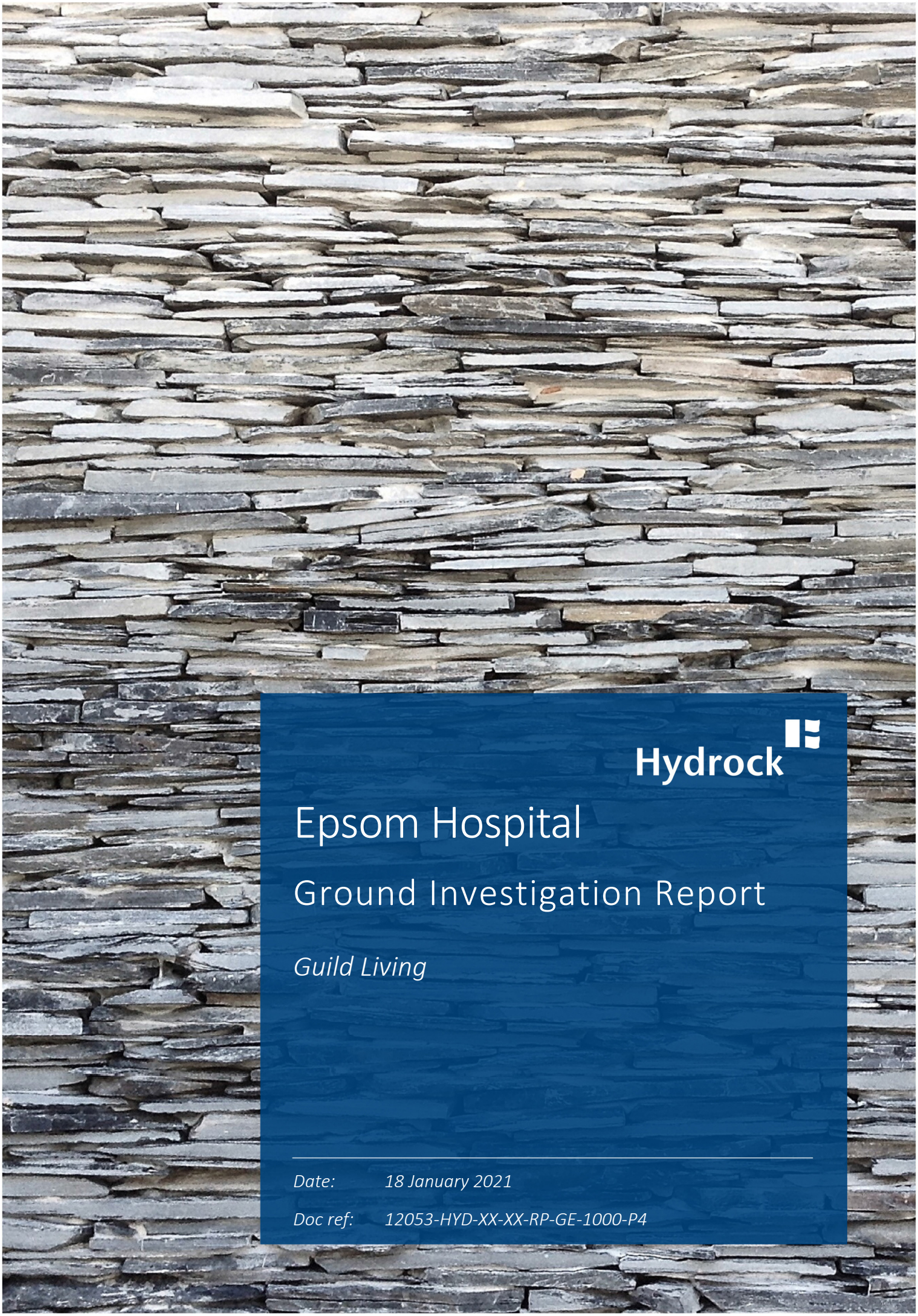

Hydrock

Epsom Hospital

Ground Investigation Report

Guild Living

Date: *18 January 2021*

Doc ref: *12053-HYD-XX-XX-RP-GE-1000-P4*

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EXECUTIVE SUMMARY

SITE INFORMATION AND SETTING	
Objectives	Phase 2 Ground Investigation
Client	Guild Living
Site name and location	Epsom Hospital, Woodcote Green Road, Epsom, KT18 7EG.
Proposed development	The site development proposals are understood to comprise private accommodation and associated leisure and care facilities for retirees and their visitors. The proposed development include new multi- storey blocks will be a mixture of mostly high-rise (4 to 8 storey) and two low rise (2-3 storey) buildings with leisure facilities, landscaped public open space and car parking.
GROUND MODEL	
Desk study summary	The site currently comprises of former hospital buildings of York House, Rowen House, Beacon Ward and existing hospital buildings including Woodcote Lodge and the energy centre. The majority of the site is currently used as a staff car park with asphalt or concrete finish and with some small areas of verge and planted landscaping. Some mature trees are present on and around the site. The site is approximately 1,4ha in area and the majority of the site is flat with levels ranging between 58.9 to 61.0m AOD. However, the northwest corner slopes to the south west from 62.0m AoD to 60m AOD. Upon review of a previous Contamination Preliminary Risk Assessment/Desk Study undertaken by Arup and also a previous ground investigation undertaken by Arcadis indicates that the site has been part of the Epsom Hospital site since the early 1950s. During this time the site has been part of a series of redevelopments over the wider hospital site. Prior to being a hospital, the southern boundary of the site was occupied by a series of large detached residential properties. A non-specialist UXO assessment indicated the site has a low bomb risk. With the exception of areas of topsoil in landscaped areas, the ground conditions underlying the site comprises a thin layer of Made Ground across the whole area overlying the London Clay to the west and a succession of Terrace Gravels over Lambeth Group silts, sands and clays to the east. The top of the London Clay on the west of the site contains varying proportions of flint and sand which suggest some localised natural reworking of this material with the upper Terrace Gravels - the 'cleaner' more granular deposits of which, now appear to be eroded off from the western half of the site (possibly by natural terracing). It is anticipated that the London Clay is underlain by the Lambeth Group. Below the Lambeth Group the geology comprises Thanet Sand, which itself is underlain by Chalk.
Ground and groundwater conditions encountered by investigation	The ground conditions as proven by the investigation undertaken at the site comprise: • Made Ground – between ground level and 1.9m below ground level (bgl), comprising dark brown to gey sandy gravelly clay with a low to medium cobble content. Including brick, concrete and sandstone; over • River Terrace Deposits – variable thickness from depths between 0.80m and 1.2m to between 2.0m and 4.5mbgl comprising of light brown to orange sandy very clayey gravel to gravelly clay. Gravel is fine to coarse flint.; over • London Clay Formation – variable thickness from between 1.10m and 4.5m to between 4.4m and >15m bgl comprising firm to stiff dark grey occasionally silty occasionally sandy clay; over • Woolwich Formation – variable thickness from between 2.15m and 8m bgl to between 8.8m and 16.3mOD comprising very stiff dark grey to red, yellow, purpleish green silty clay; over • Upnor Formation – variable thickness from between 8.8m and 16.3m to between 12.4m and 18.0m comprising of dense to very dense dark grey and green fine to medium sand to clayey sand; over

	• Thanet Sand – from depths between 12.4m and 18m to 24mbgl comprising very dense green and grey silty sand with beds of hard silt and siltstone. • Lewes Nodular Chalk Formation at depths below 24m (BH05) & >24m. There are considered to be two groundwater bodied below the site: A shallow perched groundwater regime within the River Terrace Deposits with groundwater encountered at depths ranging between 1.2-1.8m bgl and a deeper groundwater body encountered at depths ranging between 9.0 and 13.0m bgl. Pockets of both perched water and confined groundwater are also present as a result of interbedded layers of permeable and impermeable deposits. There is localised visual and olfactory evidence of hydrocarbon contamination in soils associated with fuel oils and diesel within (and deliveries to) an above ground storage tank that serves the sites energy centre. The presence of hydrocarbons within the groundwater are generally concentrated in/on perched water below the area to the east of the above ground storage tank and to the south of the energy centre.
GEOTECHNICAL CONCLUSIONS	
Conclusions of geotechnical assessment	Obstructions associated with former /current development, including foundations, floor slabs and services, should be anticipated. Excavation to proposed founding depth generally should be readily achievable with standard excavation plant. It is considered that excavations within the Made Ground and the River Terrace Deposits shall become unstable particularly below the shallow water table. Foundations are recommended to comprise: • Piled foundations for the higher loaded multi storey blocks. • Either fully piled foundations or a raft incorporating settlement reducing piles/concrete columns for moderately loaded structures. • Pad or strip foundations for lightly loaded structures. Where there is excessive thickness of Made Ground and/or influence from trees, suspended floor slabs are to be put in place. Elsewhere (or if the Made Ground is re-engineered/replaced); ground bearing floor slabs can be utilised. The Made Ground and Terrace Deposits are considered to be non-plastic in terms of shrinkage potential. Other shallow cohesive soils are of medium shrinkage potential. A design CBR of 2.5% is recommended. Soakaway drainage is considered unsuitable for this site due to the shallow groundwater regime.
GEO-ENVIRONMENTAL CONCLUSIONS	
Conclusions of contamination Generic risk assessment	***Human health:*** • Elevated concentrations of benzo(a)pyrene and lead were identified across the site . • Asbestos was found to be pervasive within the Made Ground. • Elevated concentrations of Petroleum Hydrocarbons were encountered within WS01, WS02 and BH102 a hotspot located to the south of the energy centre. ***Plant growth:*** • There are no substances which are considered to be a risk to plant life ***Controlled Waters:*** • Elevated concentrations of heavy metals have been detected in the groundwater beneath the site. This is likely to be associated with natural background concentrations of the wider area. No remedial action is required. • Elevated concentrations of hydrocarbons have been recorded within perched water within WS01, WS02 and BH02S. This is considered to be related to a localised hotspot of contamination which requires further consideration. No elevated pollutants were detected in deeper aquifers.

	Ground gases or vapours: • CS1 ground gas conditions are prevalent. • Vapour protection membrane is likely to be required associated with the hydrocarbon hotpot. The extent of this should be assessed as part of a watching brief for the demolition of the energy centre, generator and above ground fuel tank. Radon: • The site is not in a Radon Affected Area. Water supply pipes: • Brownfield site and the presumption in the guidance is that barrier pipe will be used. However, the investigation and assessment has indicated no significant wide spread Contaminants of Concern across the majority of the site. As such, standard pipework may be suitable for the majority of the site following negotiations with the supply company.
Proposed mitigation measures	The mitigation measures proposed to remove unacceptable risks include: • Delineation and the excavation and removal of heavily tarnished soils from the hydrocarbon hotspot. Also, creation of a sump just below the groundwater level to remove any significant free phase hydrocarbons within the hotspot. • The installation of a 450mm clean cover system in proposed areas of public open space, comprising a bonded geogrid break layer (e.g. Secugrid 30/30), subsoil and a minimum of 150mm of topsoil. • Installation of Protecta-line pipework. The methodology for the remediation should be presented in a Remediation Strategy, which will need to be submitted to the warranty provider and the regulatory authorities for approval. In addition, the production of a Materials Management Plan and its approval by a Qualified Person will be required to allow any planned reuse of suitable material at the site. Verification reports by a competent independent geo-environmental specialist will be required following completion of any remedial works.
Waste management	The majority of excavated soils to be disposed of as waste, are likely to be classed as inert or non-hazardous. However, material excavated from the Hydrocarbon hotspot are likely to be classed as potentially hazardous waste due to the diesel content. In addition, an elevated concentration of Chromium was identified within BH01 which classified the Made Ground in this area as being potentially hazardous waste but this is believed to be an isolated occurrence.
FUTURE CONSIDERATIONS	
Further work	Following the ground investigation works undertaken to date, the following further works will be required: • further testing of shallow groundwater at around the above ground fuel tank to better understand the changes in hydrocarbon concentrations recorded around the tank and understand any vertical migration of the contamination. • discussion and agreement with utility providers regarding the materials suitable for pipework; • discussions with regulatory bodies and the warranty provider regarding the conclusions of this report; • discussions with piling Contractors regarding conclusions of this report and design of the piles; • provision of geotechnical design for the Category 2 (foundations); • production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider). • Preparation of Piling Foundation Works Risk Assessment (if required) • Additional post-demolition investigation within/around the Energy Centre to support delineation of petroleum hydrocarbon hotspot identified. • consideration to the production of a Materials Management Plan relating to any reuse of soils at the site. • verification of the remediation and mitigation works.

This Executive Summary forms part of Hydrock Consultants Limited report number 12053-HYD-XX-XX-RP-GE-1000-P4 and should not be used as a separate document.

1. INTRODUCTION

1.1 Terms of reference

In February 2020, Hydrock Consultants Limited ('Hydrock') was commissioned by Guild Living ('the Client') to undertake a Phase 2 ground investigation at Epsom Hospital, Woodcote Green Road, Epsom ('the site').

The site currently comprises a series of former hospital buildings and a staff car park located within the south west of the wider Epsom Hospital.

Hydrock understands that the proposed redevelopment is to comprise private residential accommodation with associated leisure and care facilities and car parking for retirees and their visitors. It is understood the redevelopment will include the construction of several multi storey blocks including a mixture of high-rise (4 to 8 storey) and low rise (2-3 storey) buildings. A proposed development layout is presented in Appendix A. As part of the redevelopment some of the existing former hospital buildings and infrastructure will be demolished.

A desk study and ground investigation has already been undertaken at the Site by Arcadis (UK) Ltd ('Arcadis') and Ove Arup & Partners Ltd ('Arup') in 2018 and 2019.

The works have been undertaken in accordance with Hydrock's proposal referenced (C-12053-Hydrock fee Proposal-Geotechnical) and the Client's instructions to proceed (Ref: Email instruction from Cast Real Estate and Construction Consultancy, dated 18/02/2020).

The report herein has been revised to reflect updated design information in relation to the geo-environmental assessment. The geotechnical assessment remains unchanged and does not reflect updated design information provided within the new planning application.

1.2 Objectives

The works have been commissioned to assist in clearing planning conditions and to develop the design.

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 during previous ground investigation and assessment by refining and updating the preliminary Ground Model, determining geo-environmental and geotechnical site conditions and identifying any key contamination risks by updating and finalising the Conceptual Model in accordance with the principles of LCRM. Specifically, to:
  - Better delineate a hydrocarbon hot-spot, as identified within previous ground investigation, associated with the boiler rooms;
  - Define with more accuracy the changes in geology and soil strength encountered across (and below) the site to refine preliminary geotechnical design information;
  - Provide better coverage of sampling for the assessment of contaminated ground; and
  - Develop the understanding of the groundwater regime with particular reference to potential hydrocarbon contamination in the vicinity of the existing Energy Centre/Boiler Room.

- 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 2 Ground Investigation.

The scope of the Phase 2 Ground Investigation comprises:

- A review and summary of the previous ground investigation data;
- a ground investigation including windowless sampling, rotary drilling and hand pits 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 (including groundwater sampling);
- geotechnical and chemical laboratory analysis;
- updating of the preliminary Ground Model;
- preparation of a geotechnical risk register;
- presentation of initial geotechnical design recommendations;
- refinement of the 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 any outline mitigation requirements to ensure the site is 'suitable for use'.

1.4 Available information

The following documents have been provided to Hydrock by the Client for use in the preparation of this report:

- Arcadis (UK) Ltd, September 2018. Epsom Hospital – Plot 2A. Phase 2 Geo-Environmental and Geotechnical Assessment Report. Report Ref: 10020221-ARC-XX-XX-RP-ZZ-0007-01.
- Arcadis (UK) Ltd, October 2018. Epsom Hospital- Main Hospital Site. Phase 2 Geo-Environmental and Geotechnical Assessment Report. Report Ref: 10020221-ARC-XX-XX-RP-ZZ-0008-01.
- Ove Arup & Partners Ltd, December 2019. Ground Contamination Preliminary Risk Assessment at Epsom Hospital Desk Study. Report Ref: 270352

The Client commissioned the Arup ground contamination preliminary risk assessment and Hydrock assumes full reliance upon its contents.

The previous ground investigation undertaken by Arcadis was commissioned by Epsom and St Helier University Hospital NHS Trust. Therefore, these documents have been used for information purposes only at this stage. No formal reliance has been placed 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 current NHBC Standards, 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 10 and Section 11.

3. PHASE 1 STUDY (DESK STUDY REVIEW AND FIELD RECONNAISSANCE)

3.1 Introduction

Hydrock have undertaken an updated field reconnaissance survey on 19/03/2020 to visually assess potential geotechnical hazards, contaminant sources and receptors and compare the site conditions with those previously reported. The weather during the updated field reconnaissance survey was overcast and light rain.

3.2 Site location

The site is located within the grounds of Epsom General Hospital, approximately 1km to the south west of the centre of Epsom at approximate National Grid Reference: 520399E, 159758N. The Site is accessed from Woodcote Green Road to the south.

A site location plan (Drawing Ref. *12053-HYD-XX-XX-GI-DR-GE-1000*) is presented in Appendix A.

3.3 Site description

The site is located within the south-west of the grounds of Epsom General Hospital, comprises numerous former and existing hospital buildings and is approximately 1.4 Hectares (ha) in area. This includes York House, Rowen House and Beacon Ward (all vacant former hospital buildings), Woodcote Lodge and an Energy Centre (which are currently in use). Numerous other small outbuildings or temporary buildings are also present across the Site with some waste storage areas also noted.

Elsewhere, the majority of external areas are surfaced with asphalt or concrete and used for staff car parking and access. Localised small areas of landscaped verge and planting are also present.

The majority of the site is generally flat with elevations ranging between 61m and 58.9m AOD, exhibiting a very gentle fall in an approximately north-easterly direction. Locally within the north-west corner of the site a steeper gradient is present falling from approximately 62m AOD down to 60m AOD in a north/north-easterly direction.

A boiler house and associated infrastructure (referred to as the 'Energy Centre') is present in the northern area comprising numerous tanks, associated plant and a chimney stack. Specifically, this includes two above-ground diesel/fuel oil storage tanks, a chemical store, boiler house and medical gas storage. An external diesel fuel filling point is located on the southern wall. Two generators are also present in this area, housed within separate buildings to the north-west and south-east of the boiler house.

At the time of the Hydrock walkover and investigation the existing buildings on the site were undergoing asbestos removal prior to their planned demolition.

3.4 Additional Site Walkover Information

The following additional features and potential contaminative sources were also noted by Arup during their walkover on 29/08/2019:

- The boiler house contains three diesel-fuelled boilers. The boiler water is treated with bisulphate and sodium hydroxide. These are stored within a bund in the boiler house.

- Arup observed localised evidence of staining around the boiler pipework and pipe pits adjacent to one of the boilers. In addition, black staining was noted around buried pipe runs/ducts external to the boiler house.
- Numerous miscellaneous items were noted within chemical storage areas including paint, oil drums, gas canisters and sand. Locally oily water and purple staining was noted on the floor.
- Two generators are present on the Site. One in a separate outbuilding on the northern boundary of the Site (to the north/north-east of the Energy Centre). A second smaller generator is located within a metal container to the south-west of the Energy Centre. Localised staining was noted to the floor in the larger generator building and some oil canisters were observed.
- the pump room within the basement of Rowan House was noted to be flooded at the time of the site walkover.

3.5 Site history

Epsom Hospital is first recorded on the site in the early 1950s. Prior to the construction of the hospital the site was predominantly residential gardens with localised wooded areas. A number of large detached properties (assumed residential) were situated along the southern boundary and locally in the north of the site.

Since the construction of the hospital on the Site by the early 1950's, there have been several phases of demolition, redevelopment and minor construction as part of the expansion of the wider hospital site. At this time a Chimney is also mapped in the north of the Site within the current Energy Centre complex.

Off-site, a Workhouse was located adjacent to the north from the earliest available historical map of 1840, before becoming part of a Hospital from the 1930s.

The previous reports highlight that a historic tank and two electricity substations are located between 120-150m to the north-east and north west retrospectively of the site.

In addition, an old pond is recorded within 50m of the northern boundary of the site.

3.6 Geology

The published geology of the site is shown on the British Geological Survey (BGS) 1:50,000 geology map of Reigate (Sheet 286).

Superficial deposits of the River Terrace Deposits are present across the majority of the Site, with the exception of in the far west / north-west. Beneath these, the site is underlain by a sequence of deposits of the London Clay (clays and silts) and the Lambeth Group (clays, silt and sand). The London Clay outcrops in the west/north-west of the Site only, whereas the majority of the central and eastern areas are shown to be underlain by the Lambeth Group.

The Lambeth Group includes the Woolwich and Reading Beds.

The deeper underlying geology includes the Thanet Formation (sands) and Upper Chalk of the Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation.

Previous ground investigation undertaken by Arcadis indicates that the expected geological sequence is anticipated to comprise of a veneer of Made Ground across the whole site overlying the London

Clay in the west and a succession of River Terrace Gravels over silts, sands and clays of the Lambeth Group to the east.

As the geological mapping suggests, the River Terrace Deposits appear to be absent from the western third of the site but are present elsewhere. Furthermore, it is notable that the top horizon of the underlying London Clay in the west is distinctly weathered and contains varying percentages of flint and sand suggesting an erosional interface with the River Terrace Deposits in the geological past. At a few locations in the central and eastern area of the site the overlying River Terrace Gravels appeared to be naturally well compacted. The top of the underlying clays of the Lambeth Group appeared to be softened, sandy in nature and the presence of shallow groundwater was noted.

3.7 Hydrogeology

The overlying superficial deposits of the River Terrace Deposits are classified by the Environment Agency (EA) as a Secondary A Aquifer.

The London Clay Formation is an Unproductive Aquifer. The underlying Lambeth Group and Thanet Formation are classified as Secondary A Aquifer(s). The Upper Chalk is a Principal Aquifer.

It is probable that multiple groundwater layers may be present, as such groundwater flow direction may changeable based on the individual characteristics of each strata. However, it is inferred that in general groundwater flow direction will be in a the north or north-easterly direction, which is supported by the findings of the Arcadis' ground investigation in 2018.

There are no recorded groundwater abstraction licences within 1km of the Site. The Site is not located within a Source Protection Zone (SPZ). However, a Zone II (Outer Protection) SPZ is present approximately 190m east with a Zone I (Inner Protection Zone) just beyond, approximately 260m north-east.

The existing chemical status of the underlying groundwater body (Hogsmill) classified under the Water Framework Directive as 'fair'.

Hydrock have reviewed the groundwater monitoring undertaken as part of the Arcadis' 2018 ground investigation. Shallow groundwater was encountered within the River Terrace Deposits and Lambeth Group in the central and eastern areas of the Site, at depths typically ranging between approximately 1.1m and 2.2m bgl. In the west, it is evident that localised perched groundwater was noted to lie atop of the relatively impermeable London Clay and within deeper confined strikes recorded within the sandy horizons of the same strata.

3.8 Hydrology

There a no surface water features present on the current Site. The nearest surface water feature is a pond approximately 10m to the south-east (on the opposite side of Woodcote Green Road). An associated network of drains within Woodcote Millennium Green between 25m and 90m to the south-east, appear to drain towards and in to the pond.

3.9 Radon

With reference to the Indicative Atlas of Radon in England and Wales (Miles et al 2007) and Annex A maps in BR 211 (Scivyer 2015), the Site is in an where the maximum radon potential is between 1% and 3%.

The previous desk study and ground investigation information indicates that the site is in an area where <1% of homes are above the action level and no radon protection measures are required for new buildings at this location in line with current guidance.

3.10 Waste Management

There are no recorded waste management or landfill sites within 1km of the Site.

3.11 Unexploded ordnance (UXO)

A non-specialist UXO risk assessment has been undertaken using the Zetica Online Tool. This indicates that the site is in area which is considered to be at a low risk of UXO. No further action is considered necessary in relation to ground investigation. However, further assessment may be considered prudent for construction activities.

3.12 Sensitive Land Uses

The Site is located within a Nitrate Vulnerable Zone.

3.13 Summary of Previous Ground Investigation

Arcadis completed a ground investigation at the current Site in August 2018. This includes three deep cable percussion boreholes (BH101, BH102 & BH104) to 15m bgl and five dynamic (window sample) boreholes (WS101 to WS105) to up to 5m bgl.

The pertinent findings of the previous investigation are summarised as follows:

- Free asbestos fibres (all chrysotile) were encountered with Made Ground soils locally in three samples within WS102 and BH102. Subsequent asbestos quantification detected a concentration of 0.011% in one location.
- Elevated concentrations of PAHs were detected in soils in exceedance of soil screening values for the protection of human health within the Made Ground of BH102. Elevated concentrations of lead were also encountered locally in WS102 and WS105.
- Similarly elevated concentrations of organic contaminants of naphthalene, benzene and TPH were detected within groundwater in BH102 during two separate sampling events. A maximum TPH concentration of 3,980ug/l was recorded. The observed concentrations of organics were attributed to historic spillages / losses associated with the Energy Centre (fuel storage tank, boiler room etc.). No elevated concentrations of petroleum hydrocarbons were noted within the nearest downgradient monitoring well (BH103).
- Zinc was also elevated locally within the groundwater of BH104, however its cause was unknown.
- Three rounds of ground gas monitoring were undertaken over four weeks. Concentrations of methane and carbon dioxide were typically <0.2% and <5% v/v, however localised peaks of up to 7% v/v of carbon dioxide were locally recorded. No gas flow was recorded. Arcadis concluded that CS1 conditions prevailed, however protection requirements to CS2 was recommended on a localised basis (BH102 and WS101).
- Further ground gas monitoring and groundwater sampling was recommended.

4. OUTLINE CONCEPTUAL MODEL

4.1 Introduction

The outline Conceptual Model (oCM) incorporates evidence from the site walkover and findings of the previous reports (completed by others) 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 site physical 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.

4.2 Ground model

The preliminary ground model presented in Section 3 provides an understanding of the ground conditions and is the basis for preparing the preliminary geotechnical hazard assessment (Section 4.3) and the preliminary geo-environmental exposure model (Section 4.4).

4.3 Geotechnical hazard identification

4.3.1 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 H.1 in Appendix H for further information).

4.3.2 Plausible geotechnical hazards

Plausible geotechnical hazards identified at the site are:

- Uncontrolled Made Ground (variable strength and compressibility).
- Soft / loose compressible ground (low strength and high settlement potential).
- Shrinkage / swelling of the clay fraction of soils under the influence of vegetation.
- Variable lateral and vertical changes in ground conditions.
- Attack of buried concrete by aggressive ground conditions (particularly in the London Clay).
- Existing below ground structures to remain (Possible foundations, basements).
- Shallow groundwater.

4.3.3 Potential development elements affected

Development elements potentially affected by geotechnical hazards are:

- Buildings – foundations.
- Buildings – floor Slabs
- Roads and pavements.
- Services.
- Concrete below ground.

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 6 and the assessment is presented in Section 7.

4.4 Geo-environmental exposure model

4.4.1 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.

4.4.2 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 the historic use, demolition and redevelopment of the Hospital including elevated concentrations of metals, metalloids, asbestos fibres, asbestos containing material, PAH and petroleum hydrocarbons. (S1)
- Localised petroleum hydrocarbons / organics, fuels, lubricants and solvents from leaks/spills and operation of the Energy Centre (above ground diesel storage tank, generators, boiler house etc). (S2)
- Groundwater vapours
- Ground gases (carbon dioxide and methane) derived from Made Ground (S3)
- Asbestos in existing buildings (S4)

Potential off-site sources of contamination

- Ground gases (carbon dioxide and methane) from organic materials in off-site Made Ground and backfilled pond located to the north east of the site (S5).

4.4.3 Potential receptors

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

- People (neighbours, workers, site end users) (R1).
- Development end use (buildings, utilities and landscaping) (R2).
- Groundwater: Secondary A aquifer status of the River Terrace Deposits, deeper bedrock aquifers (including Principal Aquifer of the Upper Chalk) and downgradient SPZ (R3).
- Surface water: pond and drainage network, 25m south-east (R4).

Given the site topography and inferred groundwater flow direction, the surface water pond and drainage network to the south of the Site is considered to be hydraulically upgradient of the Site, with

no apparent direct linkage (outfalls, drainage) towards or from the Site. As such the surface water features to the south is unlikely to be a plausible receptor.

4.4.4 Potential pathways

The following potential pathways have been identified.

- Ingestion, skin contact, inhalation of dust (and/or vapours) and outdoor air by humans (P1).
- Root uptake by plants (P2)
- Migration of contaminants via leachate dispersion or mobility through the unsaturated zone to shallow groundwater (P3)
- Vertical and lateral migration within/through groundwater to underlying Secondary and Principal Aquifers (P4)
- Direct contact with substances deleterious to building materials (P5).
- Buildings: ground gas ingress (methane, VOC or hydrocarbon vapours) via permeable soils, preferential pathways (utilities) and/or construction gaps (P6).
- Potential new pathways created by piling (P7).

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 6 and the assessment is presented in Section 8. An assessment of the Source – Pathway – Receptor linkages is undertaken following the assessment (Section 8) and is presented in Appendix I (Table I.1).

5. GROUND INVESTIGATIONS

5.1 Investigation rationale

The ground investigation rationale was based on the findings of the preliminary risk assessment and is summarised in Table 5-1.

For the investigation rationale of the historical investigations, please refer to the individual historical reports. The Arcadis ground investigation report from 2018 is provided in Appendix J.

Table 5-1: Investigation rationale

Location	Purpose
Whole Site	
BH01 - BH06	To assess deeper ground conditions and to allow SPTs to be undertaken. To allow collection of samples for geotechnical characterisation. Installation of gas and leachate/groundwater monitoring and sampling wells.
CPT01 - CPT09	To investigate the strength profile of the underlying ground conditions. To investigate the occurrence of soft spots within the shallow Lambeth Group particularly on the east of the site.
HP01 - HP08	To allow the collection of contamination testing. To assess the depth of existing foundations on the site.
Energy Centre	
WS01 - WS04	To assess shallow ground conditions. To address uncertainties identified within the previous investigations. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical characterisation. Installation of gas and groundwater monitoring and sampling wells.

5.2 Constraints

The footprints of the buildings could not be investigated as most buildings were still in use, preventing intrusive ground investigation.

Live underground services exist beneath the site, particularly in and around the Energy Centre, which restricted the location of exploratory hole locations.

Accessible areas of the site comprised an active car park. As such, the works were positioned to minimise disruption to the users and operation of the site.

5.3 Site works

The fieldwork took place between 1st June 2020 and 10th July 2020 and is summarised in +Table 5-2. The ground investigation locations were surveyed in using a hand-held GPS and are shown on the Exploratory Hole Location Plan (Hydrock Drawing 12053-XX-XX-DR-GE-1001) in Appendix A.

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

The weather conditions during the Hydrock fieldwork and for the previous week were generally dry but with heavy showers between the 15th and 17th June 2020.

+Table 5-2: Summary of site works

Activity	Method	No.	Depth Range (m bgl)	*In situ* tests	Notes (e.g. installations)
Drilling, Pitting and Probing					
Boreholes	Rotary (Wireline)	6	20.00-27.00	SPT	50mm HDPE wells with gas taps in BH01-BH05.
	Windowless sampler	4	6.00		50mm HDPE wells with gas taps in all boreholes
Trial pits	Hand-excavated	9	0.20-1.20		Foundation inspection.
Probes	CPT electric cone	9	7.10-12.10	Continuous cone resistance	

Wells for monitoring groundwater levels and ground gas concentrations, and to facilitate the sampling of groundwater, were installed in a number of the windowless sample holes and boreholes. A summary of the monitoring well installations is presented in Table 5-3.

Table 5-3: Summary of monitoring installations

Location	Ground level (m OD)	Standpipe diameter (mm)	Screen top and base depth (m bgl)	Screen top and base elevation (m OD)	Strata targeted
BH01	60.35	50	21.50 to 24.00	38.85 to 36.35	Thanet Sands
BH02	59.23	50	13.5 to 17.80	45.73 to 41.43	Lambeth Group (Woolwich Formation) / Thanet Sands
BH03	59.59	50	12.00 to 15.00	47.59 to 44.59	Lambeth Group (Woolwich Formation and Glauconitic Sands) / Thanet Sands
BH04	59.67	50	20.00 to 22.50	39.67 to 37.17	Thanet Sands
BH05	59.07	50	24.00 to 27.00	35.07 to 32.07	Lewes Nodular Chalk Formation.
WS01	59.45	50	1.00 to 2.50	58.45 to 56.45	River Terrace Deposits
WS02	59.41	50	1.00 to 3.50	58.41 to 55.91	River Terrace Deposits
WS03	59.54	50	1.00 to 6.00	58.54 to 53.54	River Terrace Deposits and London Clay
WS04	59.54	50	1.00 to 2.50	58.54 to 57.04	River Terrace Deposits

5.4 Geo-environmental testing

5.4.1 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. However, contamination testing was focused around the boiler room/ energy centre and the above ground fuel tank together with available locations spread around other parts of the site to give a wider general coverage.

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

The geo-environmental assessment in Section 8, includes both the Hydrock results and those presented within the Arcadis 2018 ground investigation report.

5.4.2 Site screening tests

A photoionisation detector (PID) (MiniREA Lite) was used during the fieldwork to screen samples on approximate 300 to 500mm intervals initially and decreasing frequency with depth . The PID readings are detailed on the exploratory hole logs in Appendix C.

5.4.3 Geo-environmental monitoring

Gas monitoring boreholes have been monitored on six occasions over a two month period (August to October 2020) following the ground investigation. The results are presented in Appendix E. Monitoring is now complete with the results summarised in Section 6.4 and assessed within Section 8.6.

5.4.4 Geo-environmental laboratory analyses

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

The geo-environmental analyses undertaken on soils are summarised in Table 5-4.

Table 5-4: Geo-environmental analyses of soils (Hydrock).

Determinand Suite	Made Ground	River Terrace Deposits
Hydrock (Ground Investigation – June 2020)		
Hydrock minimum suite of determinands for solids*	22	10
Speciated aliphatic and aromatic banding Total petroleum hydrocarbons by HS-GC/MS and GC/FID (Hydrock Tier 2 TPH Suite)	6	4
Asbestos quantification	5	-

Geo-environmental testing undertaken as part of the Arcadis 2018 ground investigation has been included within the Hydrock assessment. A summary of this testing is provided in Table 5-5.

Table 5-5: Geo-environmental analysis of soil from the Arcadis Report.

Determinand Suite	Made Ground	River Terrace Deposits
Arcadis (Ground Investigation – (September 2018)		
Chemical testing including metals and inorganics	11	1
Testing suite including phenols, speciated PAH and TPH CWG (including BTX)	6	0
Asbestos quantification	3	0

The soils chemical test data are interpreted and assessed in Sections 8.3 and 8.4.

The geo-environmental analyses undertaken on waters for testing undertaken by Hydrock are summarised in Table 5-6, below.

Table 5-6: (Hydrock) Geo-environmental analyses of waters

Determinand Suite	Ground-water
Hydrock (Ground Investigation June 2020)	
Hydrock minimum suite of determinands for waters	9
Speciated aliphatic and aromatic banding Total petroleum hydrocarbons by HS-GC/MS and GC/FID (Hydrock Tier 2 TPH Suite)	9

Groundwater testing undertaken as part of the Arcadis 2018 ground investigation has been included within the Hydrock assessment. A summary is provided in Table 5.7.

Table 5-7: (Arcadis) Geo-environmental analysis of water

Determinand Suite	Ground-water
Arcadis (Ground Investigation September 2018)	
Metals and inorganics	6
Speciated PAH and TPH	6

It should be noted that the Arcadis suite of testing for metals and inorganic is smaller than the Hydrock standard suite for waterand therefore a number of background metals have not been tested for which are included on the more recent testing.

The groundwater chemical test data are interpreted and assessed in Section 8.5.

5.5 Geotechnical testing

5.5.1 Geotechnical laboratory testing

The geotechnical tests undertaken by Hydrock are summarised in Table 5-8 and the test certificates are provided in Appendix D. Wherever possible, UKAS accredited procedures have been used.

Table 5-8: Summary of sample numbers for geotechnical tests

Test	Made Ground	River Terrace Deposits	London Clay Fm	Woolwich Fm	Upnor Fm	Thanet Sand	Lewes Nodular Chalk Fm
Hydrock (Ground Investigation – June 2020)							
Natural moisture content	-	1	7	8	2	2	-
Atterberg limits	-	1	11	9	2	3	-
Sulfate and aggressive chemical environment classification for buried concrete classification (full BRE SD1 suite)	1	5	2	6	3	3	-
Single stage undrained triaxial compressive strength	-	-	4	10	0	1	-
Saturated Moisture Content of Chalk	-	-	-	-	-	-	2
Chalk Porosity	-	-	-	-	-	-	2

The geotechnical test data is summarised in Section 6.6 and interpreted in Section 7.

6. GROUND INVESTIGATION RECORDS AND DATA

6.1 Physical ground conditions

6.1.1 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.

All relevant data from the Hydrock investigation discussed in Section 5 as well as any reliable data from previous investigations noted in Section 1.4 and discussed in Section 3 are used from this point forward.

Details of the Hydrock ground investigation works are provided in the logs in Appendix C and within the geology cross sections provided in Appendix A, a summary of the ground model is presented in Table 6-1 and the individual strata are described in the sections below.

Table 6-1: Strata encountered during the Hydrock Ground Investigation.

Stratum	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m) (range)
Surface Cover – Concrete hardstanding/bituminous bound pavement hardstanding.	0.0	0.18-0.50	0.18 – 0.50
'General' Made Ground	0.00 - 0.20	0.60 - 1.90	0.75 – 1.90
River Terrace Deposits	0.60 - 1.20	2.00 – 4.50	1.25 – 2.70
London Clay Formation	1.10 – 4.50	4.40 – >15.00	1.30 – >10.55
Lambeth Group (Woolwich Formation)	2.15 – 8.00	8.80 – 16.30	4.40 – 10.20
Lambeth Group (Upnor Formation)	8.80 - 16.30	12.40 - 18.00	1.60 – 5.40
Thanet Sand Formation	12.40 - 18.00	24	10.30 - >10.3
Lewis Nodular Chalk Formation	24.00 - >27.00	un-proven	un-proven

6.1.2 Surface covering

The following surface cover was identified during the field reconnaissance and the fieldworks:

- Bituminous bound pavement hardstanding, covering approximately 60% of the site and noted to be in generally good with some areas having been recently replaced.
- Paved parking and walkway covered approximately 15% of the site.
- Structures (former hospital buildings and boiler room) covering approximately 15% of the site.
- Vegetation (grass, trees, brambles), covering approximately 10% of the site.

6.1.3 Made Ground

Made Ground was recorded across the entire site and was encountered below vegetated areas to 0.50m bgl and from below hard-standing to depths ranging between 0.50 – 1.90m bgl. The Made

Ground is believed to have been formed following several phases of redevelopment on the site and from the demolition of historic structures.

The Made Ground generally comprised of dark greyish brown sandy gravelly clay with a low cobble content. Gravel is subangular to sub-rounded fine to coarse brick, flint and sandstone. Cobbles are sub-rounded brick of up to 0.15m diameter. Sand was fine to coarse.

Minimal anthropogenic material was encountered within the Made Ground with the exception of occasional metal fragments and corrugated asbestos cement board (ACM) within CPT08.

6.1.4 River Terrace Deposits

The River Terrace Deposits were encountered underlying the Made Ground across the majority of the site (the exception being in the western corner of the site). The composition of the River Terrace Deposits varied between a light brown to orange clayey sandy gravel with subangular to sub-rounded fine to coarse flint to a sandy gravelly clay. Generally, the material had a higher clay proportion in the upper 0.5m. The River Terrace Deposits extended to depths between 2m and 3.8m.

The River Terrace Deposits thin towards the higher ground in the north west of the site. In this area of the site the upper horizon of the London Clay Formation is considered to be weathered and contains varying percentages of flint and sand which is likely to be the result of geological reworking or an erosional face with the River Terrace Deposits.

6.1.5 London Clay Formation

The River Terrace Deposits were underlain by the London Clay which was encountered as a firm becoming stiff dark grey silty to sandy clay.

The thickness of the London Clay is variable across the site. Generally, the London clay thins out in both southerly and easterly directions from approximately 5.25m in the west of the site to between around 1.3m in the south and 2.5m towards the east. In the far eastern fringes of the site, a previous Arcadis borehole (BH104) suggests that London Clay is absent and that the Woolwich Formation lies directly beneath the Terrace Deposits. However, the clay strengths of the upper cohesive body of what is described as Lambeth Group (the Woolwich Formation) by Arcadis appear to be more akin to those of the London Clay.

6.1.6 Lambeth Group (Woolwich Formation)

The Woolwich Formation was encountered underlying the London Clay in the west of the site from approximately 8m bgl and underlying the River Terrace Deposits on the east of the site from depths ranging between 2.7m and 5.1m bgl (becoming thickest in the northeast at 8.3m thick in BH01) and possibly lying directly beneath the Terrace Deposits to the east. The Woolwich Formation comprised a stiff to very stiff dark grey to green mottled purple yellow red and occasional silty clay with sandy beds.

6.1.7 Lambeth Group (Upnor Formation)

The Upnor Formation (or Glauconitic Sands) was encountered below the Woolwich Formation across the whole site and varied in thickness, but with no distinguishable pattern of variance apart from being thicker in the eastern end of the site. At its thinnest it was 1.7m within BH01 in the central western part of the site. At its thickest it was 5.2m within BH06 in the south-eastern corner of the site and seemingly 7.5m thick in Arcadis' borehole BH104 in the eastern end of the site.

The Upnor Formation is described as dense light green and grey slightly clayey sand. This deposit is considered to mark the transition between the Woolwich formation and the underlying Thanet Sands but was often indistinguishable in character from the Thanet Sands, therefore its true variance in vertical extent cannot be reliably defined.

6.1.8 'Thanet Sand Formation

The Thanet Sand Formation was encountered underlying the whole site at depths ranging between 12.40 and 18.00m bgl. The Thanet Sand Formation comprised a dense to very dense dark green and grey fine to medium sand (very similar to the glauconitic sands of the Upnor Formation above), but with occasionally hard silty and siltstone beds).

6.1.9 'Lewes Nodular Chalk Formation'

The Lewes Nodular Chalk Formation (Upper Chalk) underlies the whole of the site at depth however, this was only encountered within one borehole (BH05) at 24m bgl (35m AOD). Notably the deep borehole sunk to 27m bgl in western part of the site (BH01) did not encounter the Upper Chalk.

The chalk in BH05 is considered to be generally structured CIRIA Grade B4.

6.2 Visual and olfactory evidence of contamination (soil)

In addition to the more common man-made constituents (ash, clinker, plastic, etc), described in Section 6.1.3, visual and olfactory evidence of contamination was noted in a number of locations during the Hydrock investigation and were situated around the Energy Centre and are summarised in Table 6-2.

Table 6-2: Visual and olfactory evidence of contamination - soils

Stratum	Location	Depth (m bgl)	Description
River Terrace Deposits	WS01	1.50 - 2.00	Hydrocarbon odour and black staining.
River Terrace Deposits	WS02	1.75 – 2.00	Hydrocarbon odour and black staining.
River Terrace Deposits	BH02	1.50 – 2.00	Hydrocarbon odour and black staining.

6.3 Groundwater

6.3.1 Groundwater observations and levels

The drilling technique used a water flush and therefore true groundwater levels were masked during the investigation. As such, water strike information is not considered to be fully reliable and have not been included within our assessment of groundwater levels. Groundwater levels recorded during post-fieldwork monitoring are summarised in Table 6-3.

Table 6-3: Groundwater level data summary

Stratum	Date range	Location	Post-fieldwork monitoring	
			Depth to groundwater (range) (m bgl)	Groundwater elevation (range) (m OD)
River Terrace Deposits	11/08/2020 & 22/10/2020	WS01	1.17 – 1.67	58.28 - 57.78
		WS02	1.37 -1.82	58.04 - 57.59
		WS04	1.04 - 1.41	58.50 - 58.13

Stratum	Date range	Location	Post-fieldwork monitoring	
			Depth to groundwater (range) (m bgl)	Groundwater elevation (range) (m OD)
London Clay Formation		WS03	4.10 - 5.20	55.44 – 54.34
Woolwich Formation/ Upnor Formation / Thanet Sand		BH02	3.68 - 3.81	55.55 - 55.42
		BH03	1.64 - 1.94	57.92 - 57.65
Thanet Sand Formation		BH01	9.01 – 9.13	51.34 – 51.22
		BH04	1.60 - 1.90	58.07 - 57.77
Lewes Nodular Chalk		BH05	13.07 – 13.80	46.00 – 45.27

6.3.2 Groundwater summary

In general, shallow groundwater was encountered within the River Terrace Deposits at depths of between approximately 1.0m and 1.8m bgl (equivalent to between 58.50m to 57.59m AOD). The groundwater appearing to be perched on top of the relatively impermeable underlying strata of stiff clays of the London Clay (in WS01 and WS04) or where absent the cohesive Woolwich Formation (WS02).

Deeper groundwater horizons were measured within the London Clay (at 4.1m to 5.2m bgl), Lambeth Group (1.6m to 3.8m bgl), Thanet Sand (1.6m to 9.0m) and within the Upper Chalk (at 13.0m bgl).

The groundwater encountered within the deposits lying between the gravels and the Chalk may represent localised confined groundwater conditions at these locations but could also possibly be attributed to amounts of drilling fluid being present within the bores during installation given the levels of water monitored elsewhere within the deeper Thanet and Chalk aquifer.

A similar groundwater regime was presented within the historical Arcadis ground investigation. Shallow ground water within the River Terrace Deposits and a second, deep groundwater profile at approximately 12.50m bgl. A possible perched groundwater horizon was encountered this WS102 at approximately 4.30m bgl.

In summary, owing to the variable geology across the Site and presence of significant bands of relatively impermeable clays with interbedded granular horizons throughout, the hydrogeological regime under the Site is likely to be complex leading to multi-layered groundwater conditions with localised aquicludes, aquitards and perched horizons confined within granular bands. Furthermore, the overburden of overlying consolidated clays of the London Clay and Woolwich Beds may also give rise to sub-artesian conditions within the Thanet Formation.

6.4 Ground gases (carbon dioxide and methane)

Records from the gas monitoring boreholes are presented in Appendix E and summarised in Table 6-4.

A total of nine monitoring visits have been undertaken to date across all phases of ground investigation at the site. This includes six monitoring visits undertaken by Hydrock between August and October 2020. Arcadis had previously undertaken three initial monitoring visits between August and September 2018. The monitoring programme is considered to be complete and is discussed in Section 8.6.

Table 6-4: Range of ground gas data

Stratum	Exploration Location	No. of Visits	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Steady flow rate (l/hr)
Made Ground	WS101, WS102, WS103	9	0.1 – 0.2	0.2 – 6.4	15.7 – 21.3	0.1*
River Terrace Deposits	WS01, BH104s, BH102s	11	0.1 – 0.2	0.4 – 10.9	2.5 – 20.1	0.1*
River Terrace Deposits / London Clay	WS04	6	0.0	0.1 – 4.1	2.5 – 20.1	0.1* - 4.9
London Clay	BH101, WS03	9	0.0 – 0.1	0.2 – 4.8	13.1 – 20.6	0.1
River Terrace Deposits / Woolwich Fm	WS02	6	0.0	0.2 – 3.7	12.7 – 21.1	0.1*
Lambeth Group (Woolwich and Upnor Formations)	BH02, BH102D, BH104D	11	0.0 - 0.2	0.4 – 9.6	12.8 – 20.3	0.1 - 1.7*
Upnor Formation and Thanet Sand Formation	BH03	6	0.0 – 3.2	0.4 – 1.6	12.6 – 19.8	0.1*-0.3
Thanet Sand	BH01, BH04	9	0.1 – 0.2	0.2 – 6.4	17.6-21.7	0.1* - 1.2
Lewes Nodular Chalk Formation	BH05	6	0.0 – 0.3	0.4 - 4.1	6.9 - 19.8	0.1* - 1.6
	Notes: **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.*					

6.5 Organic vapours

The PID results are provided on the logs in Appendix C. PID results significantly above background concentration are summarised in Table 6-5. Data are assessed in Section 8.6.

*Table 6-5: PID readings significantly above background during ground investigation. **

Stratum	Location	Depth (m bgl)	Reading (ppm)
River Terrace Deposits	WS01	1.90	62
River Terrace Deposits	WS02	2.20	52

*background concentration measured as 0.3-0.6ppm.

Table 6-6: PID reading significantly above background levels during groundwater monitoring.

Location	Reading (ppm)
BH01	311
WS01	11.5

6.6 Geotechnical data

6.6.1 Introduction

Laboratory test results are currently outstanding. However, the following shear strength profiles and characteristic parameters have been determined from insitu testing shown on the relevant exploratory hole logs or datasheets in Appendix C.

6.6.2 Plasticity

The volume change potentials in terms of BRE Digest 298 with respect to building near trees have been determined from the results of plasticity index tests on samples of soil. These are summarised in Table 6-7.

Table 6-7: Volume change potential

Stratum	No. of Tests	Plasticity Index			Modified Plasticity Index			Plasticity Designation	Volume Change Potential
		Mn.	Mx.	Av.	Mn.	Mx.	Av.		
Sporadic Upper Cohesive Mantle of River Terrace Deposits	1	23			*23*			Low	Non-Plastic on consideration of granular content and limited thickness
London Clay Fm	8	45*	64	52	44	64	51	Medium to High	High
Upnor Fm	2	19	27	23	19	27	23	Low	Medium
Woolwich Formation	7	28	53	37	28	52	36	Low to Medium	Medium
Thanet Sand Fm	2	-	-	-	-	-	-	-	Non-Plastic

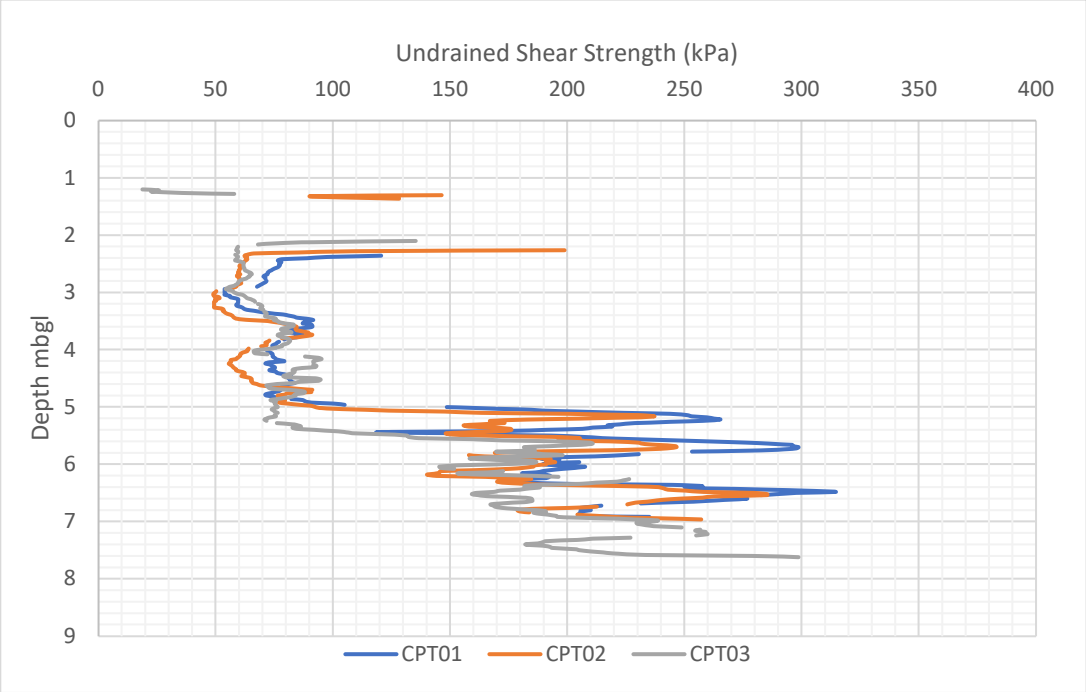
**Out of 8 tests on the London Clay Formation, one Atterberg limits test indicates a modified plasticity of 22% however this was a non-standard test and therefore the results have been discounted.*

6.6.3 Soil strength

Range of insitu Shear strength profiles through London Clay and the Woolwich Formation beneath the eastern end of the site (all terminating on the dense sands of the Upnor Formation), as determined by CPTs are illustrated below and within the lankelma CPT Report within Appendix D:

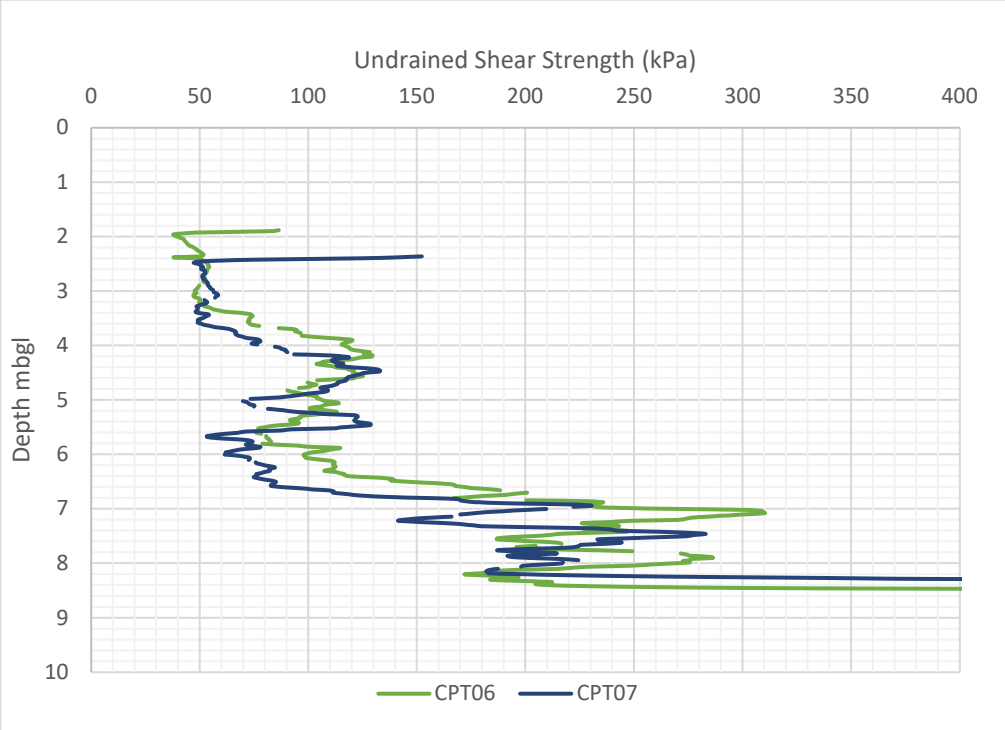
Range of insitu Shear strength profiles through the London Clay and the Woolwich Formation beneath the south eastern end of the site (all terminating on the dense sands of the Upnor Formation) as determined by CPT01, 02 and 03.

Table 6-8: Undrained Shear Strength with depth for CPT Probes CPT 01 - 03. Correlation based on Mayne & Peuchen 2018 (OC Fissured).



Range of insitu Shear strength profiles through the London Clay and the Woolwich Formation beneath the central area of the site (all terminating on the dense sands of the Upnor Formation) as determined by CPT 06 and 07.

Table 6-9: Undrained Shear Strength with depth for CPT Probes CPT 06 - 07. Correlation based on Mayne & Peuchen 2018 (OC Fissured).



Range of insitu Shear strength profiles through the London Clay and the Woolwich Formation beneath the northern central area of the site (all terminating on the dense sands of the Upnor Formation) as determined by CPT 08 and 09.

Table 6-10: Undrained Shear Strength with depth for CPT Probes CPT 08-09. Correlation based on Mayne & Peuchen 2018 (OC Fissured).

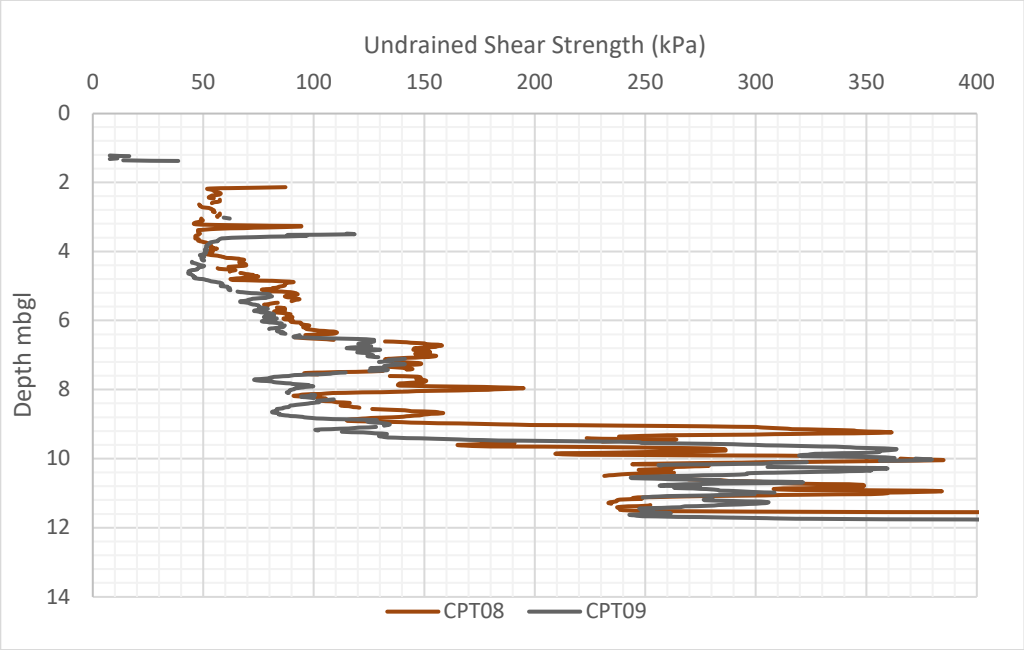


Figure 6-1: Undrained Shear Strength from SPTs - Eastern Part of Site.

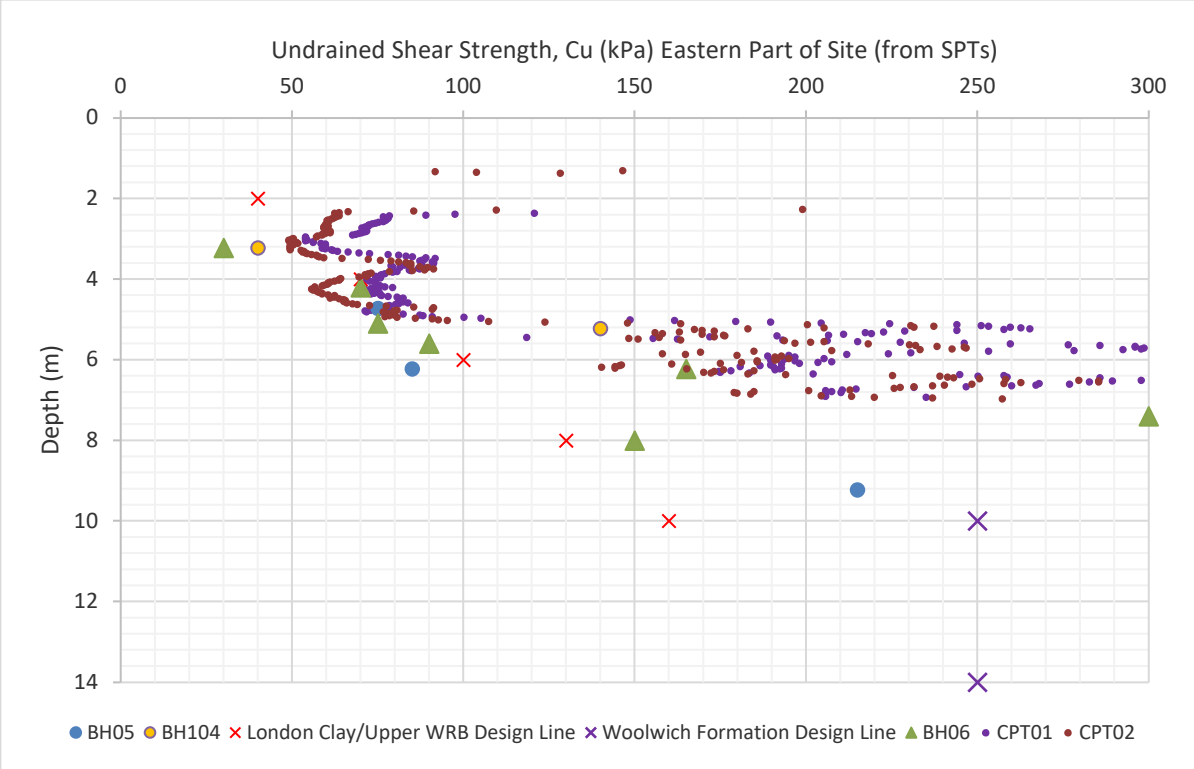


Figure 6-2: Undrained Shear Strength from SPTs - Western Part of Site.

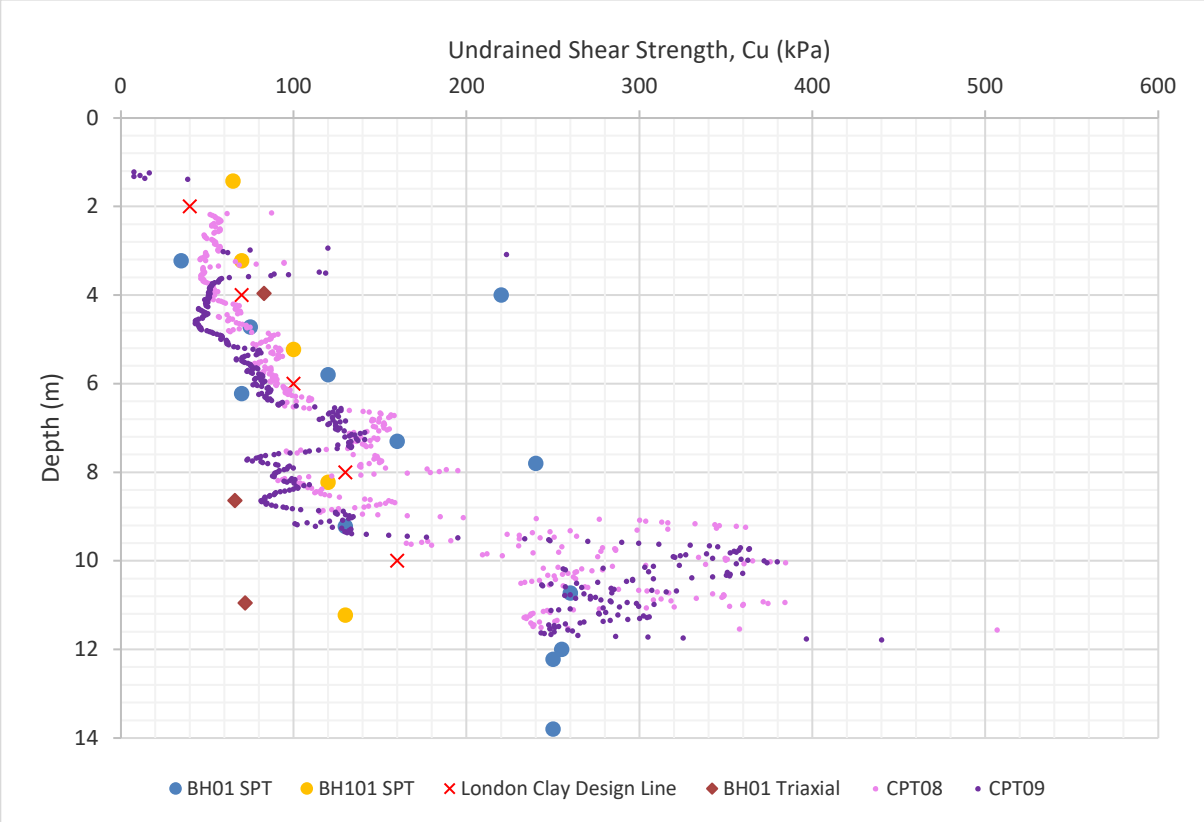
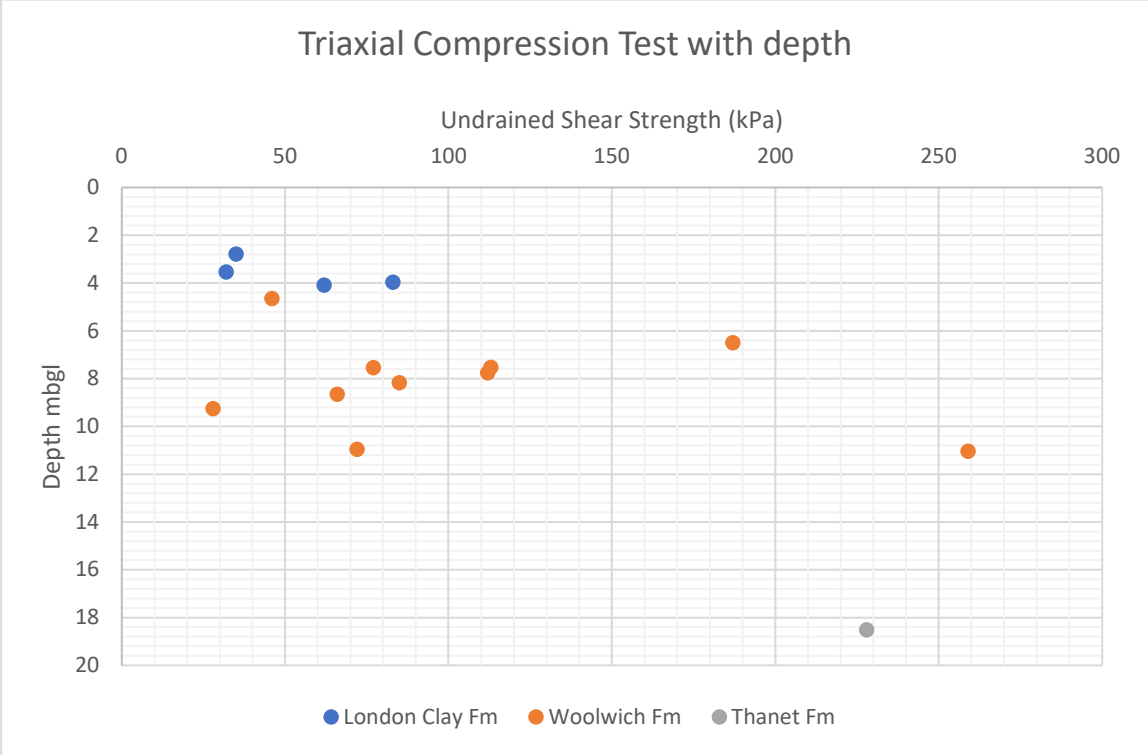
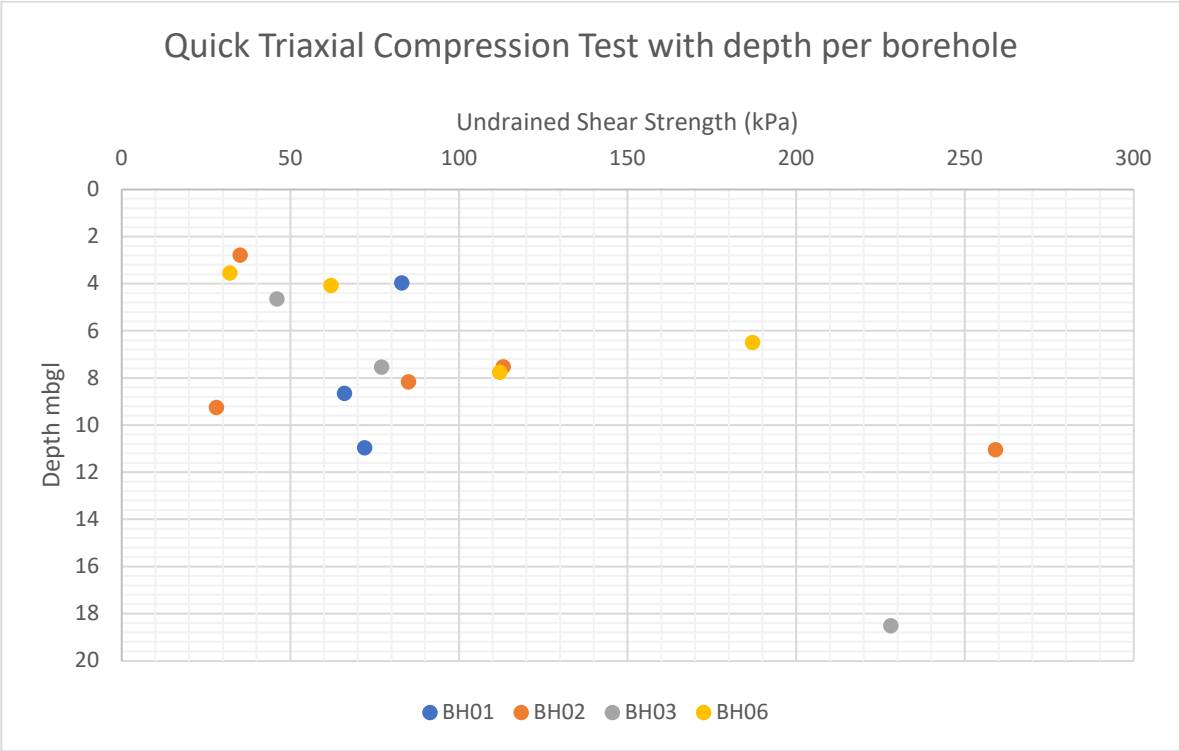


Figure 6-3: Shear Strength from Unconsolidated Quick Undrained Triaxial Compression Test. (Whole Site).



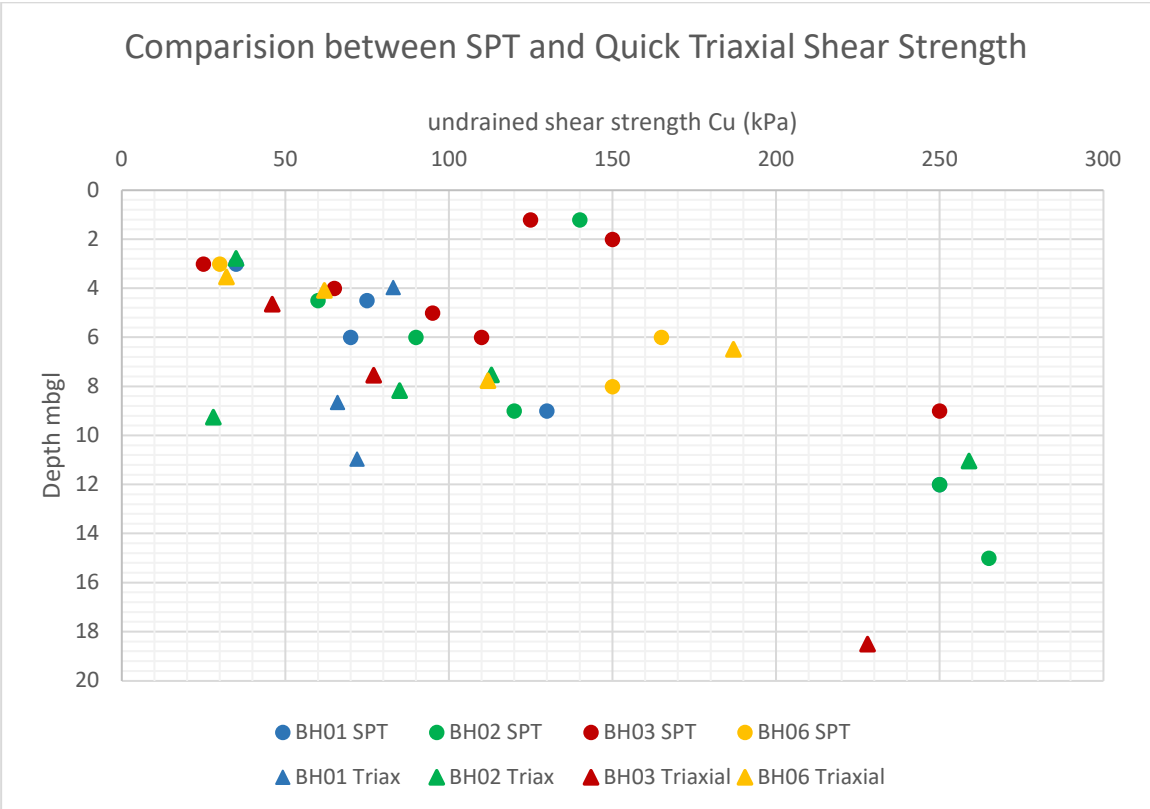
The quick triaxial testing within the London Clay show a range in undrained shear strength between 312-83 kPa. There may be a general increase in undrained shear strength with depth but this is not clear with the limited data. The quick triaxial results within the Woolwich formation show a greater range in undrained shear strength of between 28 and 259 kPa. A general increase in strength has been recorded within the Woolwich Formation.

Table 6-11: undrained Shear Strength from Quick Triaxial Test with depth per Borehole



A general increase in the undrained shear strength can be seen in all boreholes. Within the upper 10m below ground levels the undrained shear strength is generally below 150 kPa.

Table 6-12: Comparison between undrained shear strength recorded by SPT test and Quick Triaxial test.



The undrained shear strength correlated from the SPT tests and the quick undrained triaxial testing has been plotted together to show the variation between the two testing methods. Both testing methods show a general increase in undrained shear strength with depth. However, it is noted that the shear strength recorded by the quick triaxial tests were generally higher than those correlated from the SPT tests. The difference in shear strength between the two tests ranged between 2-22kPa but was on average 10kPa higher for the quick triaxial tests.

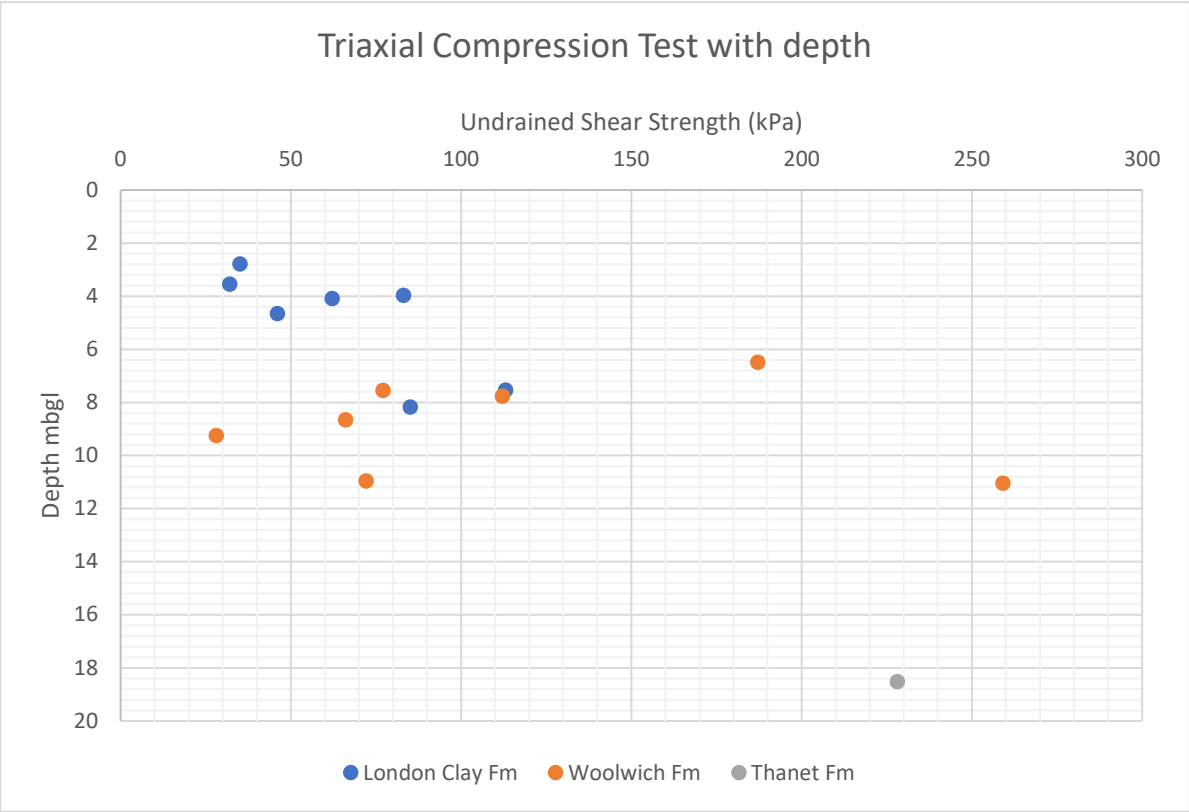
6.6.4 SPTs and Effective Angles of Shearing Resistance

Table 6-13 summarises information pertaining to the SPTs and effective angles of shearing resistance of the granular soils according to geological stratum. Factual results are appended for field tests (SPT & CPT). A SPT 'N' value versus depth profile is summarised in Figure 6.4.

Table 6-13: Relative density results and derived values

Stratum	No. of tests	Method	SPT (N-value) (Range)	phi' (°)
River Terrace Gravels	7	SPT.	5 - 30	33 - 40
Upnor Formation	4	SPT	20 - >50	33 - 36
Thanet Sands	20	SPT	41 - >50	35 - 36

Figure 6-4: SPT Depth Plot for each strata.



The data indicates that there is broadly an increasing strength with depth increasing rapidly within the Woolwich and Upnor Formation below around 6m and 10m depth and more so within the Thanet Sands below.

The River Terrace Deposits are encountered below the Made Ground and have a range in SPT N-value of between 5 and 30, but generally above 25. On account of the minimal thickness of the River Terrace Deposits no discernible trend in strength with depth can be determined from SPTs.

The SPT N-values obtained in the London Clay Formation were recorded as between 5 and 20 (low strength to high strength). The lower values occurred locally at the immediate transition from the Terrace Deposits above and generally increased rapidly to values around 10 immediately below. There is a strong increasing correlation between depth and strength of the London Clay Formation.

The London Clay Formation is underlain by the Woolwich Formation which records SPT N-values of between 20 to 50 from depths ranging between 6m bgl to 9m bgl. At depths below 9m bgl the Woolwich Formation recorded N-values of <50.

The Thanet Sand Formation was encountered from depths of 13.0m bgl. Generally, the recorded SPT N-values were <40 which classified the sands as dense. However, a lower N-value of 15 was recorded at 15m bgl. This maybe the result of an unbalanced water pressure in the borehole, hence it is likely that the in situ density is in reality much higher than indicated from the SPT.

6.6.5 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 6-14. The assessment summary sheets are presented in Appendix D.

Table 6-14: Aggressive chemical environment concrete classification

Stratum	No. tests	DS	ACEC
Made Ground	1	DS-1	AC-1
River Terrace Deposits	3	DS-2	AC-2
London Clay Formation	2	DS-2	AC-2
Woolwich Formation		DS-1	AC-1
Upnor Formation	1	DS-1	AC-1
Thanet Sand Formation	3	DS-2	AC-2

6.6.6 Chalk Testing

Table 6-15 summarises information pertaining to the density characteristics of the Chalk, based on laboratory test data.

Table 6-15: Intact rock strength results and derived values

Parameter Stratum	No. of tests	Dry Density (kg/m³)	Porosity %	Saturation Moisture Content	Dry Density (range)	Density classification (CIRIA 574)
				%	Mg/m³	
Lewes Nodular Chalk Formation	2	1640	40	24	1.63 – 1.65	Medium Density

7. GEOTECHNICAL ASSESSMENT

7.1 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 geotechnical assessment remains unchanged and does not reflect updated design information provided within the new planning application.

The proposed development comprises of two main blocks (A in the west & B to the east). Block A has 4 and 8 storey sections. To the north-west and south of the block are both 4 storey blocks. There is an area of single storey on the north of the block and 2 basements. Block B comprises of a 8-storey block in the north west and the remainder is 4 storeys. A basement is proposed in the north of the building.

Based on the above, for the purposes of this investigation, the proposed structures have been classed as Geotechnical Category 2.

Following ground investigation and as part of the assessment provided in the following section, the preliminary geotechnical hazard identification undertaken in Section 4.3 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 H (Table J.3) and will need to be updated during future design works.

7.2 Groundwork

7.2.1 Site preparation

The redevelopment will involve demolition of the existing buildings. This should be undertaken to an appropriate Specification to ensure any asset materials generated are geotechnically suitable for use.

Buried obstructions were encountered during this investigation associated with foundations of old buildings, services etc., and there is a possibility of further such obstructions being encountered.

7.2.2 Groundworks

Following breaking out of hardstanding and grubbing out obstructions, excavation of shallow soils should be readily undertaken by conventional plant and equipment.

Excavations within the Made Ground and granular River Terrace Deposits are anticipated to be unstable particularly when closer to the water table expected between 1.5m and 2.0m bgl. 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/adjoining existing roads/structures/buildings, where collapse of excavation faces could have a disproportionate effect. 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.

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).

7.3 Foundation recommendations

In accordance with EC7, BS EN 1997-1+A1 (2013), the proposed structures e.g. 4 to 8 storey buildings are considered to be Geotechnical Category 2. As such, foundation recommendations are presented to aid development proposals only and separate geotechnical design will be required.

7.3.1 Foundation Types

There is expected to be a variety of structural loads associated with the development ranging from lightly loaded walls to heavily loaded columns

7.3.2 Pad or Strip Foundations

All foundations must pass through the upper veneer of Made Ground and found in natural soils. For lightly loaded structures founded on extreme western parts of the site where Terrace Gravels are absent it can be expected that a safe net bearing capacity of 100kN/m2 can apply for strip foundations up to 1m width and pad foundations up to 3m width. Note that any pads in such conditions notionally requiring to be wider than 3m would settle beyond 25mm which is likely to be beyond the serviceability limits of a structure.

Where there are Terrace Gravels overlying natural clay deposits; a slightly enhanced safe net bearing capacity of 175kN/m2 can be achieved for pad foundations up to 2.25m width due to the load spread offered by the more granular terrace gravels. As there is often a softened stoney cohesive mantle over the upper horizon of the Terrace Gravels care must however be made to fully penetrate this weaker cohesive layer to achieve such bearing.

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.

Where there is insufficient thickness of granular stratum immediately below intended shallow foundation formations, deepening of foundations in accordance with BRE 240 and BRE 298 will be required where pad foundations are within the zone of influence of existing, removed or proposed trees and proposed shrub planting. NHBC Standards (Chapter 4.2) should also be taken into account. 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, that 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, and beneath piled ring beams and ground bearing floor slabs.

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 deepened to suitable strata.

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

Any water that collects at the base of the foundation excavations should be removed by pumping from a sump in the base.

Groundwater monitoring indicates a shallow groundwater table. Alternative methods of groundwater control (such as cut-off trenches or well pointing) may be required if fast groundwater ingress is met upon, which could result in softening of the ground and unstable excavations.

The extreme western part of the site lies over consolidated clay, which can swell and soften in contact with water. Therefore, care will be required to ensure that foundation excavations are kept as free of water as practicable. Foundation concrete should be poured as soon as practicable after excavation.

7.3.3 Piled foundations

Piled foundations are recommended for moderately to highly loaded structures and also where tree influence precludes the use of shallow strip or pad foundations.

Depending on column loads and layouts, piles should extend through the Made Ground and toe into either the London Clay, Woolwich Clay Formation or granular Upnor Formation/Thanet Sands depending on the capacity required.

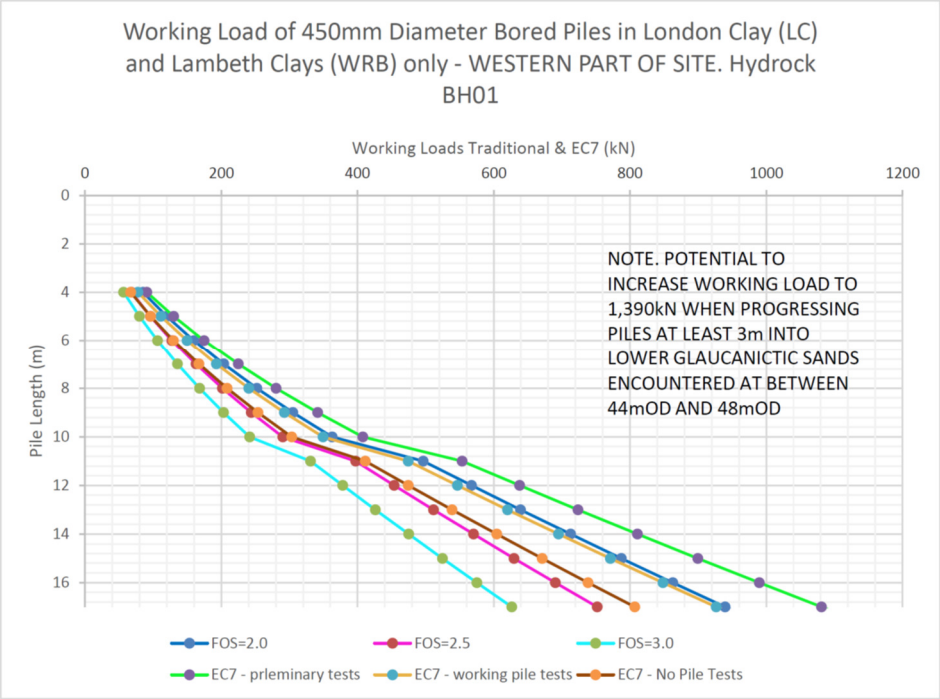
Driven piles or CFA piles should be suitable to support the foundations for the various structures. However, the choice of piling system should be undertaken by a specialist piling Contractor and the design of piles is beyond the scope of this report. The decision on pile type and design should take into account the following factors relevant to the site:

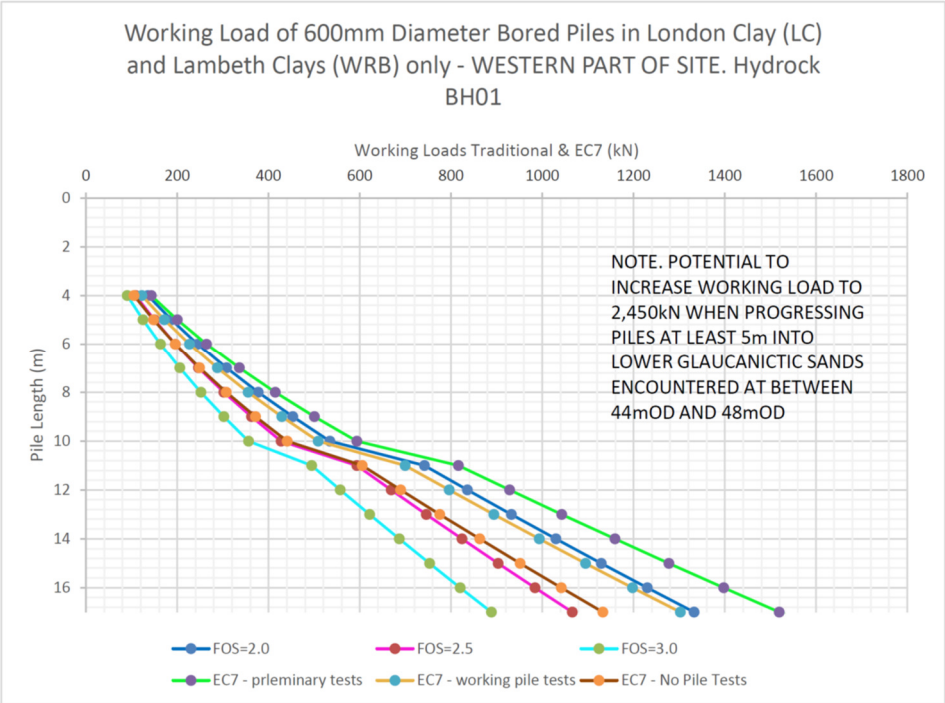
- Obstructions in the ground are expected from the previous structures, which could cause piles to stop shallower than the design depths, or to deviate from the vertical, thereby reducing their capacity. In some circumstances, obstructions can lead to pile breakage.
- Certain pile installations can create preferential pathways for the migration of contaminants to the groundwater.
- Groundwater levels are both shallow and deep. If CFA piles are used, concrete is placed as the auger is withdrawn, which can balance the water pressure if the operation is undertaken carefully.
- The groundwater in the Upnor Formation is potentially under sub-artesian pressure where it is confined by cohesive deposits, which should be taken into account in the pile design.

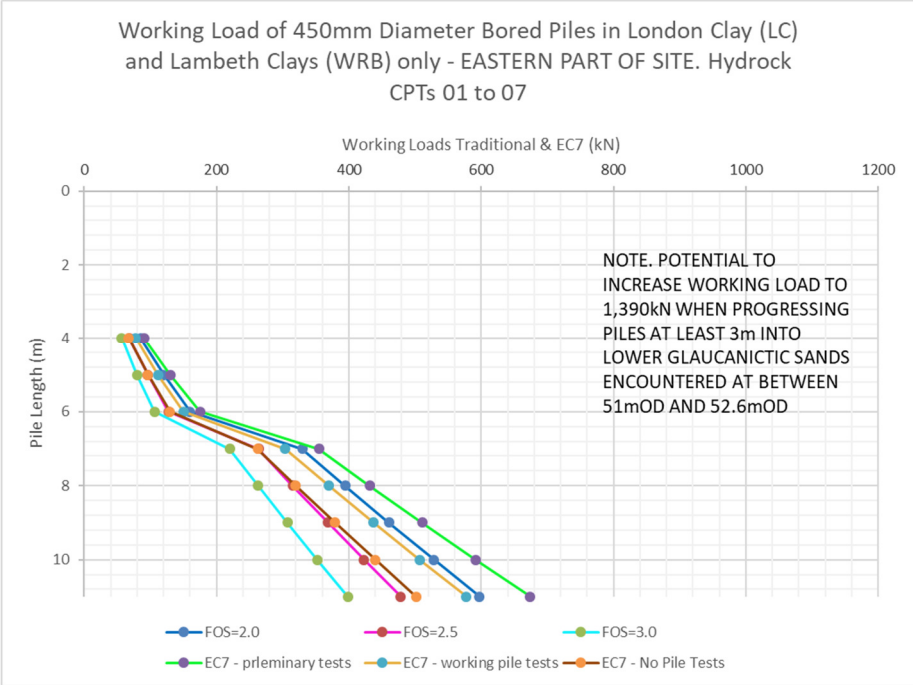
- Piles should extend a minimum of five pile diameters into the bearing stratum to mobilise sufficient shaft friction and end-bearing resistance to carry the required loads without unacceptable settlement.
- Collapse of the pile shaft can be caused by 'necking' of the pile in running sand conditions, leading to pile failure.
- Where foundations are constructed on clay soils within the influencing distance of trees design should include for the upper section of the pile to be sleeved or additional cage & pile 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.
- The production of a Piling Foundation Risk Assessment with regards to protecting the groundwater from contamination during piling is likely to be required by the EA

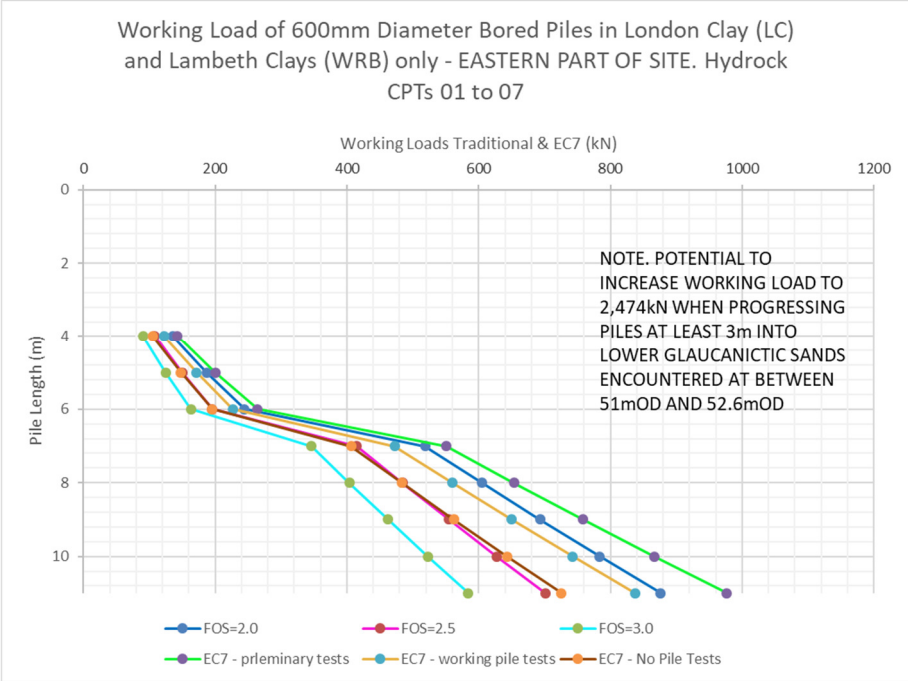
Based on the ground model and the geotechnical parameters in Section 6, the initial pile capacities for a range of pile diameters and depths are shown in the figures below. These have been calculated using both EC7 methods and traditional Lump-Sum methods by way of a comparison.

The preliminary Safe Working Loads calculated are a guide only and should not be used for design purposes. The pile design should be undertaken by a specialist based on loading criteria and the serviceability limit states provided by the structural engineer.




Working Load of 600mm Diameter Bored Piles in London Clay (LC) and Lambeth Clays (WRB) only - WESTERN PART OF SITE. Hydrock BH01
Working Loads Traditional & EC7 (kN)
0
200
400
600
800
1000
1200
1400
1600
1800
Pile Length (m)
0
2
4
6
8
10
12
14
16
NOTE. POTENTIAL TO INCREASE WORKING LOAD TO 2,450kN WHEN PROGRESSING PILES AT LEAST 5m INTO LOWER GLAUCANICTIC SANDS ENCOUNTERED AT BETWEEN 44mOD AND 48mOD
FOS=2.0
FOS=2.5
FOS=3.0
EC7 - prleminary tests
EC7 - working pile tests
EC7 - No Pile Tests


Working Load of 450mm Diameter Bored Piles in London Clay (LC) and Lambeth Clays (WRB) only - EASTERN PART OF SITE. Hydrock CPTs 01 to 07
Working Loads Traditional & EC7 (kN)
0
200
400
600
800
1000
1200
Pile Length (m)
0
2
4
6
8
10
NOTE. POTENTIAL TO INCREASE WORKING LOAD TO 1,390kN WHEN PROGRESSING PILES AT LEAST 3m INTO LOWER GLAUCANICTIC SANDS ENCOUNTERED AT BETWEEN 51mOD AND 52.6mOD
FOS=2.0
FOS=2.5
FOS=3.0
EC7 - prleminary tests
EC7 - working pile tests
EC7 - No Pile Tests



7.3.4 Raft foundations incorporating settlement reducing piles

As an alternative to piled foundations for those blocks where moderately high columns are expected, consideration to forming these on raft foundations supported over shorter settlement reducing piles or concrete columns could also be made. The design of such foundations is outside the scope of this report and would need to form part of a separate Geotechnical Design Report if deemed potentially viable.

7.4 Working platform

For piling, a working platform will be required prior to the arrival on site of tracked plant. This should be designed and installed in accordance with BR470 (BRE 2004) based on data on the piling plant in accordance with an FPS certificate for the rig loadings. For initial preliminary budgeting purposes; consideration of the possibility of requiring an unreinforced compacted Class 6F granular piling mat of 900mm thickness with terram 1000 geofabric separator layer can however be made based upon a typical heavy CFA rig (Soilmech CM120). Once the actual rig and track bearing pressures are known Hydrock can facilitate the final design of the working platform (unreinforced or reinforced) for tracking and working areas.

7.5 Roads and pavements

Proposed pavements are likely to be constructed off the Made Ground and/or the upper cohesive and weathered zones of the Terrace Deposits the stiffness of this will determine the required pavement construction thickness. The Made Ground has been found to be variable and shallow natural soils cohesive and often soft to firm. A CBR of 2.5% should therefore be assumed for initial design, subject to undertaking confirmatory testing.

7.6 Ground Floor Slab

As Made Ground is greater than 600mm thick and there is considered to be a volume change potential risk present on the site in areas underlain by cohesive deposits within the influence of trees. It is recommended that suspended floor slabs should be adopted in accordance with NHBC Standards.

The Made Ground underlying the site has a variable composition but from previous testing undertaken by Arcadis would in the main be considered as non-plastic in terms of shrink-swell potential due to the high granular content. Due to the inherent variability of the Made Ground it is perceived to have irregular compressible qualities. It is therefore not suitable to support a ground floor slab on these materials without reworking or stabilising them into a uniform engineered stratum.

Observations and test results indicate that there is an upper clayey mantle associated with the underlying River Terrace Deposits in some areas. The clay fraction of this is shown be of medium volume change potential. However, on consideration of the high granular content and the results of previous plasticity tests undertaken by Arcadis on this stratum, it would be considered as essentially non-plastic in terms of shrink-swell potential. This feature appears to be absent in many areas and also, where encountered is relatively thin (around 500mm thickness). It is considered therefore that should a more plastic horizon be encountered its influence with regards to shrink/swell due to seasonal or tree influenced moisture changes would be negligible and heave protection is not needed in this regard. The strength and depth of this clayey mantle however does not render it suitable for directly supporting ground bearing floor slabs.

7.7 Buried concrete

Based on the guidelines provided in the BRE Special Digest (BRE 2005) and the information presented in section 6.6.5, testing of the shallow soils of the River Terrace Gravel deposits and the underlying London Clay Formation indicate these soils are classified as Design Sulfate Class DS-2 and ACEC Class AC-2. In addition, the deeper soils of the Thanet Sand Formation are also classed as DS -2 and ACEC Class AC-2. Therefore, it is considered that that this should be used as a minimum class for all buried concrete.

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

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8. GEO-ENVIRONMENTAL ASSESSMENT

8.1 Updated conceptual model

8.1.1 Updated ground model

The preliminary ground model developed from the desk study and field reconnaissance survey (Section 3) has been updated using the findings of the ground investigation and is presented in Sectio n 6. This ground model is the basis for the geo-environmental assessment presented in this section.

8.1.2 Updated exposure model

Following the ground investigation, the plausible contaminant sources, receptors and pathways identified in the preliminary geo-environmental exposure model (Section 4), have been updated or confirmed as follows.

Sources

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

Receptors

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

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.

8.2 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 5 together with any reliable data from previous investigations (Arcadis, 2018) as listed in Section 2.

In cases where unacceptable risks are indicated, actions such as more advanced stages of risk assessment or remediation are proposed in Section 8.11.

8.3 Human health risk assessment

This is a Tier 2 assessment using soil screening values applicable to public open space (residential) 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 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 F.

8.3.1 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 and natural soils.

8.3.2 Risk estimation (including statistical testing)

The data set for each chemical determinand has been assessed for potential outliers (based on the conceptual model). No outliers have been removed.

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.

Based on a US_{95} exceedance of the GAC, the pervasive chemicals of potential concern which require further assessment are summarised in Table 8-1.

Table 8-1 (Hydrock)Pervasive chemicals of potential concern for which further assessment is required (human health)

Chemical of potential concern	Generic criterion (mg/kg)	Basis for generic criterion	No. samples	Min. (mg/kg)	Max. (mg/kg)	US_{95} (mg/kg)	No. samples exceeding generic criterion
Hydrock (Ground Investigation June 2020)							
Made Ground							
Benzo(a)pyrene	2.6	GAC	22	0.05	24	10.334	6
Natural Ground - No Exceedances							

Table 8-2: (Arcadis)Pervasive chemicals of potential concern for which further assessment is required (Human Health).

Chemical of potential concern	Generic criterion (mg/kg)	Basis for generic criterion	No. samples	Min. (mg/kg)	Max. (mg/kg)	US_{95} (mg/kg)	No. samples exceeding generic criterion
Arcadis (Ground Investigation September 2018)							

Chemical of potential concern	Generic criterion (mg/kg)	Basis for generic criterion	No. samples	Min. (mg/kg)	Max. (mg/kg)	US_{95} (mg/kg)	No. samples exceeding generic criterion
Made Ground							
Benzo(a)pyrene	2.6	GAC	11	0.05	10	10.334	2
Natural Ground - No Exceedances							

Benzo(a)pyrene is present in the Made Ground with a US_{95} of 7.77mg/kg, which is a significant exceedance of the GAC (2.6mg/kg). Benzo(a)pyrene (BaP) was encountered within eight locations at levels exceeding the GAC, these include, WS02, CPT01, CPT04a CPT07, CPT 10, BH03 from the Hydrock investigation and BH102 from the Arcadis investigation. The greatest concentrations of BaP were encountered in CPT01 (24mg/kg) and CPT04a (21mg/kg) along the southern site boundary.. Minor exceedances were recorded within BH102, BH03, WS02 and CPT10 around the Energy Centre, as well as CPT10 in the south.. A minor exceedance is recorded within WS02 located close to the boiler room. This exceedance is contributed to ash encountered between the layers of hardstanding. Therefore, it is likely that this hotspot will be removed as part of the removal of hardstanding across the site.

Statistically Lead is not considered to be a contaminant with a US_{95} of 393 mg/kg compared to a GAC of630mg/kg. However, three elevated concentrations of lead were located in exploration locations CPT01, CPT02 and CPT10 at concentrations of between 660mg/kg and 760mg/kg. Due to the localised area where elevated lead has been identified and knowledge that this area shall ultimately be covered by the new building footprints it is considered that further assessment of this is not warranted.

Minor exceedances of BaP and Lead have both been encountered on the south and south west of the site around Woodcote Lodge and Rowen House. Historically these was a row of residential properties with outbuilding and gardens aligned along Woodcote green Road. The majority were demolished in the 1950s for the construction of Rowan house, with further demolition and redevelopment in the 1990-2000s for the current Woodcote Lodge. It is possible that a potential source of contamination may have been disturbed and spread around this area of the site during the redevelopment works.

Asbestos

Visual evidence of Asbestos Containing Materials (ACM) was encountered within one location (CPT08 at 0.35m bgl) in the form of suspected asbestos cement sheeting.

In addition, asbestos fibres were identified during laboratory testing of soil samples as listed in Table 8-3, below.

Table 8-3: Asbestos in soil samples (laboratory testing)

Location	Depth (m bgl)	% Asbestos (w/w)	Comment
WS03	0.7	0.006	Chrysotile
BH03	0.3	0.001	Chrysotile
CPT02	0.6	0.018	Chrysotile & Amosite & Crocidolite
CPT07	0.3	0.012	Chrysotile & Amosite
BH03	0.3	0.001	Chrysotile

Location	Depth (m bgl)	% Asbestos (w/w)	Comment
WS102	0.8	<0.001	Chrysotile
BH102	0.2	0.011	Chrysotile
BH102	0.8	<0.001	Chrysotile

Petroleum hydrocarbons (PHC) and volatile Organic Compounds (VOCs)

Targeted samples of soils (based on visual/olfactory evidence of contamination and PID reading) were collected from around the Energy Centre.

No exceedances of petroleum hydrocarbons were recorded when the results were compared against the GAC for public open space residential land use scenario. However, minor concentrations of Aromatic EC12-EC16 and EC16-35 were recorded within WS01, WS02, WS101 and BH02 (E16-35 within BH102 only at 79mg/kg). The greater concentrations were encountered within the River Terrace Deposits in WS01 and WS02. A maximum concentration of petroleum hydrocarbons was recorded within the River Terrace Deposits of 3,170mg/kg within the TPH Aliphatic >C16-C35 band of WS01 in the vicinity of the Energy Centre. Within BH102 the highest concentrations were within the TPH Aromatic >C21-35 band at 440mg/kg, which is also in the vicinity of the Energy Centre.

8.3.3 Risk evaluation

The screening exercise has identified asbestos, lead and benzo(a)pyrene in Made Ground at concentrations which are considered to be detrimental to human health although not necessarily above the GAC. The majority of these exceedances were encountered on the southern half of the site around Woodcote Lodge and Rowen House. It is considered that the Made Ground in this area of the site is more pervasively contaminated. Further assessment is required.

The phrase 'further assessment' does not necessarily mean that the soil is 'contaminated' or not fit for use.

Asbestos

There have been eight exploratory hole locations where asbestos fibres (between<0.001% v/v and 0.18% v/v for chrysotile, amosite and crocidolite). In addition, suspected Asbestos containing Material has been identified in one location.

Hydrock consider it plausible for asbestos to be present in any of the Made Ground soils across the whole of the site. Asbestos, (even at low concentrations), represents an unacceptable risk and robust mitigation measures will be required.

Petroleum hydrocarbons

Petroleum hydrocarbon concentrations do not exceed the GAC for the proposed end use scenario of residential public open space. However, there is still considered to be an elevated concentration which may results in a hydrocarbon odour and further assessment is recommended.

Elevated concentrations of petroleum hydrocarbons were largely absent, with the exception of WS01, WS02 and BH102, in close proximity to the Energy Centre. Most notably, elevated concentration of TPH, predominantly within the C12-C35 range where recorded within WS01 and WS02 at 1.90m bgl

and 2.20m bgl These locations are located to the east of above ground diesel tanks and south-east of the boiler room. Elevated concentrations of Petroleum Hydrocarbons were also recorded within the Arcadis Ground Investigation report 2018, within BH102 which is located in a similar area to WS01 and WS02.

Given similar findings of the previous investigation and observation of localised staining/spills in the vicinity, the presence of petroleum Hydrocarbons is considered to be the result of the operation of the Energy Centre or associated spills / leaks.

Volatile organic compounds - groundwater (dissolved phase)

The risks to human health arising from vapours in dissolved phase groundwater have been assessed in accordance with the SoBRA GAC. This is a preliminary approach whereby GAC have been developed using the CLEA v7.01 model for indoor air and outdoor inhalation pathways only, assuming a residential or commercial end-use.

A review of the groundwater screening values, indicate that the GAC for TPH Aliphatic >EC10-EC12 of 37ug/l is exceeded within the shallow perched groundwater of WS02 (of 130ug/l). However, given the isolated exceedance and that the proposed redevelopment will remove the contaminant source (Energy Centre), Hydrock considers that it is not a significant risk.

Given that almost all of the human health risk from vapours is attributed to indoor air pathways, the installation of a suitable VOC vapour resistant barrier membrane will also mitigate this risk.

A vapour resistant membrane will be required within the vicinity of the current energy centre where the petroleum Hydrocarbon hotspot has been located. The migration of vapours is generally considered to be vertical, up through the River Terrace Deposits and Made Ground, but it is also plausible that vapours could become 'trapped' beneath the existing hardstanding and thus move laterally, find and follow a preferential pathway (eg. gravel around a service run, piles etc), or move laterally through porous geological discontinuities. The risk of vapour intrusion to a building will reduce the further away it is from the source. For buildings immediately over the contamination hot-spot, the protection system installed would need to provide adequate venting beneath, or around the building as part of the protection measures installed.

The requirement for a vapour resistant membrane may be removed via:

- The derivation of site-specific acceptability criteria for vapours in a DQRA considering parameters such as the proposed building type, depth to groundwater, foundation and soil types, and/or
- The collection and assessment of vapour samples, compared against the relevant criteria.
- Removal of the contamination hot-spot / impacted groundwater as part of the demolition and remediation activities.

8.4 Plant life risk assessment

8.4.1 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 F. 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.

Based on a US_{95} exceedance of the GAC, there are no chemicals of potential concern and therefore, no further assessment is considered necessary.

8.4.2 Risk evaluation

The are no substances at concentrations which would be considered to be a risk to plant life. However, there is no near surface material which is considered to be a suitable growing medium. Therefore, it is necessary for all topsoil for use within the landscaping areas should be imported to site. Guidance should be sought from the landscaping architects regarding the requirements for imported growing medium.

8.5 Pollution of controlled waters risk assessment

8.5.1 Risk estimation

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

Site contaminant loadings are compared with relevant screening values (Water Quality Targets), which are linked to the Conceptual Model.

Acceptable WQT are defined for protection of human health (based on Drinking Water Standards (DWS)) and for protection of aquatic ecosystems (Environmental Quality Standards (EQS)). The assessment is presented in Table 8-4 below, with the justification for the scenarios selected explained in the following text:

- The hydrogeological conditions beneath the Site are quite complex and multi-layered groundwater horizons are present. It is inferred that shallow perched groundwater is present within the River Terrace Deposits and is separated from the underlying groundwater horizons by substantial bands of relatively impermeable silts/clays of the London Clay and Woolwich Beds. As such vertical connectivity between shallow and deeper groundwater is unlikely or at least water movement is significantly retarded.
- The deeper groundwater encountered within the Glauconitic sands of the Lambeth Group, Thanet Sand Formation and Lewes Nodular Chalk Formation are considered likely to be in hydraulic continuity to a certain degree.
- Currently the nearest surface water is a pond (and associated drainage) located 25m to the south-east, but is considered to be hydraulically upgradient of the Site. This pond has been present on historical maps since 1840.

Table 8-4: Summary of water quality risk assessment protocol

Hydrock scenario	Water body receptors	Secondary receptors	Example contaminant linkages	RTM level and data used	Water quality targets
D	Groundwater. Surface water.	Aquatic ecosystem.	Contaminants from site leach or seep into a groundwater body that is a potential source of water for human consumption. Ground may feed inland surface water by base flow. The surface water may be an aquatic ecosystem.	RTM Level 2 - Groundwater.	DWS EQS (inland)

Hydrock scenario	Water body receptors	Secondary receptors	Example contaminant linkages	RTM level and data used	Water quality targets

Notes:

Some EQS are water hardness dependent. This is measured either in the receiving surface water or in groundwater (if it is part of the pathway), or is estimated from national maps.

Inland waters EQS applicable to freshwater, 'other' waters EQS applicable to coastal or transitional waters.

This table and the results of the assessment are considered as a first screening for potential risks of pollution of Controlled Waters. More specific requirements may be stipulated by the relevant Agency.

The results of the screening assessment are presented in Appendix F and are summarised in Table 8-5.

There are no WQT for petroleum hydrocarbons in water. Consequently, Hydrock has calculated risk-based guidelines for drinking water based on a methodology proposed by the WHO and using the tolerable daily intakes for the various TPH fractions as used in the derivation of the soil GAC. The results are included in Table 8-5.

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

Table 8-5: Chemicals of potential concern for which further assessment is required (controlled waters)

Chemical of potential concern	Basis for water quality target	Water Quality Target (ug/l)	Max. (µg/l)	No. samples exceeding WQT
Hydrock (Ground Investigation June 2020)				
Shallow Groundwater (River Terrace Deposits)				
Arsenic	DWS	10	17.5	1
Cadmium	EQS	0.08	1.3	1
Cobalt	EQS	3	6.9	5
Copper	EQS	1	5,4	4
Nickel	EQS	4	14	5
Manganese	EQS & DWS	123 / 50	5500	6
Selenium	DWS	10	26	1
Zinc	EQS	10.9	220	1
Ammonium	DWS	500	2.700	4
Ammoniacal Nitrogen (as N)	EQS	300	2,100	4
Sulphate	EQS & DWS	400,000 / 250,000	2,520,000	2
Phenol	EQS	7.7	9.3	4
TPH CWG Aliphatic >C10-C12	Hydrock DWS**	50	130	1
TPH CWG Aliphatic >C12-C16	Hydrock DWS**	50	1,600	2
TPH CWG Aliphatic >C16-C35	Hydrock DWS**	1,000	8,200	1
TPH CWG Aromatics >C10-C12	Hydrock DWS**	20	230	2
TPH CWG Aromatics >C12-C16	Hydrock DWS**	20	460	2
TPH CWG Aromatics >C16-C21	Hydrock DWS**	15	800	2

Chemical of potential concern	Basis for water quality target	Water Quality Target (ug/l)	Max. (µg/l)	No. samples exceeding WQT
TPH CWG Aromatics >C21-C35	Hydrock DWS**	15	210	1
Deep Groundwater (Lambeth Group, Thanet Sand Fm, Lewes Nodular Chalk)				
Cobalt	EQS	3	160	4
Copper	EQS	1	3.9	9
Manganese	EQS & DWS	123 / 50	800	8
Nickel	EQS & DWS	160	220	6
Ammoniacal Nitrogen (as N)	EQS	300	330	1
Bromate	DWS	10	38	3
Sulphate	EQS & DWS	400,000 / 250,000	1,140,000	4
Phenol	EQS	7.7	9.1	2

Note: The maximum recorded value is compared with the water quality target

** The Water Supply Regulations 1989 and the Private Water Supply Regulation 1991 both contain a prescribed concentration of 10µg/l for "dissolved or emulsified hydrocarbons (after extraction with petroleum ether); mineral oils". This was removed when the Regulations were updated in 2000 (consolidated 2007) and 2009, respectively. However, 10µg/l is used in this report as an initial screening assessment as it is frequently the preferred approach of the Environment Agency.*

*** Hydrock calculated DWS for petroleum hydrocarbon fractions based on WHO methodology.*

Chemical of potential concern	Basis for water quality target	Water Quality Target (ug/l)	Max. (µg/l)	No. samples exceeding WQT
Arcadis (Ground Investigation September 2018)				
Shallow Groundwater (River Terrace Deposits)				
Copper	EQS	1	2.4	1
Nickel	EQS	4	4.8	1
TPH CWG Aliphatic >C12-C16	Hydrock DWS**	50	260	1
TPH CWG Aliphatic >C16-C35	Hydrock DWS**	1,000	480	1
TPH CWG Aromatic >C8-C10	Hydrock DWS**	20	87	1
TPH CWG Aromatics >C10-C12	Hydrock DWS**	20	430	1
TPH CWG Aromatics >C12-C16	Hydrock DWS**	20	1,500	1
TPH CWG Aromatics >C16-C21	Hydrock DWS**	15	1,000	1
Deep Groundwater (Lambeth Group, Thanet Sand Fm)				
Copper	EQS	1	3.6	2
TPH CWG Aliphatic >C12-C16	Hydrock DWS**	50	140	1
TPH CWG Aliphatic >C16-C35	Hydrock DWS**	1.000	200	1
TPH CWG Aromatics >C10-C12	Hydrock DWS**	20	410	1
TPH CWG Aromatics >C12-C16	Hydrock DWS**	20	770	1
TPH CWG Aromatics >C16-C21	Hydrock DWS**	15	640	1

Note: The maximum recorded value is compared with the water quality target

Chemical of potential concern	Basis for water quality target	Water Quality Target (ug/l)	Max. (µg/l)	No. samples exceeding WQT
** The Water Supply Regulations 1989 and the Private Water Supply Regulation 1991 both contain a prescribed concentration of 10µg/l for "dissolved or emulsified hydrocarbons (after extraction with petroleum ether); mineral oils". This was removed when the Regulations were updated in 2000 (consolidated 2007) and 2009, respectively. However, 10µg/l is used in this report as an initial screening assessment as it is frequently the preferred approach of the Environment Agency.*				
*** Hydrock calculated DWS for petroleum hydrocarbon fractions based on WHO methodology.*				

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

In addition, the chemical suite undertaken as part of the Arcadis ground investigation screened for a smaller suite of chemicals. Therefore, while fewer metal exceedances were encountered during initial groundwater monitoring (September 2018) this is considered to be the results of testing suite and not a less contaminated groundwater.

8.5.2 Risk evaluation

Numerous elevated concentrations of metals have been recorded in exceedance of the WQT within the shallow perched groundwater, however the majority are of minor exceedance only and given the remoteness and upgradient location of the nearest surface water receptor and unlikely to represent a significant risk. Concentrations of ammonium / ammoniacal nitrogen are also locally elevated with the shallow groundwaters across both sampling rounds.

The 2018 Arcadis ground investigation reported similar heavy metal contaminations. The source of this contamination is unknown and may originate from an offsite source or be historic and (which has since been removed). Hydrock consider the likelihood of the contamination being from the Made Ground to be low on account of the hardstanding which covers the majority of the site and minimal evidence of elevated cobalt, copper, nickel, manganese or zinc within the Made Ground sampled. Hydrock do not consider these minor exceedances to pose a risk to controlled waters given the distance from the site.

Of particular note, are concentrations of petroleum hydrocarbons within the shallow groundwater. These are typically within the Aliphatic / Aromatic >C10 – C35 range, with the maximum recorded concentration of 8,200ug/l within the Aliphatic >C16-C35 range in groundwater of WS02. This includes a total TPH of 11,470ug/l within the same borehole (WS02) during the first sampling round on 12/08/2020. However, during a later sampling round, concentrations have significantly reduced to trace levels, whereas WS01 reports a total concentration of TPH of 950ug/l (within the Aromatic >C10 – C21 range). A further round of sampling and testing would be required to assess this further.

Concentrations of petroleum hydrocarbons within the deeper groundwater are all recorded at less than the laboratory limit of detection in all samples. Thus demonstrating that concentrations of TPH are not vertically migrating from the shallow groundwater to deeper groundwater horizons below.

Borehole WS01 is located adjacent to the above ground storage tank next to the energy centre/ boiler house. In addition, the petroleum hydrocarbon range encountered is considered to be consistent with diesel and/or historic weathered heavy end hydrocarbons. This is most likely attributable to a diesel spill / leakage during operation of the Energy Centre.

Groundwater results from BH102D have been excluded from further assessment. The historic ground investigation undertaken by Arcadis in 2018 recorded an elevated concentration of Petroleum Hydrocarbons within a sample collected from the deep response zone (12-15m bgl) within BH102. However, no elevated concentrations of Petroleum Hydrocarbons where recorded within any of the deep groundwater monitoring installations within Hydrock boreholes BH01, BH02 and BH03. Hydrock do not consider the hydrocarbons to have migrated into any deeper groundwater. As such it considered probable that the migration is the result of a poor environmental seal between the two response zones.

As part of the enabling phase of work the Energy Centre will be demolished which will remove the contaminant source.

It is recommended that additional investigation is completed post-demolition within current footprint of the Energy Centre to fully delineate any potential contamination and as necessary subsequently any hot-spot identified. Any grossly contaminated Made Ground and natural soils below should be removed and suitably disposed of off-site. An excavation to just below the shallow water table within the hydrocarbon hotpot should be excavated to provide a sump to remove any significant free phase diesel (by simple absorption using hydrophobic towelling).

Based on the proposed development layout, the hotspot is anticipated to be located below a building and therefore there is minimal risk from surface water leaching through the contaminated ground and therefore the hotspot is unlikely to migrate horizontally or vertically. The removal of the energy centre, above ground fuel storage tank and any grossly contaminated Made Ground and free-phase hydrocarbons is considered to offer a significant betterment to the current situation.

Further assessment is required to assess the potential pathway presented by piling and the risk to the deeper aquifer below the site. As such a Piling Foundation Works Risk Assessment should be considered as part of a Remedial Method Statement (RMS).

8.6 Ground gases risk assessment

Hydrock has undertaken a total of six ground gas monitoring visits between August and October 2020 as part of the current investigation. Previously, Arcadis had completed three rounds between August and September 2018.

The site is underlain by a layer of Made Ground which ranges in thickness between 0.60 and 1.90m. The majority of the Made Ground is believed to have been derived from demolition works on the site. Therefore, the risk of organic material within the Made Ground is considered to be low. In addition, only limited anthropogenic material was noted within the Made Ground during the ground investigation.

Within the desk study assessment a former pond is noted to be present approximately 38m to the north east of the site between 1897 and 1912. Given the age, distance and size of this feature it is a low risk of gas generation.

8.6.1 Data

It is judged from the available evidence that the gas generation potential at the site is low (due to absence of gas generating sources on the site) and that the sensitivity of the development is moderate (due to proposed developments of for apartments). Consequently, and in accordance with CIRIA C665 (Table 5.5a and 5.5b), an appropriate minimum monitoring regime is 6 readings over 2 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 the required six monitoring visits , as such the conclusions presented below are considered to approximate the worse-case conditions.

8.6.2 Assessment

The risks associated with the ground gases methane (CH_4) and carbon dioxide (CO_2) have been assessed using BS 8485:2015 +A1:2019, which cites the guidelines published by CIRIA (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[1]) in Appendix D with the published table (CIRIA Table 8.5) and the assessment is summarised in Section 8.6. The assessment is presented in Appendix E.

The measured worst-case Carbon Dioxide concentration is 10.9% v/v and occurs within WS01. Carbon dioxide concentrations were consistently recorded at >5% within WS01, but with the exception of single occasions in each of BH02, BH04, WS02, WS03, BH102D and WS101 was typically <5% elsewhere. A worst-case methane concentration of 1.5% v/v and 3.2% v/v was recorded in BH03 on two occasions. All other methane concentrations were <1%. Recorded gas flow rates were typically below the gas analyser's limit of detection (<0.1 l/hr), however were occasionally raised on single isolated occasions in BH02 (1.7l/hr), BH04 (-1.2l/hr), BH05 (1.6 l/hr) and WS04 (4.9l/hr).

During the Arcadis ground investigation in 2018 the maximum recorded concentrations of Methane and Carbon Dioxide were 0.2%v/v and 7% v/v respectively. However, carbon dioxide concentrations were typically <5% v/v.

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 CLR11 and latterly LCRM. The modified Wilson and Card assessment has been used by comparing the maximum gas concentrations and gas screening values (GSV[2]) in Appendix D with the published table (CIRIA Table 8.5, reproduced below as Table 5.4) and the assessment is summarised in Table 8-6.

Table 8-6: Ground gas risk assessment

	Min	Max	Typical	Comment
Steady Flow Rate (l/hr)	0.0	4.9	<0.1 *(at LoD)*	The gas flow rate was typically recorded at less than the limit of detection of the gas analyser (0.1l/hr). However, occasion, but isolated peaks were recorded locally, up to 4.9l/hr.

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

	Min	Max	Typical	Comment
Methane (%)	0.0	3.2	<0.2%	Methane concentrations typically less than limit of detection or trace only (<0.3%). Localised peaks of 1.5% and 3.2% v/v recorded in BH03 on two separate occasions.
Carbon Dioxide (%)	0.0	10.9	<5%	Carbon dioxide concentrations typically <5%, but consistently >5% in WS01 and locally raised on occasion elsewhere.
Oxygen (%)	2.5	21.3	>15%	Oxygen concentrations are locally depleted in BH02, BH03, BH05 & WS01, with minimum recorded concentration of 2.5% in WS01. Typical concentrations are >15% elsewhere
GSV (based on maximum flow and concentration per hole)				
Carbon Dioxide GSV (l/hr)	0	0.1632	<0.07	All readings below GSV of <0.07, with exception of single occasion with. maximum GSV of 0.1632 recorded on BH02. Suggestive of CS1 conditions overall
Methane GSV (l/hr)	0	0.0096	<0.07	Maximum GSV of 0.0096 recorded on one occasion in BH03. All GSV <0.07 suggestive that CS1 conditions are prevalent.
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.				

As indicated in Section 6.4, the computed GSV for carbon dioxide and methane indicates CS1 conditions are prevalent. In addition, methane and carbon dioxide concentrations are 'typically' below 1% and 5% respectively. As such, the site is classified as Characteristic Situation 1 (Situation A).

However; with reference to BS 8485 Code of Practice for the design of protective measures for methane and carbon dioxide for new buildings, where carbon dioxide has concentrations of greater than 5% v/v, consideration should be given to assigning a Characteristic Situation 2 (Low Risk). However, on account that gas flows are typically trace and the recorded gas concentrations summarised in Table 8-6, this approach is considered to be over conservative and a CS1 approach is recommended.

8.7 Volatile organic compounds

Elevated VOCs where encountered during the ground gas and groundwater monitoring visits within BH01 at 311 ppm as a peak reading before falling rapidly to 0ppm. Low levels of VOCs and SVOCs were locally detected within WS01 and WS02 during the ground investigation. Within WS01 and WS02 hydrocarbon staining was noted on the retrieved core sample and corresponded within these elevated VOC readings. However, within BH01 there was no visual or olfactory evidence of hydrocarbon staining and no elevated concentrations within soil or groundwater samples.

Elevated concentration of VOCs where only encountered within the exploratory hole locations located closest to the above ground storage tank and was only a peak reading. Whilst the elevated VOC concentrations within WS01 and WS02 are likely to be derived from the petroleum hydrocarbons within the impacted shallow groundwater within the River Terrace Deposits this is considered to be unlikely the be the case for the elevated VOCs in BH01 as no samples recorded petroleum hydrocarbons. It is considered that the VOCs may have migrated below the existing hardstanding are become concentrated around the top of BH01. This high reading was not recorded in subsequent monitoring visits.

A potential groundwater vapour risk has also been identified during laboratory testing. Initially it is considered that a vapour membrane will be required in the vicinity of the former above ground fuel tank.

Where encountered it is anticipated that any residual, locally hydrocarbon-impacted soils be removed during the demolition of the energy centre and fuel tank. A watching brief of the excavation within the vicinity of the energy centre will enable sufficient testing and delineation of impacted soils and assessment for volatile compounds. Should excessive volatiles be encountered (or suspected to remain after removal of impacted soils and amounts of free-phase product), vapour protection measures may be required beneath the building in this particular area.

8.8 Construction materials risk assessment

8.8.1 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 brownfield. However, the investigation has not detected widespread organic contamination in exceedance of the threshold values and Hydrock believes standard pipework may be suitable for the site. However, upgraded pipework may be needed in the area of Energy Centre owing to the petroleum hydrocarbon concentrations encountered. Confirmation should be sought from the water supply company at the earliest opportunity.

8.8.2 Other construction materials

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

The implications for buried concrete shall be discussed in Section 7.7.

8.9 Contamination risks to ground workers

8.9.1 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.

8.9.2 Metals, metalloids, PAH and petroleum hydrocarbons

The soils contain metal and locally petroleum hydrocarbons recorded within the Made Ground and River Terrace Deposits. The effect of these are considered below with regard to ground workers.

8.9.3 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 or 0.5% for long term exposure. Furthermore, soil concentrations of oxygen are below the HSE recommendations of 18%.

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

8.9.4 Vapours

During the ground investigation the highest stable PID reading associated with the petroleum hydrocarbon contamination was 64 pp. This was encountered within the vicinity of the energy centre/ boiler rooms. This concentration is considered to be low however, there is still a risk of volatilisation from the soils and groundwater, especially in confined spaces and risk assessments and method statements should be in place if vapours and odours are identified during excavation. Additional guidance can be found in EH40/2005 Workplace Exposure Limits (HSE 2011).

An allowance should be made for the inclusion of Vapour membrane within the new block overlying the Hydrocarbon Hotspot.

8.9.5 Asbestos

Occasional visible fragments of ACM are recorded in the soils in the form of Asbestos Cement, have been identified during the ground investigation and asbestos fibre (up to 0.018%) have been identified during the laboratory testing of soils.

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

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

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

8.10 Findings of the generic contamination risk assessments

The potential sources, pathways and receptors identified in the desk study (Section 3) have been investigated (Sections 5 and 6) and assessed (Sections 8.2 to 8.8). A Source-Pathway-Receptor linkage assessment has been undertaken and is presented in Appendix I (Table K.2).

The final Conceptual Model is illustrated on Hydrock Drawing 12053-HYD-XX-XX-GI-DR-GE-1010 in Appendix A and the main features of the site are summarised on the Site Zonation Plan presented in Appendix A (Hydrock Drawing 12053-HYD-XX-XX-GI-DR-GE-1011).

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 8-7.

Table 8-7: Residual risks following risk evaluation

Contaminant Linkage			Comments	
Sources	Pathways	Receptors	General	Mitigation
Localised hotspots of Benzo(a)Pyrene within Made Ground.	Ingestion or direct contact.	Human health.	Significant exceedance of the GAC.	Excavation and disposal of soils as required by construction, provision of capping layer in the form of new building/hardstanding with engineered clean cover system in areas of soft landscaping to break the contaminant pathway.
Petroleum hydrocarbons within shallow groundwater associated with Energy Centre	inhalation of vapours	Human health.	Shallow groundwater within Energy Centre area impacted with hydrocarbons which is also a vapour risk	Mitigation required in the form of removal of the above ground infrastructure (Energy Centre); and remediation verification. Further delineation of the extent of the hotspot required during validation and associated further assessment of groundwater quality.
	Lateral migration off-site.	Groundwater		Installation of vapour protection membrane in new buildings.
Asbestos fibres in soil or asbestos-containing materials in the Made Ground	Inhalation of fugitive dust.	Human health.	Made Ground seen to contain asbestos-containing materials. Asbestos fibres measured in soil samples.	Mitigation required in the form of an engineered cover system. In addition, any ACM encountered during earthworks will need to be handpicked and removed from site.
Hydrocarbons in soils and groundwater in the vicinity of the energy centre.	Direct contact	Water supply pipes.	The Made Ground contain contaminants of concern at levels in excess of the GAC in the area of the energy centre.	Installation of “Protectaline” (or similar) pipework within the vicinity if the energy centre. (extent determined by validation works).

8.11 Mitigation measures

As described in Table 8-7 (and subject to regulatory (and NHBC) agreement), Hydrock consider the following mitigation is required to ensure the site is suitable for use for the proposed end use. These mitigation works will be undertaken in a number of phases and can be separated into:

- Demolition Phase;
- Enablement Phase; and

- Construction Phase.

There will also be a requirement to undertake works to ensure the site is geotechnically suitable.

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

The writing and approval of a Materials Management Plan will be required to allow reuse of suitable material at the site. If treatment of Made Ground is required, an appropriate Environmental Permit will also be required.

Verification reports by a suitably qualified independent geo-environmental specialist will be required following completion of any remedial works (including ground gas membrane installation).

8.11.1 Demolition Phase

The existing buildings and associated infrastructure require demolition and the following works are considered necessary during the Demolition Phase of works:

- demolition asbestos survey (Currently being undertaken on site);
- site clearance;
- removal of above ground tanks, boiler house and associated infrastructure (including below ground pipework);
- demolition of site buildings and ancillary structures to slab level; and
- processing the demolition arisings to a suitable specification in accordance with the WRAP 'Quality Protocol: Aggregates from inert waste'.

8.11.2 Enablement Phase

The following works are considered necessary during the Enablement Phase of works:

- break out of all hardstanding and below ground obstructions and processing for reuse in accordance with a suitable specification and a Materials Management Plan (MMP);
- a temporary sump should be excavated within the vicinity of WS01 and WS02. Any significant free phase fuel can be removed using absorbent hydrophobic towelling.
- excavation of Made Ground and natural soils as required to allow construction with appropriate materials management and processing of excavated soils using a combination of: excavation and stockpiling and screening of soils to leave the site at the level required for the installation of a working platform, pavement construction and to allow the installation of a 450mm engineered cover system;
- off-site disposal of unsuitable or excess material; and
- verification during enablement works.

Due to the potential for low concentrations of dissolved phase hydrocarbons in the groundwater, treatment of any water pumped from excavations within the hotspot (via a granulated activated carbon plant) may be required prior to discharge from the site. This would apply to both the enablement and construction phase of works.

8.11.3 Construction Phase

The Construction Phase of works will comprise:

- appropriate materials handling and stockpiling in accordance with the Materials Management Plan (MMP);
- installation of Protectaline pipework (PL4);
- Installation of vapour membrane within the vicinity of the known Hydrocarbon hotspot.
- import of subsoil and topsoil in accordance with the Materials Management Plan (MMP); and
- the installation of an engineered cover system in public open space areas (PL1 and PL2).

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9. WASTE AND MATERIALS MANAGEMENT

9.1 Introduction

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

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

9.2 Waste disposal

9.2.1 Principles

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

Classification is a staged process:

- 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 and Peat

Topsoil and peat are 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 and peat need 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.

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.

9.2.2 HazWasteOnline™ assessment

As the site is brownfield, 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 G and a summary of the preliminary waste classification is provided below in Section 9.2.4.

9.2.3 WAC Testing

The site is brownfield. However, WAC testing has not been undertaken to date but will be required on the excavated soils that are to be disposed of, to assist with waste disposal options prior to disposal. A summary of the preliminary waste disposal options is provided below in Section 9.2.4.

9.2.4 Preliminary waste disposal options

The site is brownfield and based on the site history and the HazWasteOnline™ assessment, if suitable segregation of different types of waste is put in place, for soils to be disposed of, it is considered that:

- The natural uncontaminated subsoils are likely to be classified as Inert waste.
- The 'General' Made Ground is likely to be classified as Non-Hazardous waste.
- Localised petroleum hydrocarbons around the Energy Centre where impacted the underlying Made Ground and River Terrace Deposits are considered likely to be potentially Hazardous.
- An exceedance of Chromium (VI) of 3.1kg/kg was identified within the Made Ground within BH01 on a localised basis. Given the isolated occurrence and nature and homogeneous nature of the Made Ground across the Site, it is probable that the material can be disposed of as Non-

Hazardous. However, further testing may be required to understand the waste classification of the material in this area.

- Any soils containing > 0.1% asbestos or visible asbestos containing materials would be considered as hazardous.

9.2.5 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 the HazWasteOnline™ assessment. However, the formal classification of waste can only be undertaken on the material to be disposed of, and by the waste producer and the receiving landfill as license conditions vary from landfill to landfill.
- Basic Characterisation should be undertaken in accordance with Environment Agency guidance by the waste producer. Hydrock can assist if required and this report will assist the characterisation. However, Basic Characterisation does not form part of the current commission and would require further assessment and testing on the wastes actually to be disposed.
- Once the waste producer has undertaken an initial Basic Characterisation on each waste stream, they can manage the soils as part of the on-site processing programme (for example, stockpiling, treatment, screening and separation). The waste producer and landfill operator will then need to agree the suite of compliance testing for regularly generated waste to demonstrate compliance with the initial Basic Characterisation prior to disposal.
- At the time of disposal, additional testing on the excavated soils to be disposed of, will likely be necessary.
- Non-hazardous and hazardous soils require pre-treatment (separation, sorting and screening) prior to disposal.
- The costs for disposal of non-hazardous and hazardous soils are significant compared to disposal of inert material.
- In addition to disposal costs, landfill tax will be applicable. Non-hazardous and hazardous waste will generally be subject to the Standard Rate Landfill Tax. Inert or inactive waste will generally be subject to the Lower Rate Landfill Tax. The landfill tax value changes each April and can be found at https://www.gov.uk/government/publications/rates-and-allowances-landfill-tax/landfill-tax-rates-from-1-april-2013.
- Before a waste producer can move waste to a landfill site for disposal, they need to check the landfill site has the appropriate permit and must have completed the following[3]:
    - Duty of care transfer note / Hazardous Waste consignment note, including comment as to if pre-treatment has been undertaken; and

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

- Basic Characterisation of the waste, to include: description of the waste; waste code (using list of wastes); composition of the waste (by testing, if necessary) and; WAC testing (if required).

9.3 Materials management

9.3.1 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.

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

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

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

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

9.3.2 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

On sites where Made Ground or contaminated soils are present, 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.

Geotechnical improvement requirements

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

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

10. UNCERTAINTIES AND LIMITATIONS

10.1 Site-specific comments

The footprints of the existing buildings (including the Energy Centre) could not be investigated as most were still in use, preventing intrusive ground investigation. Similarly, buried utilities precluded investigation around the Site, but particularly in and around the Energy Centre, which restricted the location of exploratory hole locations.

Accessible areas of the site comprised an active car park as such the works were positioned to minimise disruption to the users and operation of the site.

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.

10.2 General comments

Hydrock Consultants Limited (Hydrock) has prepared this report in accordance with the instructions of Guild Living (the Client), by e-mail from Bruce Campbell at Cast Real Estate & Construction Consultancy dated 18th February 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 June and July 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 reports 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. The various methodologies used are available on request. No assessment has been made for the presence of radi oactive 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 relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

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

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

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

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

11. RECOMMENDATIONS FOR FURTHER WORK

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

- further testing of shallow groundwater at around the above ground fuel tank to better understand the changes in hydrocarbon concentrations recorded around the tank and understand any vertical migration of the contamination.
- discussion and agreement with utility providers regarding the materials suitable for pipework;
- discussions with regulatory bodies and the warranty provider regarding the conclusions of this report;
- discussions with piling Contractors regarding conclusions of this report and design of the piles;
- provision of geotechnical design for the Category 2 (foundations);
- production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider).
- Preparation of Piling Foundation Works Risk Assessment (if required)
- Additional post-demolition investigation within/around the Energy Centre to support delineation of petroleum hydrocarbon hotspot identified.
- consideration to the production of a Materials Management Plan relating to any reuse of soils at the site.
- verification of the remediation and mitigation works.

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Appendix A

Drawings