east. Caversfield is the easternmost land parcel and is formed of three fields. The whole site has an area of approximately 22 ha.
Elevation, topography and any geomorphic features	The site slopes towards the south and south-east from 94m above Ordnance Datum (OD) in the north-west, to 83m OD on the south-east. The site slopes more steeply in the southern sections of Sites A and B towards the stream immediately to the south. The south-east of Caversfield also slopes steeply towards the stream immediately to the east with a reduction in level from approximately 90m OD to 83.5m OD.

Item	Brief Description
Present land use	The site is currently undeveloped agricultural land with a wooded area partially along the south-west border. Site B was previously cropped, identified by ridge and furrow. Site A and Caversfield are grassed, undeveloped fields, possibly used for grazing, as identified by a paddock area in the south-west of Site A and animal troughs in Caversfield. A private road crosses the northern part of the Caversfield land parcel.
Vegetation	There is a dense wooded area comprising mature trees and hedges in the south-west of Site A and south east of Site B and there are mature and semi mature hedgerows and trees on the majority of field boundaries and associated with a private road crossing the north of the Caversfield land parcel.
General site sensitivity	The site is within a generally rural area with adjacent land, to the north and south, currently being developed for residential use.
Site boundaries and surrounding land	Most of the site boundaries comprise field boundaries formed of trees and hedgerows. The north-west boundary of Site B is open and formed by the remainder of an agricultural field of which Site B is a part. There are residential developments to the north and south (part of the wider Bicester development). Charlotte Avenue runs north to south between Site A and Caversfield. The B4100 is immediately north of Caversfield. Home Farm is immediately east of Caversfield, with the private access road to the farm crossing south east to north-west across the northern end of this land parcel. There was historical limestone quarrying, formed of large trenches (approximately 30-50m long by 10m to 15m wide) to the west of Site B. This was confirmed from discussions with the farmer during the walkover. Two streams run partially along the sites south-west and eastern borders.

A site features plan (Hydrock Drawing 13603-HYD-XX-ZZ-DR-CE-1001) are presented in Appendix A.

Figure 2.3: General area of Site B and mature tree / hedgerow field boundary.

Figure 2.4: Edge of the dense wooded area in the south-west of Site A.

Figure 2.5: General area of Site A.

Figure 2.6: General area of Caversfield and residential properties to the south.

2.4 Site history

A study of historical Ordnance Survey maps (Appendix C) has been undertaken to identify any former land uses at the site and surrounding areas which may have geotechnical or geo-environmental implications for the proposed development. The key findings are summarised in Table 2.3.

Table 2.3: Site history review

Reference	Key features on site	Key features off-site
OS Map[1] 1881: 1:2,500	The site is formed up of five fields demarcated by vegetation and trees. There are wooded areas along the south-west boundary of site A.	A stream runs along the site's southern boundary. A road runs along the site's eastern boundary and also between Site A and Caversfield. St Lawrence's Church is approximately 50m to the east, with a large pond and surrounding trees. Home Farm is immediately south-east of the site. A small quarry is shown approximately 75m east of the site. A stream runs approximately 50m from the site's west border flowing towards the south-east.
OS Map[1] 1885: 1:10,560	No significant changes shown.	A spring is shown approximately 300m north-east of the site. Bucknell village is approximately 1km north-west of the site.
OS Map[1] 1899: 1:2,500	No significant changes shown.	A sluice is labelled along on the stream running along the southern boundary. Quarry approximately 75m east of the site is labelled 'old quarry'. Pond part of the vicarage is labelled as 'fishing pond'.
OS Map[1] 1922 1:2,500	No significant changes shown.	A filter bed is shown on the site's southern boundary. Old quarry no longer shown 75m east of the site.
OS Map[1] 1923: 1:10,560	No significant changes shown.	Two quarries shown approximately 500m south-east of the site.

[1] Ordnance Survey Historical Map Information provided by Envirocheck. [2] Google Earth© Imagery. [3] Apple Maps © Imagery.

Reference	Key features on site	Key features off-site
OS Map[1] 1952: 1:10,560	No significant changes shown.	Filter beds are shown immediately east associated with Home Farm. Airfield shown approximately 1km south-east of the site (RAF Bicester), although was known to be present prior to this.
OS Map[1] 1970 1:10,000	No significant changes shown.	Caversfield village is further developed approximately 500m south-east of the site comprising residential properties and amenities.
OS Map[1] 1990 - 1991 1:2,500	No significant changes shown.	A new structure is shown on Home Farm immediately south-east of the site.
OS Map[1] 1996 1:10,000	No significant changes shown.	Large residential development approximately 600m south-east associated with the expansion of Bicester.
OS Map[1] 1996 1:10,000	Maps show a track crossing east to west across the east of the site south of the site coming from Home Farm.	No significant changes shown.
Google Earth[2] 2017	No significant changes shown.	Charlotte Avenue is shown and crosses the boundary between Site A and Caversfield. Construction of residential housing is shown on parcels of land immediately north and south of the site.
Google Earth[2] 2018	No significant changes shown.	Excavation of an attenuation pond immediately east of Charlotte Avenue and immediately west of Caversfield (the land parcel).
Apple Maps[3] 2020 1:10,000	No significant changes shown.	Maps show further development of the two fields immediately north of the site.

2.5 Geology

The general geology of the site area is shown on the 1:10,000 British Geological Survey (BGS) map extract reproduced as part of the Envirocheck report and is summarised in Table 2.4. Extracts from the map are shown in Figure 2.7 and Figure 2.8.

Table 2.4: Geology

Ref. for Figures	Location	Stratigraphic Name	Description
Superficial Deposits (Figure 2.7)			
1	Along the south-east site boundary of site C.	Alluvium	Comprising clay, silt, sand and gravel and potentially peat/organic rich.
Solid Geology (Figure 2.8)			
FMB	On site (higher areas)	Cornbrash Formation	Bioclastic limestone and interbedded calcareous mudstone. Bluish grey when fresh but upper layers weathered to olive or yellowish brown.
CB	On site (below the entire site and outcropping in lower areas)	Forest Marble Formation	Greenish and bluish grey limestone and silicate-mudstone weathering to clay, interbedded. Upper layers weathered brown.
WLM	Below the entire site at depth but not outcropping	White Limestone Formation	Pale grey to off-white or yellowish carbonate limestone.

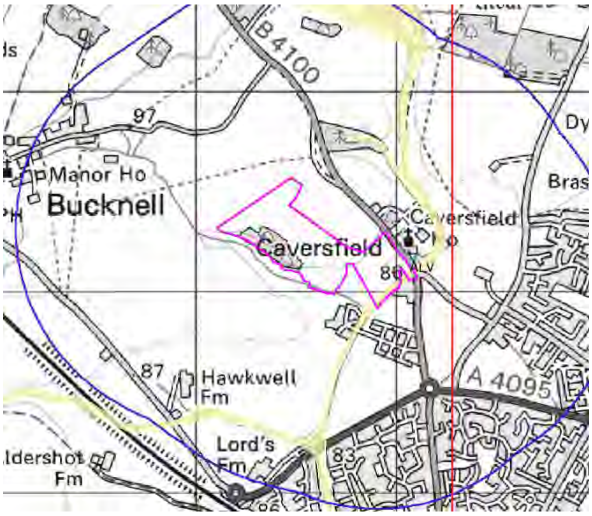


Figure 2.7: Superficial deposits.
(Reproduced with permission from Envirocheck)

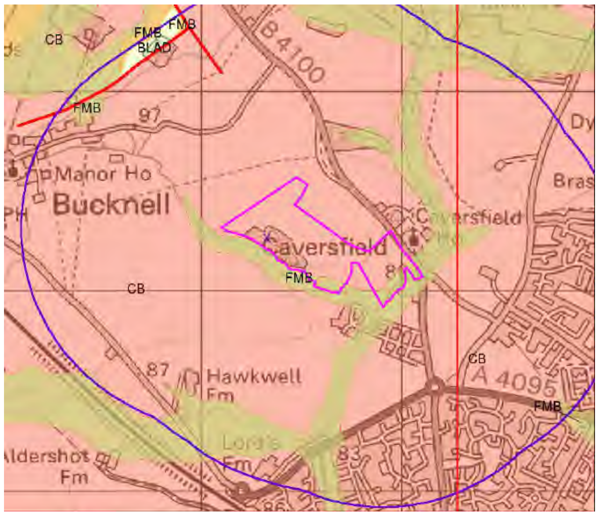


Figure 2.8: Solid geology.
(Reproduced with permission from Envirocheck)

Faulting is shown to the north of the site, tending approximately north-east to south-west and north-west to south-east. Downthrows to the south and east (throw in metres).

A number of borehole logs from the BGS archive have been reviewed. Selected records are summarised below:

- SP52SE55, located 600m to the south-west of the site at Caversfield foul water outfall sewer (NGR 458080E, 224550N), drilled to a depth of 5.50m and recorded:
  - Topsoil between ground level and 0.80m below ground level (bgl);
  - Moderately to highly weathered limestone between 0.80m and 3.05m bgl;
  - Calcareous clay interbedded with limestone between 3.05m and 5.50m bgl; and

The ground conditions proven by previous investigation of the wider NW Bicester Eco Development (Hyder Consulting (UK) Limited, 2011), comprise:

- Topsoil between ground level and 0.30m bgl;
- Superficial / Head deposits to a maximum depth of 0.80m bgl, comprising: red brown, clayey sandy gravel and cobbles, or in places gravelly sandy clay with cobbles.
- weathered limestone recovered as yellow grey sandy gravel or in places yellow grey clay to a maximum depth of 2.90m bgl (probable Cornbrash Formation).
- interbedded moderately strong to strong Limestone and stiff or hard clay and mudstone to depths greater than 7.00m bgl (probable Forest Marble Formation).

2.6 Hydrogeology

2.6.1 *Aquifer designations*

Based on the inferred geological sequence presented in Section 2.5 and the Environment Agency's interactive aquifer designation map, the aquifer system presented in Table 2.5 applies. Additional information on the hydraulic characteristics of the geological units has been abstracted from Allen et al (1997) and Jones et al (2000).

Table 2.5: Aquifer system

Stratum	Aquifer Designation	Comments
Alluvium	Secondary A Aquifer	Intergranular permeability. Varied, moderate to high permeability layers of sand and occasional gravel, interbedded with low permeability clay. Overall, this unit is likely to be relatively anisotropic in nature with horizontal permeability similar to vertical permeability (i.e. kh>kv). Groundwater flow is likely to be variable and discontinuous as water migrates around low permeability areas.
Solid Geology		
Cornbrash Formation	Secondary A Aquifer	Low permeability and low porosity clay, which is interbedded with moderate to high permeability layers of limestone. Potentially faulted and fractured, with high secondary permeability. Overall, this unit is likely to be relatively anisotropic in nature with horizontal permeability similar to vertical permeability (i.e. kh>kv).
Forest Marble Formation	Secondary A Aquifer	Dominated by low permeability and low porosity clay. Overall, this unit is likely to be anisotropic in nature due to clay bands, with horizontal permeability greater than vertical permeability (i.e. kh>kv)
White Limestone Formation	Principal Aquifer	Low intergranular permeabilities are likely, with high water secondary permeability through fractures often enlarged through solution. Overall, this unit is likely to be anisotropic in nature due to clay bands, with horizontal permeability greater than vertical permeability (i.e. kh>kv). High transmissivity and low

2.6.2 *Groundwater abstraction*

There are two active licensed groundwater abstractions within 1,000m of the site. They are listed in Table 2.6.

Table 2.6: Groundwater abstractions

Location Relative to Site	Purpose of Abstraction
674 south west	General farming and domestic
800m south east	General farming and domestic

2.6.3 *Groundwater source protection zones and groundwater vulnerability*

The site is not within a groundwater Source Protection Zone (SPZ).

The superficial and bedrock secondary A aquifers underlying the site are considered of high vulnerability, see Figure 2.9.

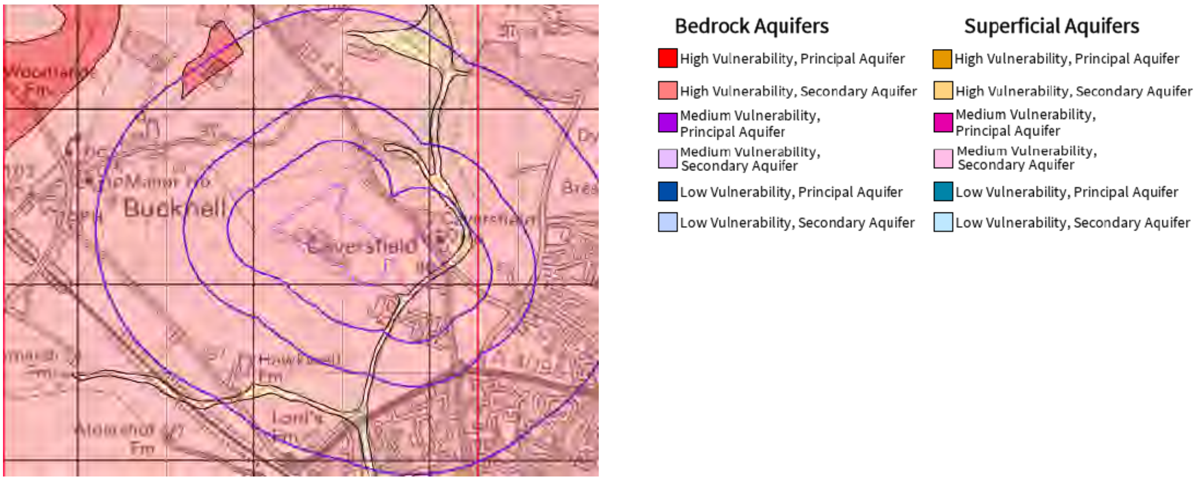


Figure 2.9: Groundwater abstraction zones
(Reproduced with permission from Groundsure)

2.6.4 Groundwater levels, recharge, and flow

Shallow groundwater is likely in the Cornbrash and Alluvial Deposits especially after heavy rainfall. There is a deeper groundwater body in the White Limestone Formation. The presence of the low permeability clays of the Forest Marble Formation is likely to inhibit vertical connection between these two potential groundwater bodies.

Where the Cornbrash Formation is at shallow depth, it is typically a seasonal aquifer, which recharges during sustained wetter periods of weather and discharges by natural drainage, or by abstraction, during drier periods.

Previous ground investigation (Hyder, 2011) recorded groundwater at between 0.6m bgl and 2.6m bgl typically in the top of limestone beds, and in six exploratory holes (off site) often after heavy rainfall. No groundwater was encountered in exploratory holes within Site A, B or Caversfield. It is anticipated that the installation of the man-made pond to the east of Charlotte Avenue (between Site A and Caversfield) in the south east corner of Site A may be locally modifying the groundwater flow regime.

Shallow groundwater below the site is likely to drain towards the adjacent streams, south of Site B and Site A and east of Caversfield.

2.6.5 Groundwater quality

The groundwater body beneath the site (Bicester-Otmoor Cornbrash) is currently (2019 Cycle 2) classified under the Water Framework Directive as ‘poor’, due to 'chemical drinking water protected area' conditions.

2.6.6 Groundwater flooding

The environmental data report indicates a potential risk of groundwater flooding to occur at the surface along the Caversfield south-east boundary and a potential risk of groundwater flooding of property situated below the ground along the Site A south-west boundary.

The areas of potential groundwater flooding correlate with the superficial Alluvium deposits and underlying Forest Marble along the streams adjacent to the site.

2.7 Hydrology

2.7.1 *Surface water system and drainage*

The surface water features in the vicinity of the site are listed in Table 2.7. Surface water on the site will runoff into the adjacent streams to the south east and south west which become the Town Brook.

Table 2.7: Surface water features

Feature	Location Relative to Site
Inland river	On site boundary (Caversfield south-east boundary).
Inland river	On site boundary (Site A and Site B south-west boundary).
Pond	10m east by Home Farm.
Town Brook	Approximately 50m south-west of the site.
Inland river	Approximately 500m north-east

2.7.2 *Surface water abstractions and discharges*

There are no recorded active licensed surface water abstractions within 500m of the site.

There is one active licensed surface water discharges within 500m of the site (as listed in Table 2.8).

Table 2.8: Surface water discharges

Location Relative to Site	Purpose of Abstraction
<10m east	Final treated effluent

2.7.3 *Surface water quality*

Reference to the Environment Agency web site shows the site is located within the catchment of the Thames River Basin District, with the specific river water body being the Town Brook - source to Langford Brook. The current (2019 cycle 2) overall status under the Water Framework Directive is 'moderate'.

The water body is currently 'moderate' status due to Polybrominated diphenyl ethers, Benzo(g-h-i)perylene levels and Mercury and Its Compounds.

2.7.4 *Surface water flooding*

The desk study information indicates that a 50m wide strip of land along the site's south-west boundary is in Flood Zone 2 (with a medium/moderate probability of flooding from rivers or the sea).

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

2.8 Mining and mineral extraction

The environmental report indicates that limestone quarrying has been undertaken in the wider area, although not within the site boundaries. A small quarry pit is recorded within 100m of the site and therefore there is a potential for unrecorded limestone extraction on site.

Limestone quarrying was recorded immediately to the west of the site (Site B) during the site walkover and was confirmed by anecdotal evidence from the farmer. Anecdotal evidence also suggests potential historic quarrying in the vicinity of the wooded area in the south-east of Site B.

2.9 Natural ground instability

The site is underlain at shallow depth by potentially soluble strata (Limestone). There is a potential risk of the formation of voids being present due to the dissolution of the limestone. There is no evidence that cavities have been, or are present, on the site. Hyder's (2011) ground investigation found no evidence of solution features. However intrusive ground investigation is required to confirm.

2.10 Waste management

There are no current or historical waste management sites recorded within 250m of the site.

2.11 Regulatory Information

Information in the Envirocheck Report (Appendix D), relating to various regulatory controls has been reviewed, with a summary presented below in Table 2.9.

Table 2.9: Regulatory information within 500m of the site

Regulatory Data	Distance from Site	Details	Potential Risk	Comment
Discharge Consents	<10m east	Environment Agency, Thames Region. Final treated effluent discharged to the Town Brook	No	Due to being down gradient of the site.
Local Authority Pollution Prevention and Controls	15m north	Teslayne Engineering PG1 Waste oil burners, less than 0.4MW net rated thermal input	No	As it is a modern permitted activity and subject to tight regulation.
	183m south east	Effective See Heat Networks Limited New Medium Combustion Plant	No	Due to distance from site and being down gradient.
Pollution Incidents	No pollution incidents are recorded within 500m of the site.			
Trade Directory Entries. (Other trade directories are recorded at greater distance down gradient of the site)	16m east	Inactive Carbon products	Yes	Due to its proximity to the site.
	567m south east	Active Cleaning services - domestic	No	Due to the small volumes of potential contaminants and its distance from the site.
	618m south east	Inactive Water coolers	No	
	644m south east	Inactive Garage equipment	No	Due to the small volumes of potential contaminants and its distance from the site. Down gradient

Regulatory Data	Distance from Site	Details	Potential Risk	Comment
Fuel Station Entries	No regulatory information recorded within 500m of the site.			
Control of major accident hazards sites (COMAH)				
Registered radioactive substances				
Notification of installations handling hazardous substances				

2.12 Local knowledge

Review of anecdotal information[2] indicates the Bicester Aerodrome, formerly RAF Bicester, had an active RAF unit until 2004, and was used during WWII.

2.13 Natural soil chemistry

Information contained within the environmental report (Appendix D) gives estimated concentrations for the natural soils at the site. These have been reproduced in Table 2.10.

Table 2.10: Natural soil chemistry

Element	Arsenic	Cadmium	Chromium	Lead	Nickel
Concentration (mg/kg)	15 - 25	<1.8	60 - 90	<100	30 - 45

2.14 Evidence of contamination

Previous ground investigation (Hyder 2011) of the wider site reported no visual olfactory evidence of contamination and chemical testing of soil samples indicated there are no chemicals of potential concern extending the relevant GAC.

Hyder 2011 ground investigation carried out between two and three rounds of monitoring of the site and wider surrounding area (two monitoring rounds of BH1, on the north east boundary of Site A), indicated:

- methane at 0%v/v;
- carbon dioxide at between 0.2 and 2.2% v/v;
- oxygen at between 12.2 and 20.5%; and
- negative flow rates of between -0.1 and -0.3 l/hr.

[2] https://en.wikipedia.org/wiki/RAF_Alconbury

2.15 Radon

The radon risk is reported in the environmental report.

The guidance indicates that the site is in a Radon Affected Area where recorded radon levels in 3 - 10% of homes are above the action level.

Basic radon protection measures are required for new buildings at this location in line with current guidance.

2.16 Unexploded ordnance (UXO)

In general accordance with CIRIA Report C681 (Stone et al 2009) a non-specialist UXO screening exercise has been undertaken for the purposes of ground investigation and is presented in Table 2.11.

Table 2.11: 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	Historic mapping shows no post war development	No
Geology type	The ground conditions comprise a thin covering of superficial deposits, over weathered limestones and clay. It is likely UXO would remain undetected. However, it is unlikely that bombs (if present) would have penetrated the ground and not exploded due to the presence of interbedded rock at shallow depth.	No
Surface cover during WWI	The surface cover during WWII comprised open fields. There is the potential that UXO, if present, would remain undetected.	Yes
Indicator of aerial delivered UXO	Screening against the regional bomb risk map (Oxfordshire) Appendix D 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 the superficial ground conditions comprising alluvium, no further assessment is required with regard to UXO in relation to ground investigation.

Furthermore, the site is recorded as being in a low-risk area, there is no indication of former military use and no post-war development, or evidence of bomb damage recorded.

2.17 Reliability of previous data

Data from the previous ground investigation reports listed in Section 1.4 have been considered during the preparation of this report, where considered to be reliable. The section below provides comment as to the applicability of the various data available.

Geological data

The geological data from the previous investigations are consistent with the anticipated ground conditions from BGS sources. However, Hydrock has not been provided with the individual exploratory hole logs from the Hyder 2011 report. Therefore, the general geology described in the text has been used for background information only.

Chemical test data

The Hyder 2011 summary soil data is MCERTS accredited. However, this data represents a wider site area with limited on-site coverage, and individual laboratory test certificates are not available. Hydrock has utilised the 2011 soils data as an indicator of expected contamination only, and additional supplementary investigation is required.

Groundwater data

With regard to the 2011 groundwater data, in addition to being subject to the limitations in the analytical methodologies of the time, there has been potential for changes to the chemicals of potential concern and their distribution and concentration (dilution, dispersion and degradation), over time within the groundwater. As such, whilst the existing groundwater data provides good background information for the wider site, Hydrock has not used the previous data in the risk assessment presented here.

Ground gas data

Gas monitoring data is limited to only one location within the site, monitored on two occasions over two months. There will be a requirement to install additional monitoring locations and undertake gas monitoring for the current site conditions to complete an up-to-date the assessment of the ground gas risks.

Geotechnical data

Whilst the available geotechnical information is relevant and remains a guide to the physical ground conditions of the wider area, no testing was carried out on samples from the site under consideration, and therefore significant supplementary investigation will be required.

3. OUTLINE CONCEPTUAL MODEL

3.1 Introduction

The outline Conceptual Model (oCM) incorporates evidence from the site walkover, the Desk Study and previous investigations carried out at the site. The formulation of an outline Conceptual Model is a key component of the LCRM methodology. The oCM incorporates a ground model of the physical site conditions and an exposure model of the possible contaminant linkages; it forms the basis for Generic Quantitative Risk Assessment (GQRA) in accordance with current guidelines.

3.2 Ground model

The preliminary ground model presented in Section 2 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

The preliminary geotechnical hazard identification has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622.

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

3.3.2 Plausible geotechnical hazards

Plausible geotechnical hazards identified at the site are:

- Localised Made Ground associated with historical farming activities or quarrying (varied strength and compressibility).
- Soft / loose compressible ground (low strength and high settlement potential) associated with Alluvium.
- Shrinkage / swelling of the clay fraction of soils under the influence of vegetation.
- Lateral and vertical changes in ground conditions.
- Attack of buried concrete by aggressive ground conditions.
- Obstructions – associated with intact limestone in the Cornbrash Formation.
- Shallow groundwater.
- Changing groundwater conditions.
- Risk from erosion or flooding.
- Slope stability issues – general slopes, notably the slope in the south-east of Caversfield.
- Earthworks – settlement (due to placement of fill on soft / loose ground).
- Earthworks – unsuitability of site won material to be reused as fill.
- Earthworks – poor bearing capacity of new fill.

3.3.3 Potential development elements affected

Development elements potentially affected by geotechnical hazards are:

- Buildings – foundations.
- Buildings – floor slabs
- Roads and pavements.
- Services.
- General slopes.
- Retaining walls.
- Gardens.
- Construction staff, vehicles and plant operators.
- Concrete below ground.
- Earthworks control, inability to place and compact fill.

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 Section 5 and the assessment is presented in Section 0.

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 pollution linkages, based on the source-pathway-receptor (SPR) approach. A viable pollution 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.

Potential on-site sources of contamination

- Made Ground, associated with farming activities, possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials, PAH and petroleum hydrocarbons (S1).
- Made Ground, associated with potential quarrying in the south east of Site B and imported fill, possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials, PAH and petroleum hydrocarbons (S2).
- Herbicides and pesticides associated with farming activities (S3).
- High levels of naturally occurring arsenic (generally considered a low risk, but requires confirmation) (S4).

- Permanent ground gases (methane and carbon dioxide) from potentially infilled ground associated with former quarry in the south east of Site B (generally considered a low risk, but requires confirmation) (S5).
- Radon (S6).

Potential off-site sources of contamination

- Potentially contaminated Made Ground associated with filter beds, shown immediately east of the Caversfield site and associated with Home Farm. (S7)
- Permanent ground gases (methane and carbon dioxide) from nearby infilled ground associated with former quarries (generally considered a low risk, but requires confirmation) (S8).

3.4.3 Potential receptors

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

- People (site users, neighbours) (R1).
- Development end use (buildings, utilities and landscaping) (R2).
- Groundwater: Secondary A aquifer status of the Cornbrash Formation & Forest Marble Formation and Principal aquifer status of the White Limestone Formation (R3) [3].
- Surface water: streams on the south west and south east site boundaries (R6) [3].

3.4.4 Potential pathways

The following potential pathways have been identified.

- Ingestion, skin contact, inhalation of dust and outdoor air by people (P1).
- Methane ingress via permeable soils and/or construction gaps (P2).
- Root uptake by plants (P3).
- Surface water via overland flow (P4).
- Surface water via drainage discharge (P5).
- Surface water via base flow from groundwater (P6).

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 considered as part of the Preliminary Risk Assessment in accordance with LCRM (2020), are considered to be plausible in the context of this site and have been carried forward for investigation and assessment. The investigation is presented in Section 5 and the assessment is presented in Section 7. An assessment of the Source – Pathway – Receptor linkages is undertaken following the assessment (Section 7) and is presented in Appendix K (Table K.1).

[3] Significant contamination has not been identified on the site during previous investigations, the site is not in a SPZ nor in close proximity to abstraction points and is underlain by bands of impermeable clay strata in the Cornbrash Formation and Forest Marble Formation. Therefore, there is a negligible risk to controlled waters unless significant contamination is found in the Hydrock ground investigation.

4. GROUND INVESTIGATIONS

4.1 Investigation rationale

The ground investigation rationale was based on the findings of the preliminary risk assessment and is summarised in Table 4.1.

Table 4.1: Investigation rationale

Location	Purpose
Site A	
September 2020 investigation	
RBH05-10	To assess deeper ground conditions and to allow SPTs to be undertaken. To investigate the thickness and competency of limestone beds. To allow collection of samples for geotechnical characterisation. To allow installation of gas and groundwater monitoring wells. Targeted across the perimeter of the site in proximity to areas influenced by trees.
TP18, 19, 25, 27, 28, 30-39, 41, 42, 45, 46, 48-50, 56 and 57.	To provide general coverage across the proposed development area. To assess shallow ground conditions. To allow collection of samples for contamination testing and geotechnical characterisation. To undertake hand shear vane testing.
TP24, TP43, TP44, TP51, TP53 and TP54	To investigate the Public Open Space (POS) areas. To assess shallow ground conditions. To allow collection of samples for contamination testing and geotechnical characterisation.
TP26, TP29, TP40, TP47, TP52, TP55 and TP58	To undertake soil infiltration testing for permeable paving.
January 2021 investigation	
RBH101-103	To assess deeper ground conditions and to allow SPTs to be undertaken in the area of the proposed attenuation pond.
TP108 and TP109	To undertake deeper soil infiltration testing, targeting the proposed attenuation pond.
TP102-107	To undertake soil infiltration testing, targeting areas of lower permeability to gain more information on the ground conditions and assist with the design of permeable paving.
Site B	
September 2020 investigation	
RBH01-04	To assess deeper ground conditions and to allow SPTs to be undertaken. To investigate the thickness and competency of limestone beds. To allow collection of samples for geotechnical characterisation. To allow installation of gas and groundwater monitoring wells. Targeted across the perimeter of the site in proximity to areas influenced by trees.
TP01-06, 08, 11-14, 16, 17, 20, 22 and 23.	To provide general coverage across the proposed development area. To assess shallow ground conditions. To allow collection of samples for contamination testing and geotechnical characterisation. To undertake hand shear vane testing.

Location	Purpose
TP07, TP09, TP10, TP15, TP21	To undertake soil infiltration testing for permeable paving.
TP90-92	To further investigate the south-east corner (where accessible) in the area of potential historic quarrying (based on anecdotal evidence).
January 2021 investigation	
TP101	To undertake soil infiltration testing, targeting areas of lower permeability to gain more information on the ground conditions and assist with the design of permeable paving.
Caversfield	
September 2020 investigation	
RBH11-15	To assess deeper ground conditions and to allow SPTs to be undertaken. To investigate the thickness and competency of limestone beds. To allow collection of samples for geotechnical characterisation. To allow installation of gas and groundwater monitoring wells. Targeted across the perimeter of the site in proximity to areas influenced by trees.
TP59, 61, 67, 69, 70-73, 75, 77-79	To provide general coverage across the proposed development area. To assess shallow ground conditions. To allow collection of samples for contamination testing and geotechnical characterisation. To undertake hand shear vane testing.
TP62-65, 74, 80, 81, 83, 84, 86-89	To target the proposed allotment and areas of POS. To assess shallow ground conditions. To allow collection of samples for contamination testing and geotechnical characterisation.
TP82 and TP85	To undertake soil infiltration testing for the proposed attenuation pond in the south east.
TP60, TP66, TP68 and TP76	To undertake soil infiltration testing for permeable paving.
January 2021 investigation	
TP110-112	To undertake soil infiltration testing, targeting areas of lower permeability to gain more information on the ground conditions and assist with the design of permeable paving.

4.2 Constraints

The south-eastern corner of Site B and the central-south of Site A are densely wooded and were not accessible during the investigation.

4.3 Site works

The fieldwork took place between 2nd and 21st September 2020, with supplementary fieldwork taking place between 5th and 7th January 2021, and is summarised in Table 4.2. 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 13603-HYD-XX-ZZ-DR-GE-1003) in Appendix A.

The logs, including details of ground conditions, soil sampling, *in situ* testing and any installations, are also presented in Appendix E.

The weather conditions during the Hydrock fieldwork and for the previous week were sunny.

Table 4.2: Summary of site works

Activity	Method	No.	Depth Maximum (m bgl)	*In situ* tests	Notes (e.g. installations)
Drilling, Pitting and Probing					
Boreholes	Rotary cored	18	5.00	SPT	63mm HDPE wells with gas taps in 15 holes
Trial pits	Machine (8T tracked)	104	3.20	Hand shear vane (HSV)	-
Other in situ *testing or monitoring*					
Infiltration	BRE 365	30	3.00	Soil infiltration	-

Wells for monitoring groundwater levels and ground gas concentrations were installed in all but two of the rotary boreholes. 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	Screen top and base depth (m bgl)	Screen top and base elevation (m OD)	Strata targeted
RBH01	91.44	50	2.00 to 5.00	89.44 to 86.44	Cornbrash Formation / Forest Marble Formation
RBH02	91.60	50	2.00 to 5.00	89.60 to 86.60	Forest Marble Formation
RBH03	92.16	50	1.00 to 5.00	91.16 to 87.16	Head Deposits / Cornbrash Formation / Forest Marble Formation
RBH04	92.18	50	0.50 to 5.00	91.68 to 87.18	Cornbrash Formation / Forest Marble Formation
RBH05	91.67	50	1.00 to 3.00	90.67 to 88.67	Head Deposits / Cornbrash Formation
RBH06	91.72	50	1.00 to 4.00	90.72 to 87.72	Head Deposits / Cornbrash Formation / Forest Marble Formation
RBH07	91.44	50	1.00 to 4.50	90.44 to 86.94	Cornbrash Formation / Forest Marble Formation
RBH08	90.33	50	1.00 to 5.00	89.33 to 85.33	Head Deposits / Cornbrash Formation / Forest Marble Formation
RBH09	88.47	50	1.00 to 5.00	87.47 to 83.47	Head Deposits / Forest Marble Formation
RBH10	90.67	50	0.50 to 3.50	90.17 to 87.17	Cornbrash Formation
RBH11	90.14	50	1.00 to 5.00	89.14 to 85.14	Cornbrash Formation / Forest Marble Formation
RBH12	90.12	50	2.00 to 5.00	88.12 to 85.12	
RBH13	88.56	50	1.00 to 5.00	87.56 to 83.56	
RBH14	87.41	50	1.00 to 5.00	86.41 to 82.41	Forest Marble Formation
RBH15	85.60	50	2.00 to 5.00	83.60 to 80.60	
RBH102	86.06	50	0.80 to 5.00	85.26 to 81.06	Head Deposits / Forest Marble Formation

4.4 Geo-environmental testing

4.4.1 *Sampling strategy and protocols*

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

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.

4.4.2 *Geo-environmental monitoring*

Gas monitoring boreholes have been monitored on four occasions. The results are presented in Appendix G.

Monitoring is ongoing and this report will be updated on completion of the monitoring.

4.4.3 *Geo-environmental laboratory analyses*

The chemical test certificates for testing undertaken by Hydrock are provided in Appendix H. Wherever possible, UKAS and MCERTS accredited procedures have been used.

The chemical test certificates for testing undertaken as part of historical investigations are provided in the relevant reports in Appendix D.

The geo-environmental analyses undertaken on soils are summarised in Table 4.4.

Table 4.4: Geo-environmental analyses of soils

Determinand Suite	Topsoil	Made Ground	Alluvium	Head Deposits	Cornbrash Formation
Hydrock minimum suite of determinands for solids*	34	4	1	9	4
Pesticide screen	8	-	-	-	-
WAC Full Solid Suite	3	1	-	3	-
BS 3882 Topsoil Suite	3	-	-	-	-
*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), sulfide, pH, asbestos fibres, speciated polynuclear aromatic hydrocarbons (PAH, by GC-FID), total phenols and fraction of organic carbon					

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

4.5 Geotechnical testing

4.5.1 Geotechnical laboratory testing

The geotechnical tests undertaken by Hydrock are summarised in Table 4.5 and the test certificates are provided in Appendix F. Wherever possible, UKAS accredited procedures have been used.

The geotechnical tests undertaken as part of historical investigations are provided in the relevant reports in Appendix D.

Table 4.5: Summary of sample numbers for geotechnical tests

Test	Made Ground	Alluvium	Head Deposits	Cornbrash Formation	Forest Marble Formation
Natural moisture content	1	1	11	30	20
Atterberg limits	1	1	3	24	12
Sulfate and aggressive chemical environment classification for buried concrete classification (full BRE SD1 suite)	-	1	9	17	6
Particle Density	-	-	-	2	1
Optimum Moisture Content / Maximum Dry Density Relationship	-	-	-	2	1
Hand Shear Vane at each compaction point	-	-	-	2	1
Remoulded California Bearing Ratio at Optimum Moisture Content	-	-	-	2	1
Organic Matter	-	-	-	2	1
Uniaxial Compressive Strength (UCS)	-	-	-	-	6
Point Load Strength	-	-	-	-	52
Los Angeles Coefficient	-	-	-	1	-
BRE SD1 suite	-	-	-	2	1

The geotechnical test data are summarised in Section 0 and interpreted in Section 06.

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 Hydrock ground investigation works are provided in the logs in Appendix E, previous data are provided in Appendix D; a summary of the ground model is presented in Table 5.1 and the individual strata are described in the sections below. Relevant cross-sections and contour plans are presented in Appendix A with extracts shown in Figures 5.1 and 5.2 in the sections below.

Table 5.1: Strata encountered

Stratum	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m) (range)	Thickness (m) (average)
Topsoil	0.00	0.20 – 0.60	0.20 – 0.60	0.32
Made Ground	0.00 – 0.30	0.25 – 1.60	0.25 – 1.30	0.56
Alluvium*	0.30	0.80	0.50	0.50
Head Deposits	0.25 – 0.80	0.50 – 2.40	0.20 – >1.75	0.77
Cornbrash Formation	0.20 – 2.00	1.00 – 3.73	>0.02 – 2.60	1.28
Forest Marble Formation	0.60 – 3.73	>1.35 - >5.00	Not proven	Not proven
*TP11 only.				

5.1.2 Topsoil

Topsoil was encountered across most of the site, from surface, to depths of 0.60m below ground level (bgl), with an average thickness of 0.32m. The Topsoil generally comprised brown, locally orangish brown, organic, variously sandy, gravelly clay, with frequent rootlets. The gravel component typically comprised 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.

Three composite samples of the topsoil were tested for compliance with BS 3882:2015. Two were found to be non-compliant when compared to multi-purpose topsoil on the basis of the grading (clay content) and all were found to be non-compliant on available plant nutrients (carbon-nitrogen ratio, nitrogen and extractable phosphate). However, this does not preclude the use of the topsoil as a growing medium as long as it is recognised that the topsoil is clayey, will require careful excavation, suitable stockpiling and limited compaction to remain suitable for reuse, as well as regular application of general-purpose fertiliser. Subject to noting the above comments, and subject to approval by the Client, the landscape architect or the landscape Contractors, the topsoil is considered suitable for use.

5.1.3 Made Ground

Made Ground was encountered in TP54, TP56 and TP109in the south-east of Site A and in TP81 and TP88 in the east of Caversfield and was encountered from the surface to 0.30mbgl to depths of between 0.25m to 1.60mbgl and has an average thickness of 0.56m. The Made Ground was recorded as:

- 'General' Made Ground comprising soft brown locally blackish brown variably sandy gravelly clay with fragments of brick, concrete, ceramic and plastic. The natural gravel component comprised limestone; and
- 'Reworked' Made Ground, in TP81, comprising soft brown slightly gravelly sandy clay and soft blackish brown slightly gravelly sandy clay. The natural gravel component comprised limestone. This is re-worked natural deposits without any anthropogenic fragments.

5.1.4 Alluvium

Alluvium was recorded in TP11 in the south of Site B and north of the adjacent watercourse and was encountered from 0.30mbgl to a depth of 0.80mbgl and was 0.50m thick. The Alluvium was recorded as soft orangish brown slightly gravelly slightly sandy clay. The Gravel component comprises quartz and limestone.

5.1.5 Head Deposits

Head Deposits were recorded across most of the site and are typically thicker at the base of, or on, sloped areas. The depth (m bgl) to the base of the Head Deposits is shown on Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1006 in Appendix A.

The Head Deposits generally comprised soft (locally firm) orangish brown, variously sandy, gravelly clay, locally with a medium cobble and boulder content; orangish brown, reddish brown and cream variously sandy clayey gravel, locally with a medium to high cobble and boulder content; and reddish brown variously gravelly, clayey sand. The gravel, cobble and boulder component comprised limestone.

The Head Deposits consist of poorly sorted and poorly stratified sediments and are likely to have formed as a result of the slow progressive downslope movement of soils (by solifluction and gelifluction), soil creep and hill wash from post-glacial times under freeze/thaw conditions through to more recent soil movements.

5.1.6 Cornbrash Formation

Beneath the superficial deposits, the Cornbrash Formation was recorded across the majority of the central and western sections of the site, but not at the lower topographic levels in the central south and the far east. The level (m OD) to the base of the Cornbrash Formation is shown on Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1007 in Appendix A.

The Cornbrash Formation was typically recorded as alternating bands of clay (weathered beds) and intact rock deposits, of varied spacing and thickness.

The clay bands comprised: firm to stiff orangish brown, light brown, yellowish brown and grey variously sandy, gravelly clay, locally with shell fragments and calcareous nodules. The gravel component comprised limestone and mudstone.

The limestone bands comprised: very weak to moderately weak locally fractured orangish brown, light grey and yellowish-brown limestone, locally with shells fragments.

5.1.7 Forest Marble Formation

The Forest Marble Formation was encountered beneath the Cornbrash Formation across the majority of the site, and locally sub-cropping below the superficial deposits, in the central south-east and east. The sub-crop of the Forest Marble Formation is shown on Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1005 in Appendix A.

The Forest Marble Formation was typically recorded as alternating bands of clay (weathered beds) and intact rock deposits and the base of the Forest Marble Formation was not proven.

The clay bands comprised: firm to very stiff bluish grey, greenish grey, light yellowish grey and orangish brown variously sandy, gravelly, silty clay. The gravel component comprised limestone and mudstone.

The limestone bands typically comprised: very weak to moderately weak light grey, dark grey, light yellowish brown and locally stained orangish brown, limestone, locally with fossil and shell fragments; and extremely weak light grey and dark grey mudstone.

5.1.8 Ground Model Summary

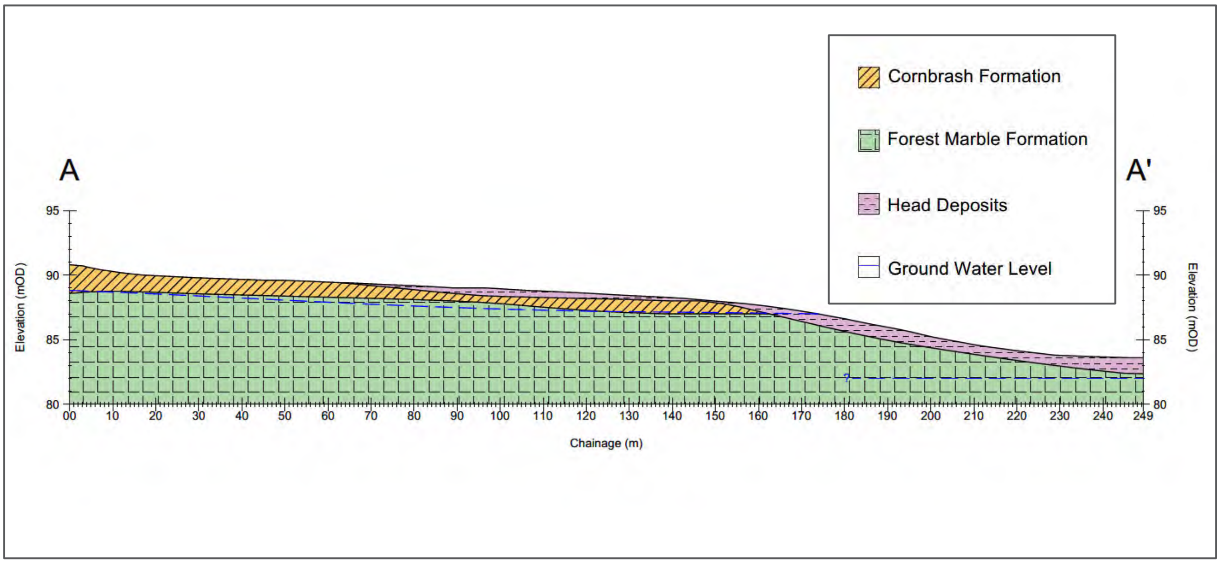
A summary of the ground model described above is shown on the extract of the 'Geology Map – Solid and Drift' (Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1005) shown in Figure 5.1 and an extract of the geological cross section for the site (Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1008) shown in Figure 5.2 below.

Figure 5.1: Extract of 'Geology Map - Solid and Drift'

As shown on Figure 5.1 there is a covering of Head Deposits across most of the site with sub-crops of the Cornbrash Formation in the west, centre and central east of the site, with the Forest Marble Formation underlying these deposits. The sub-crops of the Forest Marble Formation are limited to the far east and central south, probably associated with the close proximity of the streams in these areas, where the overlying Cornbrash Formation has been eroded away.

Figure 5.2 shows a cross section trending North-west to South east across Caversfield with the Cornbrash Formation outcropping in the north-west, Head deposits are shown on the slope, with the Forest Marble Formation sub-cropping in the south-east. The topography of the site slopes down to the stream of the south-eastern boundary. North-west of the slope, the Forest Marble Formation was encountered at approximately 87 to 88m OD.

Figure 5.2: Cross section across Caversfield trending North-west to south east.



5.2 Groundwater

5.2.1 Groundwater observations and levels

Groundwater strikes were observed in thirty-four of the exploratory holes as listed in Table 5.2. A groundwater observation represents the depth at which groundwater was first observed and is likely to be deeper than the actual water table level at that location.

Table 5.2: Groundwater occurrence

Stratum	Date	Exploratory hole	Groundwater strike (m bgl)	Approximate flow rate
Head Deposits	04/09/20	TP10	1.00	Slow
	04/09/20	TP21	1.30	Slow
	07/01/21	TP101	0.55	Moderate
Cornbrash Formation	07/09/20	RBH01	2.00	Slow
	08/09/20	RBH03	1.30	Slow
	09/09/20	RBH04	1.10	Slow

Stratum	Date	Exploratory hole	Groundwater strike (m bgl)	Approximate flow rate
Cornbrash Formation	07/09/20	TP01	1.10	Slow
	07/09/20	TP02	1.10	Slow
	08/09/20	TP03	0.80	Moderate
	08/09/20	TP04	1.00	Fast
	08/09/20	TP05	1.10	Fast
	07/09/20	TP06	1.10	Moderate
	04/09/20	TP07	1.30	Slow
	08/09/20	TP08	1.10	Fast
	04/09/20	TP09	1.30	Slow
	08/09/20	TP12	1.10	Slow
	08/09/20	TP13	0.80	Fast
	08/09/20	TP14	1.40	Moderate
	04/09/20	TP15	1.20	Slow
	07/09/20	TP16	1.10	Moderate
	07/09/20	TP17	1.30	Moderate
	10/09/20	TP18	1.40	Slow
	08/09/20	TP20	2.40	Moderate
	10/09/20	TP25	2.10	Slow
	10/09/20	TP33	2.50	Slow
	11/09/20	TP34	2.70	Slow
	07/01/21	TP110	0.50	Slow
Forest Marble Formation	07/09/20	TP11	3.20	Slow
	07/09/20	TP22	2.30	Slow
	07/09/20	TP23	2.30	Slow
	10/09/20	TP31	2.60	Slow
	15/09/20	TP43	1.75	Slow
	18/09/20	TP81	2.00	Moderate
	16/09/20	TP86	1.95	Moderate
	08/09/20	TP90	1.80	Moderate
	08/09/20	TP91	2.60	Moderate
	05/01/21	TP108	2.00	Slow
	05/01/21	TP109	1.80	Slow

Groundwater levels recorded during post-fieldwork monitoring are summarised in Table 5.3. Eight visits (of twelve) have been carried out to date.

Table 5.3: Post-fieldwork groundwater level data summary

Location	Date range	Stratum	Depth to groundwater (range) (m bgl)	Groundwater elevation (range) (m OD)
RBH01	29/09/20 – 28/01/21	Cornbrash Formation / Forest Marble Formation	0.60 – 1.90	90.84 – 89.54
RBH02		Forest Marble Formation	0.76 – 2.22	90.84 – 89.38
RBH03		Head Deposits / Cornbrash Formation / Forest Marble Formation	GL – 1.10	92.16 – 91.06
RBH04		Cornbrash Formation / Forest Marble Formation	0.41 – 1.90	91.77 – 90.28
RBH05		Head Deposits / Cornbrash Formation	0.48 – 2.75	91.19 – 88.92
RBH06		Head Deposits / Cornbrash Formation / Forest Marble Formation	0.45 – 1.85	91.27 – 89.87
RBH07		Cornbrash Formation / Forest Marble Formation	0.51 – 2.60	90.93 – 88.84
RBH08		Head Deposits / Cornbrash Formation / Forest Marble Formation	1.84 – 2.73	88.49 – 87.60
RBH09		Head Deposits / Forest Marble Formation	2.64 – >5.00 (Dry)	85.83 – >83.47 (Dry)
RBH10		Cornbrash Formation	0.54 – 1.75	90.13 – 88.92
RBH11		Cornbrash Formation / Forest Marble Formation	0.61 – 2.70	89.53 – 87.44
RBH12			0.66 – 2.35	89.46 – 87.77
RBH13			0.10 – 2.70	88.46 - 85.86
RBH14	29/09/20 – 28/01/21	Forest Marble Formation	4.20 – >5.00 (Dry)	83.21 – >82.41 (Dry)
RBH15			2.46 – 4.05	83.14 – 81.55
RBH102	08/01/21 – 28/01/21	Head Deposits / Forest Marble Formation	0.53 – 1.16	85.54 – 84.91

5.2.2 *Infiltration tests*

The results of the infiltration testing undertaken are summarised in Table 5.4. The results sheets are presented in Appendix E. 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	Range
Head Deposits	TP10	1.00	2.37×10^{-6}	1.99×10^{-6}	1.96×10^{-6}	No infiltration in a number of locations. Where infiltration achieved 2.02×10^{-4} to 1.72×10^{-6}
	TP21	1.30	3.69×10^{-6}	3.16×10^{-6}	2.35×10^{-6}	
	TP26	1.20	No infiltration			
	TP29	1.10	No infiltration			
	TP40	1.40	No infiltration			
	TP47	1.00	6.26×10^{-6}	2.57×10^{-6}	2.62×10^{-6}	
	TP55	2.00	1.73×10^{-4}	1.73×10^{-4}	2.02×10^{-4}	
	TP58	1.10	2.42×10^{-6}	2.78×10^{-6}	1.72×10^{-6}	

Stratum	Location	Depth to base of pit (m bgl)	Infiltration rate (m/s)			
			Run 1	Run 2	Run 3	Range
	TP101	0.55	No infiltration, shallow groundwater encountered at 0.50m rising to 0.20m before test.			
	TP106	0.80	1.70×10^{-5}	1.58×10^{-5}	1.26×10^{-5}	
	TP111	0.70	No infiltration			
Cornbrash Formation	TP07	1.60	4.05×10^{-5}	3.15×10^{-5}	2.44×10^{-5}	Where infiltration achieved 5.26×10^{-5} to 2.02×10^{-6}
	TP09	1.60	6.69×10^{-6}	7.61×10^{-6}	5.51×10^{-6}	
	TP15	1.50	No infiltration			
	TP66	1.30	2.55×10^{-6}	2.34×10^{-6}	2.02×10^{-6}	
	TP102	0.60	5.26×10^{-5}	3.96×10^{-5}	2.91×10^{-5}	
	TP103	0.80	No infiltration			
	TP104	0.50	1.52×10^{-5}	2.82×10^{-5}	1.83×10^{-5}	
	TP105	0.60	No infiltration			
	TP107	0.90	3.58×10^{-6}	3.17×10^{-6}	2.63×10^{-6}	
	TP110	0.60	No infiltration, shallow groundwater encountered at 0.50m rising to 0.20m before test.			
	TP112	0.80	4.34×10^{-5}	$2.70\ 10^{-5}$	1.94×10^{-5}	
Head Deposits / Forest Marble Formation	TP52	1.40	1.50×10^{-5}	1.17×10^{-5}	1.02×10^{-5}	1.50×10^{-5} to 2.15×10^{-6}
	TP108	2.30	7.06×10^{-6}	1.22×10^{-5}	2.15×10^{-6}	
Cornbrash Formation / Forest Marble Formation	TP60	1.35	No infiltration			Where infiltration achieved 9.47×10^{-7} to 3.68×10^{-7}
	TP68	1.70	No infiltration			
	TP76	1.70	9.47×10^{-7}	4.22×10^{-7}	3.68×10^{-7}	
Forest Marble Formation	TP82	2.20	4.18×10^{-5}	3.59×10^{-5}	2.36×10^{-5}	1.23×10^{-4} to 4.35×10^{-6}
	TP85	2.20	2.25×10^{-4}	1.17×10^{-4}	1.23×10^{-4}	
	TP109	3.00	6.52×10^{-6}	7.07×10^{-6}	4.35×10^{-6}	

5.2.3 Recommendations for Wallingford Procedure Modelling Software

Hydrock understands that in order to design the SuDS based drainage solution for the site, characteristic design parameters are required for use in the drainage modelling software (Micro-drainage). Hydrock have been provided with characteristic descriptions and parameters (by Vectos, the Client's drainage engineer) for comment on which soil type is considered applicable to the site. These are shown in Figure 5.3 below.

Figure 5.3: Characteristic soil descriptions and parameters (provided by Vectos).

Simulation : Network - Network Details

Each individual pipe can have a different soil index associated with it. By default the global soil index will be used. For details of how this is used by Simulation to determine please see Area, PIMP, Total Area.

Typical values are listed below:-

Soil Index	General Description	Soil Type
0.150	i) Well drained permeable sandy or loamy soils and shallower analogues over highly permeable limestone, chalk, sandstone or related drifts. ii) Earthy peat soil drained by dikes and pumps. iii) Less permeable soils in valleys.	1
0.300	i) Very permeable soils with shallow ground-water. ii) Permeable soils over rock or frangipani, commonly on slopes in western Britain associated with smaller areas of less permeable wet soils. iii) Moderately permeable soils, some with slowly permeable subsoils.	2
0.400	i) Relatively impermeable soils in boulder and sedimentary clays and in alluvium, especially in eastern England. ii) Permeable soils with shallow ground-water in low lying areas. iii) Mixed areas of permeable and impermeable soils in approximately equal proportions.	3
0.450	i) Clayey, or loamy over clayey soils with an impermeable layer at shallow depth.	4
0.500	Soils of the wet upland i) With peaty or humose surface horizons and impermeable layers at shallow depth. ii) Deep raw peat associated with gentle upland slopes or basin sites. iii) Bare rock cliffs and screes. iv) Shallow, permeable rocky soil on steep slopes.	5

Based on the advice of Vectos, Hydrock considers Soil Type 2 (with an associated soil index of 0.3) to be the most applicable to the site for SUDS applications, as:

- The geology proven by investigation comprises: superficial geology, which includes both lower permeability clays and higher permeability granular deposits, overlying Cornbrash Formation and Forest marble Formation, which comprise bands of higher permeability fractured rock deposits alternating with clay bands.
- The soils at the site have recorded varied permeability (see Table 5.4). However, in general, there are moderate infiltration rates.

5.2.4 Groundwater summary

In general, shallow groundwater was encountered towards the base of the Cornbrash Formation, above the Forest Marble Formation. However, there are local variations in the Cornbrash Formation probably associated with varied permeability in these deposits due the alternating beds of clay and limestone recorded.

There is also a deeper groundwater body in the Forest Marble Formation, notably identified in the south-east of the site (in Caversfield), where this stratum sub-crops.

The groundwater generally flows towards the south/south-east towards the streams on the southern and south-east site boundaries, and appears to be topographically controlled.

Overall, varied permeability, with highly variable infiltration rates, have been recorded.

5.3 Ground gases (carbon dioxide and methane)

Records from the gas monitoring boreholes are presented in Appendix G and summarised in Table 5.5.

To date nine monitoring visits have been undertaken, with a further three visits to be undertaken as part of the current commission. The data are assessed in Section 7.5.

Table 5.5: Range of ground gas data

Stratum	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Steady flow rate (l/hr)	Comment
Head Deposits / Cornbrash Formation	0.0 – 0.3	0.3 – 2.5	16.9 – 21.3	0.0 – 1.3	Carbon dioxide below 5%.
Head Deposits / Forest Marble Formation	0.0 – 0.3	0.1 – 1.8	18.5 – 21.7	0.0 – 0.5	
Head Deposits / Cornbrash Formation / Forest Marble Formation	0.0 – 0.3	0.1 – 3.5	13.8 – 21.7	0.0 – 20.1	
Cornbrash Formation	0.0 – 0.3	0.2 – 1.5	16.6 – 20.8	0.0 – 4.1	
Forest Marble Formation	0.0 – 0.3	0.3 – 4.1	6.2 – 20.2	0.0 – 19.4	
Cornbrash Formation / Forest Marble Formation	0.0 – 0.4	0.1 – 4.9	4.2 – 21.5	0.0 – 6.7	

5.4 Geotechnical data

5.4.1 Introduction

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

5.4.2 Plasticity

The volume change potential 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 able 5.6.

Table 5.6: Volume change potential

Stratum	No. of tests	Plasticity Index			Modified Plasticity Index			Plasticity designation	Volume Change Potential
		Min.	Max.	Av.	Min.	Max.	Av.		
Made Ground	1	33			31			High	Medium
Alluvium	1	22			20			Intermediate	Medium
Head Deposits	3	33	37	35	25	36	30	High	Medium
Cornbrash Formation	22	18	40	28	11	37	25	Intermediate to high	Medium
Forest Marble Formation	12	19	41	32	5	41	29	Intermediate to very high	Medium

5.4.3 *Particle size distribution*

Particle Size Distribution test (PSD) results are summarised in Table 5.7 and summary descriptions and PSD plots of the material analysed are presented in Appendix F.

Table 5.7: PSD results summary

Stratum	No. of tests	Silt/Clay %	Sand %	Gravel %	Cobbles %	General description
Cornbrash Formation	4	1 - 98	2 - 12	4 - 46	0 - 67	Slightly clayey slightly silty sandy very gravelly cobbles to slightly sandy slightly gravelly clay.
Forest Marble Formation	2	17 - 91	7 - 14	2 - 39	0 - 30	Slightly clayey silty sandy very cobbly gravel to slightly sandy slightly gravelly clay.

5.4.4 *Soil strength*

Table 5.8 summarises information pertaining to the shear strength of the soils according to geological stratum.

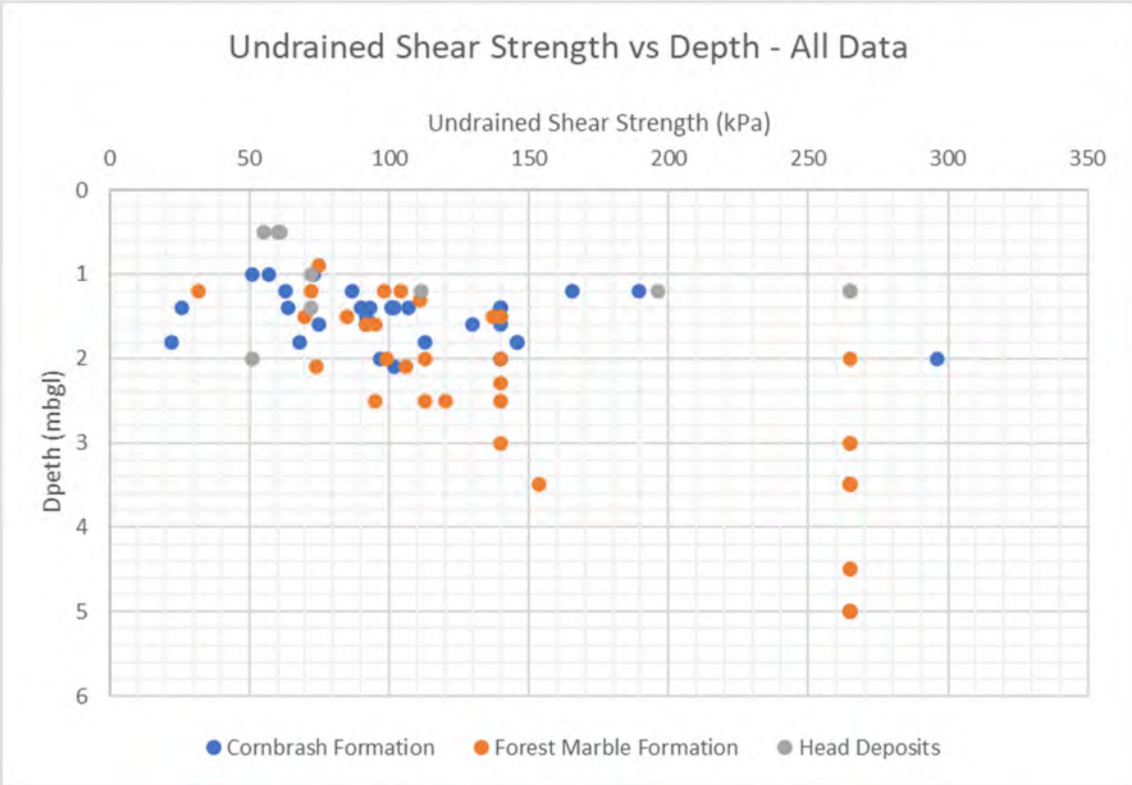
Factual results are summarised for laboratory tests, field tests (e.g. hand shear vane) and uncorrected Standard Penetration Tests (SPT). Where the SPT is used to infer shear strength by published correlation, this is also tabulated.

A shear strength versus depth profile is summarised in Table 5.8, and plots are presented in Appendix F.

Table 5.8: Soil strength results and derived values

Stratum	No. of tests	SPT (N-value) (range)	c_u (kPa)	Method
Head Deposits	4	21 - >50	111 - 265*	SPT – rotary boreholes.
	6	-	51 - 72	Hand shear vane
Cornbrash Formation	3	28 - >50	166 – 296*	SPT – rotary boreholes.
	19	-	51 - >140**	Hand shear vane
	10	-	22 - 146	Laboratory shear vane
Forest Marble Formation	23	6 - >50	32 - >265*	SPT – rotary boreholes.
	22	-	70 - >140**	Hand shear vane
*Correlation with Stroud (1975) based on 'average' plasticity and using N_{60} based on Stroud (1989) updated correlation. **140kPa is the upper recordable limit of the hand shear vane.				

Figure 5.4: Undrained shear strength vs depth plot - all data



As shown by Figure 5.4, the undrained shear strength of the Head Deposits is varied, with values recorded between 51 and 265kPa. The small clay fraction within the more granular / rock stratum of the Cornbrash Formation is also highly varied with undrained shear strength values recorded between 22 and 296kPa (between approximately 1 to 2m bgl), which is likely to be a result of the interbedded nature of this stratum with varied bands of clays and limestone (with various degrees of weathering and water softening) encountered leading to higher and lower strength bands in the Cornbrash Formation.

Undrained shear strengths of approximately 32 to 100kPa are recorded in the Forest Marble Formation at approximatley 1.00m bgl, increasing with depth to approximately 120 to 150kPa at appoximately 2.50m to 3.00m bgl, and upto 265kPa at 5.00m bgl.

It should be noted that below 3.00m bgl, primarily intact rock deposits were encountered.

5.4.5 *Relative density*

Table 5.9 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 or dynamic probe correlation).

Table 5.9: Relative density results and derived values

Stratum	No. of tests	Method	SPT (N-value) (Range)	phi' (°)
Head Deposits	2	SPT – rotary borehole (correlation after Hatanaka and Uchida 1996).	28 - 33	39 - 41

5.4.6 *Compressibility*

Table 5.10 presents a summary of the derived parameters for coefficient of consolidation and compressibility. The data indicates that the material is generally of low compressibility.

Table 5.10: Summary of compressibility

Stratum	No. of tests / results	Method	Coefficient of volume compressibility (m_v) (m^2/MN)
Head Deposits	4	Correlation with SPT*	0.09 – 0.04
Cornbrash Formation	3		0.06 – 0.03
Forest Marble Formation	24		0.06 – <0.03
*f_2 values derived based on correlation with plasticity index (Tomlinson (2001), after Stroud)).			

5.4.7 *Compaction and moisture content*

Table 5.11 presents a summary of the moisture content tests and compaction studies undertaken at the site.

Table 5.11: Compaction study results

Stratum	No. tests	Method	Natural moisture content (%) (range)	Optimum moisture content (%) (range)	Particle density (Mg/m^3) (range)	Maximum dry density (Mg/m^3) (range)
Cornbrash Formation	2	2.5kg Rammer	22 - 24	22 - 24	2.70	1.59 – 1.62
	2	Vibrating Hammer	2.2 – 8.1	8	2.65	2.11 – 2.13
Forest Marble Formation	1	2.5kg Rammer	30	24	2.65	1.57
	1	Vibrating Hammer	9.6	10	2.65	2.06

5.4.8 *Subgrade stiffness*

The subgrade stiffness (CBR and Modulus of Subgrade Reaction) results are summarised in Table 5.12.

Table 5.12: CBR results and derived values

Stratum	No. tests	Method	Modulus of Subgrade Reaction k ($MN/m^2/m$) (Range)	CBR (%) (Range)
Made Ground	-	Correlation in accordance with CD 622 and TRRL 1132 based on average plasticity and thin construction	<25	<2.5
Alluvium	-		<25	<2.5
Head Deposits	-		25 – 27	2.5 - 3
Cornbrash Formation	2	CBR on laboratory remoulded sample at Optimum Moisture Content (OMC) with 2.5kg rammer	32 - 44	4 – 6.9
	2	CBR on laboratory remoulded sample at Optimum Moisture	117 - 204	37 – 97

Stratum	No. tests	Method	Modulus of Subgrade Reaction k (MN/m²/m) (Range)	CBR (%) (Range)
		Content (OMC) with vibrating hammer		
	-	Correlation in accordance with CD 622 and TRRL 1132 based on plasticity and thin construction	27 – 155	3 – 60
Forest Marble Formation	1	CBR on laboratory remoulded sample at Optimum Moisture Content (OMC) with 2.5kg rammer	33 – 38	4.1 – 5.3
	1	CBR on laboratory remoulded sample at Optimum Moisture Content (OMC) with vibrating hammer	159 – 164	63 – 66
	-	Correlation in accordance with CD 622 and TRRL 1132 based on plasticity and thin construction	27 – 155	3 – 60
Where using the CD 622 and TRRL 1132 method, 'k' has been back calculated from the Equivalent CBR.				

5.4.9 Sulfate content

In accordance with BRE (Special Digest 1), the Design Sulfate (DS) classification and the Aggressive Chemical Environment for Concrete (ACEC) classification are presented in Table 5.13. The assessment summary sheets are presented in Appendix F.

Table 5.13: Aggressive chemical environment concrete classification

Stratum	No. tests	DS	ACEC
Alluvium	1	DS-1	AC-1
Head Deposits	9	DS-1	AC-1
Cornbrash Formation	20	DS-1	AC-1
Forest Marble Formation	6	DS-1	AC-1

5.4.10 Intact material strength – rock

Table 5.14 summarises information pertaining to the strength of the intact rock material (not rock mass) according to geological stratum and, if applicable, weathering zones or other variations within particular strata.

Factual 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 F. Note also that rock mass properties, rather than intact rock material properties, may be more suitable for 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)		
Forest Marble Formation	26	0.04 – 3.8	0.1 – 4.2	-	Axial point load
	26	0.1 – 2.7	0.1 – 3.5	-	Diametral point load
	6	-	-	11.6 – 52.7	UCS test

5.4.11 Aggregates Testing - Los Angeles Coefficient

A single sample the Cornbrash Formation was tested for Los Angeles Coefficient. The result was a value of 21.

6. GEOTECHNICAL ASSESSMENT

6.1 Geotechnical categorization of the proposed development

Eurocode 7, Section 2 advocates the use of geotechnical categorization of the proposed structures to establish the design requirements.

The proposed development is to comprise low rise (2 to 3 storey) residential dwellings, with associated gardens, Public Open Space and infrastructure. In addition, a review of the surface water drainage strategy indicates surface water will be retained in four surface water attenuation ponds in the north and south of Site B, south-east of Site A, and east of Caversfield. it is understood earthworks are proposed at the site, although the cut and fill proposals have not been confirmed at this stage. Hydrock considers cut to fill will be required associated with the slopes on site and the attenuation ponds.

Based on the above, for the purposes of this investigation, the proposed slopes and earthworks, and, if >1.0m in height, the retaining structures, will be classed as Geotechnical Category 2. However, the houses are classed as Geotechnical Category 1 structures. For Category 2 structures, the Geotechnical Category should be reassessed at the design stage and specific geotechnical design (in addition to this investigation), will be required.

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.

Assessment has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622. The preliminary Geotechnical Risk Register following investigation is provided in Appendix J (Table J.3) and will need to be updated during future design works.

6.2 Characteristic design values

The designer should determine suitable geotechnical design values for the Category 2 structures as part of the separate geotechnical design. However, the proposed houses are considered to be Geotechnical Category 1 structures and Table 6.1 provides characteristic geotechnical values to inform the design of these structures, and to assist the designer of the Category 2 structures.

These are based on laboratory testing, *in situ* testing and 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 are required for certain purposes. The reader should refer to the original test results summarised in Section 5 and provided in Appendix E and Appendix F.

Table 6.1: Characteristic geotechnical values

Parameter / Stratum	Bulk unit weight kN/m³	Effective angle of internal friction °	Effective cohesion kN/m²	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' [d]	c_u [e]	m_v [f]	k [g]
Made Ground	19	23	0	30	0.50	20
Alluvium	19	26	0	30	0.50	20

Parameter / Stratum	Bulk unit weight kN/m³	Effective angle of internal friction °	Effective cohesion kN/m²	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' [d]	c_u [e]	m_v [f]	k [g]
Head Deposits	20	24	0	60	0.10	26
Cornbrash Formation (weathered to clay)	21	25	0	60 - 100	0.08	30
Cornbrash Formation (intact)	22	25	-	>250	-	110
Forest Marble Formation (weathered to clay)	21	24	0	80 - 120	0.08	30
Forest Marble Formation (intact)	22	24	-	>250	-	150

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. *BS 8002:1994 Code of practice for Earth retaining structures, British Standards institution.*
e. *Site measurements and laboratory data.*
f. *Laboratory data.*
g. *Based upon the equilibrium long term CBR from DMRB IAN 73/06 Rev 1 Table 5.1.*

6.3 Groundwork

6.3.1 Site preparation

The site is previously undeveloped and no buried man-made obstructions were encountered by this investigation and are unlikely to be encountered.

Topsoil should be removed from beneath all building and hardstanding areas.

6.3.2 Groundworks

Excavation of shallow soils should be readily undertaken by conventional plant and equipment. Heavy duty excavation plant/breaking equipment will likely be required to excavate the limestone of the Cornbrash Formation and the Forest Marble Formation, especially with depth.

Trial pit faces were noted to remain generally vertical without collapse, and the faces of shallow, near vertically sided excavations put down at the site are likely to remain stable for short periods of time. However, the Cornbrash Formation and the Forest Marble Formation can be fractured in the limestone beds and fissured in the clay beds and whilst instability due to fissuring or fracturing was not noted in the short trial pit excavations, fissuring or fracturing can cause instability of longer excavations. Therefore, random and sudden falls should be expected from the faces of near vertically sided excavations put down at the site.

Temporary trench support, or battering of excavation sides, is recommended for all excavations that are to be left open for any length of time and will definitely be required where man entry is required.

Particular attention should be paid to excavation at, or close to, site boundaries and adjoining existing access roads/, where collapse of excavation faces could have a disproportionate effect.

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, generally, the rate of water ingress to the proposed excavations is likely to be slow to moderate. In these circumstances, groundwater control by sump pumping is likely to be sufficient. However, in periods of high rainfall, high-capacity pumps will likely be required.

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 settlement tanks (to reduce suspended solids) before being discharged to the sewer. Discharge consents may also be required.

Attenuation ponds are to be excavated at the toe of slopes in the south of Site B, south-east of Site A and east of Caversfield. Excavation at the toe of slopes can lead to instability and any such excavation should be carefully planned, following suitable assessment of short- and long-term slope stability assessment (see section 6.4). In particular, where possible, only short sections of excavation should be undertaken at any one time and no additional loads, including temporary loads such as spoil or material storage, should be placed on the crest, unless part of the designed works.

6.3.3 *Earthworks/reuse of site-won materials*

Whilst Hydrock has not been provided with the specific requirements for earthworks (cut / fill depths and volumes), it is understood earthworks are proposed at the site. An initial assessment has been completed on the potential to reuse site-won materials as a General Fill material. This is summarised in Table 6.2.

Table 6.2: Preliminary earthworks assessment

Stratum	Proposed end use	Preliminary classification (SHW Series 600)	Comment	Suitability for improvement by the inclusion of binders
Made Ground	External Areas	Class 1 General Fill	Processing to remove oversize and deleterious material required.	May be suitable subject to further detailed design and testing.
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.	Unlikely to be suitable.

Stratum	Proposed end use	Preliminary classification (SHW Series 600)	Comment	Suitability for improvement by the inclusion of binders
Head Deposits	External Areas	Class 2A /2C General Cohesive Fill Class 1A General Granular Fill	Likely to be wet of Optimum Moisture Content (OMC), moisture conditioning (e.g. lime modification) likely to be required.	Likely to be suitable.
Cornbrash Formation	External Areas	Class 2A /2C General Cohesive Fill	Initial testing recorded soils are close to the OMC. However, it is likely these soils may also be encountered wet or dry of OMC and moisture conditioning (e.g. lime modification or wetting up) likely to be required.	Likely to be suitable.
		Class 1A General Fill		Likely to be suitable.
Forest Marble Formation	External Areas	Class 2A General Cohesive Fill		Likely to be suitable.
		Class 1A General Fill		Likely to be suitable.

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 sulfate values are recorded.

Where it is proposed to reuse site won materials as an engineered fill it will be necessary to develop an appropriate 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.

The earthworks are likely to need to be undertaken under a Materials Management Plan (see Section 8.3).

6.4 Slope stability

There are a number of slopes on site (locally steep and with a significant level difference), which are noted as remaining, on the proposed development plan.

The site walkover did not note any evidence of slope movements. However, attenuation ponds are proposed at the toe of slopes in the south of Site B, south-east of Site A and east of Caversfield which will create slopes. Residential properties are proposed at the crest of, and on, the slopes.

Slope gradients of up to 1(v):3(h) are considered at this stage to likely be stable. However, separate geotechnical design will be required to fully assess the stability of the slopes in both the short- and long-term, as well as during reprofiling. Subject to further assessment and design, slopes may require reprofiling and or retaining to ensure their stability. Care should be taken not to over-steepen the slopes during construction.

6.5 Retaining walls

As there are to be earthworks across the site, it is likely that there will also be a requirement for retaining structures to retain both cut soils and placed soils. No details of any such structures are currently available, so the following recommendations should be taken as indicative only, subject to detailed design.

Retaining walls greater than 1.0m high are considered likely to be Category 2 structures and geotechnical design will be needed. The characteristic geotechnical values provided in Table 6.1 can be used, subject to the detailed design.

A permissible bearing pressure of 100 kN/m² is recommended if the retaining walls are founded at a depth of 1.0 to 2.5m bgl in firm (or better) clay of the Head Deposits, or clay or rock of the Cornbrash Formation and Forest Marble Formation. Detailed geotechnical design will be required for retaining walls over 1.0m high along with design by a structural engineer.

It is recommended that all retaining walls are individually designed using site specific design criteria, assessed as part of the required geotechnical design. Associated as-built records will be required for verification purposes.

Allowance should be made in the design of the retaining walls for adequate drainage behind the structure, or for water seepage through the face of the wall. The overall stability of the retaining wall is not considered in this report. The stability of the retaining wall should be considered in the design process.

6.6 Foundations

This section provides recommendations for the foundations for houses, garages and related buildings as indicated on David Lock Associates 'Caversfield, Bicester. Illustrative Master Plan' (Reference: RPC001-016 Rev A, dated 27th February 2018) and 'Illustrative Master Plan, North-west, Bicester' (Reference: ZMK363/006, dated October 2019) (showing Site A and Site B).

The recommendations in this report are based on the current NHBC Standards (2020).

In accordance with EC7, BS EN 1997-1+A1 (2013) whilst the earthworks and attenuation ponds are considered to be Geotechnical Category 2 structures, the proposed buildings are considered to be Geotechnical Category 1.

Subject to detailed geotechnical design, the permissible bearing pressures for foundations in this report take into consideration the risk of shear failure of the ground (ultimate limit state). However, they do not assess acceptable limits of settlement (serviceability limit state). Serviceability limit state assessment will need to be undertaken as part of the separate geotechnical design.

6.6.1 Foundation type

On the basis of the ground conditions indicated from the current investigations, the foundation recommended are as follows:

- Strip/trench fill foundations across the majority of the site (with deepening due to trees as required to a maximum depth of 2.5m bgl); and

- Piled foundations, where foundations need to be deepened to depths in excess of 2.5m bgl due to Made Ground, low strength soils, newly placed fill or tree influence in shrinkable soils.

6.6.2 Trench fill/strip foundations

Based on current ground levels, strip or trench fill foundations are considered suitable across most the site, constructed below any Made Ground, Alluvium (south of Site B), soft layers in the underlying deposits (Head Deposits, Cornbrash Formation and Forest Marble Formation), or newly placed fill. Foundations should be constructed at least 300mm into the undisturbed natural strata, which comprise clay of the Head Deposits, or clay or rock of the Cornbrash Formation and Forest Marble Formation.

A permissible net bearing pressure of 125kN/m² is considered appropriate for foundations up to 1.0m wide. If enlarging the foundations is considered (for example because loads are such that the quoted safe net 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), the minimum founding depth for strip or trench fill foundations is 0.9m below final ground level, in areas of cut, or original ground level, in areas of fill, or where finished ground levels are the same as original. However, foundations may need to be deepened to penetrate strata unsuitable for founding, as noted above, or to below the depth of influence of trees and roots.

As shrinkable clays are interbedded with beds of limestone, locally, excavation through the limestone may be necessary to achieve the required founding depth. However, it may be more economical to undertake engineer designed deep trench fill foundations.

Where foundation depths are stepped, for instance to match changes in depths due to trees or changes in ground conditions, the steps should be designed in accordance with the requirements of the 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. In addition, deepening of foundations in accordance with NHBC Standards will be required where strip or trench fill 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 5837:2012 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 foundations are within the zone of potential desiccation from trees and are deeper than 1.5m bgl, a suitable compressible material or void former will be required on the inside faces of foundations to external walls.

Excavation of trench fill foundations in excess of 2.5m bgl is unlikely to be uneconomical and where required, piled foundations are recommended. However, if it is proposed to construct trench fill foundations deeper than 2.5m depth, they need to be designed by a Structural Engineer in accordance with the requirements of the NHBC Standards (Chapter 4.2.8) and NHBC Technical Requirement R5. Furthermore, if it is proposed to construct trench fill foundations deeper than 2.5m due to tree influence, the design should take into account soil desiccation risk based on plot specific testing.

Foundation formations should be inspected by a geotechnical engineer or other 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 the foundation deepened to a suitable bearing stratum. If this is not possible, consideration should be given to piling the foundation.

As the ground conditions at foundation level are likely to be of variable type and stiffness, it is recommended that mesh reinforcement be installed at the top and bottom of the foundation.

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 but generally low flow groundwater table. Any water that collects at the base of the foundation excavations should be removed by pumping from a sump in the base. Fast inflows were recorded locally and as such, alternative methods of groundwater control may be required, as fast groundwater ingress could result in unstable excavations.

The clays of the Head deposits, Cornbrash Formation and Forest Marble Formation are over consolidated clays, 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.

6.6.3 *Piled foundations*

Depending on column loads and layouts, piles should extend through the Made Ground, Alluvium and any newly placed fill and to a suitable depth into the underlying Head deposits, Cornbrash Formation and Forest Marble Formation.

Rotary drilled piles with the use of casing/CFA piles with rock bits should be suitable to support the foundations for the proposed structures. Driven piles are not recommended due to the presence of interbedded rock.

However, 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. 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 limestone beds, 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.
- Groundwater levels are shallow and temporary casing may be required for bored piles. If CFA piles and possibly also rotary drilled piles are used, concrete can be placed as the auger/bit 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 end-bearing resistance to carry the required loads without unacceptable settlement.
- As the piles are to be constructed through compressible soils and, locally at least, have fill placed over them, piles should also be designed to cater for the potential down-drag effects of negative skin friction on piles from the secondary consolidation/creep of the Alluvium and/or recently placed fill.
- Where bored piles extend through very soft ground, bulging of the concrete can occur, leading to lateral pressure on adjacent piles.

- 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.

6.7 Ground floor slabs

In accordance with the NHBC standards, as the site is underlain by clay soils of medium volume change potential, locally at least, Made Ground greater than 600mm thick, and following the earthworks, newly placed fill greater than 600mm thick, it is recommended that suspended floor slabs with a void be adopted. A void is also required due to the requirement for radon protection.

6.8 Roads and pavements

Based on the test results and subject to *in situ* testing during construction, it is considered likely an equilibrium CBR of 3.0% will be achievable over the majority of the site. However, in the areas of Made Ground and Alluvium (TP11, TP54, TP56, TP81 and TP88) an equilibrium CBR of <2.5% is recommended.

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 rain water 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.

Where the CBR is found to be less than 2.5%, the sub-grade may be unsuitable for both the trafficking of site plant and as support for a permanent foundation, without improvement works being undertaken. Improvement works should be carried out in accordance with DMRB IAN 73/06 Rev 1 Chapter 5. In summary, consideration may be given to the following potential remedial techniques:

- excavation and re-engineering or replacement of weaker soils;
- the inclusion of geosynthetic reinforcement within the unbound layers of the capping and sub-grade;
- where cohesive soils are present and they are deemed suitable for treatment with hydraulic binders, to employ modification and/or stabilisation techniques on the formation; and
- where granular soils are present, dewatering and re-engineering the formation.

6.9 Drainage

Indicative infiltration rates for the ground investigation are presented in Appendix F and are summarised in Table 5.4 in Section 5.2.2. These values can be used for preliminary assessment of the feasibility of soakaway drainage.

Indicative infiltration rates are highly variable and range from no infiltration to 1.23x 10-4m/s. This data indicates soakaways or infiltration as part of a Sustainable Urban Drainage System (SUDS) are potentially suitable for the site, subject to detailed drainage design by a specialist. However:

- The data suggests that infiltration is sporadic across the site, with the same geological units being highly variable in infiltration rates, and as such the effectiveness of any single infiltration feature will be highly variable.
- Whilst the infiltration tests indicate infiltration may work in principle, there is shallow groundwater at the site (up to 0.5 m bgl in places) as recorded in the monitoring standpipes. Therefore, in order to maintain the required minimum distance from groundwater when adopting a soakaway system (1.00m), it is likely that it may only be possible to adopt a very shallow permeable paving (or similar) system for soakaway surface water drainage at the site, and even then, it is probably only possible where site levels are raised.
- The designer would need to consider the effects of soakaways on water levels and the potential for increased infiltration to cause spring-lines down slope, particularly in the south and south east where the Forest Marble Formation sub-crops.

Whilst specialist assessment is required. Hydrock's recommendation is that infiltration drainage is not adopted at the site.

Given the shallow groundwater present at the site, Hydrock consider that the ponds should be lined to prevent groundwater ingress.

It should be noted that if it is proposed to line the ponds, the potential hydrostatic uplift needs to be taken into account 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.

6.10 Concrete Class

Based on guidelines provided in BRE Special Digest 1 (BRE 2005) and the information presented in Section 5.4.9 (Table 5.13) the natural soils below the site (Alluvium, Head Deposits, Cornbrash Formation and Forest Marble Formation) can be classified as Design Sulfate Class DS-1 and ACEC Class AC-1. This equates to a Design Chemical Class[4] of DC-1.

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

[4] 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 preliminary ground model developed from the desk study and field reconnaissance survey (Section 2) has been updated using the findings of the ground investigation and is presented in Section 5. This ground model is the basis for the geo-environmental assessment presented in this section.

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.

Sources

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

Receptors

As significant contamination has not been identified on the site during the Hydrock investigation, the site is not in a SPZ, nor in close proximity to any licensed abstractions, and is underlain by bands of impermeable clay strata (in the Cornbrash Formation and Forest Marble Formation) there is a negligible risk to controlled waters and the following potential receptors have therefore been removed from the exposure model.

- Groundwater: Secondary A aquifer status of the Cornbrash Formation (R3).
- Groundwater: Secondary A aquifer status of the Forest Marble Formation (R4).
- Groundwater: Principal aquifer status of the White Limestone Formation (R5).
- Surface water: streams on the south west and south east site boundaries (R6).

Pathways

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

Using the updated ground model and updated exposure model, generic risk assessment is undertaken as presented below.

7.2 Risk assessment approach

Generic risk assessments have been undertaken in accordance with the principles of LCRM (Environment Agency, 2020) using the CM that has been updated following the ground investigation.

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 unacceptable risks are indicated, actions such as more advanced stages of risk assessment or remediation would be proposed.

7.3 Human health risk assessment

This is a Tier 2 assessment using soil screening values applicable to the residential with plant uptake CLEA land use scenario.

The soil screening values used are generic assessment criteria (GAC). It should be noted that Category 4 Screening Levels (C4SL) for lead have been used as there is no recognised GAC for lead and the use of the term 'GAC' in this report includes the C4SL for lead.

Statistical testing is used where data sets are suitable. The critical issue is sample numbers. For data sets with low sample numbers and / or where sampling is targeted at specific areas, individual sample test results are compared directly with the screening values. Larger and non-targeted data sets are subject to statistical testing.

The phrase 'further assessment required' is used to denote soil concentrations that are equal to, or 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'.

The results of the assessment are presented in Appendix H.

7.3.1 Averaging areas

The 'averaging area' used in this report is based on the conceptual model and the proposed development, and is taken to be the entire area of the site, with the data separated into Made Ground, Topsoil and natural soils.

Statistical testing has been used for the Hydrock default list of determinands in the Topsoil and natural soils. For the Made Ground, the test results are compared directly against the screening values due to low sample numbers (only limited Made Ground was recorded on site).

The results of the pesticide screen in Topsoil are also compared directly against the screening values.

7.3.2 Risk estimation (including statistical testing)

Statistical assessment

In accordance with the guidance provided by the CIEH (May 2008) the 95th upper confidence level on the true mean (US_{95}) has been calculated from the sample data.

There were not any US_{95} exceedances of the GAC for the chemicals of potential concern (CoPC) screened in either the Topsoil or the natural soils.

7.3.3 Risk estimation (without statistical testing)

Hydrock default list of determinands

There were no individual test results that exceed the respective CoPC GAC for Made Ground.

Pesticide Screen

There were no individual test results where pesticides were recorded above the laboratory limit of detection, in the Topsoil.

Based on the test results summarised in the previous sections, Hydrock considers that no further assessment is required for human health in relation to soil contamination at the site.

7.4 Plant life 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 and the findings presented in Appendix H. As with human health, statistical testing is used where data sets are suitable, otherwise individual sample test results are compared directly with the screening values.

None of the US_{95} values exceed the GAC for the CoPC screened in either the Topsoil or the natural soils.

There were no individual test results that exceed the respective CoPC GAC for Made Ground.

Based on the test results summarised in the previous sections, Hydrock considers that no further assessment is required for plant life in relation to soil contamination at the site.

7.5 Ground gases risk assessment

7.5.1 Data

It is judged from the available evidence that the gas generation potential at the site is very low (due to predominantly natural ground conditions and no gas source) but that the sensitivity of the development is high (due to proposed residential properties). Consequently, and in accordance with CIRIA C665 (Table 5.5a and 5.5b), an appropriate minimum monitoring regime is six readings over three 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 nine of the twelve readings planned, including during periods of falling and low atmospheric pressure. However, as the full monitoring programme is not yet complete, the conclusions presented below should be considered interim, pending a review of ongoing supplementary ground gas monitoring.

On a small number of occasions, high gas flow rates have been measured immediately on opening the gas taps (up to 20.1 l/hr). The incidence of initial high flow rates corresponds with a rise in the groundwater level between monitoring rounds and is likely to be caused by this change. The rise in the water level in the standpipe will compress the gas in the standpipe head-space, resulting in a short, high-pressure release on opening the monitoring tap. As such, the temporary initial high gas flow rates are discounted as not typical of emission rates.

7.5.2 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 (Wilson et al 2007) (known as Situation A).

There is an alternative assessment method described by the NHBC (Boyle and Witherington 2007) (known as Situation B). Whilst 'Situation B' may also be suitable for the assessment, it is Hydrock's opinion that the NHBC Guidelines are not at the current time fully aligned with current ground gas risk assessment principles (as described in BS 8485:2015 +A1:2019). As such, 'Situation A' has been chosen as the means by the gas risk will be assessed.

The assessment guidelines published by CIRIA are based on interpretation of the gas concentrations and the gas flow rates, amongst other variables, and are compliant with the model procedures of LCRM. The modified Wilson and Card assessment has been used by comparing the maximum gas concentrations and gas screening values (GSV[5]) in Appendix D with the published table (CIRIA Table 8.5) and the assessment is summarised in Table 7.1. The assessment is presented in Appendix G.

In addition, Table 7.1 summarises a ternary plot assessment of the data (assessment of ground gas ratios (O_2 + N_2, CO_2 and CH_4)), undertaken in general accordance with guidance by Wilson et. al. (2018). The ternary plot assessment is presented in Appendix G.

Table 7.1: Ground gas risk assessment

	Min	Max	Typical (i)	Comment
Steady Flow Rate (l/hr)	0.1	20.1	<1	Typically, (all but 14 readings out of 138) <1. Most of the higher flows were influenced by rising groundwater.
Methane (%)	<0.1	0.4	<1	Carbon dioxide readings are all below 5%.
Carbon Dioxide (%)	0.1	4.9	<5	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 is likely to primarily represent fresh air, with the slightly higher carbon dioxide levels representative of microbial respiration of organic material in soil.
Oxygen (%)	4.2	21.7	17	
Carbon dioxide GSV maximum concentration per hole (l/hr)	0.0001	0.9849	<0.07	CS1
Methane GSV maximum concentration per hole (l/hr)	0	0.0804	<0.07	CS1
For the purposes of the calculation, where the recorded gas flow rate is below the manufacturer's limit of detection for the instrument used, the detection limit has been adopted for the gas flow rate. High gas flows, discounted as anomalous data (and atypical for the site) due to the effects of groundwater changes in the monitoring well.				

As indicated in Table 7.1, the computed GSV for carbon dioxide and methane (excluding the anomalous high gas pressure readings) indicate CS1 conditions. Therefore, the site is provisionally classified as Characteristic Situation 1 (Situation A) on the basis that:

- The methane and carbon dioxide at concentrations are consistently recorded below 1% and 5% respectively.
- The higher flow rates are considered to be attributed to rising groundwater and are not typical for the site (only 14 of 138 flow readings have been recorded as >1).
- Based on typical conditions for the site calculated GSV indicate CS1 conditions.

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

- Assessment of data on a ternary plot indicates the ground gas present is likely to primarily represent fresh air, with the slightly higher carbon dioxide levels typical of microbial respiration in soils.
- No source of ground gas has been identified on, or close to, the site.

Based on the data to date no mitigation measures are required.

7.6 Construction materials risk assessment

7.6.1 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, to give an indication of the possible restrictions to the use of plastic pipes for water supply to the site.

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 the site. However, confirmation should be sought from the water supply company at the earliest opportunity.

7.6.2 Radon

As indicated by Section 2.15, basic radon protection measures are required.

7.6.3 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 organic contaminants (PAHs, TPH, BTEX etc) have not been recorded at the site PVC-U, PP or PE pipework is considered suitable.

7.7 Contamination risks to ground workers

7.7.1 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.

7.7.2 *Metals, metalloids, PAH and petroleum hydrocarbons*

Recorded concentrations of CoPC are all below GAC, indicating a low risk to human health from contamination. Further consideration of these are not required.

7.7.3 *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 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.

7.7.4 *Asbestos*

As no clearly identifiable ACM has been seen during the site walkover or during the ground investigation and no fibres have been detected in soil samples analysed by laboratory testing, CAR2012 does not apply. However, there is always the possibility of unexpected contamination and the Contractors should undertake a watching brief during the works. If any suspect material is encountered, works in that area of the site should stop, the area fenced off and Hydrock should be notified.

7.7.5 *Findings of the generic contamination risk assessments*

The potential sources, pathways and receptors identified in the desk study (Section 2) have been investigated (Sections 4 and 5) and assessed (Sections 7.2 to 7.6). A Source-Pathway-Receptor linkage assessment has been undertaken and is presented in Appendix K (Table K.2).

The main features of the site are summarised on the Site Features Plan presented in Appendix A (Hydrock Drawing 13603-HYD-XX-ZZ-DR-GE-1001).

A summary of the Source-Pathway-Receptor (SPR) contaminant linkages for which the risks may be unacceptable and require mitigation (those that are moderate or higher) are discussed in Table 7.2.

Table 7.2: Residual risks following risk evaluation

Contaminant Linkage				Comments	
Pollutant Linkage	Sources	Pathways	Receptors	General	Mitigation
PL 1.	Radon.	Migration through soils indoor air.	End users of new buildings.	The site is within an area where basic radon protection is required.	Installation of basic radon protection measures.

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8. WASTE AND MATERIALS MANAGEMENT

8.1 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 8.2 below describes the key issues relating to off-site disposal to landfill and Section 8.3 considers requirements relating to reuse of soils and materials management.

8.2 Waste disposal

8.2.1 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:

- A 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 is 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.

Further discussion with regards to the characterisation process for different scenarios and waste types is provided below.

Topsoil

Topsoil is biodegradable, therefore if they are surplus to requirements and cannot be re-used in accordance with a Materials Management Plan, they cannot be classified as inert. As such, topsoil needs to be classified by a staged assessment and sampling process and would either be classified as hazardous or non-hazardous, depending upon the results of the assessment.

Greenfield Sites

Waste from completely greenfield sites may be accepted at a landfill as inert waste if it meets the requirements of paragraph 10 (wastes acceptable without testing at landfills for inert waste) of the Landfill (England and Wales) (Amendment) Regulations (2005) ('the Regulations') can be met. Paragraph 10 of the Regulations states, "soils may be able to be classified as inert waste without testing, if:

- they are single stream waste of a single waste type;
- there is no suspicion of contamination and they do not contain other material or substances such as metals, asbestos, plastics, chemicals, etc….."

As such, where the site is greenfield and the waste producer is confident about the quality of a soil (i.e. naturally occurring and uncontaminated), further sampling and laboratory testing is not necessary for the Basic Characterisation and this can be undertaken on qualitative Waste Acceptance Criteria testing.

In this instance the waste producer can characterise the waste based on visual assessment and written description of the waste in addition to supporting evidence such as a desk study assessment of the greenfield status. However, it should be noted this characterisation is subject to agreement by the landfill operator who may require testing to be undertaken to confirm classification.

Contaminated or potentially contaminated sites

If the site is brownfield, contaminated or potentially contaminated, the waste must undergo an initial waste classification exercise using background information on the source and origin of the waste and assessment of chemical test data in accordance with Environment Agency Technical Guidance WM3.

If following the initial waste classification exercise, the soils are acceptable for disposal to a non-hazardous landfill, further qualitative Waste Acceptance Criteria (WAC) testing is not required.

However, if soils are potentially able to be disposed to an inert landfill as non-hazardous waste, or require testing to determine if they can be disposed of to a stable non-reactive hazardous or hazardous class of landfill, the next stage of assessment is to undertake qualitative WAC testing. This will determine the Basic Characterisation and the landfill category at which the soils can be accepted.

Hazardous material must be subjected to WAC testing to determine whether it requires treatment before it can be accepted at the hazardous landfill, while non-hazardous material can be tested to determine whether it may be suitable for placement in an inert landfill.

8.2.2 HazWasteOnline™ assessment

The site is predominantly greenfield; however, some local areas of Made Ground have been recorded (probably associated with historic farming activities), therefore, in order to inform the preliminary waste characterisation process, Hydrock has undertaken an exercise using the proprietary web-based tool HazWasteOnline™. The output of the HazWasteOnline™ assessment is provided in Appendix I and a summary of the preliminary waste classification is provided below in Section 8.2.4.

8.2.3 WAC Testing

The qualitative WAC tests are provided in Appendix I and a summary of the preliminary disposal options are provided below in in Section 8.2.4.

8.2.4 Preliminary waste disposal options

The site is predominantly greenfield with some local areas of Made Ground (as proven by the desk study assessment and a visual assessment of the soils). However, WAC testing and the HazWasteOnline™ assessment have been undertaken. If suitable segregation of different types of waste 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. However, this would be subject to assessment at the time of disposal.
- The Made Ground is classified as non-hazardous waste and is likely be able to be disposed of an inert landfill based on the WAC testing.
- The natural uncontaminated subsoils are classified as non-hazardous waste and based on the WAC testing should be able to be disposed of at an inert landfill.

8.2.5 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[6]:
  - 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).

8.3 Materials management

8.3.1 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, 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.

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

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.

8.3.2 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.

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.

Made Ground and other contaminated soils

Whilst no contaminated soils are present, Made Ground is present on site. As such, any soils excavated will be a waste as soon as they are excavated (even if they are clean, naturally occurring materials), unless they are subject to reuse in accordance with the DoWCoP. As such, for any brownfield site or a site where Made Ground is present and soils are being moved and reused, the materials could be deemed a waste, subject to either:

- a Materials Management Plan (MMP), to prevent the material being classified as a waste following reuse; or
- an exemption (for limited volumes); or
- an environmental permit, dependant on its status.

Other commonly occurring circumstances are:

If Made Ground is being moved between sites, it must be ensured that appropriate permits are in place to ensure the soils are not classified as a waste. Made Ground cannot be moved between sites under

DoWCoP alone and would require relevant permits as part of the MMP documentation for the Hub site the material is being treated at.

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.

9. UNCERTAINTIES AND LIMITATIONS

9.1 Site-specific comments

The gas monitoring undertaken to date and included in this report is insufficient to fully characterise the site in accordance with CIRIA Report C665. Monitoring is ongoing and the conclusions of this report will be updated following completion of the scheduled monitoring.

The wooded areas in the south-east of Site B and south-west of Site A have not been investigated due to the dense vegetation in these areas which were inaccessible to plant and drilling rigs at the time of our investigation. However, this area is not to be developed. Unless development is proposed, or it is requested by regulators, Hydrock do not believe investigation is required in this area.

9.2 General comments

Hydrock Consultants Limited (Hydrock) has prepared this report in accordance with the instructions of Firethorn Development Ltd (the Client), by e-mail and contract document dated 24th August 2020 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 September 2020. 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.

Plans that provide assessment of foundation types and depths are indicative and subject to further design. This design should incorporate a detailed assessment of the influence of trees, influence of cut to fill proposals and geological conditions.

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.

Assessment and testing for the presence of coal tar has only been completed at the locations of exploratory holes undertaken for risk assessment purposes. This investigation is not designed to provide a definitive assessment of the risk from coal tar, nor the waste classification for bituminous bound pavement arisings at the site.

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 water supply company be contacted at an early stage to confirm its requirements, 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).

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.

10. RECOMMENDATIONS FOR FURTHER WORK

Following the ground investigation works undertaken to date, the following further works will be required:

- completion and reporting of the ongoing gas monitoring, hence the conclusions in this report are provisional, subject to the completion of monitoring;
- discussions with regulatory bodies and the warranty provider regarding the conclusions of this report;
- further assessment and writing of an earthworks specification once the cut to fill proposals for the site are finalised;
- production of a Materials Management Plan relating to reuse of soils at the site;
- verification of the earthworks and MMP works.

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