GeoDyne

Geotechnical & Environmental Consultants

Ivanda Nursery, Monks House Lane
Spalding

Supplementary Phase II Exploratory Investigation Report
For
Seagate Homes

GeoDyne Limited
9 Brunel Park Way, Pride Park,
Derby, DE24 8HR
Tel: 01332 290798 email: info@geodyne.co.uk

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Project No: D44101		**Date: 5th March 2025**	
Issue/revision	Prepared by	Checked By	Approved By
	Daniel Brunt BSc (Hons) MSc CGeol FGS Associate	**Paul Kershaw BSc (Hons) PGDip CGeol FGS** Director	**Paul Kershaw BSc (Hons) PGDip CGeol FGS** Director
Comments			

EXECUTIVE SUMMARY

GEOTECHNICAL CONSIDERATIONS	
Ground Conditions	Made Ground was encountered in the western two-thirds of the site to depths of up to 0.90m begl, although localised deeper Made Ground to a depth of 2.00m begl was locally encountered (in BH1) in the far western portion. No Made Ground noted within the eastern third where Natural Topsoil was encountered to an average depth of 0.30m begl. The Natural Strata encountered was noted to be highly variable both laterally and vertically in terms of strength and composition and included CLAY and SILT and locally SAND (associated with the Tidal Flat Deposits), along with PEAT at variable depths. Beneath the Tidal Flat Deposits, a firm or stiff CLAY was encountered from depths ranging between 9.50m to 11.00m begl, underlain by very stiff CLAY (associated with the bedrock of the Oxford Clay Formation).
Foundation Design	A piled foundation solution is recommended for the proposed development.
Floor Slab Design & Ground Gases	Characteristic Situation CS2 in accordance with Table 4 of BS 8485. The most appropriate floor slab solution will need to take into account the requirements for CS2 precautions.
Radon	No radon precautions required.
Building Near Trees	Heave precautions may need to be incorporated into the design of ground beams in accordance with NHBC Standards Chapter 4.2, when building near existing, proposed or recently removed trees / hedgerows. The cohesive soils should be assumed to be of high volume change potential for design purposes
Water	Water was generally encountered as seepages at depths of between 1.50m and 2.80m begl (although 1.00m begl locally), with standing water within monitoring standpipes noted from depths of between 1.38m and 2.29m begl. Dewatering of excavations is therefore considered more likely at the site if excavations are left open for a period of time as water held within the surrounding low permeability soils will gradually seep / ingress into open excavations after relatively short periods.
Excavations / Stability	During excavation, it was generally possible to advance trial pits to depths ranging between 1.80m and 2.90m begl but as soon as these depths were achieved, collapse of the pit sides commenced relatively quickly. Excavations during the proposed development works may require trench support, including for health and safety reasons. The assessment of excavations and provision of support will be the responsibility of the contractor on site.
Sulphate Classification	Laboratory testing indicated a range in potential classifications between DS-1 and DS-5 and an ACEC AC-1s to AC-4s.
Coal Mining	No precautions required.
CBRs	A CBR value of less than 2% may be anticipated in the Made Ground and a CBR value of between 2% and 4% can be anticipated within the shallow Natural Strata, subject to confirmation by in-situ testing.
Surface Water Drainage	Based on the presence of natural soils of relatively low permeability and shallow water levels, soakaways may not be feasible at the site. It is recommended that alternative forms of surface water drainage are explored in the first instance.
ENVIRONMENTAL CONSIDERATIONS	
Soil & Water Contamination Assessment	<u>Human Health</u> • The Made Ground and Natural Strata beneath the majority of the site (outside areas of hydrocarbon impaction) may be considered to be uncontaminated for the proposed residential end-use. • Elevated TPH carbon fractions above Tier 1 human health generic assessment criteria (based on a residential with plant uptake end-use), along with hydrocarbon impacted soils have been identified in two locations: o Borehole WS103 located adjacent to the bunded above ground fuel storage tanks – approximate extent of hydrocarbon impacted soils to be remediated is indicated on Figure No. D44101/06 (within Appendix XI). o Borehole WS113 located adjacent to the small (off-site) above ground heating oil storage tank – approximate extent of hydrocarbon impacted soils to be remediated is indicated on Figure No. D44101/07 (within Appendix XI). <u>Controlled Waters</u> • Hydrocarbon impaction of the soils have been identified in localised areas of the site in the area of the on and off-site tanks. • The environmental sensitivity of the site is considered to be relatively low, therefore the potential risks posed to Controlled Waters by the findings of the laboratory analysis undertaken are considered to be relatively low. However, further inspection / assessment of the soils directly beneath the tanks following removal of the bund and removal of the tanks is recommended. • It should also be noted that the area of hydrocarbon impaction associated with the small (off-site) heating oil tank is relatively close to the open drain (Edward Road Dyke), therefore precautionary remedial actions are considered prudent. <u>Further Assessment Works</u> It is recommended that further inspection and assessment of the soils directly beneath the bunded tanks and the boiler house equipment is carried out during / following the remaining site clearance works. Should any localised hydrocarbon impaction of the ground be noted, then localised source removal works may be necessary following assessment.

Remediation Proposals	Based on the findings of our intrusive works, remediation (where possible) of any grossly hydrocarbon impacted soils in the vicinity of the tanks is required, together with appropriate post-removal validation sampling. If unacceptably elevated contaminated soils are identified beneath the disused boiler house equipment, then this would also require remediation. Details of the required remediation works would be set out within a Remediation Strategy and Verification Plan, which should be prepared in advance of the works in accordance with the Planning Conditions. Following completion of the remediation works, a Verification / Validation report will be required in accordance with the Planning Conditions. Based on the findings of soil contamination assessment, provision of a remedial capping layer to proposed gardens / soft landscaping is not considered necessary. The provision of topsoil is considered necessary in proposed gardens and the area of public open space to provide a suitable growing media for plants.
GENERAL CONSIDERATIONS	
Construction Workers	It is recommended that construction personnel involved with direct contact with the soils at the site use appropriate PPE / RPE equipment together with hygiene facilities in accordance with general health and safety guidelines.
Utilities	Prior to development of the site, we would recommend that a copy of this report is supplied to utility companies, and that their recommendations relating to appropriate supply pipes are adhered to. With regard to water supply pipes, the use of protective / barrier water supply pipes may be required locally within the *'Brownfield'* area of the proposed development site. However, consideration should be given to localised remediation of the soils within the depths where pipework is likely to be laid which may negate the requirement for protected pipework, subject to the outcome of liaison with Anglian Water.
Unforeseen Circumstances	Should any areas of potentially contaminated soil be encountered during site construction works we would recommend consultation with GeoDyne to ensure that our recommendations continue to apply.
Licenses etc.	The Contractor/Developer is responsible for, and must ensure that, all necessary licenses, permits, plans, registrations and approvals are in place prior to commencing with the construction works at the site.
Statutory Consultation	In accordance with normal planning requirements, we would recommend that a copy of our report is issued by the Client to the Local Authority (and Warranty Provider, if necessary) for review / comment and approval prior to commencing with the development of the site.
Further Works	• It is recommended that copies of the Ground Engineering and GeoDyne reports should be submitted to the Local Authority for their review and comment prior to any remedial works at the site. • Following the receipt of comments on the above and details of the requirements of the Local Authority, a Remediation Strategy and Verification Plan document should be prepared and approved by the Local Authority in advance of the remedial works. • Following approval of the Remediation Strategy and Verification Plan, the remedial works should be carried out. Following removal of the tanks etc., this is likely to comprise removal (where possible) of any grossly hydrocarbon impacted soils in the vicinity of the tanks and former boiler house equipment (if present), together with appropriate post-removal validation sampling. • Following completion and verification / validation of the remedial works, a Remediation Completion / Validation Report should be prepared and submitted to the Local Authority for approval. • Following finalisation of the design of gas protection measures, it is likely to be necessary to prepare a Ground Gas Verification Plan (GGVP), followed by installation, inspection and validation of the gas resistant membranes by a third party (in accordance with the requirements of CIRIA C735).

1.0 INTRODUCTION

1.1 Introduction

GeoDyne Limited has been appointed by the Client, Seagate Homes, to undertake supplementary Phase II Exploratory Investigation works on a parcel of land located at the former Ivanda Nursery site situated to the east of Monks House Lane in Spalding, Lincolnshire. A site location plan (Figure No. D44101/01) is included in Appendix I.

1.2 Project Understanding

We understand that it is the intention of the Client to redevelop the site with low-rise residential properties, including gardens, with the remaining areas to comprise open space including an attenuation basin and an ecological corridor. A proposed Site Layout plan provided by the Client is included in Appendix II.

The foregoing understanding has formed the basis of our assessment. Where the proposed site end-use is not consistent with our current understanding, it would be necessary to review our assessment to ensure it continues to apply.

1.3 Previous Report

The following reports have previously been prepared for the site:

- Ground Engineering *'Report On A Phase 1 Desk Study – Ivanda Nursery, Monks House Lane, Spalding, Lincolnshire'*, Report Reference C15847, dated January 2023.

- Ground Engineering *'Report On A Ground Investigation – Ivanda Nursery, Monks House Lane, Spalding, Lincolnshire'*, Report Reference C15847A, dated March 2023.

It is assumed that the Client benefits from formal reliance on the above referenced reports and we would recommend that the foregoing reports are read in conjunction with this report.

1.4 Objectives

The scope of works detailed herein have been designed based on the findings of the previous Ground Engineering reports (referenced above) and the requirements of the Client to enable supplementary geotechnical and environmental assessment works to be carried out at the site, as requested by the Client.

1.5 Scope of Works

Based on the defined objectives of the works (detailed in Section 1.4) and taking account of the findings and recommendations within the previous Ground Engineering reports (referenced above), the following scope of supplementary Phase II works was designed for the site.

- A sub-contracted sub-surface service avoidance scan of proposed exploratory hole locations.
- A programme of exploratory holes at the site, to provide an inspection of the ground conditions from a geotechnical and environmental perspective, as follows:
  - A series of window sampling boreholes in accessible areas.
  - A series of mechanically excavated trial pits in accessible areas.
  - Cable percussive boreholes to assess the deeper ground conditions.
- Environmental and geotechnical soils testing.
- A programme of ground gas and water level monitoring.

- Production of a revised Conceptual Site Model.
- Production of a factual and interpretative Supplementary Phase II report.

1.6 Limitations

The conclusions and recommendations made in this report are limited to those that can be made based on the findings of the investigation. Where comments are made based on information obtained from third parties, GeoDyne Limited assumes that all third party information is true and correct. No independent action has been undertaken to validate the findings of third parties.

This report has been prepared in accordance with our understanding of current good practice. However, changes to good practice, guidance or legislation may necessitate revision of this report after the date of issue.

GeoDyne Limited has prepared this report for the sole use and reliance of Seagate Homes, in accordance with our standard Conditions & Limitations (included in Appendix XII). This report may not be used or relied upon by any unauthorised third party without the explicit written agreement of GeoDyne Limited. Reliance may not be placed on our report until all invoices associated with the project have been paid.

2.0 SITE SETTING

2.1 Introduction

The site comprises an elongated roughly rectangular shaped parcel of land situated to the east of Monks House Lane in Spalding. The site covers an area of approximately 2 hectares.

The following reports have previously been prepared for the site:

- Ground Engineering *'Report On A Phase 1 Desk Study – Ivanda Nursery, Monks House Lane, Spalding, Lincolnshire'*, Report Reference C15847, dated January 2023.

- Ground Engineering *'Report On A Ground Investigation – Ivanda Nursery, Monks House Lane, Spalding, Lincolnshire'*, Report Reference C15847A, dated March 2023.

The above Phase 1 Desk Study report provides an appraisal of the geological, historical and environmental setting of the site, and provides a Conceptual Site Model identifying possible contaminants of concern and issues requiring further consideration as part of a Phase II exploratory investigation.

The above Ground Investigation report involved the advancement of window sample boreholes across the site as part of an initial investigation.

The following comments provide a summary of the findings of the previous reports, as well as a brief introduction to the site for the benefit of the reader. However, we would recommend that the above reports are read in conjunction with this report.

It should be noted that the site boundary shown in the above reports has changed in the western portion of the site. The new site boundary is shown on the proposed Site Layout plan (included in Appendix II of this report). The site boundary in the Ground Engineering report previously included the now vacant existing residential property (including the adjacent small heating oil tank to the rear of the property) in the south-western portion and also a strip of land alongside Monks House Lane. However, these areas are no longer part of the proposed development site.

2.2 Summary of Previous Desk Study

A summary of the site location and description (at the time of the Ground Engineering report) and geological setting is provided below. The following summary is taken from Ground Engineering Ground Investigation report.

'The site lies on western outskirts of Spalding, and is situated about 1km to the west of Spalding Railway Station…'

'The site comprises a 50m wide by 400m long plot of land previously used by a horticultural nursery with two large glasshouses occupying the western half of the site and an overgrown grass field covering the eastern half. Access to the site was from the west via a drive off Monks House Lane, adjacent a detached dwelling within the south-western corner of the site. To the north, east and south, the site was surrounded by a housing estate. A drainage ditch called Edward Road Dyke runs along the southern site margin.

There was a set of surfaced mounted heating oil tanks, housed within a bunded area situated directly to the north-west of the western greenhouse that are connected to a central heating boiler between the glasshouses. A smaller unbunded surface mounted heating oil tank [now off-site] *was located at the side of an outbuilding to the rear/east of the dwelling within the south-western corner.'*

'The geological map for the area, sheet 144 'Spalding' at 1:50,000 scale, and Geology of Britain online viewer, show the site to be covered by Tidal Flat Deposits. These comprise a thick superficial cover of clay, silt and sand tidal creek deposits of the Terrington Beds. Older salt marsh and tidal creek deposits of the Barroway Drove Beds are indicated to underlie the Terrington Beds the boundary of which is often marked by the Nordelph Peat. The underlying solid geology is indicated to comprise the Oxford Clay at depth.'

A summary of the findings of the Ground Engineering Phase 1 Desk Study report is provided as follows.

'In 1889 the site was undeveloped and situated within fenland off Monks House Lane. In the 1950s a small nursery was present at the western end of the site, which otherwise remained as open land. The nursery appears to have remained fairly small until the 1970s/80s when it became established as the Ivanda Nursery and installed large glasshouses across the western half of the site and kept the eastern half as an open field possibly used for crops. The site has remained as a horticultural nursery through to the time of this investigation and is believed to have produced fresh fruit, vegetables, flowers and plants for wholesale distribution.

There are no landfill sites or waste sites within a 250m radius.

The property is in an area where less than 1% of properties are above the action level for radon. The site lies within an area where no radon protection measures are necessary.

The superficial Tidal Flat Deposits and underlying solid geology Oxford Clay Formation are both identified as Unproductive in terms of aquifer classification.

The desk study concluded that it would be prudent to carry out a ground investigation, which should determine the thickness and nature of made ground across the site, and check the near surface soil and water for potential contaminants and soil gas. The areas around the fuel tanks, fuel lines and central heating boiler should be investigated to check whether the underlying soil or groundwater has been impacted.'

Since the issue of the previous Ground Engineering reports, some of the structures (including the greenhouses) at the site have been demolished. An Annotated Site Plan (Figure No. D44101/02) showing the current main features of the site and immediate surrounding area and a plan showing general views of the site (Figure No. D44101/03) are enclosed within Appendix III and IV of this report respectively.

2.3 Summary of Previous Ground Investigation

The ground investigation works carried out by Ground Engineering comprised the following:

- 12 No. window sample boreholes (referenced WS1 to WS12) were advanced at the site on 23rd and 24th January 2023. The boreholes were advanced to depths of between 1.20m and 4.45m below ground level.
- Standard penetration testing (SPTs) was carried out in selected boreholes.
- Gas and groundwater level monitoring standpipes were installed in 4 No. of the boreholes (WS2, WS7, WS9 and WS11), with monitoring carried out on 3 No. visits (3rd, 10th and 16th February 2023).

The main findings of the contamination assessment are provided as follows.

*'**Contamination Risk - Near Surface Soil***

Made ground, which included made ground/topsoil within the landscaped areas, was present to depths between 0.30m to 0.85m depth and comprised layers of dark brown, brown, grey brown and grey layers of gravelly sand; sand and gravel; and soft, slightly sandy, slightly gravelly clay and silt.

Apart from PAHs in a single sample from WS3 [now off-site] *at 0.30m depth, none of the determinand concentrations, within the near surface soils, exceeded the respective SSVs for residential with home grown produce, residential without home grown produce end use, or public parks open space usage.*

Evidence of petroleum pollution was however encountered in the vicinity of WS2 and WS3 [now off-site] *(both adjacent surface mounted fuel tanks) and WS7 (adjacent central heating boiler).'*

Contamination Risk – Oil/Petroleum Pollution

There was a set of surfaced mounted heating oil tanks, housed within a bunded area situated directly to the north-west of the western greenhouse that are connected to a central heating boiler between the glasshouses. A smaller unbunded surface mounted heating oil tank [now off-site] *was located at the side of an outbuilding to the rear/east of the dwelling within the south-western corner. There is significant evidence that leakage or a spillage of fuel oil has occurred adjacent the storage tanks impacting both the underlying soil and groundwater.*

The fuel oil would be expected to migrate vertically downwards beneath the source and then on entering the groundwater, would migrate as a plume in the direction of groundwater flow. Due to seasonal fluctuations, groundwater levels tend to rise and fall and any petroleum hydrocarbons or solvents floating at the top of the groundwater become absorbed or adsorbed onto the soil particles forming a 'smear zone', which can often be visually identified by grey staining or by a petroleum/solvent odour.

It is recommended that all the sources of petroleum/oil pollution are established and removed. Further investigation would be necessary to establish the extent of oil pollution and when redevelopment is considered, the removal of all such sources would be recommended in order to eliminate future risk. This would include the decommissioning and removal from across the whole site of all buried or surface fuel/oil tanks, fuel lines, drums, chemicals and oil interceptors. The latter measures should reduce the future risk to human health and water environment from moderate/high to low.

'Human Health - Residential Usage Areas Beneath Yard & Hardstanding Areas and by Fuel Tanks

The potential for variability of the made ground beneath these areas means that, in addition to this made ground being unsuitable as topsoil, it could be unsuitable for use at the surface within residential gardens. Consequently, in the absence of further testing the made ground should be considered unsuitable for use at the surface within landscape or residential garden areas. Unsuitable soil at the surface within gardens or landscaped areas should be replaced with a suitably thick, clean capping layer.

- *For front garden areas it would be recommended that the underlying natural ground be exposed, or in deeper areas the made ground should be removed to a minimum depth of 0.60m and replaced with an equivalent thickness of clean inert soil.*

- *For rear gardens it is recommended that the underlying natural ground should be exposed, or in deeper areas the made ground should be removed to a minimum depth of 1.00m and replaced with an equivalent thickness of clean inert soil.*

All garden/landscaped areas should be inspected prior to final capping to ensure that unsuitable materials have not been inadvertently placed in the garden or landscaped areas during the preceding stages of redevelopment works.

Human Health - Residential Usage Areas beneath Green Houses and the Field to the East

Whilst the chemical test results suggest that the near surface soils are suitable for use at the surface, it would be prudent to check all landscaped/garden areas prior to final capping with clean topsoil.

All garden/landscaped areas should be inspected prior to final capping to ensure that unsuitable materials have not been inadvertently placed in the garden or landscaped areas during the preceding stages of redevelopment works.

All imported soils should be certified 'clean' fill and should be suitable for use in accordance with UK legislation and Environment Agency policy.

Methane and Carbon Dioxide Soil Gas

According to database information, whilst there are no landfills within 250m of the site, the presence of peat below the site would suggest a low hazard potential.

The presence of elevated carbon dioxide concentrations of 9.3% combined with a low flow/emission rate indicates that for design purposes it would be prudent to adopt a CS2 soil gas categorisation as defined by BS8485:2015+A1:2019 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'.

Tables 3 to 7 within this British Standard identify a points-based method for defining the need for gas precaution measures. Based on this method and on the basis of a Type A building (representative of a private dwelling), a minimum gas protection score of 3.5 would be required and could be achieved using a ventilated underfloor void, a low permeability gas membrane, and minimal penetration of the ground slab by services.

The Ground Engineering report also contained comments on the ground conditions in relation to foundation design and construction issues and a summary is provided as follows:

'The strata encountered in the boreholes comprised typically 0.30m to 0.85m thickness of made ground covering the western two-thirds of the site. The field within the eastern third of the site was covered by a 0.40m to 0.50m thickness of topsoil. The made ground and topsoil layers are considered unsuitable as founding strata and spread foundations should not be placed in the made ground, topsoil or any soft, very soft, loose, or highly compressible materials.

The made ground and topsoil rested on a variable sequence of soft and very soft, slightly sandy silt, with interbedded layers of organic clay/silt and sand. These Tidal Flat Deposits were present to at least 4.45m depth, the base of the deepest boreholes.

The depth of the footings would need to be deep enough to protect against the effects of soil desiccation or soil heave within the clay/silt Tidal Flat Deposits.

Laboratory testing the near surface clay and silt Tidal Flat Deposits gave modified plasticity indices of between 13% and 46%, which indicates low to high volume change potential, according to the National House Building Council (NHBC) Standards Chapter 4.2 "Building near Trees" (2023).'

'In order to address any potential future shrinkage or heave effects, a high volume change potential has been assumed for the clay/silt beneath the site. At an open position well away from the influence of trees and shrubs a minimum foundation depth of 1.00m below ground level or finished floor level, whichever is deepest, would be required for foundations in order to avoid the zone of seasonal volume change in accordance with the above document.

Below a depth of 1.00m the soft/very soft and organic nature of the Tidal Flat Deposits would provide very poor bearing properties, which would be considered unsuitable for traditional footings. Traditional footings, and ground bearing floor slabs, even under modest loadings would be expected to generate high differential movement of the ground due to variances of settlement occurring between constituent silt/sand and organic clay lenses/channels. Further ground investigation on a plot by plot basis would be required to determine if the ground conditions between borehole positions could be suitable for traditional foundations.

With the absence of a plot by plot investigation, it is recommended that consideration be given to the option of piled foundations, which would support all structural loadings including the floors.

Further ground investigation in the form of deep boreholes would be necessary in order to provide information to inform the design of piled foundations.'

With regard to potential aggressive attack to buried concrete, the Ground Engineering report stated the following:

'Tests on near surface soil samples to determine the risk of sulphate attack on buried concrete indicate levels that fall into Class DS-1 as defined by Table C2 of BRE Special Digest 1, 2005. The pH results indicate slightly alkaline ground conditions with pH values ranging between 7.3 and 8.2.

Due to the presence of organic/peaty soils across the site, for the purposes of design, an Aggressive Chemical Environment for Concrete (ACEC) Class of AC-3 should be considered when specifying a Design Chemical Class (DC Class) for concrete used within shallow footings. Peat is listed in the latter publication as being a stratum that may contain sulphides, such as pyrite, hence oxidation due to disturbance during the excavation of foundations may increase the total potential sulphate content.'

2.4 Summary of Sites Environmental Setting

An appraisal of the sites environmental setting is documented within the Phase I Desk Study report. The salient points are summarised as follows:

- The site is indicated to be directly underlain by superficial Tidal Flat Deposits with the underlying solid geology identified as the Oxford Clay Formation, which are both Unproductive in terms of aquifer classification.
- The site does not lie within a Source Protection Zone (SPZ). There are no groundwater abstractions or potable abstractions recorded within 250m of the site.

- For surface water features, there are 6 drains listed within 250m of the site including the Edward Road Dyke, which runs along the southern site boundary. There is a surface water abstraction point (for irrigation of farmland) located 228m to the north-west of the site.
- No radon precautions are required at the site.

2.5 Rationale for Supplementary Phase II Exploratory Investigation Works

Based on the findings of the previous phase of ground investigation works carried out by Ground Engineering, together with the requirements of the Client, GeoDyne were requested to carry out supplementary Phase II geo-environmental exploratory investigation works at the site. The purpose of the further works are summarised as follows:

- Carry out initial contamination delineation works (where possible) around the two areas containing above ground fuel storage tanks / hydrocarbon impaction of the ground and also further investigation around the boiler house (where possible), with associated laboratory contamination testing for petroleum hydrocarbons.
- Undertake initial contamination delineation works (where possible) around WS3 where elevated concentrations of PAHs were previously identified in a sample of the Made Ground, including laboratory PAH testing.
- Collect samples of the near surface soils across the site for laboratory testing for a suite of pesticides / herbicides testing given the previous use of the site as a plant nursery – as these particular contaminants were not tested for previously by Ground Engineering.
- Installation of gas monitoring standpipes and undertake a programme of further gas monitoring at the site.
- Collect soil samples at locations along the route of the proposed roads for specific laboratory testing to aid in the selection of the proposed pipework for potable water with the aim of meeting Anglian Water's requirements.

It should be noted that the area of the small above ground heating oil storage tank (and the adjacent vacant residential house), together with the location of window sample borehole WS3 (where hydrocarbon impacted soils and elevated PAH concentrations were previously recorded by Ground Engineering) is now situated outside of the proposed development site boundary, although relatively close to the site.

3.0 SUPPLEMENTARY GROUND INVESTIGATION

3.1 Introduction

Sub-Surface Utility Avoidance Scan

Prior to the commencement of our intrusive works at the site, a sub-contracted sub-surface utility scan was undertaken to attempt to avoid buried services during the intrusive works. Based on the results of the service scan and taking account of the requirement to avoid buried services, the exploratory holes were positioned to maximise the amount of information obtained at the site.

Window Sampling Borehole Works

A total of 14 No. window sampling boreholes (WS101 to WS114) were advanced at the site between 8th and 10th January 2025 to facilitate the collection of shallow soil samples, delineation purposes and the installation of gas monitoring points. The boreholes were advanced to depths of either 4.00m or 5.00m below existing ground level (begl).

Standard Penetration Tests (SPTs) were undertaken in selected boreholes generally at either 0.5m or 1m centres in order to provide initial strength data for the near surface soils.

Following completion, six of the window sampling boreholes (WS105, WS106 and WS109 to WS112) were installed with combined ground gas and water monitoring standpipes in order to facilitate a programme of monitoring.

Trial Pits

In total, 9 No. trial pits (TP1 to TP9) and 1 No. hand dug pit were excavated at the site on 10th and 13th January 2025 to facilitate the collection of shallow soil samples, delineation purposes and as part of the foundation engineering assessment. The trial pits were excavated to depths of between 0.30m and 2.90m begl.

Cable Percussive Boreholes

Five cable percussive boreholes (BH1 to BH5) were advanced at the site between 6th and 16th January 2025 to depths of between 15.00m and 20.21m begl as part of the foundation engineering assessment.

SPTs were undertaken at regular intervals in the boreholes in order to provide initial strength data for both the near surface and deeper soils.

Exploratory Hole Locations / Logs

The approximate locations of the exploratory holes are indicated on the plans presented in Appendix V of this report (Figure Nos. D44101/04a and D44101/04b). The exploratory hole logs are presented in Appendix VI of this report.

3.2 Ground Conditions

The general ground conditions encountered across the site may be summarised as follows.

3.2.1 Made Ground

Made Ground was encountered in the exploratory holes advanced in the approximate western two-thirds of the site at generally similar depths to those encountered by Ground Engineering, i.e. generally to depths of up to 0.90m begl, although localised deeper Made Ground to a depth of 2.00m begl was locally encountered (in BH1) in the far western portion.

No Made Ground was encountered within the eastern third of the site which comprised a grassed field.

The Made Ground soils comprised a variety of materials, as summarised below:

- 'Topsoil' – was encountered in WS101 to WS103, WS114, TP7 and BH1 to depths of between 0.10m and 0.50m begl.
- 'Sand' was encountered at surface within the footprint of the former large greenhouses in WS104 to WS106, WS108, WS109, WS112, TP1, TP9, BH4 and BH5. This was underlain by a black plastic membrane above and below a 25mm thick layer of polystyrene, often with pea gravel beneath, with occasional plastic water pipes (for insulation and irrigation purposes). This horizon of 'Sand' etc. was encountered to depths of up to 0.30m begl.
- 'Sand and Gravel' was encountered at surface locally in WS107, WS113 and HDP1, to depths of between 0.15m and 0.60m begl. This horizon contained mainly limestone, quartzite and possible igneous gravel as minor constituents, along with occasional fragments of concrete / breeze block locally. In WS113, pockets / bands of ash and clinker were noted to a depth of 0.35m begl; and in HDP1 occasional clinker with fragments of metal and glass was noted.
- 'Clay' (locally Silt) was encountered within WS103 to WS106, WS108, WS109, WS112 to WS114, TP1 and BH1 to depths of between 0.35m and 0.90m begl, with up to 2.00m begl locally in BH1. The 'Clay' was considered to potentially comprise reworked natural soils and was noted to contain occasional / rare man-made materials locally, such as brick fragments and rare clinker as minor inclusions (in WS105). In one location (HDP1) occasional fragments of metal and glass and whole bricks were noted.

A plan showing the depth to the base of the Made Ground at each exploratory hole location is presented in Appendix VII (Figure No. D44101/05).

3.2.2 Natural Strata

Natural Strata was generally encountered beneath the Made Ground or at surface in the remaining exploratory holes advanced across the site.

In areas where no Made Ground was encountered, Natural Topsoil was encountered at surface in WS110 and WS111, TP2 to TP6 and BH2 and BH3, to an average depth of approximately 0.30m begl.

The Natural Strata encountered directly beneath the Made Ground or Natural Topsoil typically comprised the following:

- The Natural Strata encountered across the site was noted to be highly variable in terms of strength and composition both laterally and vertically, with CLAY and SILT and locally SAND deposits being encountered at shallow depths. These soils were considered to be representative of the Tidal Flat Deposits.
- The CLAY and SILT soils were noted to vary between soft and firm at shallow depth, with the firm soils rapidly becoming soft with increased depth.

- PEAT was encountered at variable depths within a number of the exploratory holes advanced across the site, along with observations of horizons / pockets with a variable content of organic matter within the Clay, Silt and Sand deposits. For example, a 0.55m thickness of PEAT was encountered at a depth of 0.95m to 1.50m begl (in WS105) in the western third of the site. PEAT inclusions or bands were noted in 4 No. of the 5 No. cable percussion boreholes at depths ranging between 2.00m begl and up to 10.00m begl.
- Beneath the Tidal Flat Deposits (where penetrated in the deeper cable percussion boreholes only), a firm or stiff CLAY (containing fragments of chalk) was encountered from depths ranging between 9.50m to 11.00m begl. These deposits were underlain by very stiff CLAY containing fragments of chalk from depths ranging between 11.70m to 12.50m begl to the base of the boreholes, which are considered to be associated with the bedrock of the Oxford Clay Formation indicated on the geological mapping to be present beneath the site.

3.3 Visual & Olfactory Evidence of Soil Contamination

Hydrocarbon odours and occasional staining were noted locally in the window sampling boreholes and trial pits advanced in the vicinity of the above ground fuel storage tanks (ASTs).

The visual and olfactory evidence of hydrocarbon impaction within the exploratory works advanced at the site are summarised in Table 1.

TABLE 1 – SUMMARY OF VISUAL & OLFACTORY EVIDENCE OF POTENTIAL CONTAMINATION

Ref:	Visual / Olfactory Evidence	Depth Encountered (m begl)	Material
WS101	Faint hydrocarbon (diesel-like) odour (from 2.30m) with slight dark discolouration from 2.40m to 2.60m begl, becoming a very faint hydrocarbon odour to 3.00m begl	2.30 – 3.00	Natural SAND
WS102	Slight to faint hydrocarbon (diesel-like) odour from 2.40m begl, with a slight sheen between 2.40m and 2.60m begl, becoming a faint then very faint hydrocarbon odour (with no sheen)	2.40 – 3.50	Natural SAND
WS103	Faint hydrocarbon (diesel-like) odour at 1.95m	1.95 – 2.60	Natural SILT
	Very faint hydrocarbon (diesel-like) odour	2.60 – 3.50	Natural SAND
WS113	Slight hydrocarbon (diesel-like) odour	1.20 – 2.70	Natural SILT
	Slight to faint hydrocarbon (diesel-like) odour from 2.70m, becoming a faint hydrocarbon odour from 3.00m to 3.70m	2.70 – 3.70	Natural SAND

3.4 Photo-Ionisation Detector Screening

Following the intrusive works, soil samples were analysed using a portable MiniRAE 2000 Photo Ionisation Detector (PID).

The MiniRAE 2000 is a robust, portable PID used to investigate the potential presence of Volatile Organic Compounds (VOCs) and hydrocarbon vapours. Whilst the PID does not quantitatively discriminate between discrete VOCs, the gross presence of VOCs is taken to be a reliable indicator of soil impaction.

The soil samples (small disturbed jar samples) were placed in sealed containers, agitated, and the headspace in each container aspirated into the PID for analysis. Screening revealed values (in ppm Isobutylene Equivalent Units) within some of the soil samples recovered from the exploratory holes.

The headspace testing undertaken (using the PID) on the soil samples recovered from the exploratory holes is summarised in Table 2, with only those revealing a concentration above 1ppm reported:

TABLE 2 – PID READINGS RECORDED IN SOIL SAMPLES

Ref:	Sample Depth (m begl)	Material	PID Reading (ppm)
WS101	2.40 – 2.60	Natural SAND	3.3
	2.90 – 3.00	Natural SAND	1.4
WS102	3.00 – 3.20	Natural SAND	1.7
WS103	2.10 – 2.40	Natural SILT	5.2
WS113	0.90 – 1.00	Natural CLAY	2.2
	1.50 – 1.60	Natural SILT	44.3
	2.20 – 2.40	Natural SILT	19.0
	3.00 – 3.30	Natural SAND	27.5

Screening revealed values below background levels (taken as </=1ppm) in all of the remaining soil samples obtained from within the subject site, which indicates the absence of any significant volatile contamination within the analysed soil samples across the wider site area.

3.5 Water

Water was generally encountered as seepages during the site investigation works, or as damp soils in a number of the trial pits (prior to the collapse of the sidewalls). The water seepages were typically encountered at depths of between 1.50m and 2.80m begl within the natural deposits, with an average depth of approximately 2.00m begl (although water was encountered at 1.00m locally).

3.6 Stability

The sides of most of the trial pits advanced to depths greater than 1m were noted to be unstable when the excavations reached depths ranging between 1.80m and 2.90m begl. This resulted in rapid and total collapse of the trial pits.

Casing was typically used to varying depths within the boreholes during exploratory works.

3.7 Plates

A photographic record of the exploratory investigation was obtained during the intrusive works. Selected photographs are presented on the Plates presented in Appendix VIII of this report (Plate Nos. 1 to 19).

3.8 Shear Vane Testing

In-situ shear vane testing was undertaken within the natural Clay or Silt soils within a number of the trial pits at various depths ranging between 0.70m and 1.50m begl to establish a strength / depth profile of the near surface soils.

A chart showing the in-situ shear vane values in relation to depth is provided on page 14 for information. Table 3 below shows a summary of the shear vane values between specific depth ranges. Individual shear vane results are provided on the exploratory hole logs included in Appendix VI of this report.

TABLE 3 – SUMMARY OF IN-SITU SHEAR VANE RESULTS

Depth (m begl)	Number of SV Readings	Minimum SV Reading (kN/m²)	Maximum SV Reading (kN/m²)	Average SV Reading (kN/m²)
0.70 – 1.00	22	28	58	46
1.00 – 1.30	15	20	56	32
1.30 – 1.50	9	15	22	17

3.9 Standard Penetration Test (SPT) Data

In order to establish a strength / depth profile of the strata beneath the site, SPT testing was undertaken at regular intervals within selected boreholes advanced at the site.

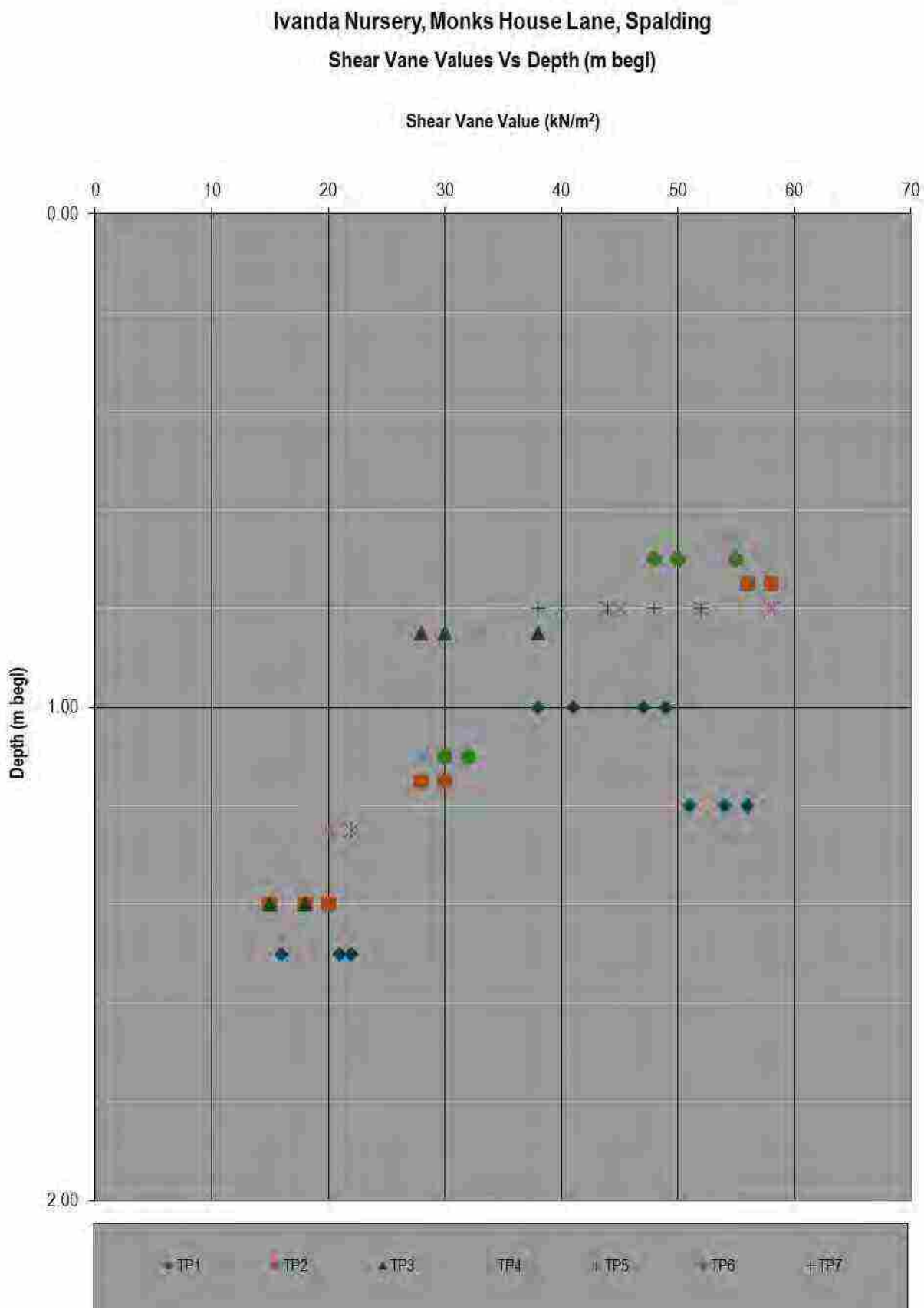
The uncorrected SPT 'N' values within the Made Ground are summarised as follows:

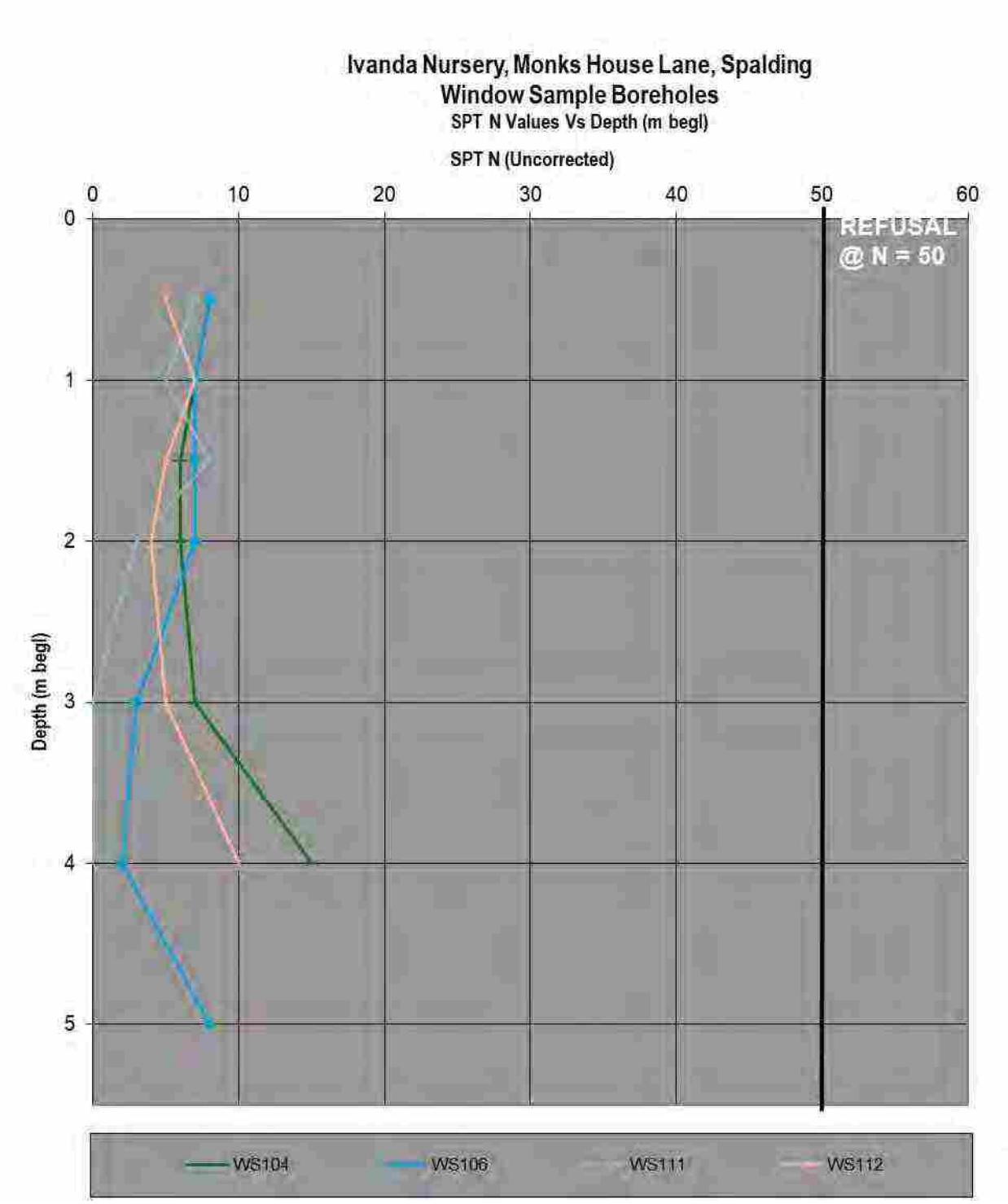
- Depths of 0.50m and 1.00m begl: Uncorrected SPT 'N' values ranged between 3 and 8.

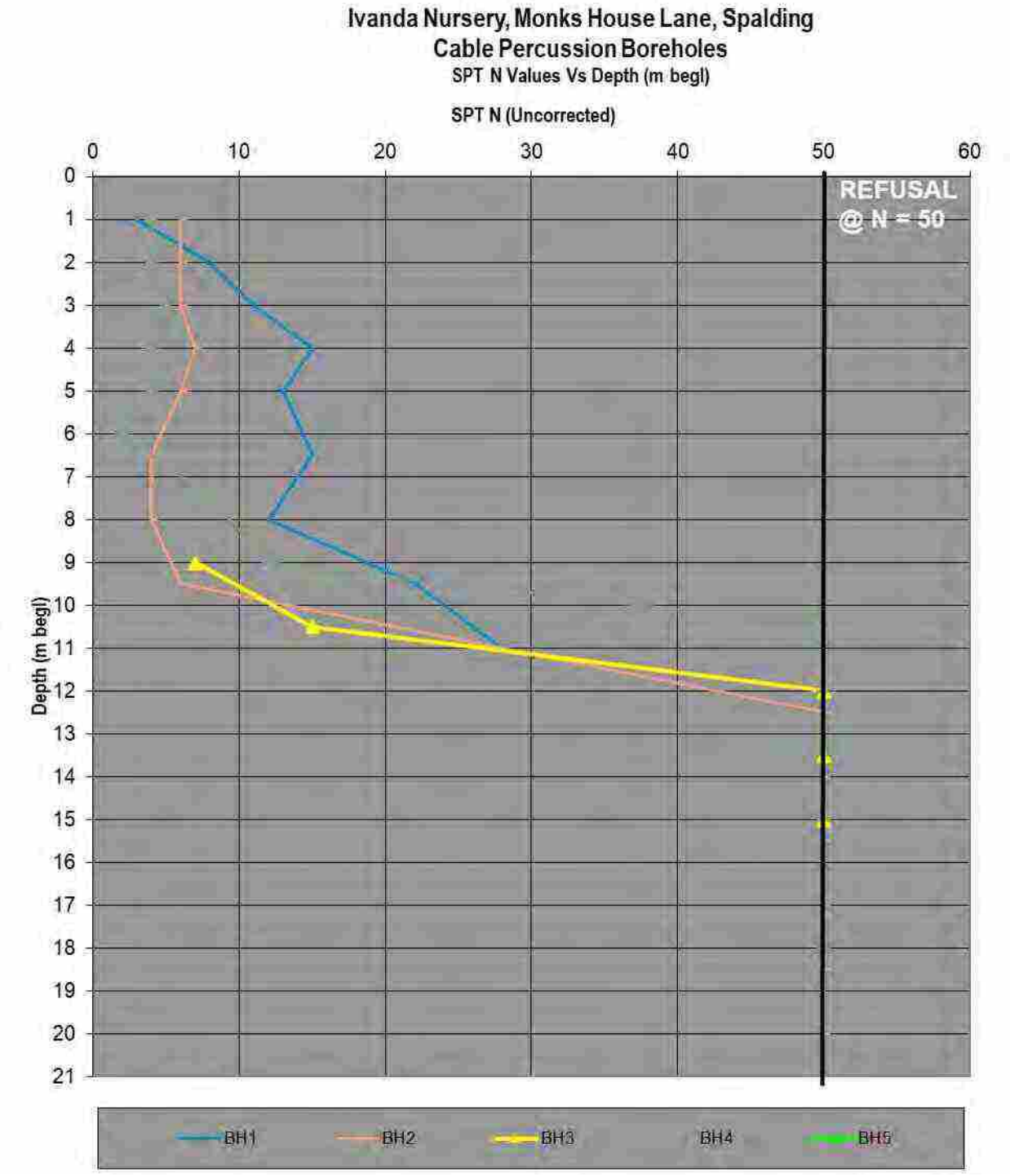
The uncorrected SPT 'N' values within the Natural Strata are summarised as follows:

- Depths of 0.50m and 1.00m begl: Uncorrected SPT 'N' values ranged between 4 and 8.
- Depths of 1.50m to 3.00m begl: Uncorrected SPT 'N' values ranged between 0 and 12.
- Depths of 4.00m to 5.00m begl: Uncorrected SPT 'N' values ranged between 0 and 15.
- Depths of 6.00m to 9.00m begl: Uncorrected SPT 'N' values ranged between 2 and 15.
- Depths of 9.50m to 11.50m begl: Uncorrected SPT 'N' values ranged between 6 and refusals (i.e. an SPT 'N' value equal to or in excess of 50).
- Depths of 11.50m to 20.00m begl: Uncorrected SPT 'N' values were all refusals.

An SPT Vs Depth Chart of the data obtained from the window sample boreholes and the cable percussion boreholes advanced at the site are shown on the charts on Pages 15 and 16 respectively.


Ivanda Nursery, Monks House Lane, Spalding
Shear Vane Values Vs Depth (m begl)
Shear Vane Value (kN/m²)
0
10
20
30
40
50
60
70
0.00
1.00
2.00
Depth (m begl)
TP1
TP2
TP3
TP4
TP5
TP6
TP7


Ivanda Nursery, Monks House Lane, Spalding
Window Sample Boreholes
SPT N Values Vs Depth (m begl)
SPT N (Uncorrected)
0
10
20
30
40
50
60
REFUSAL
@ N = 50
Depth (m begl)
0
1
2
3
4
5
WS104
WS106
WS111
WS112


Ivanda Nursery, Monks House Lane, Spalding
Cable Percussion Boreholes
SPT N Values Vs Depth (m begl)
SPT N (Uncorrected)
0
10
20
30
40
50
60
REFUSAL
@ N = 50
Depth (m begl)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
BH1
BH2
BH3
BH4
BH5

4.0 LABORATORY TESTING & CONTAMINATION ASSESSMENT

4.1 Introduction

Geotechnical Analysis of Soils

As part of our works, a suite of geotechnical laboratory soils testing has been undertaken, which comprised the following:

- 9 No. Plasticity Index tests.
- 1 No. Particle Size Distribution test.
- 20 No. Water soluble sulphate tests.
- 20 No. Total sulphate tests.
- 20 No. Total Sulphur tests.
- 20 No. pH tests.

Chemical Analysis of Soils

Environmental soil testing was carried out on visually representative samples recovered from the exploratory holes. The testing strategy was based on the findings and recommendations of the existing Ground Engineering Ground Investigation report, the rationale for the supplementary Phase II works (as discussed within Section 2.5 of this report) and the ground conditions encountered during our supplementary works.

The following testing has been undertaken as part of our works:

- 15 No. Speciated TPH tests (aliphatic/aromatic split, BTEX & MTBE).
- 5 No. Speciated Polycyclic Aromatic Hydrocarbons (PAHs).
- 5 No. Total Organic Carbon (TOC).
- 7 No. Pesticides and Herbicides suites.
- 6 No. Anglian Water Suites (for assessing the requirements for potable water supply pipes) which included the following determinands:
  - Total phenols.
  - Volatile organic compounds (VOCs).
  - Semi-volatile organic compounds (SVOCs).
  - Speciated Total Petroleum Hydrocarbons (TPH) by Criteria Working Group (CWG) method tests (including aliphatic / aromatic carbon fractions, BTEX & MTBE) – as included above.

All laboratory soil test results are included in Appendix IX.

4.2 Geotechnical Soil Test Results

Sulphates / pH

The results of the pH and sulphate testing (and the associated calculations) are summarised in Table 4 below:

TABLE 4 – SUMMARY OF PH AND SULPHATE TEST DATA				
Stratum	pH Value Range	Water Soluble Sulphate Range (mg/l)	Total Potential Sulphate Range (%)	Oxidisable Sulphate (OS) Range (%)
Made Ground	7.99 & 8.88 2 No. samples tested	<10 & 38 2 No. samples tested	0.06 & 0.15 2 No. samples tested	0.00 & 0.07 2 No. samples tested
Tidal Flat Deposits - (Clay / Silt / Sand, including Peat)	7.85 – 9.18 13 No. samples tested	24 – 1,130 13 No. samples tested	0.09 – 10.95 13 No. samples tested	0.03 – 10.48 13 No. samples tested 6 No. samples with OS >0.3% SO_4
Oxford Clay Formation	8.69 – 8.85 5 No. samples tested	125 – 471 5 No. samples tested	0.54 – 3.27 5 No. samples tested	0.38 – 3.14 5 No. samples tested All 5 No. samples with OS >0.3% SO_4

In accordance with the Building Research Establishment publication Special Digest 1 *'Concrete in Aggressive Ground'* (2005), the mean of the highest 20% of the sulphate concentrations (for all soil types detailed in Table 4) should be used to indicate the Design Sulphate Class (i.e. 601mg/l SO_4), together with the mean of the lowest 20% of the pH values (7.83).

As the Ground Engineering Ground Investigation report stated that the soils beneath the site may potentially contain sulphides such as pyrite, the soil test results have therefore been assessed in this regard. To classify site locations where ground materials (natural ground or clean fill derived from natural ground) may contain sulfides (e.g. pyrite), BRE Special Digest 1 states that the total potential sulfate content of the soils (which might result from oxidation following ground disturbance) should be taken into account. The laboratory total sulphur and sulphate results have been utilised to determine the oxidisable sulphate content of the samples tested. If the amount of oxidisable sulfides is greater than 0.3% SO_4 in a significant number of samples, pyrite is probably present. It is noted that in 11 No. of the 20 No. samples tested (i.e. six samples of the Tidal Flat Deposits and five samples of the Oxford Clay Formation), the calculations indicate that pyrite is 'probably' present.

The following classification has been made based on the assumption of a natural ground location and the presence of potentially static groundwater conditions beneath the site.

Based on the results of the laboratory testing carried out, the site indicates a range in potential classifications between Design Sulfate Class DS-1 and DS-5 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1s to AC-4s. The most onerous classification was influenced by the results of the samples of the Tidal Flat Deposits containing Peat and also samples of the Oxford Clay Formation.

In view of the above, it would appear that the concrete classification is variable depending upon the soil / material types encountered at the site. The results should therefore be considered during the detailed design of foundations by the Structural Engineer (including the piling contractor). However, at this stage it is considered that given the findings of the testing carried out on samples of the Tidal Flat Deposits and the Oxford Clay Formation, it is anticipated that the upper classification is likely to be required for buried concrete.

Plasticity Index (PI) Testing

A total of 9 No. Plasticity Index tests have been undertaken on selected samples of the Natural Strata obtained during the site works from across the site. In accordance with NHBC standards Chapter 4.2 '*Building Near Trees*' and BRE Digest 240 '*Low-rise buildings on shrinkable clay soils: Part 1*' (1993) the reported PI values may be modified based on the portion of the sample passing the 425μm sieve.

The result of the PI analysis is summarised in Table 5.

TABLE 5 – SUMMARY OF PLASTICITY INDEX (PI) DATA

Sample Reference & Location	Reported PI Value (%)	Portion Passing 425μm Sieve (%)	Modified PI Value (%)	Volume Change Potential
BH1 2.00m (CLAY / SILT with PEAT – TFD)	35	100	35	Medium
BH1 3.00m (Silty SAND – TFD)	-	-	-	Non-plastic
BH2 0.60-1.20m (CLAY – TFD)	16	100	16	Low
BH2 1.20-2.00m (SAND / SILT – TFD)	13	100	13	Low
BH3 12.10-13.00m (CLAY – OCF)	20	98	19.6	Low
BH4 1.00-2.00m (SILT – TFD)	-	-	-	Non-plastic
BH4 2.00-3.00m (SILT – TFD)	-	-	-	Non-plastic
BH4 9.60-10.00m (CLAY – TFD)	18	98	18	Low
BH5 15.00m (CLAY – OCF)	18	97	17	Low

Notes:
TFD = Tidal Flat Deposits
OCF = Oxford Clay Formation

Table 5 confirms that the Clay / Silt and Silt soils associated with the Tidal Flat Deposits encountered at the site that have been tested by GeoDyne may be regarded as being of low to medium volume change potential. The testing has revealed that some of the samples of the Sand and Silt were indicated as being Non-Plastic.

With regard to the samples of the Oxford Clay Formation tested, Table 5 reveals that these soils may be regarded as being of low volume change potential.

Particle Size Distribution (PSD) Test

Particle Size Distribution (PSD) testing was undertaken on a sample of the Sand obtained from borehole BH4 (at 7.00-7.50m begl). The results revealed the granular content of this soil type (i.e. Sand) to be 56%, with a fine particles (Silt / Clay) content of 44%. This generally confirms the visual granular description of this soil type, which on the basis of this test result, may be potentially shrinkable.

Summary of PI and PSD Testing

The previous Ground Engineering Ground Investigation report stated that the testing carried out as part of the initial phase of exploratory works on soils associated with the Tidal Flat Deposits revealed soils up to a high volume change potential. In view of this, soils of a high volume change potential should be assumed for design purposes where these soils (the Tidal Flat Deposits) are encountered. The underlying Clay soils at depth associated with the Oxford Clay Formation are regarded as being of a low volume change potential.

4.3 Contamination Assessment of Soils

We understand that it is the intention of the Client to redevelop the site with low-rise residential properties, including gardens, with the remaining areas to comprise open space including an attenuation basin and an ecological corridor.

4.3.1 Assessment Methodology

In order to undertake a Generic Quantitative Risk Assessment (GQRA) we have adopted the Suitable for Use Levels (S4ULs) published by LQM/CIEH in their publication referenced: Nathanail, C.P., McCaffrey, C. Gillett, A.G., Ogden, R.C. and Nathanail, J.F, 2015. '*The LQM/CIEH S4ULs for Human Health Risk Assessment. Land Quality Press, Nottingham. All rights reserved.*' In the absence of an S4UL screening value, we have made reference to the Category 4 Screening Levels (C4SLs) published by DEFRA.

In consideration of the available generic land uses utilised in the derivation of the adopted screening criteria, we have adopted a residential with plant uptake end-use scenario for the purposes of our assessments.

For assessment purposes, we have adopted a policy whereby determinands within the dataset are individually compared to the relevant screening value (i.e. individual S4ULs). Where determinands within the dataset are less than the appropriate screening value, the determinand is considered to be present at an acceptable concentration and no further assessment is required. Additional comment, statistical assessment or further Detailed Quantitative Risk Assessment (DQRA) may be provided where elevated values are revealed.

4.3.2 Selection of Soil Organic Matter (SOM) Content

The SOM content and soil type are used to provide an assessment of the applicability of the screening values adopted (the S4UL values are typically based upon SOM of 1%, 2.5% and 6%, as applicable, with all metals derived utilising 6% SOM as standard).

Where available at Tier 1 level, determinands have in the first instance been compared to screening values adopting a conservative SOM of 1%.

Where the determinand exceeds the relevant screening value at 1% SOM, a site-specific SOM may be adopted as appropriate to derive more site-specific screening values and the dataset reassessed.

4.3.3 Sampling Strategy

The sampling strategy for the supplementary Phase II works was primarily to retrieve visually representative soil samples from a selection of locations as outlined in Section 2.5 'Rationale for Supplementary Phase II Exploratory Investigation Works' (where access allowed) which are summarised as follows:

- Carry out initial contamination delineation works around the two areas containing above ground fuel storage tanks / hydrocarbon impaction and also around the disused boiler house, with associated laboratory contamination testing for petroleum hydrocarbons. This also included assessment of the area adjacent to the filling point at the end of the pipeline to the bunded tanks.
- Undertake contamination delineation works closest to WS3 (now off-site) where elevated concentrations of PAHs were previously identified in a sample of the Made Ground, including laboratory contamination testing.

- Collect samples of the near surface soils across the site for laboratory testing for a suite of pesticides / herbicides testing given the previous use of the site as a plant nursery – as these particular contaminants were not tested for previously by Ground Engineering.
- Installation of gas monitoring standpipes and undertake a programme of further gas monitoring at the site.
- Collect soil samples at locations along the route of the proposed roads for specific laboratory testing to aid in the selection of the proposed pipework for potable water with the aim of meeting Anglian Water's requirements.

Based on the findings of the previous phase of ground investigation works, specific areas of concern were identified at the site with respect to potential ground contamination (including TPH contamination associated with Ground Engineering's boreholes WS2 and WS3) and PAH contamination associated with WS3 (which is now off-site).

Table 6 summarises the reasoning behind the exploratory hole positions.

TABLE 6 – REASONING FOR EXPLORATORY HOLE LOCATION

Exploratory Hole Reference	Reasoning Behind Location
WS101 to WS104	Targeted to the area around the bunded above ground fuel storage tanks associated with the heating system for the former greenhouses
WS106 to WS108	Targeted to the area around the former boiler house
WS113, WS114 and HDP1	Targeted to the area closest to the off-site small above ground heating oil storage tank associated with the off-site vacant residential house. WS114 was also situated adjacent to the filling point at the end of the pipeline to the bunded tanks.
TP1	Targeted to the location of a former tank shown on the historical maps (unknown whether contents were fuel or water).
WS104, WS108 to WS112 and TP7	Targeted to the areas of the former plant nursery buildings (including greenhouses) and the cultivation areas for the purposes of soil sample collection for pesticide and herbicide testing
WS101, TP1, TP2, TP5, TP8 and TP9	Targeted to the route of the proposed road for soil sampling for laboratory testing for Anglian Water potable water supply pipework selection.
WS105, WS106, WS109 to WS112	General site coverage for the purposes of installing supplementary ground gas monitoring points, including beneath the footprints of the proposed houses.
All remaining exploratory hole positions, i.e. BH1 to BH5 and TP2 to TP6	General site coverage (avoiding known utilities) for the cable percussion boreholes to aid potential pile design; and trial pits within the grassed field areas in the eastern portion for foundation engineering assessment purposes.
Key WS – Window Sampling Borehole TP – Trial Pit BH – Cable Percussive Borehole	

The ground conditions encountered during our supplementary Phase II works revealed the presence of three distinct types of material, i) Made Ground (including topsoil), ii) Natural Topsoil and iii) Natural Strata.

Representative samples of these soil types were obtained during our supplementary Phase II works and subjected to chemical analysis for specific contaminants deemed appropriate based on the findings of the previous Desk Study and initial ground investigation works carried out by Ground Engineering, together with the requirements of the Client and the ground conditions encountered during our supplementary Phase II investigation.

It is noted that the suite of contaminants detailed in Section 2.5 were considered to remain applicable following completion of our supplementary investigation works.

4.3.4 Soil Contamination Analysis

Contamination tests were undertaken on visually representative samples of the Made Ground, the Natural Topsoil and the underlying Natural Strata obtained from the site during our works.

Targeted analysis was commissioned on samples recovered from areas of the site where specific contaminants were considered more likely to be present based on the Sampling Strategy (see Section 4.3.3).

For initial assessment purposes, the laboratory test results for the Made Ground (including topsoil), Natural Topsoil and Natural Strata have been individually compared against appropriate GACs. The laboratory results have been assessed in relation to a proposed residential with plant uptake end-use scenario.

The results of the laboratory analysis have been separated out for the specific areas where our supplementary investigation works (including delineation works etc.) have been carried out.

4.3.5 Contamination Soil Test Results

Bunded Above Ground Fuel Storage Tanks

The contamination assessment for the soils tested in the area of the bunded above ground fuel storage tanks associated with the former heating system for the greenhouses at the site is summarised in Table 7.

Please note that screening values have only been used for determinands where they are present at concentrations in excess of the laboratory limit of detection (LOD) on at least one occasion.

TABLE 7 – SUMMARY OF TIER 1 GAC ASSESSMENT (BUNDED ABOVE GROUND FUEL STORAGE TANKS – RESIDENTIAL WITH PLANT UPTAKE END-USE)

Contaminants – Potentially Harmful to Human Health	No. of Samples Tested	Concentration Range (mg/kg)	Tier 1 GAC (mg/kg)	Tier 1 GAC Exceeded (Yes/No) & No. of Exceedances
TPH				
Aliphatic >C6-C8	5	<0.01 – 0.03	100 $_{S4UL}$	No
Aliphatic >C8-C10	5	<1 – 20	27 $_{S4UL}$	No
Aliphatic >C10-C12	5	<1 – 44	130 $_{S4UL}$	No
Aliphatic >C12-C16	5	<1 – 221	1,100 $_{S4UL}$	No
Aliphatic >C16-C35	5	<2 – 257	65,000 $_{S4UL}$	No
Aromatic >C8-C10	5	<1 – 3	34 $_{S4UL}$	No
Aromatic >C10-C12	5	<1 – 44	74 $_{S4UL}$	No
Aromatic >C12-C16	5	<1 – 209	140 $_{S4UL}$	Yes (1 No.)
Aromatic >C16-C21	5	<1 – 176	260 $_{S4UL}$	No
Aromatic >C21-C35	5	<1 – 25	1,100 $_{S4UL}$	No

Key
S4UL – CIEH/LQM Suitable 4 Use Levels (2015). Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3026. All rights reserved.

The data within Table 7 may be summarised as follows.

TPH

The laboratory testing carried out has revealed a concentration of only one of the TPH carbon fractions to be in excess of its respective Tier 1 GAC for a residential with plant uptake end-use scenario, as follows:

- Aromatics C12-C16 within WS103 at 2.10-2.40m begl comprising Natural Silt which exhibited a hydrocarbon (diesel-like) odour.

WS103 was situated on the northern side of the bunded above ground fuel storage tanks. It should be noted that the samples collected and tested from WS101 and WS102 on the western side of the tanks – where further hydrocarbon odours were noted in the soils – were found to contain TPH concentrations below their respective Tier 1 GAC. Furthermore, WS104 on the south-eastern side of tanks contained only very low TPH concentrations.

All of the samples contained concentrations of the BTEX compounds which were below the laboratory detection limits and also below their respective human health Tier 1 GAC for a residential with plant uptake end-use.

The TPH results have also been assessed in relation to the potential risks posed to Controlled Waters. Three of the soil samples tested contained cumulative TPH concentrations above 500mg/kg, with concentrations of 995mg/kg in WS103 (at 2.10-2.40m begl), 630mg/kg in WS102 (at 2.40-2.60m begl) and 528mg/kg in WS101 (at 2.40-2.60m begl). These samples are above the Environment Agency's arbitrary value of 500mg/kg for cumulative TPH above which further Controlled Waters risk assessment is sometimes required. However, if the cumulative concentrations are assessed in terms of the published water solubility values for each of the TPH carbon fractions (ref: TPH CWG Series Report Volume 3), it is apparent that the concentration of cumulative soluble TPH is reduced significantly. The reason for this is that the cumulative soluble TPH fractions represent a much lower proportion of the overall cumulative TPH result. If the concentrations of the four fractions of low solubility (Aliphatic C12 –C16, Aliphatic C16 – C21, Aliphatic C21 – 35 and Aromatic C21 – C35) are removed from the cumulative total, the results are revised to 492mg/kg, 313mg/kg and 301mg/kg respectively, which are all below the Environment Agency's arbitrary value of 500mg/kg.

VOCs and SVOCs

In the sample tested as part of the Anglian Water suite (for the assessment of potable water supply pipes), the concentrations of all of the VOCs and SVOCs analysed were all below their respective laboratory limits of detection and below their respective human health Tier 1 GAC for a residential with plant uptake end-use (where published).

Further Comments

All remaining determinands assessed were present at individual concentrations below the Limit of Detection of the method of analysis adopted by the laboratory and / or below the appropriate Tier 1 GAC based on a residential with plant uptake end-use.

Former Boiler House

The contamination assessment for the soils tested in the area of the former boiler house (used for heating the greenhouses at the site) is summarised in Table 8.

Please note that screening values have only been used for determinands where they are present at concentrations in excess of the laboratory limit of detection (LOD) on at least one occasion.

TABLE 8 – SUMMARY OF TIER 1 GAC ASSESSMENT (FORMER BOILER HOUSE – RESIDENTIAL WITH PLANT UPTAKE END-USE)				
Contaminants – Potentially Harmful to Human Health	No. of Samples Tested	Concentration Range (mg/kg)	Tier 1 GAC (mg/kg)	Tier 1 GAC Exceeded (Yes/No) & No. of Exceedances
TPH				
Aliphatic >C12-C16	3	<1 – 1	1,100 S4UL	No
Aliphatic >C16-C35	3	<2 – 4	65,000 S4UL	No
Aromatic >C21-C35	3	<1 – 1	1,100 S4UL	No
Key S4UL – CIEH/LQM Suitable 4 Use Levels (2015). Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3026. All rights reserved.				

All determinands assessed were present at individual concentrations below the limit of detection of the method of analysis adopted by the laboratory and / or below the appropriate Tier 1 GAC based on a residential with plant uptake end-use.

Speciated TPH

The contamination assessment has revealed that the individual concentrations of all of the TPH carbon fractions were below their respective Tier 1 GAC for human health for a residential with plant uptake end-use.

VOCs and SVOCs

In the sample tested as part of the Anglian Water suite (for the assessment of potable water supply pipes), the concentrations of all of the VOCs and SVOCs analysed were all below their respective laboratory limits of detection and below their respective human health Tier 1 GAC for a residential with plant uptake end-use (where published).

Small Above Ground Heating Oil Storage Tank (Off-Site)

The contamination assessment for the soils tested in the area closest to the off-site small above ground heating oil tank associated with the residential property adjacent to the site is summarised in Table 9. Window sample borehole (WS113) was positioned on the boundary of the site closest to the location of WS3 which was previously advanced by Ground Engineering and found to exhibit hydrocarbon impaction. A further borehole (WS114) was advanced further into the study site (at the opposite side of the access road).

The previous Ground Engineering Ground Investigation report also identified elevated concentrations of PAHs in a sample of the Made Ground from WS3. In view of this, samples of the Made Ground were tested from two locations on the site boundary nearest to WS3 (i.e. within WS113 and HDP1) and also slightly further into the site (WS114).

Please note that screening values have only been used for determinands where they are present at concentrations in excess of the laboratory limit of detection (LOD) on at least one occasion.

TABLE 9 – SUMMARY OF TIER 1 GAC ASSESSMENT (SMALL ABOVE GROUND HEATING OIL STORAGE TANK – RESIDENTIAL WITH PLANT UPTAKE END-USE)				
Contaminants – Potentially Harmful to Human Health	No. of Samples Tested	Concentration Range (mg/kg)	Tier 1 GAC (mg/kg)	Tier 1 GAC Exceeded (Yes/No) & No. of Exceedances
Aliphatic >C6-C8	2	<0.01 – 0.3	100 S4UL	No
Aliphatic >C8-C10	2	<1 – 331	27 S4UL	Yes (1 No.)
Aliphatic >C10-C12	2	<1 – 845	130 S4UL	Yes (1 No.)
Aliphatic >C12-C16	2	<1 – 474	1,100 S4UL	No
Aliphatic >C16-C35	2	<2 – 52	65,000 S4UL	No
Aromatic >C8-C10	2	<1 – 62	34 S4UL	Yes (1 No.)
Aromatic >C10-C12	2	<1 – 464	74 S4UL	Yes (1 No.)
Aromatic >C12-C16	2	<1 – 381	140 S4UL	Yes (1 No.)
Aromatic >C16-C21	2	<1 – 1	260 S4UL	No
Aromatic >C21-C35	2	<1 – 1	1,100 S4UL	No
PAH				
Benzo(a)anthracene	3	<0.1 – 0.07	7.2 S4UL	No
Benzo(a)pyrene	3	<0.1 – 0.09	2.2 S4UL	No
Benzo(b)fluoranthene	3	<0.1 – 0.12	2.6 S4UL	No
Benzo(ghi)perylene	3	<0.1 – 0.07	320 S4UL	No
Chrysene	3	<0.1 – 0.08	15 S4UL	No
Fluoranthene	3	<0.1 – 0.1	280 S4UL	No
Indeno(123-cd)pyrene	3	<0.1 – 0.07	27 S4UL	No
Pyrene	3	<0.1 – 0.11	620 S4UL	No
Key S4UL – CIEH/LQM Suitable 4 Use Levels (2015). Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3026. All rights reserved.				

The data within Table 9 may be summarised as follows.

TPH

The laboratory testing carried out has revealed concentrations of certain TPH carbon fractions to be in excess their respective Tier 1 GAC for a residential with plant uptake end-use scenario, as follows:

- Aliphatics C8-C10 and C10-C12.
- Aromatics C8-C10, C10-C12 and C12-C16.

The elevated TPH carbon fractions were all detected within one sample tested from WS113 at 1.50-1.60m begl which exhibited a hydrocarbon (diesel-like) odour. WS113 was situated on the boundary of the site, however, the borehole advanced slightly further into the site (WS114) contained very low TPH concentrations which were all below their respective Tier 1 GAC.

All of the samples contained concentrations of the BTEX compounds which were below the laboratory detection limits and also below their respective human health Tier 1 GAC for a residential with plant uptake end-use.

The TPH results have also been assessed in relation to the potential risks posed to Controlled Waters. One of the soil samples tested contained a cumulative TPH concentration above 500mg/kg, i.e. 2,610mg/kg in WS113 (at 1.50-1.60m begl). This sample is above the Environment Agency's arbitrary value of 500mg/kg for cumulative TPH above which further Controlled Waters risk assessment is sometimes required. However, if the cumulative concentration is assessed in terms of the published water solubility values for each of the TPH carbon fractions (ref: TPH CWG Series Report Volume 3), it is apparent that the concentration of cumulative soluble TPH is reduced. The reason for this is that the cumulative soluble TPH fractions represent a much lower proportion of the overall cumulative TPH result. If the concentrations of the four fractions of low solubility (Aliphatic C12 –C16, Aliphatic C16 – C21, Aliphatic C21 – 35 and Aromatic C21 – C35) are removed from the cumulative total, the result is revised to 2,084mg/kg, which is still above the Environment Agency's arbitrary value of 500mg/kg.

Speciated PAHs

The contamination assessment has revealed that the individual concentrations of all of the PAH compounds were below their respective Tier 1 GAC for human health for a residential with plant uptake end-use.

Further Comments

All remaining determinands assessed were present at individual concentrations below the Limit of Detection of the method of analysis adopted by the laboratory and / or below the appropriate Tier 1 GAC based on a residential with plant uptake end-use.

Supplementary Laboratory Analysis for Pesticides and Herbicides

Seven samples of the near surface soils across the site were analysed for a suite of pesticides and herbicides testing given the previous use of the site as a plant nursery – as these particular contaminants were not tested for previously by Ground Engineering.

The results of the pesticide and herbicide testing revealed individual concentrations below the Limits of Detection of the method of analysis adopted by the laboratory for all of the pesticides and herbicides tested.

4.4 Anglian Water Testing

Based on previous experience of sites within the Lincolnshire area, it was considered likely that Anglian Water would classify the western two-thirds of the site as a *'Brownfield'* site for their assessment purposes, with the eastern third comprising a grassed field (previously used for horticultural purposes) designated as *'Greenfield'*. It is our opinion that based on the findings of the desk study and the ground conditions encountered during our Supplementary Phase II works, the entire site should not simply be classed as brownfield, as the evidence from our exploratory holes indicates that the eastern third of the site is greenfield.

In view of the above, soil samples were obtained from each area of the site to enable an initial assessment of the likely requirements for the composition of the water supply pipework, although a higher proportion of samples were targeted to the *'Brownfield'* area, as normally expected. As required by Anglian Water, soil samples should be obtained from depths of a minimum of 500mm below ground level and tested for a suite of contaminants deemed appropriate based on the guidance detailed within Anglian Water document entitled *'Information for developers about contaminated land and ground condition assessment'* dated November 2023.

The purpose of the testing was to determine the presence of possible contaminants at the site and assess whether PE pipes would be sufficient for the site or whether protective / barrier water supply pipes would be necessary at the site.

As stated within the *'Contaminated Land Assessment Guidance'* published by Water UK in January 2014, *'where the proposed depth of the pipes is unknown at the time of application, soil samples representative of the ground condition between surface level and 1.50m below finish ground level shall be taken as a minimum.'*

The samples selected for specific testing were obtained from WS101, TP1, TP8 and TP9 in the *'Brownfield'* area and TP2 and TP5 in the *'Greenfield'* area. Based on the current proposed layout, the sampling points are situated approximately within the 15m corridor of the proposed roads / likely pipeline routes. Given the 15m corridor, the results of the TPH testing carried out on a further sample (from WS113) within this distance of the proposed roads have also been assessed.

The testing included the following:

- 7 No. Speciated TPH tests (aliphatic/aromatic split, BTEX and MTBE).
- 6 No. Volatile Organic Compounds (VOCs).
- 6 No. Semi-Volatile Organic Compounds (SVOCs) including Cresols, Chlorinated Phenols and Speciated PAHs.
- 6 No. Total Phenols tests.

All laboratory soil test results are included in Appendix IX of this report.

The results have been examined in relation to the Anglian Water threshold values. The contamination assessment for the samples obtained at the site is summarised in Table 10 on the next page.

Brownfield Area

TABLE 10 – ANGLIAN WATER SUITE DATA ASSESSMENT
BROWNFIELD AREA

Parameter Group	No. of Samples Tested	Concentration Range (mg/kg)	PE Threshold (mg/kg)	PE Threshold Exceeded (Yes or No)	Protective / Barrier Pipes Required (Yes or No)
Total VOCs	4	All results below LOD (<0.001 to <0.01)	0.5 $_{AW}$	No	No
BTEX + MTBE	4	All results below LOD (<0.01)	0.1 $_{AW}$	No	No
Total SVOCs (excluding PAHs)	4	All results below LOD (<0.2)	2 $_{AW}$	No	No
EC5-EC10 Aliphatic and Aromatic Hydrocarbons	5	<0.01 – 393.3	2 $_{AW}$	Yes	Yes*
EC10-EC16 Aliphatic and Aromatic Hydrocarbons	5	<LOD (<1) – 1,292	10 $_{AW}$	Yes	Yes*
EC16-EC40 Aliphatic and Aromatic Hydrocarbons	5	<LOD (<1) – 18	500 $_{AW}$	No	No
Phenols	4	All results below LOD (<0.2)	2 $_{AW}$	No	No

TABLE 10 – ANGLIAN WATER SUITE DATA ASSESSMENT BROWNFIELD AREA					
Parameter Group	No. of Samples Tested	Concentration Range (mg/kg)	PE Threshold (mg/kg)	PE Threshold Exceeded (Yes or No)	Protective / Barrier Pipes Required (Yes or No)
Cresols and Chlorinated Phenols	4	All results below LOD (<0.1 or <0.2)	2 AW	No	No

Key

LOD – Laboratory Limit of Detection.
AW – Values taken from Pipe Selection Table within Anglian Water guidance document *'Investigation for developers about contaminated land and ground condition assessment'* dated November 2023, which is reproduced from UKWIR publication *'Guidance for the selection of water supply pipes to be used in Brownfield sites'*, (2010).
Total Phenols includes a sum of phenols, cresols, xylenols and resorcinol.
* indicates protective / barrier pipes are required unless remediation is carried out.

The data within Table 10 may be summarised as follows.

TPH

Elevated concentrations of TPHs have been identified within borehole WS113 which is situated at the southern edge of the proposed road which runs close to the area of the hydrocarbon impaction associated with the off-site small heating oil tank in the south-western portion of the site.

It should also be noted that further hydrocarbon impacted soils are situated in the area of the bunded above ground fuel storage tanks, although the impacted soils were noted to be greater than a depth of 1.50m begl. It is suspected, however, that hydrocarbon impacted soils are anticipated from ground level (i.e. within the upper 1.5m of soils) beneath the actual footprint of the tanks (not obviously accessible during the investigation) and this should be taken into account.

Greenfield Area

TABLE 11 – ANGLIAN WATER SUITE DATA ASSESSMENT GREENFIELD AREA					
Parameter Group	No. of Samples Tested	Concentration Range (mg/kg)	PE Threshold (mg/kg)	PE Threshold Exceeded (Yes or No)	Protective / Barrier Pipes Required (Yes or No)
VOCs	2	All results below LOD (<0.001 to <0.01)	0.5 AW	No	No
BTEX + MTBE	2	All results below LOD (<0.01)	0.1 AW	No	No
SVOCs (excluding PAHs)	2	All results below LOD (<0.1 or <0.5)	2 AW	No	No
EC5-EC10 Aliphatic and Aromatic Hydrocarbons	2	All results below LOD (<0.01 or <1)	2 AW	No	No
EC10-EC16 Aliphatic and Aromatic Hydrocarbons	2	All results below LOD (<1)	10 AW	No	No
EC16-EC40 Aliphatic and Aromatic Hydrocarbons	2	<LOD (<1) – 7	500 AW	No	No

TABLE 11 – ANGLIAN WATER SUITE DATA ASSESSMENT GREENFIELD AREA					
Parameter Group	No. of Samples Tested	Concentration Range (mg/kg)	PE Threshold (mg/kg)	PE Threshold Exceeded (Yes or No)	Protective / Barrier Pipes Required (Yes or No)
Phenols	2	All results below LOD (<0.2)	2 AW	No	No
Cresols and Chlorinated Phenols	2	All results below LOD (<0.1 or <0.2)	2 AW	No	No

Key

LOD – Laboratory Limit of Detection.
AW – Values taken from Pipe Selection Table within Anglian Water guidance document *'Investigation for developers about contaminated land and ground condition assessment'* dated November 2023, which is reproduced from UKWIR publication *'Guidance for the selection of water supply pipes to be used in Brownfield sites'*, (2010).
Total Phenols includes a sum of phenols, cresols, xylenols and resorcinol.

Based on the results of the soil sampling detailed herein, all contaminant concentrations are below the PE threshold values.

4.5 Contamination Assessment Summary

Human Health

Contamination testing was carried out on selected samples of the Made Ground and Natural Strata. On the basis of the chemical contamination assessment undertaken, the main findings are summarised as follows:

- Elevated TPH carbon fractions above Tier 1 human health generic assessment criteria (based on a residential with plant uptake end-use), along with hydrocarbon impacted soils have been identified in two locations:
  - Borehole WS103 located adjacent to the bunded above ground fuel storage tanks.
  - Borehole WS113 located adjacent to the small (off-site) above ground heating oil storage tank.

- No further elevated concentrations of PAHs have been identified on site within the area immediately adjacent to the off-site location of borehole WS3 where Ground Engineering previously identified elevated PAH concentrations.

- No elevated concentrations of pesticides or herbicides have been identified

Based on the chemical contamination assessment undertaken, the remainder of the Made Ground and Natural Strata (outside areas where hydrocarbon impaction has been noted) may be considered to be uncontaminated for the proposed end-use.

Controlled Waters

The contamination assessment has revealed hydrocarbon impaction of the soils in localised areas of the site. Cumulative TPH concentrations have been recorded within one of the soil samples tested which exceeds the arbitrary assessment criteria of 500mg/kg used (above which further Controlled Waters risk assessment is sometimes required). However, it should be noted that the investigation works carried out were restricted to the areas adjacent to the existing on and off-site tanks.

During the course of the gas and groundwater monitoring (see Section 5.0), an optical oil-water interface meter was utilised during the monitoring visits to determine whether any free product / non-aqueous phase liquids (NAPLs) were present floating on the surface of the groundwater. No NAPLs were detected on any of the monitoring visits. The results of the water level monitoring are reported within Appendix X.

The environmental sensitivity of the site is considered to be relatively low as the aquifer status of the underlying groundwater has been classified as Unproductive Strata, with no groundwater abstractions or Source Protection Zones within 250m of the site. The closest surface watercourse is an open drain (known as Edward Road Dyke) along the southern boundary of the site, with the closest surface water abstraction situated approximately 228m north-west of the site.

In view of the above, it is considered that the potential risks posed to Controlled Waters by the findings of the laboratory analysis undertaken are considered to be relatively low. However, it is recommended that further inspection and assessment of the soils is carried out directly beneath the on-site bunded above ground fuel tanks following removal of the tanks. It should also be noted that the area of hydrocarbon impaction associated with the small heating oil tank is relatively close to the open drain (Edward Road Dyke), therefore precautionary remedial actions would be considered prudent.

5.0 GROUND GAS & WATER LEVEL MONITORING RESULTS

5.1 Introduction

Based on the presence of potential on-site sources of harmful ground gas as highlighted by the previous Phase 1 desk study, monitoring points were installed in selected completed boreholes to facilitate a programme of further monitoring at the site (including for methane and carbon dioxide).

5.2 Monitoring Installations

Upon completion, 6 No. of the window sample boreholes (WS105, WS106, WS109, WS110, WS111 and WS112) were installed with combined ground gas and water monitoring standpipes to facilitate a programme of monitoring. In addition, the monitoring standpipe previously installed by Ground Engineering within WS2 was still present, therefore monitoring was also carried out from this location.

The ground gas and water monitoring data obtained from the site is presented in Appendix X of this report.

5.3 Results of the Ground Gas Monitoring

A total of seven ground gas and water monitoring visits have been undertaken at the site over a seven week period. The ground gas monitoring results are summarised in Table 12.

TABLE 12 – SUMMARY OF GROUND GAS MONITORING DATA

Parameter	Minimum	Maximum
Methane (v/v)	0.0	1.5
Carbon Dioxide (v/v)	0.4	13.5
Oxygen (v/v)	0.4	20.2
Carbon Monoxide (ppm)	0	0
Hydrogen Sulphide (ppm)	0	0
Peak Flow (L/h)	0.0	0.0
Steady Flow (L/h)	0.0	0.0

KEY
v/v - % by volume
L/h – litres/hour

The highest concentrations of methane (1.5% by volume) and carbon dioxide (13.5% by volume) were recorded with WS2 previously installed by Ground Engineering. This monitoring point was situated immediately adjacent to the bunded above ground fuel storage tanks associated with the former heating system for the greenhouses. In addition, a portable MiniRAE Lite Photo Ionisation Detector (PID) was also used to assess for potential volatile organic compounds (VOCs) during the gas monitoring carried out on 4 No. occasions. VOC concentrations up to 30ppm were recorded with WS2 (Ground Engineering) where hydrocarbon impacted soils were encountered. It is considered that the VOCs recorded at this location are highly likely to be due to degradation of the hydrocarbons in the ground at this location.

In the remaining monitoring points installed across the site as part of the supplementary monitoring works, no methane or VOCs were recorded. However, carbon dioxide concentrations were recorded up to 9.5% by volume.

No flow rates (positive or negative) were recorded during the monitoring carried out at the site.

Consideration has also been given to the potential effect of atmospheric pressure trends on ground gas emissions and flow rates. Periods of rapidly falling atmospheric pressure are considered to be the optimum barometric conditions for recording gas emissions from the ground. The gas monitoring carried out on 3 No. of the 7 No. monitoring visits followed periods of falling atmospheric pressure during the 24 hour period prior to monitoring as summarised below (based on a review of available weather station data local to the site). One of the monitoring visits (24th January 2025) was undertaken following a period of relatively rapidly falling atmospheric pressure, i.e. a fall of 14mb during the 24 hours prior to monitoring.

The atmospheric pressure trends are summarised below:

- 16th January 2025 – Rise of 2mb from 1032mb to 1034mb.
- 24th January 2025 – Fall of 14mb from 1000mb to 986mb.
- 30th January 2025 – Rise of 18mb from 1002mb to 1020mb.
- 5th February 2025 – Rise of 20mb from 1017mb to 1037mb.
- 12th February 2025 – Rise of 2mb from 1018mb to 1020mb.
- 19th February 2025 – Fall of 8mb from 1023mb to 1015mb.
- 24th February 2025 – Fall of 9mb from 1017mb to 1008mb.

The atmospheric pressure trends noted during the monitoring period do not appear to have affected the ground gas concentrations recorded or more pertinently the flow rates. No variations in flow rates were noted during the monitoring carried out during the differing atmospheric conditions, as no flow rates were recorded during the monitoring visits.

It should be noted that the highest recorded methane concentration of 1.5% by volume was detected during the monitoring carried out after the atmospheric pressure had risen in the 24 hours prior to monitoring by only 2mb on 16th January 2025. However, the next highest methane concentration of 1.4% by volume was recorded when the atmospheric pressure had fallen by 8mb in the 24 hour period prior to monitoring on 19th February 2025. It should be noted that no methane was recorded during the monitoring visit carried out following the highest fall in atmospheric pressure (of 14mb) in the 24 hour period prior to monitoring on 24th January 2025

The highest carbon dioxide concentration of 13.5% by volume was recorded following a fall of 8mb in the 24 hour period prior to monitoring on 19th February 2025. However, one of the second highest carbon dioxide concentrations of 13.4% by volume was recorded when the atmospheric pressure had risen by 2mb in the 24 hour period prior to monitoring on 12th February 2025.

In light of the above, it would appear that there was no consistent correlation / relationship between the noted falls in atmospheric pressure and the ground gas emissions.

Water was encountered within all of the boreholes during the programme of monitoring, typically from depths of between 1.38m and 2.29m begl.

5.4 Appropriate Guidance

5.4.1 British Standard & CIRIA

The results of the gas monitoring have been reviewed with reference to the following documentation:

- British Standard BS 8485 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*' (2015+A1:2019).
- CIRIA Report C665 '*Assessing risks posed by hazardous ground gases to buildings*' (2007).
- CIRIA Report C735 '*Good practice on the testing and verification of protection systems for buildings against hazardous ground gases*' (2014).

5.4.2 Gas Screening Value Calculation

BS 8485 and CIRIA Report C665 recommend a risk-based methodology to ground gas assessment, the first step of which includes the calculation of a site-specific Gas Screening Value (GSV). The GSV of a particular ground gas regime equates to:

- GSV (l/h) = maximum borehole flow rate (l/h) x (maximum gas concentration/100).

The GSV should be calculated for both Methane and Carbon Dioxide (where appropriate) to determine a site-specific Characteristic Situation for each gas. The higher the calculated GSV, the greater the risk posed by the presence of ground gas. The CIRIA guidance document notes that '*…the GSV is a guideline value and not an absolute threshold*'.

5.4.3 Site Classification

The next step in the assessment process is determining the sites classification. Table 2 of BS 8485 (reproduced below) presents six Characteristic Situations (CS) to assist in the classification of the site, based on the calculated GSV for Methane and Carbon Dioxide.

Table 2 — *CS by site characteristic GSV*

CS	Hazard potential	Site characteristic GSV [A)] L/h	Additional factors
CS1	Very low	<0.07	Typically <1% methane concentration and <5% carbon dioxide concentration (otherwise consider an increase to CS2)
CS2	Low	0.07 to <0.7	Typical measured flow rate <70 L/h (otherwise consider an increase to CS3)
CS3	Moderate	0.7 to <3.5	–
CS4	Moderate to high	3.5 to <15	–
CS5	High	15 to <70	–
CS6	Very high	>70	–

A) The figures used in this column are empirical.

NOTE The CS is equivalent to the characteristic GSV in CIRIA C665 [6].

5.4.4 Proposed Building Type

In accordance with BS 8485, the CS classification for the site should be considered in conjunction with the proposed Building Type to determine the appropriate level of ground gas protection measures that should be installed to mitigate the risk posed by ground gases.

BS 8485:2019 notes '*The Building Type is determined based the proposed construction and use of the building, together with the control of future structural changes to the building and its maintenance (the building's management) should be assessed, since potential risks posed by ground gases are strongly influenced by these factors*'.

Subject to the development proposals, each building may be categorised as a whole, or for each different part of the building.

The Building Types presented in Table 3 of BS 8485, are reproduced on the next page.

Table 3 — *Building types*

	Type A	Type B	Type C	Type D
Ownership	Private	Private or commercial/ public, possible multiple	Commercial/ public	Commercial/ industrial
Control (change of use, structural alterations, ventilation)	None	Some but not all	Full	Full
Room sizes	Small	Small/ medium	Small to large	Large industrial/ retail park style

- **Type A building**: private ownership with no building management controls on alterations to the internal structure, the use of rooms, the ventilation of rooms or the structural fabric of the building. Some small rooms present. Probably conventional building construction (rather than civil engineering). Examples include private housing and some retail premises.
- **Type B building**: private or commercial property with central building management control of any alterations to the building or its uses but limited or no central building management control of the maintenance of the building, including the gas protection measures. Multiple occupancy. Small to medium size rooms with passive ventilation of rooms and other internal spaces throughout ground floor and basement areas. May be conventional building or civil engineering construction. Examples include managed apartments, multiple occupancy offices, some retail premises and parts of some public buildings (such as schools, hospitals, leisure centres) and parts of hotels.
- **Type C building**: commercial building with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, including the gas protection measures. Single occupancy of ground floor and basement areas. Small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas. Probably civil engineering construction. Examples include offices, some retail premises, and parts of some public buildings (such as schools, hospitals, leisure centres and parts of hotels).
- **Type D building**: industrial style building having large volume internal space(s) that are well ventilated. Corporate ownership with building management controls on alterations to the ground floor and basement areas of the building and on maintenance of ground gas protective measures. Probably civil engineering construction. Examples are retail park sales buildings, factory shop floor areas, warehouses. (Small rooms within these style buildings should be separately categorized as Type B or Type C).

NOTE 2 Type A buildings are those where the risk of failure of the gas protection measures is likely to be most significant to the safety of the occupants and Type D buildings are those where this same risk is likely to be least significant.

5.4.5 Gas Protection Score (Number of Points to be Achieved)

Table 4 of BS 8485, reproduced below, should be used to derive the minimum level of gas protection applicable to the Building Type, based on the CS determined from the calculated GSV. The Gas protection Score in Table 4 below is used to determine the level and type of protection measures used.

Table 4 — *Gas protection score by CS and type of building*

CS	Minimum gas protection score (points)			
	High risk		Medium risk	Low risk
	Type A building	Type B building	Type C building	Type D building
1	0	0	0	0
2	3.5	3.5	2.5	1.5
3	4.5	4	3	2.5
4	6,5 [A]	5.5 [A]	4.5	3.5
5	— [B]	A1 or A2 [A]	5.5	4.5
6	— [B]	— [B]	A1 — [B] A2	A1 or A2

[A] Residential buildings should not be built on CS4 or higher sites unless the type of construction or site circumstances allow additional levels of protection to be incorporated, e.g. high-performance ventilation or pathway intervention measures, and an associated sustainable system of management of maintenance of the gas control system, e.g. in institutional and/or fully serviced contractual situations.

[B] The gas hazard is too high for this empirical method to be used to define the gas protection measures.

5.4.6 Methods of Achieving Gas Protection Scores

The appropriate level of precautions, to be designed in accordance with the point scoring system of BS 8485, should therefore be determined for the specific type of developments based on the GSV and CS of the site. These may include a combination of two or more of the following three types of protection measures, which could be used to achieve the required score:

- The structural barrier of the floor slab, or of the basement slab and walls if a basement is present;
- Ventilation measures; and
- Gas resistant membrane which may include an element of verification and potentially integrity testing.

Verification and integrity testing should be undertaken in accordance with CIRIA report C735 '*Good practice on the testing and verification of protection systems for buildings against hazardous ground gases*' (2014) and would be detailed in a Remediation Method Statement report in advance of construction which should be agreed with the Local Planning Authority.

The points achieved for each element of the ground gas precautions are summarised in Tables 5, 6 and 7 of the British Standard. These tables are reproduced in the following pages.

Table 5 — *Gas protection scores for the structural barrier*

Floor and substructure design (see Annex A)	Score [A]
Precast suspended segmental subfloor (i.e. beam and block)	0
Cast in situ ground-bearing floor slab (with only nominal mesh reinforcement)	0.5
Cast in situ monolithic reinforced ground bearing raft or reinforced cast in situ suspended floor slab with minimal penetrations	1 or 1.5 [B]
Basement floor and walls conforming to BS 8102:2009, Grade 2 waterproofing [C] [A1] [D] ⟨A1⟩	2
Basement floor and walls conforming to BS 8102:2009, Grade 3 waterproofing [C] [A1] [D] ⟨A1⟩	2.5

[A] The scores are conditional on breaches of floor slabs, etc., being effectively sealed.

[B] To achieve a score of 1.5 the raft or suspended slab should be well reinforced to control cracking and have minimal penetrations cast in (see **A.2.2.2**).

[C] The score is conditional on the waterproofing [A1] being provided by a suitable structural barrier with the design and detailing of the walls and floor meeting the requirements for Type B protection. The score cannot be assigned for Type A (waterproof membrane) or Type C (drained cavity wall). ⟨A1⟩

[D] [A1] If a membrane is installed beneath and around the basement to provide Type A waterproofing (BS 8102:2009), it can be assigned a gas protection score in accordance with Table 7, if it meets all the criteria for a gas resistant membrane in that table. ⟨A1⟩

Table 6 — *Gas protection scores for ventilation protection measures*

Protection element/system	Score	Comments
(a) Pressure relief pathway (usually formed of low fines gravel or with a thin geocomposite blanket or strips terminating in a gravel trench external to the building)	0.5	Whenever possible a pressure relief pathway (as a minimum) should be installed in all gas protection measures systems. If the layer has a low permeability and/or is not terminated in a venting trench (or similar), then the score is zero.

Table 6 *(continued)*

Protection element/system	Score	Comments
(b) Passive sub floor dispersal layer:	2.5	Performance criteria for methane and carbon dioxide are shown in Figure B.6 and Figure B.7, respectively.
Very good performance:	1.5	
Good performance:		
Media used to provide the dispersal layer are:		The ventilation effectiveness of different media depends on a number of different factors including the transmissivity of the medium, the width of the building, the side ventilation spacing and type and the thickness of the layer. The selected score should be assigned taking into account the recommendations in Annex B. Passive ventilation should be designed to meet at least "good performance", see Annex B.
• Clear void		
• Polystyrene void former blanket		
• Geocomposite void former blanket		
• No-fines gravel layer with gas drains		
• No-fines gravel layer		
(c) Active dispersal layer, usually comprising fans with active abstraction (suction) from a subfloor dilution layer, with roof level vents. The dilution layer may comprise a clear void or be formed of geocomposite or polystyrene void formers	1.5 to 2.5	This system relies on continued serviceability of the pumps, therefore alarm and response systems should be in place. There should be robust management systems in place to ensure the continued maintenance of the system, including pumps and vents. Active ventilation should always be designed to meet at least "good performance", as described in Annex B.
(d) Active positive pressurization by the creation of a blanket of external fresh air beneath the building floor slab by pumps supplying air to points across the central footprint of the building into a permeable layer, usually formed of a thin geocomposite blanket	1.5 to 2.5	This system relies on continued operation of the pumps, therefore alarm and response systems should be in place. The score assigned should be based on the efficient "coverage" of the building footprint and the redundancy of the system. Active ventilation should always be designed to meet at least "good performance".
(e) Ventilated car park (floor slab of occupied part of the building under consideration is underlain by a basement or undercroft car park)	4	Assumes that the car park is vented to deal with car exhaust fumes, designed to *Buildings Regulations 2000, Approved Document F* [9].

Table 7 — *Gas protection score for the gas resistant membrane*

Protection element/system	Score	Comments
Gas resistant membrane meeting all of the following criteria: • sufficiently impervious [A1], both in the sheet material [A)] and in the sealing of sheets and sealing around sheet penetrations, to prevent any significant passage of methane and/or carbon dioxide through the membrane; [A1] • sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • [A1] *Text deleted* [A1] • sufficiently strong [A1] [B)] [A1] to withstand the installation process and following trades until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, dropping tools, etc); [A1] and to withstand in-service stresses (e.g. settlement if placed below a floor slab); [A1] • capable, after installation, of providing a complete barrier to the entry of the relevant gas; and • verified in accordance with CIRIA C735 [N1].	2	The performance of membranes is heavily dependent on the quality and design of the installation, resistance to damage after installation and integrity of joints. [A1] *Text deleted* [A1] If a membrane is installed that does not meet all the criteria in column 1 then the score is zero.

[A)] [A1] A membrane with a methane gas transmission rate <40.0 ml/day/m²/atm (average) for sheets and joints (tested in accordance with BS ISO 15105-1:2007 manometric method) is regarded as sufficiently impervious.

[B)] For example, reinforced LDPE (virgin polymer) membranes having a minimum mass per unit area of 370 g/m² and not significantly less than 0.4 mm thickness between the reinforcement scrim (tested in accordance with Procedure D (2 mm diameter tip) of BS EN ISO 9863-1:2016) installed above floor slabs are considered sufficiently strong to meet the performance criteria (see also **C.3**). Thicker and more robust membranes or an additional membrane protection layer should be installed directly beneath cast-in-situ floor slabs. [A1]

5.5 Ground Gas Analysis

5.5.1 Gas Screening Value & Site Classification

The ground gas monitoring has identified maximum methane and maximum carbon dioxide concentrations of 1.5% v/v and 13.5% v/v respectively. In the absence of a measurable steady flow rate, the limit of detection of the gas monitoring instrument (0.1 l/h) should be utilised. The atmospheric pressure trends noted during the monitoring period do not appear to have affected the ground gas concentrations recorded.

The GSV for methane at the site may be calculated as follows:

- 0.1 x (1.5/100) = 0.0015 l/h

The GSV for carbon dioxide at the site may be calculated as follows:

- 0.1 x (13.5/100) = 0.0135 l/h

Therefore, with a maximum GSV of 0.0135 l/h, the site may initially be classified as 'CS1', in accordance with Table 2 of BS 8485 and based on the visits undertaken. However, where methane concentrations exceed 1% by volume and carbon dioxide concentrations exceed 5% by volume, the British Standard recommends that consideration should be given to increasing the ground gas regime from CS1 to CS2.

Based on the monitoring results obtained at the site, methane concentrations over 1% by volume have only been recorded in one location on two of the monitoring visits, i.e. WS2 (Ground Engineering) where hydrocarbon impacted soils have been identified in the western portion of the site. Carbon dioxide concentrations over 5% by volume were also recorded within WS2 (Ground Engineering), as well as within three other gas monitoring standpipes installed by GeoDyne at the site, i.e. within WS105, WS111 and WS112.

Given the distances between the hydrocarbon impacted soils in the western portion of the site (where the highest methane and carbon dioxide concentrations have been recorded) and the locations of WS105 and WS112 (and also WS111 further to the east), it is considered that the areas of hydrocarbon impacted ground are unlikely to be the cause of the notable carbon dioxide concentrations recorded within the other monitoring points. It is considered possible that the source of carbon dioxide may therefore be the peat / organic soils within the natural drift deposits underlying the site. In view of this, it is recommended that the site is uplifted to 'CS2'.

5.5.2 Building Type

We understand that it is proposed to construct low-rise residential properties at the site. In accordance with Table 3 of BS 8485, **Building Type A** is considered to be the most appropriate classification.

5.5.3 Gas Protection Score

On the basis of Characteristic Situation (CS2) and the development proposals with structures that may be designated as Building Type A and in accordance with Table 4 of BS 8485:2015+A1:2019, the minimum gas protection score for the site is 3.5 points.

5.5.4 Comments

In summary, notable concentrations of methane and carbon dioxide have been detected at the site, but no significant flow rates have been recorded during the programme of gas monitoring undertaken.

The results of the gas monitoring indicate that **CS2** ground gas precautions will be required within the proposed plots based on a gas protection score of 3.5 points and in accordance with BS 8485 (2015+A1:2019). Further comments are contained within Section 7.2.3 of this report.

6.0 REVISED CONCEPTUAL SITE MODEL

6.1 Introduction

In accordance with good practice, the Conceptual Site Model (CSM) for the site should be refined following acquisition and collection of additional data following completion of the supplementary Phase II site investigation works.

Our revised assessment following the acquisition and collection of information from the site investigation works is provided in Table 13.

In preparing this CSM, it has been assumed that construction personnel involved with the development of the site (typically short term (acute) exposure) will adopt all necessary personal protective equipment (PPE and RPE etc.) and confirm to all appropriate health and safety requirements, including their site-specific Risk Assessments and Method Statements (RAMS). Site workers have therefore not been included within the following table, as adoption of these appropriate mitigation measures will ultimately result in an overall low risk of exposure to the C-P-R linkages identified.

TABLE 13 – RISK ASSESSMENT SUMMARY TABLE							
Potential Contaminant Source [C]	Potential Pathway(s) [P]	Potential Receptor [R]	Probability of CPR Linkage	Consequence of CPR Linkage	Risk Level	Comments / Justification	Residual Risk After Remedial / Mitigation Measures
General Made Ground & Near Surface Soils	Direct contact, ingestion and/ or inhalation of fugitive dust & vapours	End users	Likely	Medium	Moderate	Based on the chemical contamination assessment undertaken, the majority of the Made Ground and Natural Strata at the site (outside of the areas where hydrocarbon impaction has been noted) may be considered to be uncontaminated for the proposed residential end-use. The supplementary Phase II works have revealed elevated concentrations of certain TPH carbon fractions (in relation to the proposed residential end use) in the natural soils in localised areas around / adjacent to the on and off-site above ground fuel storage tank areas. End users may come into contact with the in-situ soils and / or via exposure from the inhalation of residual hydrocarbon vapours. Remedial / mitigation measures required.	Low
	Plant uptake	End users	Likely	Medium	Moderate	Based on the chemical contamination assessment undertaken, the majority of the Made Ground and Natural Strata at the site (outside of the areas where hydrocarbon impaction has been noted) may be considered to be uncontaminated for the proposed residential end-use. The supplementary Phase II works have revealed elevated concentrations of certain TPH carbon fractions (in relation to the proposed residential end use) in the natural soils in localised areas around / adjacent to the on and off-site above ground fuel storage tank areas. The consumption of home-grown produce may be anticipated at the site. Remedial / mitigation measures required.	Low

TABLE 13 – RISK ASSESSMENT SUMMARY TABLE							
Potential Contaminant Source [C]	Potential Pathway(s) [P]	Potential Receptor [R]	Probability of CPR Linkage	Consequence of CPR Linkage	Risk Level	Comments / Justification	Residual Risk After Remedial / Mitigation Measures
General Made Ground & Near Surface Soils Cont.	Vertical and lateral migration	Neighbouring properties / land	Low Likelihood	Medium	Moderate/Low	Based on the chemical contamination assessment undertaken, the majority of the Made Ground and Natural Strata at the site (outside of the areas where hydrocarbon impaction has been noted) may be considered to be uncontaminated for the proposed residential end-use. The supplementary Phase II works have revealed elevated concentrations of certain TPH carbon fractions (in relation to the proposed residential end use) in the natural soils in localised areas around / adjacent to the on and off-site above ground fuel storage tank areas. Potentially mobile hydrocarbon contamination has been identified during the intrusive works carried out in localised areas situated relatively close to site boundaries. No free product / non-aqueous phase liquids (NAPLs) were identified floating on the surface of the groundwater during the water level monitoring visits. Remedial / mitigation measures required locally. Further inspection and assessment works are recommended beneath the locations of the tanks (following removal), including to assess the potential off-site migration of contamination.	Low – subject to the findings of the further works
	Leaching of Contaminants through unsaturated zone and/or vertical and lateral migration	Controlled Waters	Low Likelihood	Medium	Moderate/Low	Based on the chemical contamination assessment undertaken, the majority of the Made Ground and Natural Strata at the site (outside of the areas where hydrocarbon impaction has been noted) may be considered to be uncontaminated for the proposed residential end-use. The supplementary Phase II works have revealed elevated concentrations of certain TPH carbon fractions (in relation to the proposed residential end use) in the natural soils in localised areas around / adjacent to the on and off-site above ground fuel storage tank areas. Potentially mobile hydrocarbon contamination has been identified during the intrusive works carried out in localised areas situated relatively close to site boundaries. No free product / non-aqueous phase liquids (NAPLs) were identified floating on the surface of the groundwater during the water level monitoring visits.	Low – subject to the findings of the further works

TABLE 13 – RISK ASSESSMENT SUMMARY TABLE							
Potential Contaminant Source [C]	Potential Pathway(s) [P]	Potential Receptor [R]	Probability of CPR Linkage	Consequence of CPR Linkage	Risk Level	Comments / Justification	Residual Risk After Remedial / Mitigation Measures
General Made Ground & Near Surface Soils Cont.	Leaching of Contaminants through unsaturated zone and/or vertical and lateral migration Cont.	Controlled Waters	Low Likelihood	Medium	Moderate/Low	The drift deposits and the bedrock underlying the site comprise 'Unproductive Strata'. The site is not situated within a groundwater Source Protection Zone and there are no groundwater abstractions recorded within 250m of the site. The closest surface watercourse is an open drain (known as Edward Road Dyke) along the southern boundary of the site, with the closest surface water abstraction situated approximately 228m north-west of the site for farmland irrigation purposes. Remedial / mitigation measures required locally. Further inspection and assessment works are recommended beneath the locations of the tanks (following removal), including to assess the potential off-site migration of contamination (and potential risks to Controlled Waters).	Low – subject to the findings of the further works
	Direct contact or contact with vapours	Plastic buildings products (i.e. water supply pipes)	Low Likelihood	Medium	Moderate/Low	The supplementary Phase II works have revealed elevated concentrations of certain TPH carbon fractions locally which may pose a risk to plastic water supply pipes. Protection of potable water supply pipes are considered likely to be required in the areas of hydrocarbon impacted soils. However, elsewhere at the site outside of the areas of hydrocarbon impaction, no protection of potable water supply pipes is considered necessary. With respect to buried concrete; the site falls into a range between Design Class DS-1 and DS-5 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1s to AC-4s (BRE Spec. Digest 1:2005). An appropriate concrete mix should be adopted for all buried concrete in contact with the ground.	Low
Fuel Storage Tanks & Pipelines	Leakages and spillages	Soil and groundwater	Likely	Medium	Moderate	The existing tanks should be removed and the surrounding ground inspected and assessed and if necessary remediated and validated.	To be confirmed following tank removal / validation works
Made Ground, Hydrocarbon Impacted Soils & Natural Drift Deposits	Vertical and lateral migration of ground gases and hydrocarbon vapours to indoor air	End users of new buildings (asphyxiation) or new buildings (damage via explosion)	Low Likelihood	Severe	Moderate	Based on the findings of the ground gas monitoring, elevated concentrations of carbon dioxide have been identified at the site, along with elevated concentrations of methane locally. Gas protection measures required in proposed new buildings.	Low

7.0 CONCLUSIONS & RECOMMENDATIONS

7.1 Site Summary

At the time of our intrusive works, the site comprised a former plant nursery with recently demolished greenhouses in the western two thirds of the site and a grassed field in the eastern third. Bunded above ground fuel storage tanks associated with a disused boiler house were situated in the north-western portion of the site. An off-site small above ground heating oil storage tank associated with an off-site vacant residential property was present adjacent to the south-western portion of the site.

Previous ground investigation works carried out Ground Engineering in 2023 identified hydrocarbon impacted soils around the on and off-site areas of above ground tanks.

The site is indicated to be directly underlain by superficial Tidal Flat Deposits with the underlying solid geology identified as the Oxford Clay Formation.

7.2 Geotechnical Information

7.2.1 Ground Conditions

Made Ground was encountered in the exploratory holes advanced in the approximate western two-thirds of the site at generally similar depths to those encountered by Ground Engineering, i.e. generally to depths of up to 0.90m begl, although localised deeper Made Ground to a depth of 2.00m begl was locally encountered (in BH1) in the far western portion.

A plan showing the depth to the base of the Made Ground at the exploratory hole locations is presented in Appendix VII of this report (Figure No. D44101/05).

No Made Ground was encountered within the eastern third of the site which comprised a grassed field where Natural Topsoil was encountered at surface to an average depth of 0.30m begl.

The Natural Strata encountered across the site was noted to be highly variable both laterally and vertically in terms of strength and composition and included CLAY and SILT and locally SAND associated with the Tidal Flat Deposits.

The CLAY and SILT soils were noted to vary between soft and firm at shallow depth, with the firm soils rapidly becoming soft with increased depth. In addition, PEAT was encountered at variable depths within a number of the exploratory holes advanced across the site, along with observations of horizons / pockets with a variable content of organic matter within the Clay, Silt and Sand deposits. For example, a 0.55m thickness of PEAT was encountered at a depth of 0.95m to 1.50m begl (in WS105) in the western third of the site. PEAT inclusions or bands were noted in 4 No. of the 5 No. cable percussion boreholes at depths ranging between 2.00m begl and up to 10.00m begl.

Beneath the Tidal Flat Deposits, a firm or stiff CLAY was encountered from depths ranging between 9.50m to 11.00m begl, underlain by very stiff CLAY (associated with the bedrock of the Oxford Clay Formation).

7.2.2 Foundation Design

Based on the evidence of our works and irrespective of proposed finished levels, a piled foundation solution is recommended for the proposed development. The findings of the cable percussive boreholes should be provided to a specialist contractor(s) to assist with the design of a piled foundation solution for the proposed development.

The use of traditional shallow foundations (i.e. strips and rafts) are considered unsuitable for the site. This is due to the presence of Peat and / or other organic soils, which are present sporadically at variable depths beneath the site, together with other soils of low geotechnical competency which would preclude the use of a shallow foundation solution due to the poor ground bearing capacity associated with these soils.

7.2.3 Floor Slab Design & Ground Gases

Based on the results of the ground gas monitoring undertaken, and our understanding of the development proposals, the site has been classified as Characteristic Situation CS2, in accordance with Table 4 of BS8485:2015+A1:2019 *'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings'*.

Taking account of the current development proposals to construct low-rise residential properties at the site, the proposed structures are considered to be classified as Building Type A in accordance with Table 3 of BS8485.

On the basis of Characteristic Situation CS2 and the development proposals with buildings designated as Building Type A and in accordance with Table 4 of BS8485, the minimum gas protection score for the site is 3.5 points.

Appropriate precautions should therefore be included within the design of the proposed buildings to accommodate the requirements of this classification. The following mitigation measures are considered appropriate for the site to achieve the required level of protection to dwellings:

- Suspended floors (i.e. beam and block / beam and thermal insulation infill) = 0 Points.
- Provision of a clear ventilated void and periscopic air-brick ventilation on two sides of each dwelling with sufficient sub-floor cross ventilation gaps = 1.5 Points (Good Performance Clear Void Dispersal Layer).
- To achieve a Very Good Performance Clear Void Dispersal Layer (2.5 points) in accordance with BS8485, the number of side vents (i.e. air-bricks) for a small to medium width buildings (up to 15m) should be 1500mm^2/m run of wall on at least two sides, or 500mm^2 per square metre of floor area, whichever gives the greater area of opening. The minimum clear void space should be 100mm (solely with respect to ground gas measures – excludes NHBC considerations) and there should be four or five times the area of the side vents provided to the internal obstructions (i.e. beams) to provide sub-floor cross ventilation.
- Provision of a well installed and verified low permeability proprietary gas resistant membrane = 2 Points.

- The membrane should have proven resistance to the ground gases of concern, including methane and carbon dioxide. It should also be noted that hydrocarbon impacted soils have been encountered in the immediate vicinity of the bunded above ground fuel storage tanks and the small (off-site) heating oil tank (in the north-western and south-western portions of the site). Although remedial works are to be recommended in relation to these soils, residual hydrocarbons may ultimately remain in the ground. In view of this, for the plots constructed in the immediate vicinity of these areas, the gas protection measures should also be designed to mitigate against the potential ingress of any remaining hydrocarbon vapours and nuisance odours, subject to the final proposed layout and the outcome of further investigation / delineation works and any source removal works.
- The membrane should be suitably lapped and sealed and should be extended across wall cavities and lapped with cavity trays to effectively exclude ground gases from the footprint of the proposed buildings. The membrane should be inspected by a third party in accordance with the requirements of CIRIA C735.
- The membrane must be suitably robust to withstand the construction process and should be suitably protected following installation and inspection to minimise damage during construction.
- Service penetrations through the membrane should be kept to a minimum and should be suitably sealed to the membrane. Where the service penetrations (typically 150mm pipes) are to be used as ducting for smaller service pipes (e.g. water, electricity or gas supply etc) the ducts should be sealed by the injection of a suitable depth of partially or fully closed cell expanding foam, with liquid gas membrane painted over the top.

The foregoing precautions would score 3.5 Points (based on a Good Performance Clear Void Dispersal Layer) in accordance with BS8485 (2015+A1:2019) and are therefore considered appropriate for the plots.

Alternative floor slab and ground gas protection measures that give a minimum protection score of 3.5 Points may be adopted at the site, to suit the requirements of the Client and subject to Local Authority approval.

In order to accord with Table 7 of BS8485 where a gas resistant membrane is proposed as part of gas protection measures, the membrane should be installed, inspected and validated by a third party in accordance with the requirements of CIRIA C735 *'Good practice on the testing and verification of protection systems for buildings against hazardous ground gas'* (2014), for the gas protection points associated with installation of a gas resistant membrane to apply.

We would recommend that the membrane specified for the proposed buildings is installed by a suitably qualified specialist contractor in a quality controlled / quality assured (QA/QC) manner.

Verification of the membrane should include a third party visual inspection of the installed membrane, as a minimum, and may require integrity testing such as air lancing of the joints, dependent on the qualifications of the installer and the characteristic situation of the site. Otherwise a score of zero is awarded for the membrane and therefore the installed solution would fail to comply with BS 8485.

For the avoidance of doubt, garages that form part of the habitable structure, or could be altered to form part of the habitable structure in the future, should be provided with gas protection measures consistent with CS2.

Where the proposed dwellings are to benefit from a Buildmark warranty (i.e. NHBC, or similar) we would recommend liaison with the warranty provider with respect to the floor slab design and ground gas protection measures to ensure that the proposals fully satisfy their requirements.

Following finalisation of design, it is likely to be necessary to prepare a Ground Gas Verification Plan for the affected plots in due course.

7.2.4 Radon

No radon precautions are required at the site.

7.2.5 Building Near Trees

Heave precautions may need to be incorporated into the design of ground beams in accordance with NHBC Standards Chapter 4.2 *'Building near trees'*, when building near existing, proposed or recently removed trees / hedgerows. The cohesive soils should be assumed to be of high volume change potential for design purposes (as confirmed by laboratory testing carried out by Ground Engineering).

It may be necessary to undertake an arborist survey (where not already completed) to identify the species and heights of the existing trees and hedgerows within influencing distance of the site (if not already completed), where appropriate.

7.2.6 Water

Water was generally encountered as seepages during the site investigation works, or as damp soils in a number of the trial pits. The water seepages were typically encountered at depths of between 1.50m and 2.80m begl within the natural deposits, with an average depth of approximately 2.00m begl (although water was encountered at 1.00m locally).

Standing water was encountered within all of the monitoring standpipes installed in the boreholes during the programme of monitoring, typically from depths of between 1.38m and 2.29m begl.

Based on the ground conditions encountered, excavations in excess of approximately 1.50m begl may encounter water ingress. Dewatering of excavations is considered more likely at the site if excavations are left open for a period of time (i.e. prior to the pouring of concrete and / or laying of drainage materials, for example) as water (held within the surrounding low permeability soils) will gradually seep / ingress into open excavations after relatively short periods. Excavations are also prone to instability (see Section 7.2.7).

The low permeability soils at the site are also susceptible to standing water following periods of wet weather, which will increase the likelihood of needing to dewater.

The site is underlain by Tidal Flat Deposits and these deposits extend across much of South Lincolnshire and into Cambridgeshire. These soils are typically of generally low permeability. The soils encountered in trial pits advanced within these deposits generally become damper / water bearing with depth. Whilst there may be no initial evidence of water seepage / ingress within the trial pits immediately upon completion of excavation, water eventually finds its way into the pits if they are left open for several minutes. This is supported by the water levels encountered within monitoring wells, which often record shallow water within the Tidal Flat Deposits during periods of monitoring.

We would note that groundwater levels, and the presence of surface standing water, may vary due to seasonal or other effects.

7.2.7 Excavations / Stability

During excavation of the trial pits advanced for geotechnical assessment purposes (mainly in the eastern third of the site), the sides of the pits were noted to be initially stable until the pits were advanced beyond approximately 2m begl. It was possible to advance the trial pits to depths ranging between 1.80m and 2.90m begl but as soon as these depths were achieved, collapse of the pit sides commenced relatively quickly. The collapse was noted to be either total collapse of all pit sides or total collapse of one side of the pit, extending to ground level or just below ground level.

Based on field observations, it is possible that shallower excavations would also suffer from instability where left open for prolonged periods of time.

Therefore, excavations may require trench support for health and safety reasons. The assessment of excavations and provision of support will be the responsibility of the contractor on site. The natural soils may be subject to deterioration and softening if excavations are left open and exposed to wet weather. Any softened soils should be removed from excavations prior to the pouring of concrete.

7.2.8 Sulphate Classification

Based on the results of the laboratory testing carried out, the site indicates a range in potential classifications between Design Sulfate Class DS-1 and DS-5 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1s to AC-4s. The most onerous classification was influenced by the results of the samples of the Tidal Flat Deposits containing Peat and also samples of the Oxford Clay Formation.

Therefore, an appropriate concrete mix should be adopted in accordance with BRE Special Digest 1 for all buried concrete in contact with the ground. It is understood that the concrete mixes used during construction / formation of piles are inherently more resistant to sulphate attack.

7.2.9 Coal Mining

No coal mining precautions or associated investigation works are required at the site.

7.2.10 California Bearing Ratios (CBRs)

A CBR value of less than 2% may be anticipated in the Made Ground and a CBR value of between 2% and 4% can be anticipated within the shallow Natural Strata, subject to confirmation by in-situ testing.

No frost susceptible material should be within 450mm of the ground surface in road construction.

7.2.11 Surface Water Drainage

Based on the presence of variable ground conditions across the site, including the presence of natural soils of relatively low permeability and shallow water levels, it is considered that soakaways may not be feasible at the site. We would recommend that alternative forms of surface water drainage are explored in the first instance.

7.3 Environmental Considerations

7.3.1 Soil Contamination Assessment

Human Health

Contamination testing was carried out on selected samples of the Made Ground and Natural Strata. On the basis of the chemical contamination assessment undertaken, the main findings are summarised as follows:

- The Made Ground and Natural Strata encountered beneath the majority of the site area (outside areas where hydrocarbon impaction have been noted, as discussed below) may be considered to be uncontaminated for the proposed residential end-use.

- Elevated TPH carbon fractions above Tier 1 human health generic assessment criteria (based on a residential with plant uptake end-use), along with hydrocarbon impacted soils have been identified in two locations:
  - Borehole WS103 located adjacent to the bunded above ground fuel storage tanks. The approximate extent of hydrocarbon impacted soils to be remediated in the vicinity of WS103 is indicated on Figure No. D44101/06 (enclosed within Appendix XI).
  - Borehole WS113 located adjacent to the small (off-site) above ground heating oil storage tank. The approximate extent of hydrocarbon impacted soils to be remediated in the vicinity of WS113 is indicated on Figure No. D44101/07 (enclosed within Appendix XI).

- No further elevated concentrations of PAHs have been identified on site within the area immediately adjacent to the off-site location of borehole WS3 where Ground Engineering previously identified elevated PAH concentrations.

- No elevated concentrations of pesticides or herbicides have been identified

Controlled Waters

The contamination assessment has revealed hydrocarbon impaction of the soils in localised areas of the site. Cumulative TPH concentrations have been recorded within one of the soil samples tested which exceeds the arbitrary assessment criteria of 500mg/kg (above which further Controlled Waters risk assessment is sometimes required).

It should be noted, however, that the investigation works carried out around the bunded fuel storage tanks were restricted to the areas adjacent to the existing tanks. Given the findings of the exploratory holes around the tanks (which indicate historical leakage / spillage of hydrocarbons), it is considered that higher concentrations are likely to be present directly beneath the footprint of the tanks.

During the course of the gas and groundwater monitoring (see Section 5.0), an optical oil-water interface meter was utilised during the monitoring visits to determine whether any free product / non-aqueous phase liquids (NAPLs) were present floating on the surface of the groundwater. No NAPLs were detected on any of the monitoring visits.

The environmental sensitivity of the site is considered to be relatively low as the aquifer status of the underlying groundwater has been classified as Unproductive Strata, with no groundwater abstractions or Source Protection Zones within 250m of the site. The closest surface watercourse is an open drain (known as Edward Road Dyke) along the southern boundary of the site, with the closest surface water abstraction situated approximately 228m north-west of the site.

In view of the above, it is considered that the potential risks posed to Controlled Waters by the findings of the laboratory analysis undertaken are considered to be relatively low. However, it is recommended that further inspection and assessment of the soils is carried out directly beneath the above ground fuel tanks following removal of the bund and removal of the tanks. It should also be noted that the area of hydrocarbon impaction associated with the small (off-site) heating oil tank is relatively close to the open drain (Edward Road Dyke), therefore precautionary remedial actions would be considered prudent.

Based on the chemical contamination assessment undertaken, the remainder of the general Made Ground and the Natural Strata at the site would appear to be uncontaminated from a Controlled Waters protection perspective.

Further Assessment Works

Given that the bunded above ground fuel storage tanks and the equipment associated with the disused boiler house remained in situ at the site, it is recommended that further inspection and assessment of the soils is carried out directly beneath the bunded tanks and the boiler house equipment during / following the remaining site clearance works. Should any localised hydrocarbon impaction of the ground be noted (such as beneath the former boiler house equipment), then localised source removal works may be necessary following assessment.

7.3.2 Remediation Proposals

Based on the findings of our intrusive works, remediation (where possible) of any grossly hydrocarbon impacted soils in the vicinity of the tanks is required, together with appropriate post-removal validation sampling. In addition, if any unacceptably elevated contaminated soils are identified beneath the disused boiler house equipment (following removal), then this would also be required to be remediated. It is anticipated at this stage that the remediation works are likely to be carried out by removal (where possible) off-site of unacceptable contaminated soils.

Details of the required remediation works would be set out within a Remediation Strategy and Verification Plan, which should be prepared in advance of the works in accordance with the Planning Conditions. The remediation strategy would include a programme of validation to demonstrate how the successful implementation of the remediation strategy will be monitored and verified. Following completion of the remediation works, a Verification / Validation report will be required in accordance with the Planning Conditions.

Based on the findings of soil contamination assessment carried out across the site by Ground Engineering, together with the outcome of the supplementary contamination testing carried out by GeoDyne, it would appear that provision of a remedial capping layer (comprising subsoil and topsoil) to proposed gardens / soft landscaping is not considered necessary.

The provision of topsoil is considered necessary in proposed gardens and the area of public open space to provide a suitable growing media for plants. It may be necessary to increase the thickness of topsoil around the root balls of trees to suit the proposed planting regime. The physical suitability of the existing topsoil should be assessed by the developer.

Whilst the existing topsoil in the eastern third of the site is considered uncontaminated and suitable for re-use from a human health protection perspective, should there be a requirement to import additional quantities of topsoil to the site, it will be necessary to test the topsoil at source to ensure it is suitably clean (prior to importation) in accordance with CLEA / generic guidance.

The topsoil should also conform to BS3882: 2015 *'Specification for topsoil'*, with respect to the presence of foreign objects, and ideally nutrient levels etc. The results of the chemical analysis on topsoil proposed for importation should be forwarded to the Local Authority (Environmental Health Officer) for approval (prior to importation).

Similarly, if soils are proposed to be imported as part of the raising of site levels and are to be placed in proposed gardens and / or the area of public open space, it will be necessary to test the soils at source to ensure they are suitably clean (prior to importation) in accordance with CLEA / generic guidance. The results of the chemical analysis on soils proposed for importation should be forwarded to the Local Authority (Environmental Health Officer) for approval (prior to importation).

Any soils brought onto site that are placed in gardens and / or the area of public open space that have not been tested at source may need to be subject to post-placement testing, subject to the requirements of the Local Authority (Environmental Health Officer) in accordance with the National Contaminated Land Officers Group (NCLOG) document entitled *'A Regulator's Guide to Cover Systems and their Verification'* (2024).

7.3.3 Off Site Disposal & Waste Acceptance Criteria Testing

If off-site disposal is required, the chemical testing regime can be different to the chemical testing required to assess the suitability of the soils for retention on site and the risks to human health. Therefore, a separate contamination assessment may be required to include bespoke leachate analysis (i.e. Waste Acceptance Criteria [WAC] testing) to classify the soils for off-site disposal with testing criteria to assess whether the soil is hazardous, non-hazardous or inert waste. However, the existing chemical test data will assist this process.

If disposal is necessary then the environmental laboratory test results (included within Appendix IX) should be provided to several landfill operators for consideration and cost provision in the first instance, prior to the material being removed from the site.

7.4 General Considerations

7.4.1 Construction Workers

It is recommended that construction personnel involved with direct contact with the soils at the site use appropriate PPE / RPE equipment together with hygiene facilities in accordance with general health and safety guidelines. The chosen Contractor should undertake the necessary Risk Assessments and Method Statements (RAMS) to determine the most appropriate protection required for safe working practices at the site.

A copy of all reports relating to the site should be included in the site health and safety file, and site workers should be made fully aware of the sites setting.

7.4.2 Utilities

Prior to development of the site, we would recommend that a copy of this report is supplied to utility companies, and that their recommendations relating to appropriate supply pipes are adhered to.

With regard to water supply pipes, based on the results of the soil sampling, as the PE threshold has been exceeded in localised areas of the site (associated with hydrocarbon impaction from the above ground fuel storage tanks), it is considered that the use of protective / barrier water supply pipes may be required locally within the *'Brownfield'* area of the proposed development site. However, consideration should be given to localised remediation of the soils within the depths where pipework is likely to be laid which may negate the requirement for protected pipework, subject to the outcome of liaison with Anglian Water.

For the eastern third of the site which is *'Greenfield'* where no Made Ground and no sources of potential contamination have been identified, based on the results of the soil sampling carried out within this area, all contaminant concentrations are below the PE threshold and the use of protective / barrier water supply pipes within the *'Greenfield'* area is considered not necessary.

If protected pipework is ultimately required by Anglian Water within the *'Brownfield'* area, then the extent of the affected area / protected pipework would require agreement with Anglian Water following prior liaison.

7.4.3 Unforeseen Circumstances

Should any areas of potentially contaminated soil be encountered during site construction works we would recommend consultation with GeoDyne to ensure that our recommendations continue to apply. Any potentially contaminated soils should be left in-situ and subjected to further assessment, to potentially include further chemical testing and risk assessment.

The following procedure should be adhered to if any areas of previously unidentified suspected contamination are encountered during the development of the site:

i. Suspected contaminated material will remain in-situ.
ii. GeoDyne to be notified. We will then undertake a visual assessment of the possible contamination, followed by appropriate sampling/testing (as necessary).
iii. If necessary, contamination will then be treated or removed from site. All necessary remediation works should be validated by testing in accordance with an approved strategy, with the relevant Regulators informed accordingly.

7.4.4 Licenses, Permits, Registrations, Plans and Approvals

The Contractor / Developer is responsible for, and must ensure that, all necessary licenses, permits, plans, registrations and approvals are in place prior to commencing with the construction works at the site.

These may include any Materials Management Plans (MMPs), Site Waste Management Plans (SWMPs) and / or Environmental Permits / Exemptions as necessary to enable the completion of the proposed works. Any MMP should be accompanied by a Qualified Person Declaration (QPD) and will require verification in due course.

7.4.5 Statutory Consultation

In accordance with normal planning requirements, we would recommend that a copy of our report is issued by the Client to the Local Authority (and Warranty Provider, if necessary) for review / comment and approval prior to commencing with the development of the site.

7.5 Further Works

The following additional investigation / assessment works are recommended to be carried out:

- It is recommended that copies of the Ground Engineering and GeoDyne reports should be submitted to the Local Authority for their review and comment prior to any remedial works at the site.

- Following the receipt of comments on the above and details of the requirements of the Local Authority, a Remediation Strategy and Verification Plan document should be prepared and approved by the Local Authority in advance of the remedial works.

- Following approval of the Remediation Strategy and Verification Plan, the remedial works should be carried out. Following removal of the tanks etc., this is likely to comprise removal (where possible) of any grossly hydrocarbon impacted soils in the vicinity of the tanks and former boiler house equipment (if present), together with appropriate post-removal validation sampling.

- Following completion and verification / validation of the remedial works, a Remediation Completion / Validation Report should be prepared and submitted to the Local Authority for approval.

- Following finalisation of the design of gas protection measures, it is likely to be necessary to prepare a Ground Gas Verification Plan (GGVP), followed by installation, inspection and validation of the gas resistant membranes by a third party (in accordance with the requirements of CIRIA C735).