

Dunsbury Park, Plot 400

Phase 2 Ground Investigation Report

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Appendix E	Site Monitoring Data and Ground Gas Risk Assessment
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Executive Summary

Site Information and setting	
Objectives	To resolve any geotechnical and geoenvironmental uncertainties identified in the Phase 1 desk study and provide preliminary geotechnical recommendations for design.
Client	Portsmouth City Council
Site name and location	Dunsbury Park, Plot 400, Fitzwygram Way, Portsmouth, postcode PO9 4EE
Proposed development	A warehouse (141,750 ft ²) with first floor office (7,460 ft ²) with associated car park, loading docks and infrastructure.
Site Description	Plot 400 area is a 3.3ha area split over two terraces formed by recent earthworks, with minimal vegetation and aggregate surfacing, previously used for construction storage and now holding stockpiles soil from Plot 500
Ground model proven by investigation	
Ground and groundwater conditions encountered by investigation	<p>The ground conditions as proven by the investigation undertaken at the site comprise:</p> <ul style="list-style-type: none">• Groundwater was encountered at depths between 1.95m bgl and 11.30m bgl during the investigation.• Bognor Sand Member – between 1.40m and 2.62m below ground level (bgl),• London Clay Formation– between 2.20m and m bgl. <p>Water levels recorded post-fieldwork ranged from 2.14m bgl to 3.47m bgl (34.30m OD to 33.34m OD).</p> <p>There was no visual and olfactory evidence of petroleum hydrocarbon contamination in soils on site.</p>
Further work	<p>Following the ground investigation works undertaken to date, the following further works will likely be required:</p> <ul style="list-style-type: none">• Engagement with relevant regulatory authorities;• Development of geotechnical design solutions for Category 2 structures;• Preparation of a Remediation Strategy and Verification Plan;• Formulation of a Materials Management Plan;• Implementation of remediation and mitigation measures;• Verification of the completed earthworks.

This Executive Summary forms part of Stantec Hydrock Limited report number 02010-STN-XX-XX-RP-GE-1001 and should not be used as a separate document.



1 Introduction

1.1 Terms of reference

In July 2021, Hydrock Consultants Limited (Hydrock) was commissioned by Portsmouth City Council (the Client) to undertake a Phase 2 ground investigation at Dunsbury Park, Plots 100, 400, 600 and 700, Fitzwygram Way, Portsmouth, postcode PO9 4EE.

In October 2025, Hydrock now Stantec was commissioned to re-issue and update these reports on a plot by plot basis with this report focussing solely on Plot 400.

Dunsbury Park comprises a commercial development comprising 7 plots of industrial/ warehouse units. The Dunsbury Park Masterplan (reference DHF-BMD-MP-XX-DR-A-10004-p19) is presented in Appendix A. Plot 2 is completed and occupied by Fat Face, Plots 3a and 3b are completed and occupied by DPD and Volkswagen, Plot 4a is completed and occupied by Biopure Technology, Plot 500 has been recently completed and construction is in progress, comprising the construction of three steel framed warehouse buildings and associated parking and landscaping.

Remaining areas designated for development comprise Plot 100 (unit 100: hotel conference and gymnasium), Plot 400 (unit 400: warehouse and offices), Plot 600 (units 600-601: warehouse and offices) and Plot 700 (unit 700: warehouse and offices). The entire development comprises approximately 16.44 Ha in area and is set at various levels. Plots 100, 400, 600 and 700 areas are currently unoccupied and undeveloped. A site location plan (19453-HYD-XX-XX-DR-GE-1001) is provided in Appendix A.

The works have been undertaken in accordance with Hydrock's proposal referenced (19453-HYD-XX-XX-SP-G-1000 dated 09/06/2021 and 19453-HYD-XX-XX-SP-G-1001 date 11/06/2021) and the Client's instructions to proceed (PO3004424 dated 12/07/2021).

The updates and re-issue have been undertaken in accordance with Stantec proposal referenced (21082025-STN-FP-ACGEO-00003 dated August 2025).

1.2 Objectives

The works have been commissioned to assist with the design of the proposed Plot 400.

The objectives of the Phase 2 Ground Investigation are:

- to resolve any geotechnical and geo-environmental uncertainties identified in the Phase 1 Desk Study by refining and updating the preliminary Ground Model, based on the conditions met in accordance with the principles of Environment Agency (EA) 'Land Contamination: Risk Management' (LCRM) (20210);
- to identify any geo-environmental mitigation requirements to enable development to progress; and
- to provide preliminary geotechnical recommendations for design.

1.3 Scope

The scope of the Phase 2 Ground Investigation comprises:

- a ground investigation including trial pitting, windowless sampling, and cable percussive boring, to:



- obtain data on the ground and groundwater conditions of the site;
 - allow collection of samples for geotechnical and chemical laboratory analysis;
 - install gas and groundwater wells;
- gas concentration and groundwater level monitoring;
- gas and groundwater sampling;
- geotechnical and chemical laboratory analysis;
- updating of the preliminary Ground Model;
- preparation of a geotechnical risk register;
- presentation of an initial geotechnical design recommendations;
- formulation of an updated Conceptual Site Model (CSM), including identification of any plausible contaminant linkages;
- completion of a generic quantitative risk assessment of any identified chemical contaminants to establish 'suitability for use' under the current planning regime;
- discussion of any potential environmental liabilities associated with land contamination (soil, water and gas); and
- identification of outline mitigation requirements to ensure the site is 'suitable for use'.

1.4 Available information

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

- Hydrock, March 2022. 'Dunsbury Park Plots 500-502. Controlled waters and ground gas risk assessment' undertaken for Portsmouth City Council. Reference: 19453-HYD-XX-XX-RP-GE-1006.
- Hydrock, December, 2021. 'Dunsbury Park Plots 500-502. Ground Investigation Report' undertaken for Portsmouth City Council. Reference: 19453-HYD-XX-XX-RP-GE-1004.
- Hydrock, June, 2021. 'Dunsbury Park Plots 100, 400, 600 and 700. Ground Investigation Factual Report' undertaken for Portsmouth City Council. Reference: 19453-HYD-XX-XX-RP-GE-1003.
- 1st Line Defence, July, 2021. 'Dunsbury Park - Detailed Unexploded Ordnance (UXO) Risk Assessment' undertaken for Avison Young Holdings Limited. Reference: DA13636-00.
- Hydrock, June, 2021. 'Dunsbury Park Phase 1 Desk Study' undertaken for Portsmouth City Council. Reference: 19453-HYD-XX-XX-RP-GE-1001.
- UMC Architects, June 2021. 'Dunsbury Park Masterplan, Portsmouth'. Drawing reference: 20179 F0009 A.
- Murphy Geospatial, June 2021. 'Dunsbury Park – Topographical survey'. Drawing reference: MGS42248-T-RevB- 01 to 14.
- Avison Young, March 2021. 'Project Brief Dunsbury Park Portsmouth PO9 4EE';
- Bam design, 17th May 2017. 'Dunsbury Park Masterplan'. Drawing reference: DHF-BMD-MP-XX-DR-A-10014-S2-P19.
- Bam design, 11th May 2017. 'Dunsbury Park – Site infrastructure: External works Eastern access road construction details'. Drawing reference: DHF-BMD-ZZ-XX-DR-S-20511 RD.
- Bam design, October 2014. 'Dunsbury Hill Farm – Below ground drainage strategy'. Drawing reference: 4330.



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

The following documents have been reviewed by Hydrock from publicly available sources for use in the preparation of this report:

- Havant Borough Council. Ordnance Survey Map. Havant Borough Conservation areas. Recovered from <https://www.havant.gov.uk/conservation-areas-and-listed-buildings/details-conservation-areas>.
- British Geological Survey. England and Wales. Sheet 316 Fareham. Recovered from <https://largeimages.bgs.ac.uk/iip/mapsportal.html?id=1001806>
- Havant Borough Council. February 2018. 'Draft Havant Borough Local Plan 2036'.

Hydrock acknowledge that these documents are not assigned to The Client, and have been used for information purposes only. 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+A1:2020, 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, EA Land Contamination Risk Management LCRM (2021) 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 any potential geo-environmental risks assessed qualitatively. This is done using the 'source-pathway-receptor contaminant linkage' concept to assess risk as introduced in the Environmental Protection Act 1990 (EPA, 1990). Any potential geotechnical risks are also assessed from the Phase 1 desk study and site reconnaissance stage.

Phase 2 comprises intrusive ground investigation work and testing. The factual information from the desk study and the ground investigation are used to develop the Conceptual Site Model (CSM). This CSM is based on a ground model of the site physical conditions and an exposure model of the possible contaminant linkages. The CSM 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.

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

Remaining uncertainties and recommendations for further work are listed in Section 9 and Section 10.



2 Desk study review

2.1 Introduction

Hydrock has undertaken a previous desk study in June 2021 (reference 19453-HYD-XX-XX-RP-GE-1001) which has been updated in 2025 as part of the same package of works and this is provided in Appendix B. The following section is a summary of the pertinent information presented in that Desk Study, and relevant information gathered after the Desk Study.

2.2 Site location

The site is located at Fitzwygram Way, Havant, Hampshire, nearest postcode PO9 4EE, at the east of A3 (M), adjacent to junction 3, approximately 8 miles north of Portsmouth. The National Grid Reference of the approximate centre of the site is 470044E, 109383N.

A site location plan (Hydrock Drawing 19453-HYD-XX-XX-DR-GE-1001) is presented in Appendix A.

2.3 Site description

Plot 400 area is located to the east of Plot 500 and to the west of Plot 600. The Plot is split over two plateaus formed by recent earthworks, separated by a slope of approximately 4m height. The northern terrace sits at approximately 36m AOD and the southern approximately at 32m AOD. The area is partially covered by aggregate surfacing and is predominantly free of vegetation. The area is surrounded by heras fencing. A high-pressure service asset is known to run north south into the east of the site. The centre of the Plot is at approximate NGR 470020E, 109353N. This area comprises approximately 3.30 Ha.

The area was previously occupied as part of the BAM construction works for Plot 4a, including the trafficking and storage of plant and materials including topsoil, subsoil and aggregate.

Since the time of the investigation works Plot 400 has been used to stockpile excess soil from the development on Plot 500. This material currently occupies the upper terrace only and comprises a series of irregular mounds and stockpiles up to 3-4m in height with access tracks and drainage. The walkover noted that extensive revegetation had occurred since placement of these materials in 2022.

Updated photos are presented within the updated Desk Study in Appendix B.

2.4 Site history

The site has previously remained predominantly undeveloped, with the exception of the road traversing roughly across the centre of the site, which was first noted in 1867, later named as Park Lane (1897). A footpath was noted across the northern area of the site. Portsmouth City Council has been engaged in development of infrastructure since 2014 (including site roads, site levelling/plateaus and utility connections). The construction of the roundabout and main road infrastructure (Fitzwygram Way) at the south boundary of the site appeared to be completed in 2016. Plots 2, 3, 4a and 5 are now completed.

With regards the surrounding areas, some features such as a clay pit, brick and tile works and brick kiln were noted within 200m of the site between 1859 and 1867. In 1970s the construction of residential developments across the surrounding area started and continued to increase until 1985. Earthworks were noted along the west boundary of the site between 1980 and 1991 related to the construction of A3 (M).



One historical tank record was noted to the west of the site in 1970 over 100m away. No historical records related to historical garages or military land was identified within 500m of the site during the desk study research. Eight records of electricity substations were identified within 167m to 500m of the site between 1970 and 1993. One record of a gas governor was identified at 478m west of the site between 1984 and 1992.

2.5 Geology

The superficial geology comprises Head Deposits within the east and southwest areas of the site, which is recorded as clay, silt, sand and gravel.

The solid geology is formed by Bognor Sand Member, comprising glauconitic bioturbated or cross-bedded fine- and medium-grained partially cemented sands (with an average thickness of 5-10m according to BGS records), overlying the London Clay Formation, comprising blue-grey or grey-brown bioturbated or poorly laminated slightly calcareous, silty to very silty clay/ clayey silt and sometimes silt, with some layers of sandy clay (with a thickness up to 150m according to BGS records).

Localised Made Ground is likely to be present as a result of reported landfill activities, earthworks and construction works associated with the development of the surrounding area. This is specifically relevant to the current use of Plot 400 as a stockpile area for the development on Plot 500.

The materials stockpiled comprise a mixture of London Clay, Bognor Sand and some topsoil materials.

2.6 Hydrogeology

The Superficial Head Deposits are classed by the Environment Agency as Secondary Undifferentiated Aquifer. The Bognor Sand Member is classed as Secondary A Aquifer and the London Clay Formation as Unproductive.

The site is within a Zone 1C Source Protection Zone for a confined aquifer body, assumed to be the underlying (at depth) Chalk. There are no groundwater abstractions within 2km of the site.

2.7 Hydrology

There are two surface water features located at the east (unnamed) and southwest (Hermitage Stream) boundaries of the site, flowing south and southwest respectively.

Reference to the Environment Agency web site shows the site is located within the catchment of the East Hampshire Rivers, with the specific river water body being the Hermitage Stream - source to confluence with Langstone Harbour. The current (2019 cycle 2) overall status under the Water Framework Directive is 'moderate'.

The nearest licensed surface water abstraction is 1558m northeast of the site corresponding to direct spray irrigation.

2.8 Flood risk

The desk study information indicates the majority of the proposed development is in Flood Zone 1 (with a low probability of flooding from rivers or the sea). However, a partial area of the east boundary is considered as Flood Zone 2 (1 in 1000 (0.1%) chance of flooding each year) and Flood Zone 3 (with a 1 in 100 (1%) or greater chance of flooding each year from rivers)

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



2.9 Mining or mineral extraction

In summary, the risk associated with mining or mineral extraction within the site boundary is considered low. The desk study information indicates several records of surface mining and surface groundworks in the vicinity of the site, as listed below:

- Cuttings, between 28m to 211m west, probably associated with the construction of the A3 (M).
- Ponds, approximately at 30m west and 90m east, probably related to old surface mining.
- Brick kiln and tile works are recorded at 155m east and 124m south of the site.

2.10 Natural ground instability

The majority of the site lies within Bognor Sand Member, and the risk of shrink swell clay is negligible to low due to its likely non-plastic condition.

The Groundsure report indicates risk of running sands, landslides, compressible and collapsible deposits within site boundary is very low to low. However, due to the unknown composition and extend of the made ground and landfill, risk of running sands cannot be discounted.

2.11 Waste management

There is one historical landfill record which covers a large proportion of the east and northern area of the site, between Plots 600 and 700, classed as inert waste (assumed to be from construction activities of the A3 (M)).

2.12 Regulatory Information

Information provided in the previous desk study indicate the following significant regulatory controls in the vicinity of the site:

Two entries of discharge consent for sewage discharge to an unnamed tributary of the River Wallington located 219m north.

2.13 Natural soil chemistry

Information provided in the previous desk study gives indicative (estimated) concentration values for the natural soils at the site for a selection of Contaminants of Potential Concern (CoPC). These have been reproduced in Table 2-1 below:

Table 2-1: Natural soil chemistry

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

2.14 Radon and ground gas

The previous desk study indicated that the site is not in a Radon Affected Area (less than 1% of homes are above the action level). A recent review of the BGS radon mapping updated in December 2022 confirmed this conclusion. Therefore, no radon protection measures are required.



2.15 Unexploded ordnance (UXO)

A specialist UXO risk assessment was undertaken by 1st Line Defence in July 2021. The full report (reference DA13636-00) is presented in Appendix B. This indicates a Low-Medium Risk from items of German aerial delivered UXO and Low from Allied UXO across the site. However, it is recommended that all works have:

- A written site-specific site management plan for UXO.
- Site specific UXO awareness briefings to all personnel conducting intrusive works.

2.16 Environmental and agricultural designations

There are 39 entries related to areas with environmental designations within 2,000m from the site boundary, relating to Local Natural Reserve, Ancient and Semi-Natural Woodland and Ancient Replanted Woodland. There are 3 entries related to agricultural land, one open access land record, one nitrate vulnerable zone record, one environmental and countryside stewardship schemes record.



3 Initial conceptual site model

3.1 Introduction

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

3.2 Ground model

The preliminary ground model presented in Section 2 provides an understanding of the ground conditions and is the basis for preparing the preliminary geotechnical hazard assessment (Section 3.3) and the preliminary geo-environmental exposure model (Section 3.4).

3.3 Geotechnical hazard identification

3.3.1 Context

The preliminary geotechnical hazard identification has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622. The following section sets out the identified geotechnical hazards and the development elements potentially affected (see Table H.1 in Appendix H for further information).

3.3.2 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.
- Shallow groundwater.
- Changing groundwater conditions.
- Running sands and / or loose Made Ground, leading to difficulty with excavation and collapse of side walls.
- Risk from erosion.
- Obstructions.
- Slope stability issues – general slopes.
- Slope stability issues – retaining walls.
- Earthworks – settlement (due to placement of fill on soft / loose ground).
- Earthworks – poor bearing capacity of new fill.
- Earthworks – unsuitability of site won material to be reused as fill.



3.3.3 Potential development elements affected

Development elements potentially affected by geotechnical hazards are:

- Buildings – foundations.
- Buildings – floor Slabs
- Roads and pavements.
- Services.
- General slopes.
- Retaining walls.
- Public open spaces (POS).
- Construction staff, vehicles and plant operators.
- 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 5 and the assessment is presented in Section 6.

3.4 Geo-environmental exposure model

3.4.1 Context

The preliminary exposure model is used to identify geo-environmental hazards and to establish potential contaminant linkages, based on the source-pathway-receptor (SPR) approach.

A viable contaminant linkage requires all the components of an SPR to be present. If only one or two are present, there is no linkage and no further assessment is required.

3.4.2 Potential contaminants

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

3.4.2.1 Potential on-site sources of contamination

The following potential on-site sources of contamination have been identified:

- Made Ground, associated with historical landfill activities and current earthworks/construction works, possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials, PAH and petroleum hydrocarbons (S1).
- Ground gases (carbon dioxide and methane) from organic materials in the Made Ground / landfill / earthworks and Head Deposits (S2).

3.4.2.2 Potential off-site sources of contamination

The following potential off-site sources of contamination have been identified:



- Made Ground, associated with landfill, historical mining activities (old clay pit, brick and tile works), possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials, PAH and petroleum hydrocarbons (S3).
- Made Ground, associated with earthworks for the construction of A3 (M) in the west boundary on the site, possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials, PAH and petroleum hydrocarbons (S4).
- Ground gases (carbon dioxide and methane) from organic materials in the Made Ground / landfill / backfilled clay pits/brick works. (S5).
- Hydrocarbon vapours from potential VOC and petroleum hydrocarbon spillages/leaks from unspecified tank located at 110m N of the site. (S6).

3.4.3 Potential receptors

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

- People (neighbours, site end users) (R1).
- Development end use (buildings, utilities) (R2).
- Groundwater: Secondary A aquifer status of the Bognor Sand Member (R3).
- Surface water: on-site Hermitage Stream in the southeast area of the site and an unnamed stream on the eastern boundary of the site (R4).
- Soft landscaping areas (R5)
- Ecology: Habitat Creation Area at the west side of the site (R6).
- Ecology: Designated Ancient and Seminatural Woodland / Ancient Replanted Woodland in the surrounding areas of the site (R7).
- Aquatic ecosystem in the Hermitage Stream (R8).

3.4.4 Potential pathways

The following potential pathways have been identified.

- Ingestion, skin contact, inhalation of dust and outdoor air by people (P1).
- Direct contact with substances deleterious to building materials (P2).
- Ground gas (Methane, carbon dioxide, etc.) ingress via permeable soils and/or construction gaps (P3).
- Root uptake by plants (P4).
- Migration of contaminant via leachate migration through the unsaturated zone in Head Deposits / Bognor Sand Member (P5).
- Surface water via overland flow (P6).
- Surface water, via drainage discharge (P7).
- Surface water via base flow from groundwater (P8).
- VOC and petroleum hydrocarbon vapour ingress via permeable soils and/or construction gaps (P9).

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 (2021), are considered to be plausible in the context of this site



and have been carried forward for investigation and assessment. The investigation is presented in Section 5 and the assessment is presented in Section 7. An assessment of the Source – Pathway – Receptor linkages is undertaken following the assessment (Section 7) and is presented in Appendix I (Table I.1).

3.4.5 Potential implications of climate change

Climate change has the potential to change the risk profile for conceptual site models and associated contaminant linkages. The impact of climate change on the CSM is site-specific, and a qualitative assessment of the potential impact of climate change on the CSM for this site is summarised below. The assessment has primarily utilised the guidance in Environment Agency (2010)¹ and SoBRA (2022)² which set out the UK context to climate change and land contamination. Both guidance documents advocate a “what if” scenario approach in the context of changes in ambient temperatures, an increase in the frequency of extreme rainfall/storm events and heatwaves/droughts, and long-term changes in groundwater and sea levels.

Those “what if” scenarios that are relevant to this CSM are:

- Increased long-term rainfall leading to increased infiltration and seasonally higher groundwater and water levels in surface waters.
- Increased frequency and/or magnitude of extreme rainfall events leading to short-term surface flooding, surface water run-off, groundwater flooding, and/or land-based erosion.
- Increased frequency and/or magnitude of storm events leading to short-term drops in barometric pressure and/or high winds.
- Occurrence of extreme cold and hot weather events leading to changes in ground conditions such as soil temperature, evapo(trans)piration, and soil moisture (for example freeze-thaw effects and desiccation), decreased infiltration and fall in groundwater and surface water levels.
- Long-term decrease in rainfall leading to lower infiltration and fall in groundwater and surface water levels.

¹ *Environment Agency, 2010. Guiding Principles for Land Contamination. Part 2. FAQs, technical information, detailed advice and references, March 2010.*

² *SoBRA, 2022. Guidance on Assessing Risk to Controlled Waters from UK Land Contamination Under Conditions of Future Climate Change, Society of Brownfield Risk Assessment, August 2022.*



4 Ground investigations

4.1 Investigation rationale

The ground investigation rationale was based on the findings of the preliminary risk assessment and is summarised in Table 4-1.

Table 4-1: Investigation rationale

Location	Purpose
TP4.02 - TP4.06	To assess shallow ground conditions. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical characterisation. Targeting the areas of the proposed road and car parking/ loading areas.
TP4.07	To assess shallow ground conditions. To allow collection of samples for contamination testing. Targeting areas where mechanical excavation could not be carried out.
TP4.01	To assess shallow ground conditions. To allow collection of samples for contamination testing. To allow collection of samples for geotechnical characterisation. To undertake infiltration testing.
WS4.01 - WS4.05	To assess shallow ground conditions and to allow SPTs to be undertaken. To allow collection of samples for geotechnical characterisation. To allow collection of samples for contamination testing. Installation of gas and groundwater monitoring and sampling wells. Targeting the proposed building footprints and car parking/ loading areas.
BH4.01 - BH4.02	To assess deeper ground conditions and to allow SPTs to be undertaken. To allow collection of samples for geotechnical characterisation. To allow collection of samples for contamination testing. Installation of gas and groundwater monitoring and sampling wells. Targeting the proposed building footprints.

4.2 Constraints

Location TP4.07 could not be accessed with a mechanical excavator. Therefore, a hand-dug pit was excavated to 0.80m bgl for collection of environmental and geotechnical samples.

Location BH4.02 was installed with monitoring well; however, subsequent monitoring has not been undertaken due to technician being unable to access the borehole.

4.3 Site works

The ground investigation works, including the rationale which was based on the findings of the fieldwork took place between 19/07/2021 and 26/08/2021 and is summarised in Table 4-2. The ground investigation locations were surveyed in using a Total Station GPS survey instrument or a topographic survey quality GPS in areas of difficult access and are shown on Hydrock Drawings 19453-HYD-XX-XX-DR-GE-1004-P2 and 19453-HYD-XX-XX-DR-GE-1012, 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 sunny and hot with occasional showers.

Table 4-2: Summary of site works

Activity	Method	No.	Depth Maximum (m bgl)	In situ tests	Notes (e.g. installations)
Boreholes	Cable Percussive	2	20.45	SPT	63mm HDPE wells with gas taps in 1 hole.
	Windowless Sampler	6	5.45	SPT	50mm HDPE wells with gas taps in 3 holes.
Trial Pits	Machine (JCB 3X)	6	3.50	HSV	-
	Hand Excavated	1	0.80	-	At TP4.07
Infiltration	BRE 365 / Indicative	1	2.90	-	In TP4.01

SPT denotes Standard Penetration Test
HSV denotes Hand Shear Vane Test

Wells for monitoring groundwater levels and ground gas concentrations, and to facilitate the sampling of groundwater, were installed in a number of the windowless sampler and cable percussion boreholes. A summary of the monitoring well installations is presented in Table 4-3.

Table 4-3: Summary of monitoring installations

Activity	Method	No.	Depth Maximum (m bgl)	In situ tests	Notes (e.g. installations)
BH4.02	32.55	63	1.00 to 10.00	31.55 to 22.55	Made Ground / London Clay Formation
WS4.03	36.78	42	1.00 to 5.00	35.78 to 31.78	Bognor Sand Member / London Clay Formation
WS4.04	36.47	42	1.00 to 5.00	35.47 to 31.47	
WS4.05	32.42	42	1.00 to 5.00	31.42 to 27.42	

4.4 Geo-environmental testing

4.4.1 Sampling strategy and protocols

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

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

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



4.4.2 Geo-environmental monitoring

Ground gas and groundwater monitoring boreholes have been monitored on 9 occasions. The results are presented in Appendix E.

4.4.3 Geo-environmental laboratory analyses

The chemical test certificates for testing undertaken by a specialist laboratory in behalf of 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 4-4.

Table 4-4: Geo-environmental analyses of soils

Determinand Suite	Made Ground	Topsoil	Head Deposits	Bognor Sand Member	London Clay Formation
Hydrock minimum suite of determinands for solids*	6	-	-	2	-
Hydrock Tier 2 TPH Suite	5	-	-	1	-
WAC Full Solid Suite	-	-	-	1	-

*Hydrock minimum soil suite comprises: As, B (water soluble), Be, Cd, Cr (total), Cr (VI), Cu, Hg, Ni, Pb, S (elemental), Se, V, Zn, cyanide (total), sulfide, pH, asbestos fibres, speciated polynuclear aromatic hydrocarbons (PAH, by GC-FID), total phenols and fraction of organic carbon.

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

The geo-environmental analyses undertaken on waters for testing undertaken by a specialist laboratory on behalf of Hydrock are summarised in Table 4-5.

Table 4-5: Geo-environmental analyses of waters

Determinand Suite	Groundwater
Plot 400	
Hydrock Minimum Suite of Determinands for Water	2
Hydrock Tier 2 TPH Suite - Water	2
Hydrock Tier 2 TPH Suite - Water comprises: speciated aliphatic and aromatic banding Total petroleum hydrocarbons by HS-GC/MS and GC/FID	

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

4.5 Geotechnical testing

The geotechnical tests undertaken by a specialist laboratory in behalf of Hydrock are summarised in Table 4-6 and the test certificates are provided in Appendix D. Wherever possible, UKAS accredited procedures have been used.



Table 4-6: Summary of sample numbers for geotechnical tests

Test	Made Ground	Head Deposits	Bognor Sand Member	London Clay Formation weathered	London Clay Formation
Natural moisture content	3	-	3	1	8
Atterberg limits	-	-	2	2	5
Particle size distribution (wet sieve)	4	-	1	-	-
Sulfate and aggressive chemical environment classification for buried concrete classification (BRE SD1 suite)	1	-	3	-	4
One dimensional oedometer consolidation	-	-	-	-	2
Optimum Moisture Content / Maximum Dry Density Relationship (vibrating hammer)	-	-	-	-	-
Optimum Moisture Content / Maximum Dry Density Relationship (4.5kg hammer)	2	-	-	-	-
Remoulded California Bearing Ratio at natural moisture content (soaked)	-	-	-	-	-
Remoulded California Bearing Ratio at natural moisture content (unsoaked)	-	-	-	2	-
Quick shear box 60mm	-	-	-	-	-
Single stage undrained triaxial compressive strength	-	-	-	-	8

The geotechnical test data are summarised in Section 4.5 and interpreted in Section 6.



5 Ground investigation records and data

5.1 Physical ground conditions

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 4 are used from this point forward.

Details of the Hydrock ground investigation works are provided in the logs in Appendix C, a summary of the ground model is presented in Table 5-1 to Table 5-4 and the individual strata are described in the sections below. Relevant cross-sections are presented in Appendix A.

5.1.1 Summary of strata encountered

A summary of the ground model for Plot 400 is presented in Table 5-1 and the individual strata are described in the sections below.

Table 5-1: Strata encountered

Stratum	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m) (range)	Thickness (m) (average)
Plot 400				
Made Ground - Surface Covering	0.0	0.10 - 0.18	0.10 - 0.18	0.12
Made Ground - Engineered Fill	0.10 - 0.15	0.40 - 1.20	0.25 - 1.10	0.55
Made Ground - General	0.10 - 0.70	0.30 - 1.80	0.15 - 1.40	0.80
Bognor Sand Member	0.10 - 1.80	1.40 - 4.00	1.00 - 3.50	1.95
London Clay Formation (weathered)	0.12 - 4.00	1.95 - 4.40	0.10 - 2.18	0.92
London Clay Formation	0.30 - 4.40	>2.90 - >20.45	>18.45	Not proven

5.1.1.1 Made Ground - Surface covering

Plot 400 is generally covered by sporadic grass and limestone aggregates between ground level and up to 0.12m bgl, with an average thickness of 0.12m, generally comprising reddish grey/brown, greyish brown, pinkish brown silty sandy subangular to angular fine to coarse gravel of limestone, brick and flint.

5.1.1.2 Made Ground - Engineered Fill

Below the surface covering, Made Ground – Engineered Fill was recorded across Plot 400 between 0.10m bgl and 1.20m bgl, with an average thickness of 0.55m. It generally comprises yellowish/ greyish brown silty fine sand, thought to represent possible lime/cement-based stabilised soils, with occasional gravel of subangular to angular fine to medium limestone and flint.



5.1.1.3 Made Ground - General

Below the surface covering, Made Ground - General was recorded across Plot 400 between 0.10m bgl and 1.80m bgl, with an average thickness of 0.80m. It generally comprises orangish brown silty sand with occasional gravel and cobbles of sandstone, flint, brick, tiles fragments.

5.1.1.4 Bognor Sand Member

The Bognor Sand Member was encountered underlying the made ground mainly in the southern half of Plot 400 at locations BH4.02, TP4.03, TP4.04, TP4.05, TP4.06, WS4.03, WS4.04 and WS4.05, within 0.10m and 4.00m bgl, with an average thickness of 1.95m. This generally consisted of greyish brown or light grey and orange brown mottled silty fine sand with locally rare black staining and slight sea/salt odour.

5.1.1.5 London Clay Formation (weathered)

A weathered fraction of the London Clay Formation was encountered underlying the made ground mainly in the northern half of Plot 400 at locations BH4.01, TP4.01, TP4.02, WS4.03 and WS4.04 between 0.12m and 4.40m bgl, with an average thickness of 0.92m. It generally comprises greyish brown or orangish brown mottled grey sandy clay/ silt or clayey fine to medium sand.

5.1.1.6 London Clay Formation

The London Clay Formation was encountered underlying the Bognor Sand Member and weathered London Clay Formation across Plot 400 between 0.30m and to a maximum depth of 20.45m bgl. The base of the strata was not proven. This generally consisted of firm to stiff dark grey/ blueish grey, silty clay or clayey/ silty fine sand with rare to occasional white shell fragments and rare orange brown staining. Becoming stiff to very stiff and generally silty clay from 7.40m bgl.

5.2 Obstructions

No obstructions were encountered during ground investigation works.

5.3 Groundwater

5.3.1 Groundwater observations and levels

Groundwater encountered during the investigation is listed in Table 5-2. A groundwater observation represents the depth at which groundwater was first observed and is likely to be deeper than the actual water table level at that location.



Table 5-2: Groundwater occurrence

Stratum	Date	Location	Fieldwork				Comment
			Groundwater observation		Rose to after 20 min		
			m bgl	m AOD	m bgl	m AOD	
Bognor Sand Member	27/07/21	WS4.03	1.40	35.38	-	-	Soil recovered wet.
	27/07/21	WS4.04	2.62	33.85	-	-	Soil recovered wet.
	27/07/21	WS4.05	1.95	30.47	-	-	
London Clay Formation	24/08/21	BH4.01	5.80	30.86	5.50	31.16	Slow seepage.
	24/08/21	BH4.01	11.30	25.36	11.00	25.66	Slow seepage.
	23/08/21	BH4.02	6.60	25.95	6.30	26.25	Slow seepage.
	23/08/21	BH4.02	11.30	21.25	11.00	21.55	Slow seepage.
	21/07/21	TP4.01	2.20	34.40	-	-	Slow seepage.
	23/07/21	TP4.05	2.90	30.40	-	-	Slow seepage.

Groundwater levels recorded during post-fieldwork monitoring are summarised in Table 5-3.

Table 5-3: Post fieldwork monitoring

Stratum	Date range	Location	Post-fieldwork monitoring	
			Depth to groundwater (range) (m bgl)	Groundwater elevation (range) (m OD)
Bognor Sand Member/ London Clay Formation	27/08/21	WS4.03	2.14 - 2.48	34.30 - 34.64
	-	WS4.04	3.13 - 3.47	33.00 - 33.34
	24/09/21	WS4.05	2.57 - 2.77	29.65 - 29.85

5.3.2 Infiltration tests

The result of the infiltration testing undertaken at location SA401 summarised in Table 5-4. The results sheets are presented in Table 5-4.

Testing was carried out in accordance with Hydrock's 1-day assessment methodology. This is in general accordance with BRE Digest 365 (BRE DG 2016) where infiltration rates allow three test runs during a working day (or where there is no infiltration), but where low infiltration rates were encountered the available time may not have been sufficient to fully comply with the BRE test method (i.e. three runs of the test).

Table 5-4: Infiltration test results

Stratum	Location	Depth to base of pit (m bgl)	Infiltration rate (m/s)			
			Run 1	Run 2	Run 3	Range
London Clay Formation	SA401	1.70	No infiltration*			-

*Test was aborted due to no infiltration rates recorded.

5.3.3 Groundwater summary

At Plot 400, groundwater was encountered during fieldworks within the Bognor Sand Member between 1.40m and 2.62m bgl (30.47 and 35.38m AOD), and within the London Clay Formation between 2.20m and 5.80m bgl (30.40 and 34.40m AOD). A deeper groundwater body was encountered between 6.60m and 11.3m bgl (21.25m to 25.95m AOD). Post field works indicate the presence of groundwater between the Bognor Sand Member and London Clay Formation between 2.14m to 3.47m bgl (29.65m



to 34.64m AOD), following a north to south flow direction. One infiltration test was undertaken within the London Clay Formation in unit 400 area; however, test was aborted after no infiltration recorded. Therefore, this stratum is not expected to provide any infiltration potential for the site.

It is thought likely that groundwater within the London Clay Formation is hosted within sand rich units or lenses and as such may be confined.

Soakaway infiltration tested was aborted due to negligible infiltration.

5.4 Ground gases (carbon dioxide and methane)

Records from the gas monitoring boreholes are presented in Appendix E and summarised in Table 5-5.

A total of nine monitoring visits have been undertaken and the monitoring programme is complete. The data are assessed in Section 7.6.

Table 5-5: Range of ground gas data

Stratum	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Steady flow rate (l/hr)	Comment
Bognor Sand Member	ND - 1.1	0.1 - 5.8	6.5 - 21.0	-5.0 to 1.6	Six out of nine methane readings were below detection limits. Three carbon dioxide readings were above 5% (at location WS4.03)
London Clay Formation	ND - 4.0	ND - 3.6	0.5 - 21.3	-2.4 to 0.0	The majority of the CH ₄ readings were below detection limits or 1%, however, two readings were above 1% (at location WS4.05). CO ₂ readings were below 5%.

ND denotes Not Detected

5.5 Geotechnical data

5.5.1 Introduction

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

5.5.2 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 5-6.

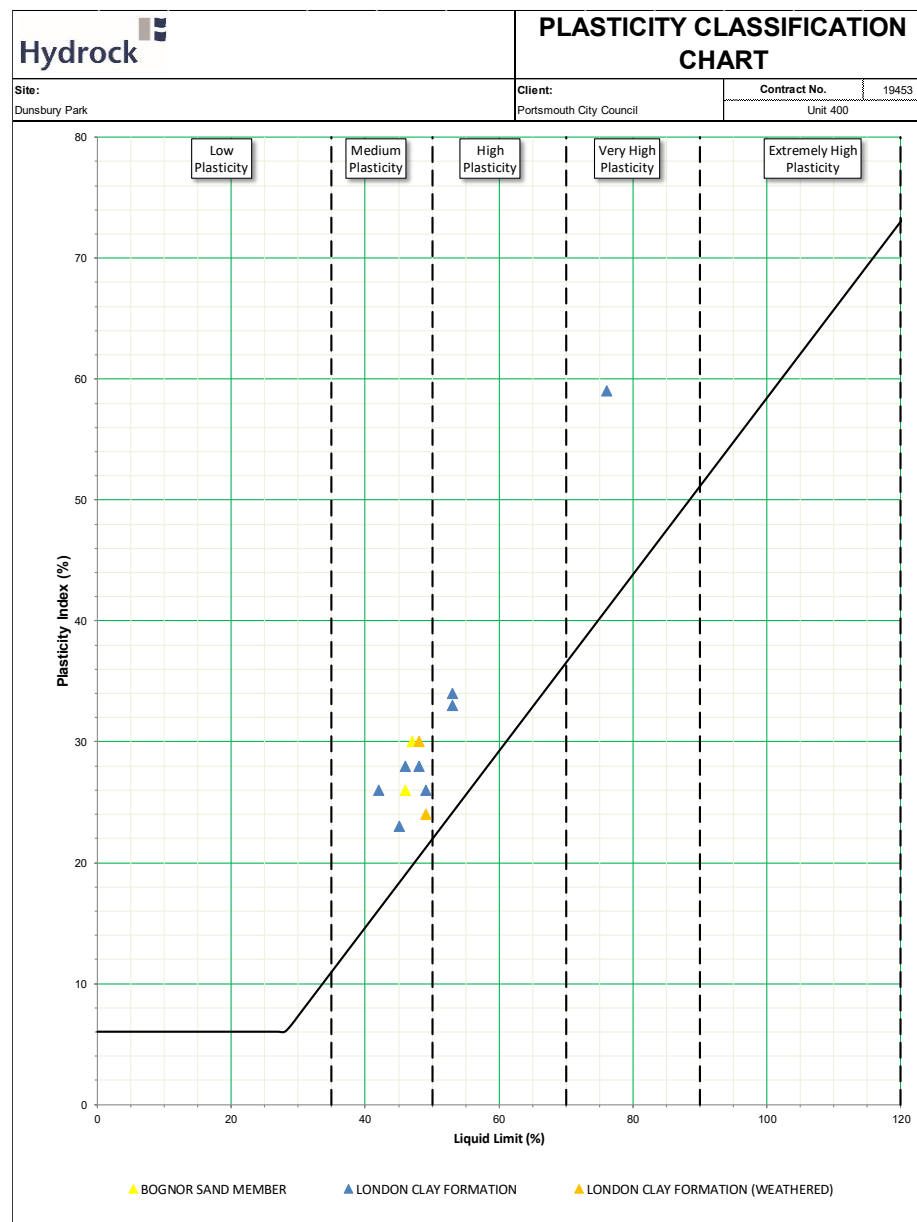


Table 5-6: Volume change potential

Stratum	No. of tests	Plasticity Index			Modified Plasticity Index			Plasticity designation	Volume Change Potential
		Min.	Max.	Av.	Min.	Max.	Av.		
Bognor Sand Member	1	26	30	28	26	30	28	Medium	Medium
London Clay weathered	2	24	30	27	24	30	27	Medium	Medium
London Clay	6	23	59	32	23	59	32	Medium to Very high	Medium to high

A plasticity chart is presented in Figure 5.1 below:

Figure 5.1: Plasticity Chart



5.5.3 Particle size distribution

Particle Size Distribution test (PSDs) results are summarised in Table 5-7 and summary descriptions and PSD Plots of the material analysed are presented in Appendix D.

Table 5-7: PSD results summary

Stratum	No. of tests	Silt/Clay %	Sand %	Gravel %	General description
Plot 400					
MG	4	11 - 65	35 - 80	0 - 9	Brown fine slightly gravelly silty clayey fine to coarse SAND / Brown fine to medium gravelly fine to coarse sandy silty CLAY.
BSM	1	24	75	1	Brown fine slightly gravelly silty clayey fine to coarse SAND.

5.5.4 Soil strength

Table 5-8 summarises information pertaining to the shear strength of the soils according to geological stratum. Factual results are summarised for laboratory tests, field tests (e.g. hand shear vane) and uncorrected Standard Penetration Tests (SPT). Where the SPT is used to infer shear strength by published correlation, this is also tabulated. Plots presenting soil strength versus depth for each unit are shown in Figure 5.2 below.

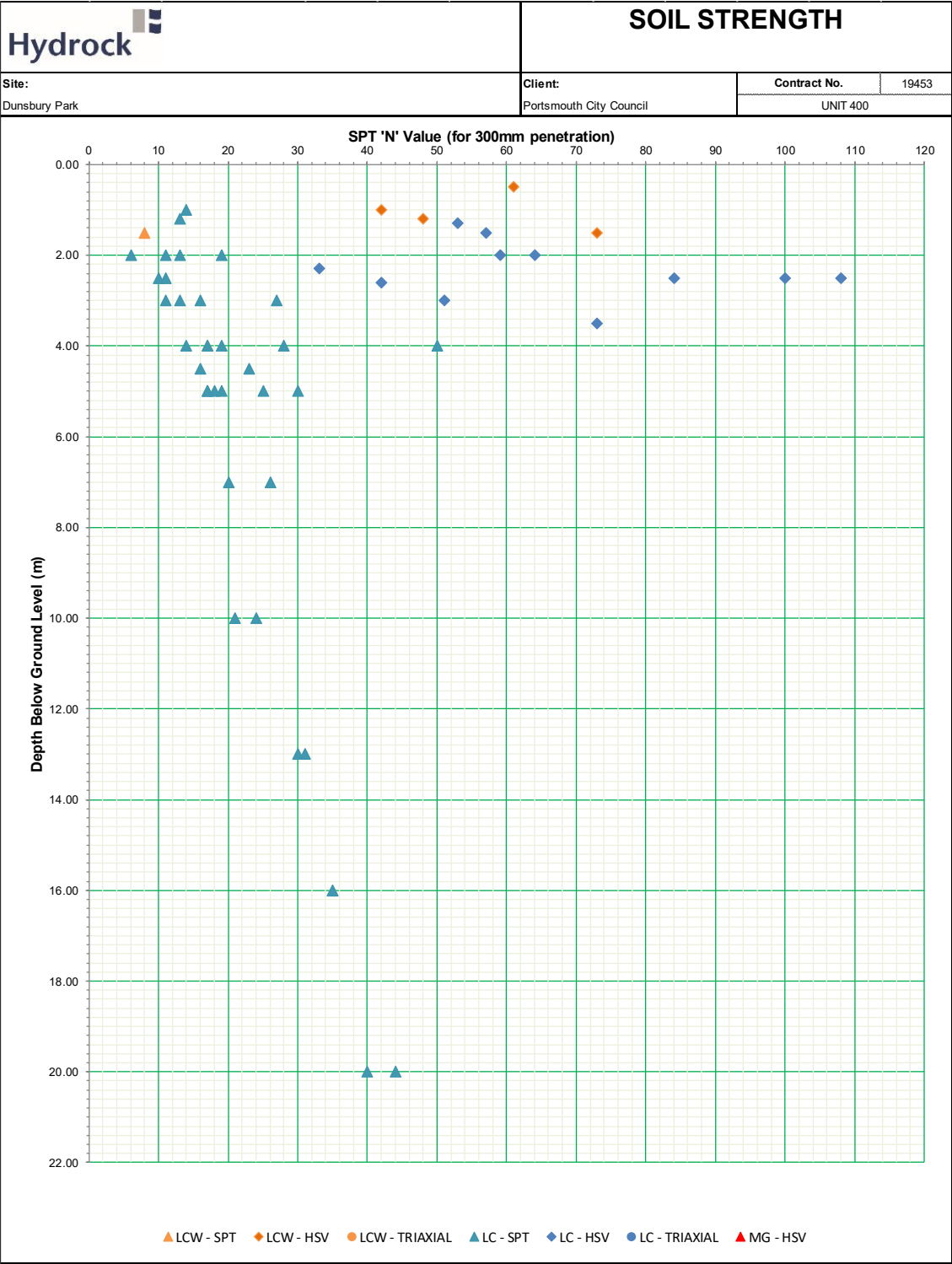
Table 5-8: Soil strength results and derived values

Stratum	No. of tests	SPT (N-value) (range)	cu (kPa)	c' (kPa)	phi' (°)	Method
Plot 400						
Made Ground	1	6	NA	-	-	SPT – cable percussion and windowless sampler boreholes.
Weathered London Clay	2	8 - 17	36 - 77	-	-	SPT – cable percussion and windowless sampler boreholes.
	4	-	42 - 73	-	-	Hand Shear Vane
London Clay Formation	34	6 – 44	27 – 198	-	-	SPT – cable percussion and windowless sampler boreholes.
	11	-	33 – 108	-	-	Hand Shear Vane
	9	-	71 - 181	-	-	Laboratory Triaxial

Undrained Shear strength from SPT – N derived using Stroud & Butler 1975 and a F1 value of 4.5.



Figure 5.2: Soil strength versus depth



5.5.5 Relative density

Table 5-9 summarises information pertaining to the relative density of the granular soils according to geological stratum. Factual results are summarised for laboratory tests, field tests (e.g. SPT, CPT, dynamic probe correlation).

Table 5-9: Relative density results and derived values

Stratum	No. of tests	Method	SPT (N-value) (Range)	phi' (°)
Bognor Sand Member	8	SPT – cable percussion windowless sampler boreholes (Peck et. al. (1967).	9 - 23	28 - 33

5.5.6 Compressibility

Table 5-10 presents a summary of the derived parameters for coefficient of consolidation and compressibility.

Table 5-10: Summary of compressibility

Stratum	No. of tests	Method	Pressure range2 (kN/m ²)		Coefficient of volume compressibility (mv) (m ² /MN)	Coefficient of consolidation (Cv) (m ² /yr)
Weathered London Clay	6	Correlation with SPT*	NA		0.12-0.28	NA
London Clay	27	Correlation with SPT*			0.05-0.37	
	2	One Dimensional Oedometer Testing	0-75	0-100	0.6 & 0.3	1.7 & 6.9
			75-150	100-200	0.28 & 0.13	1.6 7 6.7
			150-300	200-400	0.17 & 0.1	1.5 & 9.7
			300-600	400-800	0.09 & 0.06	2.2 & 6.3
			Unload		0.015 & 0.018	3.6 & 6.2

* All f2 values have been used based on a 'average' plasticity index with Mv calculated using the relationship $Mv=1/F2*N$. (Tomlinson (2001), after Stroud)).

All oedometer tests carried out on remoulded samples

5.5.7 Compaction and moisture content

No Compaction tests were carried out on samples from Plot 400.



5.5.8 Subgrade stiffness

The subgrade stiffness (CBR and Subgrade Surface Modulus) results are summarised in Table 5-11.

Table 5-11: CBR results and derived values

Stratum	No. tests	Method	Subgrade Surface Modulus (MPa) ^a (Range)	CBR (%) (Range)
London Clay (weathered and non-weathered)	2	Laboratory remoulded sample (not soaked)	29.2	2.2

^a From CD225 revision 1 (2020)

According to Table 5-11, laboratory CBR values are above 2.5% for all stratum, with some exceptions on the Head Deposits and Bognor Sand Member, which present values of CBR of 0.26% and 0.22% respectively.

5.5.9 Sulfate content

In accordance with BRE (Special Digest 1), the Design Sulfate (DS) classification and the Aggressive Chemical Environment for Concrete (ACEC) classification are presented in Table 5-12. The assessment summary sheets are presented in Appendix D.

Table 5-12: Aggressive chemical environment concrete classification

Stratum	No. tests	DS	ACEC
Plot 400			
MG	2	DS-4m	AC-5m
BSM	2	DS-1	AC-1
LC	4	DS-4	AC-4

^aClass based on one sample only. If critical for design additional testing recommended.



6 Geotechnical assessment

6.1 Geotechnical categorization of the proposed development

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

The proposed development is shown UMC Architects drawing 20179 F0009 Revision in Appendix A. This comprises a warehouse (141,750 ft²) with first floor office (7,460 ft²) with associated car park, loading docks and infrastructure at Plot 400. The design also includes an access road in the east of the site.

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

For Category 2 structures, the Geotechnical Category should be re-assessed at the design stage and specific geotechnical design (in addition to this investigation), is required.

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

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

6.2 Characteristic design values

In accordance with BS EN ISO 1997-1 (EC 7), Hydrock consider the proposed structures would be classified as Category 2 structures. As part of the separate geotechnical design, the designer should determine the geotechnical design values.



Table 6-1 provides characteristic geotechnical values to assist the designer. These are based on laboratory testing, *in situ* testing and by professional judgement using published data together with knowledge and experience of the ground conditions. Care should be exercised in using these assumed soil strength parameters for any purpose beyond the scope of this report because it may be that additional sampling and testing are required for certain purposes. The reader should refer to the original test results summarised in Section 5 and provided in Appendix C and Appendix D.



Table 6-1: Characteristic geotechnical values

Parameter	Bulk unit weight kN/m ³	Effective angle of internal friction °	Effective cohesion kN/m ²	Undrained shear strength kN/m ²	Modulus of subgrade reaction (IAN73/06) MN/m ² /m
Stratum	γ^a	$\phi'^{b\ c}$	c'^d	c_u^e	k^f
Made Ground - General	17.0	-	-	-	-
Made Ground - Engineered Fill	19.0	26	0	-	35.6
Bognor Sand Member	19.0	32	-	-	35.6
London Clay Formation (weathered)	18.0	23	0	Min 45kPa between 0-5mbgl ^g	35.6
London Clay Formation	19.0	23	2.5	$C_u=7z+45.6$	35.6

^aLaboratory data and BS8004-2015.

^bTomlinson 2011 after Peck et al 1967

^cSorensen & Ockels (2013)

^dBS8002:1994 Code of Practice for Earth Retaining Structures, BSI

^eLaboratory data and SPT (After Stroud & Butler 1974)

^fCD225 Rev1 (2020) assuming CBR of 3

^gSignificant scatter above 5mbgl.

6.3 Groundwork

6.3.1 Site preparation

The site is previously undeveloped and no buried man-made obstructions were encountered by this investigation. The possibility of buried obstructions being encountered is low.

It should be noted that areas of previously placed engineered fill have been identified and that these materials may have been stabilised with lime/cement. These areas may require the use of heavier plant to excavate and process.

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

6.3.2 Groundworks

As no breaking out of hardstanding or obstructions is anticipated, excavation of shallow soils should be readily undertaken by conventional plant and equipment.

It should be noted that areas of previously placed engineered fill have been identified and that these materials may have been stabilised with lime/cement. These areas may require the use of heavier plant to excavate and process.



Trial pit faces within the Made Ground – Engineering Fill and both weathered and unweathered London Clay Formation, were noted to remain generally vertical without collapse, while excavations within the general Made Ground and Bognor Sand suffered small scale collapse and spalling.

The faces of shallow, near vertically sided excavations put down within the Engineered Fill and London Clay Formation at the site are likely to remain stable for short periods of time.

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.

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

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

Based on site observations, the rate of water ingress to the proposed excavations is likely to be slow. In these circumstances, groundwater control by sump pumping is likely to be sufficient.

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

Any water pumped from excavations may need to be passed via settlement tanks (to reduce suspended solids) before being discharged to the sewer. Discharge consents may also be required.

6.3.3 Earthworks/reuse of site-won materials

The classification of materials depends on both the proposed end use and whether the material will meet the performance requirements of that end use. Based on Hydrock's understanding, the following assessment is based on General Fill for external yard areas and Structural Fill for the building footprint.

An initial assessment of classification data has been completed based on Hydrock's understanding of the development and the potential to reuse site-won materials as an engineered fill material. This is summarised in Table 6-2.

The presence of sulfates, or the potential for sulfates to form within the London Clay (weathered and unweathered) in combination with water and natural minerals may allow for the formation of expansive materials if soils are to be modified or stabilised with lime and/or cement. Current guidance suggests that:

- Values of total sulfate (as SO₄) below 0.2% may be acceptable.
- Values recorded between 0.2% and 1.0% require careful consideration and may require further testing, and
- Values in excess of 1.0% indicate that sulfates may make the soil unsuitable for modification/stabilisation.

In addition to these values for total sulfate, stabilised soils are required to be designed in accordance with HA 74/07 (Treatment of fill and capping materials using either lime or cement or both).



Table 6-2: Preliminary earthworks assessment

Stratum	Proposed end use	Preliminary classification (SHW Series 600)	Comment	Suitability for improvement by the inclusion of binders
Made Ground	Open Space	Class 4 (Landscape Fill) Subject to contamination screening	Unsuitable for General Fill due to its heterogeneity. Can only be used in areas which are not sensitive to settlement.	Unlikely to be suitable
Made Ground - Engineering Fill	External Areas	Class 1 General Fill	Hinging of the assessment for its suitability	May be suitable subject to further detailed design and testing.
Bognor Sand Formation	External Areas	Class 1A General Fill Class 1B General Fill	May be dry of OMC – may require moisture conditioning.	May be suitable subject to further detailed design and testing.
	Below Structures	Class 6 Structural Fill	May be dry of OMC – may require moisture conditioning.	May be suitable subject to further detailed design and testing.
London Clay Formation (weathered)	Below Structures	Class 2 General Fill & 7A Select Fill	Subject to testing in accordance with a suitable EWS	Unlikely to be suitable due to the high sulfate concentrations.
London Clay Formation	Below Structures	Class 2 General Fill & 7A Select Fill	Subject to testing in accordance with a suitable EWS	Unlikely to be suitable due to the high sulfate concentrations.

The earthworks may need to be undertaken under a Materials Management Plan (see Section 8).

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

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

6.4 Foundation recommendations

In accordance with EC7, BS EN 1997-1+A1 (2013), the proposed structures (1 and 2-storey office buildings and the warehouse 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.

6.4.1 Foundation Types

The exact nature of the proposed development is unknown but is thought likely be similar to the works carried out on Plot 500, with the construction of a series of level development platforms.



The Made Ground (surface covering and general) is considered unsuitable in its present condition for use as founding soils on the basis of its unpredictable nature and likely deposition in an uncontrolled manner. The Made Ground - Engineered Fill is considerable suitable although further assessment is necessary to avoid differential settlement between the foundations built in natural strata and in Engineering Fill.

The Bognor Sand Member, where present is considered suitable in its present condition for use as founding soils.

On the basis of the ground conditions indicated from the current investigation, the foundations will likely comprise spread foundations across the site to support the columns for the proposed warehouse units. The pad foundations should be founded at least 300mm into the re-engineered Structural Fill, Bognor Sand Formation which comprise medium dense (or better) sands and firm (or better) clay from the London Clay Formation.

On the basis that an appropriate Earthworks Specification is followed, including all comments relating to over-excavation, proof-rolling and removal of soft spots, then a permissible net bearing pressure (for a pad foundation of 2.5m by 2.5m) of 100kN/m² for the re-engineered fill and 150kN/m² for the Bognor Sand formation and the London Clay Formation is likely achievable.

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

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

Deepening of foundations in accordance with 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. 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 it is not practical to deepen individual pads beyond the influencing distance of the desiccated soils, it is recommended that bulk excavation of the affected area be undertaken and, following moisture conditioning, the soils are replaced to an Engineered Specification.

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.

Groundwater monitoring indicates a shallow groundwater table. Alternative methods of groundwater control may be required as fast groundwater ingress is anticipated, which could result in softening of the ground and unstable excavations.

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



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

6.5 Ground floor slabs

Subject to geotechnical design and on the basis that excavation and replacement of the softer soils will be undertaken and all structural fill will be placed strictly in accordance with an appropriate Earthworks Specification, then ground bearing floor slabs may be adopted.

The floor slab should be designed by a structural engineer and a limit state assessment undertaken as part of the geotechnical design.

Prior to the placement of the founding materials and the construction of the ground bearing floor slab, the sub-formation and formation will need to be inspected and checked by a competent person to ensure the ground conditions at time of construction are consistent with the Specification and the design parameters derived from this ground investigation. Testing should be undertaken in accordance with The Concrete Society Technical Report 34 (The Concrete Society 2013) and DMRB IAN 73/06. It is recommended that the verification of the sub-formation and formation include, as a minimum, the measurement of modulus of sub-grade reaction (k) determined by static plate load testing.

6.6 Roads and pavements

Based on the test results and subject to in situ testing during construction, it is considered likely an equilibrium CBR of 3% will be achievable over the majority of the site.

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

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

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

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

6.7 Drainage

Indicative infiltration rates for the ground investigation are presented in Appendix D and are summarised in Table 5-4.



Soakaways are considered unsuitable for the site based on the low infiltration rates obtained from testing. However, the infiltration rates recorded may assist with attenuation as part of a Sustainable Urban Drainage System (SUDS).

6.8 Buried concrete

Based on guidelines provided in BRE Special Digest 1 (BRE 2005) and the information presented in Section 5.5.9 (Table 5-12).

- The shallow soils (Made Ground) can be classified as Design Sulfate Class DS-4 and ACEC Class AC-5.
- The shallow soils of the Bognor Sand Formation can be classified as Design Sulfate Ds-1 and ACEC Class AC-1.
- The deeper soils of the London Clay Formation can be classified as Design Sulfate Class DS-4 and ACEC Class AC-4 for strip / trench fill / pad foundations.

This equates to a Design Chemical Class³ of:

- DC-4 for the shallow soils (Made Ground);
- DC-1 for the shallow Bognor Sand;
- DC-4 for the deeper soils (clays of the London Clay Formation).

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

³ The calculated ACEC class can be used in accordance with BS 8500-1+A2 (2019), Table A.9 to select the Designated Concrete (DC) class for an intended working life of 50 years. However, the designer is referred to BS 8500-1+A2 (2019), for full details and notes to Table A.9, including any Additional Protective Measures (APMs).



7 Geo-environmental assessment

7.1 Updated conceptual site model

7.1.1 Updated ground model

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

7.1.2 Updated exposure model

Following the ground investigation, the plausible contaminant sources, receptors and pathways identified in the preliminary geo-environmental exposure model (Section 3.4) have been updated or confirmed as follows.

7.1.2.1 Sources

The following off-site source of contamination has been removed from the exposure model:

- Hydrocarbon vapours from potential VOC and petroleum hydrocarbon spillages/leaks from unspecified tank located at 110m North of the site (S6). This is due to the distance to the site and no evidence of contamination encountered in relation with petroleum hydrocarbon spillages during the ground investigation.

7.1.2.2 Receptors

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

7.1.2.3 Pathways

The following pathway has been removed from the exposure model:

- VOC and petroleum hydrocarbon vapour ingress via permeable soils and/or construction gaps (P9).

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

7.2 Risk assessment approach

Generic risk assessments have been undertaken in accordance with the principles of LCRM (Environment Agency, 2021) using the CSM that has been updated following the ground investigation.

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

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



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

7.3 Human health risk assessment

This is a Tier 2 assessment using soil screening values applicable to commercial / industrial CLEA land use scenario.

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

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

The phrase 'further assessment required' is used to denote soil concentrations that are equal to, or exceed, a GAC. This does not necessarily mean that the soil is 'contaminated' or not otherwise suitable for use. The assessment and any mitigation required are to ensure the site does not pose an 'unacceptable risk'.

The results of the assessment are presented in Appendix F.

7.3.1 Averaging areas

The 'averaging area' used in this report is based on the conceptual site 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 for each of the Plots.

7.3.2 Risk estimation (without statistical testing)

7.3.2.1 Hydrock default list of determinands

Based on individual test results that exceed the GAC, the chemicals of potential concern (CoPC) which require further assessment are summarised in Table 7-1.

Table 7-1: CoPC in soils which require further assessment (human health)

CoPC	GAC (mg/kg)	GAC Source	No. samples	Min. (mg/kg)	Max. (mg/kg)	No. samples >GAC
Made Ground = No Exceedances						
Natural soils = No Exceedances						

The individual analytical results have been compared with the relevant GAC in the summary table in Appendix F. From this, there are no exceedances on any of the chemicals of potential concern. Therefore, the risk for human health in regards chemicals of potential concern is considered very low.

7.3.2.2 Asbestos

There was no visual evidence of Asbestos Containing Materials (ACM) in any of the exploratory hole locations during site works. In addition, laboratory test results indicate no asbestos fibres were detected.



in any of the samples tested. Therefore, the risk for human health in regards asbestos is considered very low.

7.3.2.3 Petroleum hydrocarbons (PHC)

There was not visual or olfactory evidence of petroleum hydrocarbons in any of the exploratory hole locations during site works. In addition, laboratory test results indicate no exceedances on petroleum hydrocarbons were detected when compared to the corresponding GAC in any of the samples tested. Therefore, the risk for human health in regards petroleum hydrocarbons is considered very low.

7.3.3 Risk evaluation

The screening exercise has not identified any chemicals, asbestos, or petroleum hydrocarbons at concentrations above the GAC. Therefore, no further assessment is required.

7.4 Phytotoxicity risk assessment

7.4.1 Risk estimation

Priority phytotoxic chemical concentrations have been screened against published values to determine the likely risk to plant growth 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 test results that exceed the GAC, the chemicals of potential concern which require further assessment are summarised in Table 7-2.

Table 7-2: Chemicals of potential concern for which further assessment is required (risk to plants)

CoPC	GAC (mg/kg)	Basis for GAC	No. samples	Min. (mg/kg)	Max. (mg/kg)	No. samples >GAC
Plot 400						
Made Ground = No exceedances						
Natural soils = No exceedances						

7.4.2 Risk evaluation

There were no specific risks associated with Plot 400.

At Plot 100, one reported concentration of zinc within the made ground is slightly elevated when compared to the GAC (location TP1.04 at 0.45m bgl). The exceedance is considered minor and should not be detrimental to plant growth in the context of a typical landscaped area within a commercial development.

At Plot 700, reported concentrations of zinc within the made ground (at locations HP7.01 at 0.20m and 0.80m bgl) and copper (at locations HP7.01 at 0.80m bgl) exceed the GAC. For the one slightly elevated concentration of copper the exceedance is considered minor and should not be detrimental to plant growth in the context of the proposed development. The maximum reported concentration of zinc is outside the natural range for rural and urban soils reported across England in the Environment Agency's soil and herbage survey (EA, 2007) and the source of the elevated zinc is unclear. This does not mean that the reported concentration will adversely affect plant growth, however, as made ground is physically unsuitable as a growing medium, clean, imported soils will be required in areas of public open space.



7.5 Pollution of controlled waters risk assessment

7.5.1 Risk estimation

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

Site contaminant loadings are compared with relevant screening values (Water Quality Targets), which are linked to the Conceptual Site 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 choice of WQT is presented in Table 7-3 below, with the justification for the WQT selected explained in the following text:

1. Head Deposits is classed as Secondary Undifferentiated Aquifer. Bognor Sand Member is a secondary Aquifer A and may provide base flow to the Hermitage Stream located at the southwest and to the (unnamed) surface water feature located at the east boundary of the site.
2. There is a low risk of surface water runoff or contaminants leached from the Made Ground entering the secondary Aquifer A of the Bognor Sand Member.
3. Although there are no groundwater abstractions within 2km of the site, and the nearest surface water abstraction located at 1.5km of the site corresponds to spray irrigation, a conservative scenario is used to compare water samples with Drinking Water Standards.

Table 7-3: 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.	Human health (abstraction) Aquatic ecosystem.	Contaminants from site leach or seep into a groundwater body that feeds inland surface water by base flow. The surface water may be used for human consumption and is an aquatic ecosystem.	RTM Level 2 - Groundwater. Direct comparison of surface water samples	DWS EQS (inland)

Notes:

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

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

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

The results of the screening assessment are presented in Appendix F and are summarised in Table 7-4.

There are no WQT for petroleum hydrocarbon fractions in water. However, because of the sensitivity of the water environment to petroleum hydrocarbons, an initial screening exercise is also included in Table 7-4 irrespective of the assessment scenario(s) stated in Table 7-3.

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



Table 7-4: Chemicals of potential concern for which further assessment is required (controlled waters)

CoPC	WQT (µg/l)	Basis for WQT	No. samples	No. samples above LoD	Min. (µg/l)	Max. (µg/l)	No. samples exceeding WQT and above LoD
Plot 400							
Cobalt	3	EQS	2	2	0.8	3.5	1
Chromium IV*	3.4	EQS	2	0	<5		0
Copper+	1	EQS	2	2	1.1	3	2
Manganese+	50 123	DWS EQS	2	2	360	570	2
Nickel+	4	EQS	2	2	4.3	4.4	2
Benzo(a)pyrene*	0.00017	EQS	2	0	<0.01		0
Fluoranthene*	0.0063	EQS	2	0	<0.01		0

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

† The EQS for these substances represents a bioavailable concentration, which will be a proportion of the actual dissolved concentrations in water. No site-specific bioavailability testing was undertaken at the site and therefore the EQS bioavailable represents a conservative screening approach.

* Laboratory detection limit exceeds EQS. Contaminants with concentrations recorded below the laboratory detection limit, where the limit exceeds the EQS (such as chromium VI, chromium III, benzo(a)pyrene and fluoranthene) are not considered a significant risk.

7.5.2 Risk evaluation

In regards to groundwater, it is considered that:

- The inland waters EQS for copper, manganese, nickel, and zinc are exceeded across the entire site.
- EQS concentration for chromium VI, benzo(a)pyrene and fluoranthene are below the laboratory detection limit, and as such, further assessments of these substances have not been undertaken.
- Cadmium concentrations were detected above the EQS at Plots 100 and 700 (0.16 and 0.17 µg/l when compared to a EQS of 0.08 µg/l).
- Cobalt concentrations were detected above the EQS across all the Plots, with values between 3.5 and 10 µg/l (when compared to a EQS of 3 µg/l).
- A single exceedance on Chromium III was detected at Plot 700 (9.7 µg/l when compared to a EQS of 4.7 µg/l).
- Concentrations of iron, selenium and nitrite were detected above the DWS at Plot 700.
- Groundwater samples collected from monitoring wells within Plots 600, 400 and 100, which are located down gradient to Plot 700, have shown no exceedances in Chromium III, iron, selenium or nitrite, indicating these substances are not migrating through the ground and as such are thought unlikely to pose a risk to the groundwater body.
- There are no registered groundwater abstractions for drinking water purposes within 2km of the site, and the nearest registered surface water abstraction (spray irrigation) is located upstream at 1.5km north of the site.
- An additional controlled water risk assessment was carried out as part of recommendations for Plot 500 (Hydrock report reference 19453-HYD-XX-XX-RP-GE-1006), involving the collection of surface water samples from Hermitage Stream, located to the southwest of the site. This assessment indicated that no concentrations in exceedance of the WQT were detected in the surface water samples collected from the Hermitage Stream.

Reported groundwater concentrations above the WTQ are all less than an order of magnitude greater than the WTQ. In the context of the site setting and the absence of an obvious source for the elevated concentrations other than naturally occurring soils (and re-worked natural soils making up the Made



Ground) Hydrock believes that the theoretical risks to Controlled Waters do not need further consideration.

7.6 Ground gases risk assessment

7.6.1 Data

Nine rounds of monitoring were undertaken across the wider site (Plots 100-700), six during August-September 2021 and an additional three monitoring visits during January-February 2022.

7.6.2 Assessment

The risks associated with the ground gases methane (CH₄) and carbon dioxide (CO₂) have been assessed using BS 8485:2015 +A1:2019.

The maximum gas concentrations and gas screening values (GSV⁴) in Appendix D have initially been compared with the published thresholds in Table 2 of BS8454 and the assessment is summarised in Appendix E.

Table 7-5. The full assessment is presented in Appendix E.

Table 7-5: Ground gas risk assessment

	Min	Max	Typical (i)	Comment
Steady Flow Rate (l/hr)	-5.0	1.6	<0.1	Maximum flow recorded in WS4.03 on 22/1/22 during high groundwater levels that rose above the slotted section of the monitoring well. Methane <LOD and carbon dioxide at 2.6%
Methane (%)	0.0	4.0	<1	One methane reading was 1.1% at location WS4.03. Two methane readings were above 1% at location WS4.05 (2.7% and 4%).
Carbon Dioxide (%)	0.0	5.8	<5	Three carbon dioxide readings were slightly above 5% (between 5.6% and 5.8%) at location WS4.03)
Carbon Monoxide (ppm)	ND	3.0	<1.0	-
Hydrogen Sulphide (ppm)	ND	1.0	<1.0	-
Oxygen (%)	0.5	21.3		-
Carbon Dioxide GSV (l/hr)	-0.0800	0.0416 0.0928*	<0.07 <0.7	CS1 CS2
Methane GSV (l/hr)	-0.0054	0.0040 0.0640*	<0.07	CS1

(i) Hydrock assumes that values are considered to be atypical if 95% or more of the remaining data are less than the value under consideration.

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.

*Represents worst case GSV value (using max CH₄/ CO₂ values and worst-case flow from any well during any visit)

⁴ Note: GSV is synonymous with 'site characteristic hazardous gas flow rate' (Q_{hgs}) of BS 8485:2015 +A1:2019 Table.



As indicated in Appendix E.

Table 7-5, Plot 400 presents occasional methane readings above 1% at location WS4.05 and carbon dioxide readings slightly above 5% at WS4.05 and WS4.03. The maximum gas flow was 1.6l/hr and is likely the result of the high groundwater level which will have pressurised the air trapped in the upper plain section of the monitoring well. The calculated GSV for carbon dioxide and methane for Plot 400 indicates CS1 conditions. Considering the worst-case check (max CH₄/CO₂ values and worse case gas flow), the CS could increase to CS2 for carbon dioxide. However, as the worst-case hazardous gas flow (Q_{hg}) is only 0.09l/hr and no source of ground gas has been identified on site other than naturally occurring soils, the use of the worst-case Q_{hg} is considered unnecessarily conservative.

In conclusion, Plot 400 is classed as CS1 and, subject to confirmation with the LPA and the warranty provider, no mitigation measures are required.

7.7 Construction materials risk assessment

7.7.1 Water pipelines

A formal water pipe investigation and risk assessment is beyond the scope of this report. However, the findings of this investigation have been compared to the threshold values in Water UK HBF (2014), Table 1 as far as is practicable, to give an indication of the possible restrictions to the use of plastic pipes for water supply to the site.

The majority of the site is previously undeveloped, with a former landfill area covering a large proportion of the east and northern area of the site (between Plots 600 and 700). However, the preliminary risk assessment and ground investigation has not detected organic contamination in exceedance of the threshold values. Therefore, Hydrock believes standard pipework should be suitable for the site. However, confirmation should be sought from the water supply company at the earliest opportunity.

7.7.2 Other construction materials

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

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

The implications for buried concrete are discussed in Section 6.8.

7.8 Contamination risk to groundworkers

7.8.1 Introduction

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

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



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

7.8.2 Metals, metalloids, PAH and petroleum hydrocarbons

The soils do not contain significantly elevated concentrations of metals, metalloids, PAH or petroleum hydrocarbons and standard PPE is considered suitable for the handling of soils.

7.8.3 Ground Gas

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

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

7.8.4 Asbestos

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

7.9 Findings of the generic contamination risk assessments

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

The final Conceptual Site Model is illustrated on Hydrock Drawings 19453-HYD-XX-XX-DR-GE-1013A to 1013D in Appendix A.

None of the Source-Pathway-Receptor (SPR) contaminant linkages for the site were found to present an unacceptable risk or require mitigation.



8 Waste and materials management

8.1 Introduction

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

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

8.2 Waste disposal

8.2.1 Principles

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

Classification is a staged process:

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

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

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

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

Topsoil 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.

Greenfield Sites

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

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

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

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

Contaminated or potentially contaminated sites

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

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

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

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

8.2.2 HazWasteOnline™ assessment

As the site is greenfield, HazWasteOnline™ assessment is not technically required. However, it has been undertaken for completeness during the site investigation. The output of the HazWasteOnline™ assessment is provided in Appendix G and a summary of the preliminary waste classification is provided below in Section 8.2.4.

A total of 32 samples were assessed using the HazWasteOnline™ assessment tool. The assessment indicates the majority of the samples are classified as non-hazardous, except for two samples obtained within the Made Ground (WS1.02 at 1.5m bgl and WS4.06 at 0.5m bgl) classified as potentially hazardous on account of the designation 'HP8' (with regards to high pH - corrosive).



8.2.3 WAC Testing

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

One soil sample was obtained from Plot 400 (WS4.03 at 0.40m bgl) was classed as suitable for disposal as 'Inert Landfill Waste'.

8.2.4 Preliminary waste disposal options

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

1. The topsoil generally has a low organic content (as proven by the Loss on Ignition and Total Organic Carbon tests) and is likely to be classified as non-hazardous waste for disposal at a non-hazardous landfill.
2. The Made Ground is likely to be classified as non-hazardous waste (with exception of the two samples classified as potentially hazardous and stable non-reactive hazardous waste in non-hazardous landfill).
3. The natural uncontaminated subsoils are likely to be classified as 'inert' waste and based on the WAC testing should be able to be disposed of at an 'inert' landfill.

8.2.5 General waste comments

It should be noted that:

1. 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.
2. The above preliminary assessment has been made on the basis of the soils tested as part of the ground investigation, using WAC testing and the HazWasteOnline™ assessment. However, the formal classification of waste can only be undertaken on the material to be disposed of, and by the waste producer and the receiving landfill as license conditions vary from landfill to landfill.
3. 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.
4. 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.
5. At the time of disposal, additional testing on the excavated soils to be disposed of, will likely be necessary.
6. Non-hazardous and hazardous soils require pre-treatment (separation, sorting and screening) prior to disposal.
7. The costs for disposal of non-hazardous and hazardous soils are significant compared to disposal of inert material.



8. 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>.
9. 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 following⁵:
10. Duty of care transfer note / Hazardous Waste consignment note, including comment as to if pre-treatment has been undertaken; and
11. Basic Characterisation of the waste, to include: description of the waste; waste code (using list of wastes); composition of the waste (by testing, if necessary) and; WAC testing (if required).

8.3 Materials management

8.3.1 Introduction

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

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

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

The reuse of soils at sites should be considered during the planning and development design process so that compliance with issues such as fixed quantity and certainty of use clearly relate to agreed site levels. Suitability of Use is normally evident from the remediation strategy or the design statement, which form an integral part of a MMP. However, some soils may need to be tested post-excavation to prove they are suitable for use.

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

⁵ ENVIRONMENT AGENCY. November 2010. Guidance on waste acceptance procedures and criteria. Waste acceptance at landfills. The Environment Agency.

operators of illegal waste sites will now be liable for Landfill Tax. Further information is available at: <https://www.gov.uk/government/publications/landfill-tax-disposals-not-made-at-landfill-sites/landfill-tax-disposals-not-made-at-landfill-sites>.

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

8.3.2 Materials management scenarios

The materials management scenarios present on site are discussed below.

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

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

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

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

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

8.3.2.2 Clean, naturally occurring materials – transferred to other sites

Where soils are naturally occurring, uncontaminated and are transferred to other sites (i.e. direct transfer), they will not become waste as long as the transfer is undertaken in accordance with the DoWCoP. A MMP must be prepared for the receiving site and the materials movement must be noted in the MMP of the Donor site. This movement must have been declared to CL:AIRE prior to the works commencing.

8.3.2.3 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:

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

Other commonly occurring circumstances are:



If Made Ground is being moved between sites, it must be ensured that appropriate permits are in place to ensure the soils are not classified as a waste. Made Ground cannot be moved between sites under DoWCoP alone and would require relevant permits as part of the MMP documentation for the Hub site the material is being treated at.

8.3.2.4 Geotechnical improvement requirements

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

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



9 Uncertainties and limitations

9.1 Site-specific comments

The initial gas monitoring programme was completed between August/ September 2021. However, as it did not reach falling / low pressure conditions, additional monitoring was recommended within ground investigation report Plots 500-502 (reference: 19453-HYD-XX-XX-RP-GE-1004). The supplementary monitoring was undertaken between January/ February 2022. It is considered that falling/ low pressure conditions were achieved during the supplementary gas monitoring exercise and therefore, it is considered that the site is been fully characterised in accordance with CIRIA Report 665.

9.2 General comments

Hydrock Consultants Limited (Hydrock) has prepared this report in accordance with the instructions of Portsmouth City Council (the Client), by purchase order number PO3004424 dated 12/07/2021 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 between July/ August 2021 and January/ February 2022. The report has been prepared by Hydrock on the basis of available information obtained during the study period. Although every reasonable effort has been made to gather all relevant information, not all potential environmental constraints or liabilities associated with the site may have been revealed.

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

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

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

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

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

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



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

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.

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

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



10 Recommendations for further work

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

- discussions with regulatory bodies regarding the conclusions of this report;
- Investigation of the area of stockpiled material and additional geo-environmental and geotechnical testing to allow for potential re-use and/or disposal.
- provision of geotechnical design for the Category 2 structures (earthworks, retaining, floor slabs, foundations);
- production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies);
- production of a Materials Management Plan relating to reuse of soils at the site (if required);
- remediation and mitigation works; and
- verification of the earthworks, remediation and mitigation works.



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