



Geotechnical &
Environmental
Consultants

North-East Area – Holbeach Meadows
Holbeach

**Combined Phase I Desk Study &
Phase II Exploratory Investigation
For
Ashwood Homes**



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Project No: D42030A		Date: 21st June 2022	
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Comments			

EXECUTIVE SUMMARY

GEOTECHNICAL CONSIDERATIONS	
Ground Conditions	Made Ground was only encountered within, and immediately around, the disused former agricultural buildings and offices and was encountered to depths of between 0.60m and 1.40m begl. TOPSOIL was encountered within the majority of the exploratory holes, with an average thickness of 0.40m begl. The near surface Natural Strata generally comprised loose to medium dense very silty SAND, which become loose, damp and locally wet with depth. In the western portion of the site, the Sand was proven to the full depth of the exploratory holes. In the majority of the eastern portion of the site, the Sand was underlain by soft, soft to firm and firm sandy clayey SILT / silty sandy CLAY. These Silt / Clay soils become soft and very soft to soft with depth and locally graded into damp slightly peaty CLAY. The near surface Sand was absent from the south-eastern corner where firm sandy clayey SILT / silty sandy CLAY (which became very soft to soft with depth) was encountered.
Foundation Design	Reference should be made to the Foundation Zoning Plan in Appendix XIV. <u>Zone 1</u> Structural Engineer designed strip or raft foundations, or potentially piles. The natural near surface Sand appears suitable to support a nett allowable ground bearing pressure of up to 75kN/m². An allowance should be made for suitable mesh reinforcement to all foundations. Foundations should be advanced to a minimum depth of 0.60m below existing or proposed ground level (whichever being the deeper) and founded within undisturbed suitably competent natural soils. The proposed site layout will need to take into account the route of the culverted drain, which is present in the eastern area of the site. <u>Zone 2</u> Structural Engineer designed strip or raft foundations, or potentially piles. The natural near surface Clay / Silt appear suitable to support a nett allowable ground bearing pressure of up to 75kN/m². An allowance is made for suitable mesh reinforcement to all foundations. Foundations should be advanced to a minimum depth of 0.90m below existing or proposed ground level (whichever being the deeper) and founded within undisturbed suitably competent natural soils. Some foundations may require locally deepening in accordance with NHBC Standards, due to the effects of trees. <u>Zone 3</u> The presence of Made Ground is likely to preclude the use of traditional shallow foundations. It is recommended that piles are adopted. <u>Comments Regarding Piles</u> The use of piles (within any of the indicated zones) would be subject to advice from a specialist piling contractor. It would be necessary to undertake further intrusive works, involving cable percussive boreholes, to assess the deeper ground conditions to assist with a piled foundation solution.
Floor Slab Design	Ground bearing floor slabs or a suspended slab, which may be either cast in-situ or a pre-cast suspended floor with a clear ventilated void (i.e. beam and block).
Ground Gas	No precautions required.
Radon	No precautions required.
Building Near Trees	Foundation designs are unlikely to require adjusting based on the predominant presence of granular / non-plastic soils and the absence of existing trees / hedgerows. If proposed trees are to be planted within the eastern portion of the site, foundation designs should take into account the recommendations within NHBC Standards Chapter 4.2.9. Cohesive soils of medium volume change potential should be assumed for design purposes.
Water	Water is unlikely to be encountered within foundation excavations. Deeper excavations (i.e. for sewers) may encounter water seepages and dewatering of deeper excavations may be necessary.
Excavations / Stability	The sides of the trial pits advanced in the western portion became unstable and began to slump / collapse when excavating generally in excess of 2m begl. The sides of the trial pits advanced in the eastern portion remained stable.

	Excavations deeper than approximately 2m begl within the western portion are likely to require trench support for health and safety reasons. The assessment of excavations and provision of support across the entire site will be the responsibility of the contractor on site.
Sulphate Classification	DS1 – AC1.
Coal Mining	No precautions required.
CBRs	The remoulded soaked CBR testing has revealed CBR values for the Natural Strata ranging between 0.2% and 0.4%. No frost susceptible material should be within 450mm of the ground surface in road construction.
Surface Water Drainage	The site is unlikely to be suitable for the use of soakaways.
ENVIRONMENTAL CONSIDERATIONS	
Soil Contamination Assessment	The soils may be considered to be uncontaminated for the proposed end-use (i.e. in relation to human health). There are considered to be no specific risks posed to Controlled Waters by the findings of the laboratory analysis undertaken.
Remediation Proposals	No specific remediation works anticipated.
GENERAL CONSIDERATIONS	
Construction Workers	A copy of this report should be included in the site health and safety file, and site workers should be made fully aware of the sites setting.
Asbestos Survey	It is recommended that a suitable asbestos survey is undertaken on all site buildings prior to demolition.
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.
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.
Licences etc	The Contractor / Developer is responsible for, and must ensure that, all necessary licences, 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 NHBC or other Warranty Provider, if necessary) for review / comment and approval prior to commencing with the development of the site.

1.0 INTRODUCTION

1.1 Introduction

GeoDyne Limited has been appointed by the Client, Ashwood Homes, to undertake a combined Phase I Desk Study & Phase II Exploratory Investigation on a parcel of land at the Holbeach Meadows development site, which is located to the south-west of Holbeach town centre.

The Client has named the parcel of land subject to this investigation (hereby referred to as 'the site') as '*North-East (NE) Area – Holbeach Meadows*', to distinguish it from the Client's ongoing first phase of development at Holbeach Meadows.

A site location plan (Figure No. D42030A/01) is included in Appendix I.

1.2 Project Understanding

We understand that it is proposed to demolish the existing buildings, which are present within part of the site, and develop the site for a low-rise residential end-use incorporating private gardens as broadly indicated on the proposed masterplan contained within Appendix II (Figure No. D42030A/02). The final site layout has yet to be confirmed.

It should be noted that the western extremity of the site is to be the subject of a separate planning application (to include commercial renovation works of the existing former farm buildings and potential construction of a new school) and is excluded from our intrusive investigation area, which is focussed on the proposed residential development part of the site. The western extremity of the site will need to be the subject of a separate exploratory investigation at the appropriate time.

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 Objectives

The scope of works detailed herein have been designed to ascertain the key geotechnical and environmental issues pertaining to the proposed development.

1.4 Scope of Works

Based on the defined objectives of the works (detailed in Section 1.3), the scope of the Phase I Desk Study included the following:

- A site walkover.
- Review of available historical and contemporary Ordnance Survey publications relating to the site.
- Review of the sites geology, hydrology and hydrogeology.
- Review of the sites coal mining status.
- Review of the sites radon status.
- Commission of a full detailed Landmark Envirocheck Report relating to the site.
- Commission of Landmark geological mapping data.
- Production of a preliminary Conceptual Site Model (pCSM).

Phase II Exploratory Investigation works comprised:

- A sub-contracted sub-surface utility scan of proposed exploratory hole locations.
- A programme of trial pits and window sample boreholes across the site to provide an initial inspection of the near surface ground conditions for geotechnical and environmental assessment purposes.
- Geotechnical and environmental soils testing.
- A programme of ground gas and water monitoring.
- Revision of the pCSM.

1.5 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 Ashwood Homes, in accordance with our standard Conditions & Limitations (included in Appendix XV). 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 DESCRIPTION & HISTORY

2.1 Site Description

The site comprised a near rectangular shaped plot of land, accessed off Fen Road to the east. The access from Fen Road comprised a concrete surfaced driveway, which ran parallel with the northern site boundary. The site may be located centred around approximate Ordnance Survey National Grid Reference 535710E 324210N and covers an area of approximately 6.7 hectares.

At the time of our site works (April 2022), the majority of the site comprised two cropped agricultural fields. The western extremity of the site (excluded from our intrusive investigation area as detailed in Section 1.2) comprised a series of disused farm buildings to the south of an area of exposed soils/scrub.

The agricultural fields were separated by a north to south trending drain and disused agricultural buildings and offices. These buildings were located to the south of the concrete driveway. The drain was culverted beneath the western extremity of the eastern field. A spur to the drain was also culverted through the central area of the eastern field, trending in an approximate west to east direction.

To the south of the disused agricultural buildings, an open-sided barn was present. To the north of the barn, two square-shaped areas of exposed soil were present. The northern area of exposed soil was locally planted with vegetables and incorporated a small polytunnel.

Two vacant semi-detached residential properties with associated gardens were present to the north-west of the western agricultural field, accessed via the concrete driveway.

The large square-shaped brick-built disused agricultural building in the central northern area of the site was being used by Ashwood Homes to store dry building products (i.e. timber and tiles) for their ongoing Holbeach Meadows residential development site located further to the west. The eastern half of the building comprised disused offices including a kitchen and toilet facilities.

The adjacent smaller rectangular-shaped disused agricultural building was empty and incorporated a chimney. A disused external plastic above ground heating oil tank was present to the immediate south of this building located on a concrete base. To the south of the tank, a small gravel surfaced former office car park was present.

The area in-between and around the disused agricultural buildings comprised concrete surfacing. To the south of the concrete surfacing and former offices, an area of buried drainage facilities was present.

The area to the north and east of the site comprised existing residential properties and associated gardens. The area to the south of the eastern agricultural field (beyond an open spur of the drainage ditch) also comprised residential properties. The area to the south of the western agricultural field comprised a continuation of the field (the actual site boundary being undefined). The existing ongoing Holbeach Meadows residential development site was present to the west of the site.

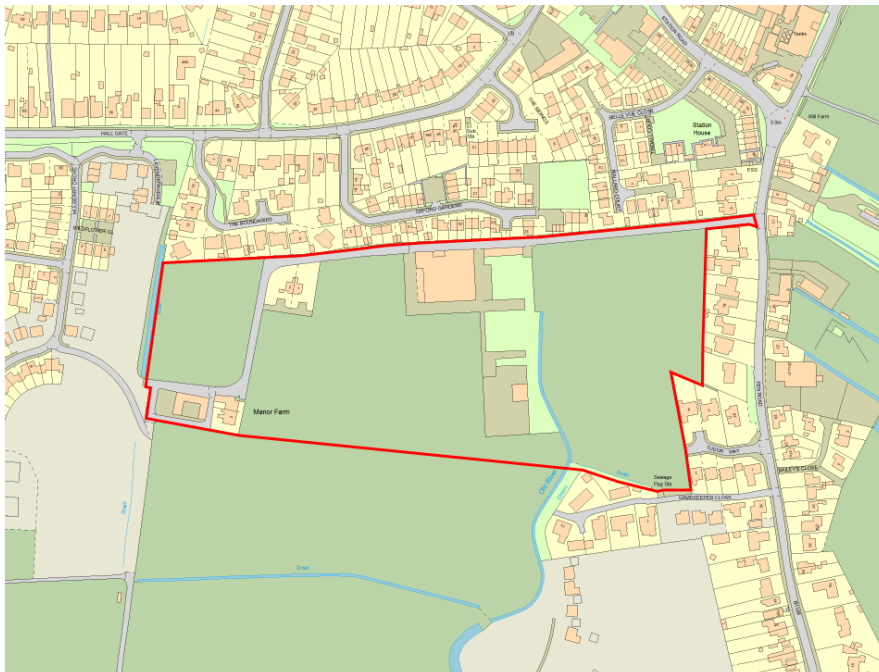
The Annotated Site Plans in Appendix III of this report (Figure Nos. D42030A/03A and D42030A/03B) show the main features of the site and immediate surrounding area. General views of the site are included on the plans in Appendix IV of this report (Figure Nos. D42030A/04A to D42030A/04C).

An aerial photograph of the site, obtained from the Landmark Analysis tool commissioned as part of our works, is presented in Figure 1 below, with the current OS mapping plan for the site and surrounding area presented in Figure 2 below. The absence of topographic contour levels on the OS mapping is indicative of the generally flat nature of the site and its environs.

Figure 1: Aerial photograph of the site (2022 image).



Figure 2: Current OS Mastermap Plan.



2.2 Site History

The historical and contemporary Ordnance Survey publications included within the Landmark Envirocheck Report have been reviewed by GeoDyne to establish the history of the site and its environmental setting. The historical Ordnance Survey maps are included as Appendix V of this report.

We would note that the boundary marked on the historical sheets within the Envirocheck Report appears to 'shift' on several of the maps due to scaling inaccuracies between maps of differing dates. This is a function of Envirocheck transposition algorithms.

The key findings of the historical search are summarised in Table 1.

TABLE 1 – HISTORICAL PUBLICATION DATA		
Date	Features on Site	Features off Site
1880s	- The majority of the site comprises undeveloped fields. - Buildings associated with 'Manor Farm' are present in the south-western corner of the site. An access track runs north-easterly from the farm buildings through the site. - A pond is present between the farm buildings and the western site boundary, which is defined by an open drain. A second pond is present to the east of the farm buildings in the south-western area of the site. A much smaller pond is also indicated to be present adjacent to the central portion of the southern site boundary. - A north to south trending open drain is present close to the centre of the site. An open spur to this drain is present in the eastern area of the site.	- Undeveloped fields are present to the immediate south and west of the site. - Two ponds are present within the field to the south of the site. - A road (now Fen Road) is present to the east of the site. Properties are present on the eastern side of Fen Road. - An east to west trending railway line is present to the north of the site (beyond the northern site boundary). 'Holbeach Station' and associated sidings are present on the northern side of the railway line. - A pond is present to the north-west of the site beyond the railway line. - A 'Brick Works' and associated excavations (indicated as apparent ponds) are indicated to be present approximately 125m to the east of the site.
1890s	No maps available for viewing.	No maps available for viewing.
1900s	The site remains essentially unchanged, although the access track from the farm buildings now runs along the northern boundary of the site and appears to link-up with Fen Road to the east.	- The sidings have expanded to the north of the railway line, to the north of the site. - The brick works to the east are no longer labelled but the excavations remain present.
1910s & 1920s	No maps available for viewing.	No maps available for viewing.
1930s	- Some of the farm buildings associated with Manor Farm have been replaced with new structures. - The pond in the area of the farm buildings, the pond in the south-western area of the site and the pond adjacent to the southern site boundary are no longer present (presumed infilled). - The western site boundary is no longer defined by an open drain. - Two semi-detached residential properties are present in the north-western area of the site, accessed by a track from the northern site boundary that also now feeds Manor Farm.	The surrounding area remains essentially unchanged, although the two ponds within the field to the south of the site are no longer present (presumed infilled) and the majority of the excavations associated with the former brick works to the east are no longer present (presumed infilled).

TABLE 1 – HISTORICAL PUBLICATION DATA

Date	Features on Site	Features off Site
1930s cont.	- A building is present in the northern central area of the site together with a glasshouse. - The south-eastern area of the site is indicated to comprise an orchard.	
1940s	No maps available for viewing.	No maps available for viewing.
1950s	- The site remains essentially unchanged, although two potentially temporary structures are indicated to be present on each side of the building located in the central northern area of the site. - By the late 1950s, the south-eastern area of the site is no longer indicated to comprise an orchard.	The surrounding area remains essentially unchanged, although the remaining excavation associated with the former brick works to the east is no longer present (presumed infilled).
1960s	- Buildings are present in the central northern area of the site, including two structures later identified as glasshouses. - The northern portion of the north to south trending open drain, near the centre of the site, is now potentially culverted.	- The railway line and sidings to the north of the site are no longer present and have been dismantled. Some of the former railway buildings including the station remain present. - The pond to the north-west of the site is no longer present (presumably infilled). The area of the former pond and immediate surrounds is now occupied by properties and a garden nursery. 'Poultry Houses' off Fen Road are indicated to be present to the south-east of the site beyond an open drain. - An elongated building is present to the south-west of the site, to the south of Manor Farm.
1970s	The site remains essentially unchanged, although another structure (now identified as an open-sided barn) is present in the central area of the site).	Commercial properties, including a 'Depot' and 'Garage' have been constructed to the north of the site in the area of the former railway line and sidings.
1980s	The site remains essentially unchanged, although a small structure (identified as a 'Tank' on the maps of the 1990s) is present immediately beyond the north-western corner of the western glasshouse.	- The depot to the north of the site has expanded. - The poultry houses are no longer present to the south-east of the site.
1990s	- The eastern glasshouse in the central northern area of the site is no longer present. - The spur to the open drain in the eastern area of the site is no longer present (presumed infilled). <i>The route of this drain appears to have been realigned and culverted as evidenced during our works.</i> - The aerial photograph of 1999 shows the majority of the site to comprise agricultural fields. The buildings in the central northern area of the site appear as today with the exception of a large glasshouse shown to the east of the semi-detached residential properties in the north-western area of the site. The area of the former eastern large glasshouse appears undeveloped. The concrete access driveway is clearly shown off Fen Road.	- Residential properties have been constructed between the eastern site boundary and Fen Road. - A pond has been created in the area of the former poultry houses to the south-east of the site. - The garden nursery buildings to the north-west of the site are no longer present. - The aerial photograph of 1999 shows a residential development site being constructed to the north-west of the site, in the area of the former nursery and railway line. The pond to the south-east of the site has been potentially infilled as this area is indicated to comprise grass/scrub.

TABLE 1 – HISTORICAL PUBLICATION DATA		
Date	Features on Site	Features off Site
2000	The site remains essentially unchanged.	The surrounding area remains essentially unchanged.
2006	The site remains essentially unchanged.	Further residential properties have been constructed in the area of the former railway line to the north of the site.
2021	The remaining glasshouse on the site is no longer present and the adjacent tank has been removed.	- The depot to the north has been replaced with residential properties. - A sewage pumping station is indicated to be present to the south-east of the site adjacent to residential properties constructed in the area of the former poultry houses and infilled pond. - The elongated building to the south-west of the site is no longer present. - Residential properties (part of the first phase of the Holbeach Meadows development) are present to the north-west and west of the site.

2.3 Aerial Photography & Historical Map Overlays

As part of the commissioned Landmark Report, the use of the Landmark Envirocheck Analysis tool was purchased to provide site specific aerial photographic imagery, and to provide the ability to undertake limited historical map overlay manipulation.

The following pictures (Figures 3 to 7) show overlays of the historical map publications from 1888, 1932, 1969, 1982 and 1992, as shown on current aerial imagery.

Figure 3: Current Aerial Imagery Overlain with 1888 Historical Map Data.

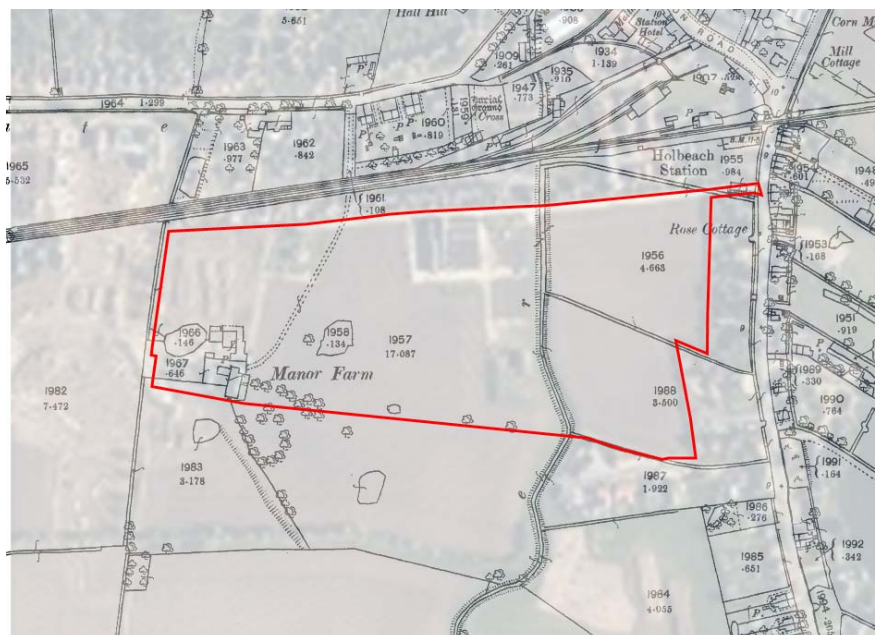


Figure 3 shows the Manor Farm buildings in the south-western corner of the site and the presence of on-site ponds. The open drains are visible passing through the site.

Figure 4: Current Aerial Imagery Overlain with 1932 Historical Map Data.

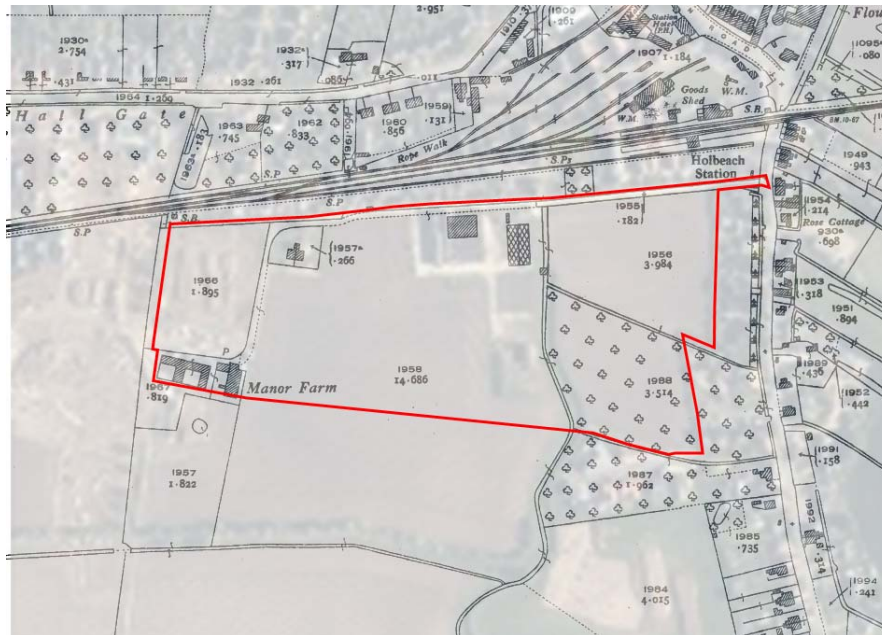


Figure 4 shows the absence of the on-site ponds and the presence of two semi-detached residential properties in the north-western area of the site. A building and glasshouse are present in the central northern area.

Figure 5: Current Aerial Imagery Overlain with 1969 Historical Map Data.

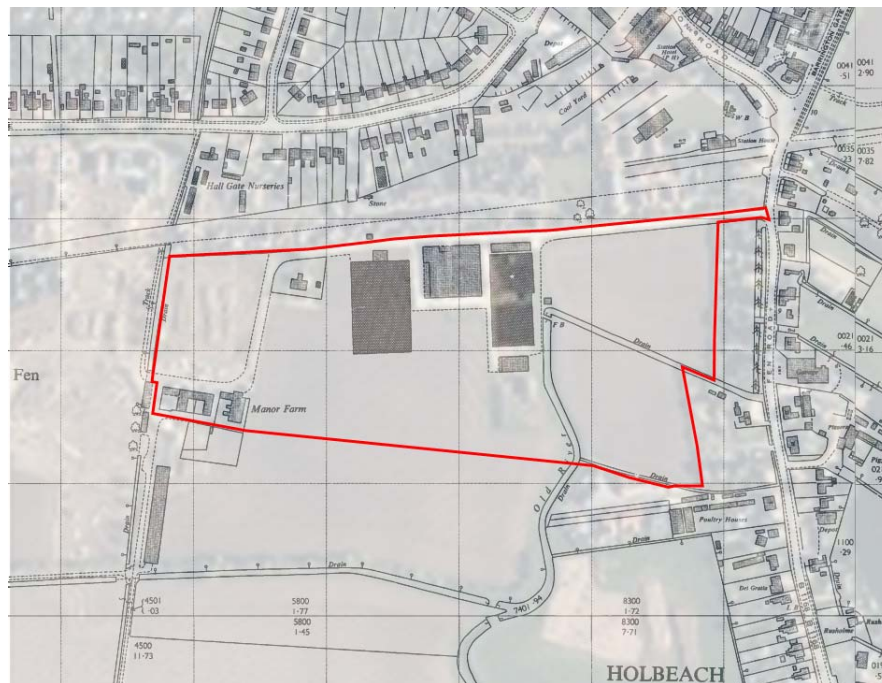


Figure 5 shows the presence of buildings and glasshouses in the central northern area of the site. The drain passing through the site also appears to be now partially culverted.

Figure 6: Current Aerial Imagery Overlain with 1982 Historical Map Data.

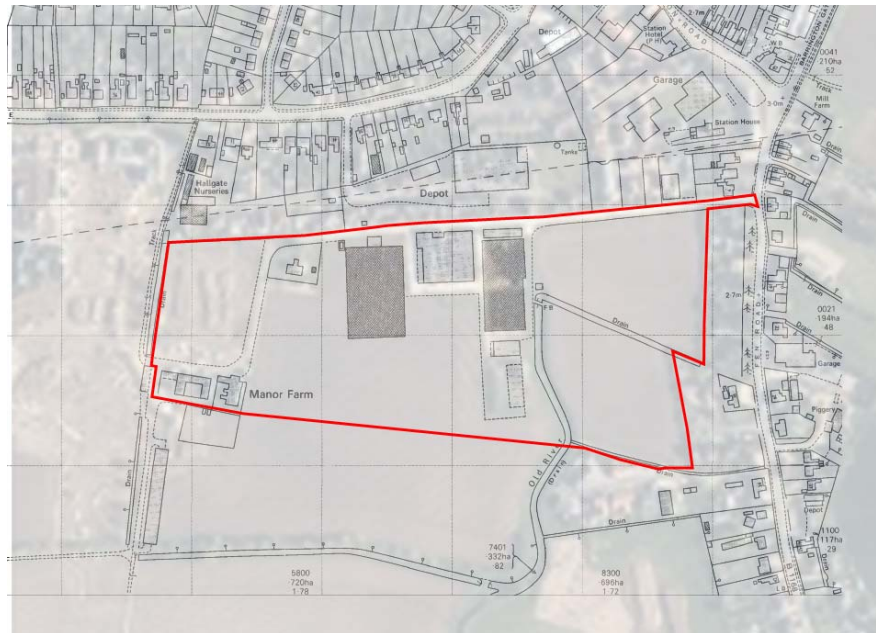


Figure 6 shows the presence of the barn in the central area of the site and a tank immediately beyond the north-western corner of the western glasshouse.

Figure 7: Current Aerial Imagery Overlain with 1992 Historical Map Data.

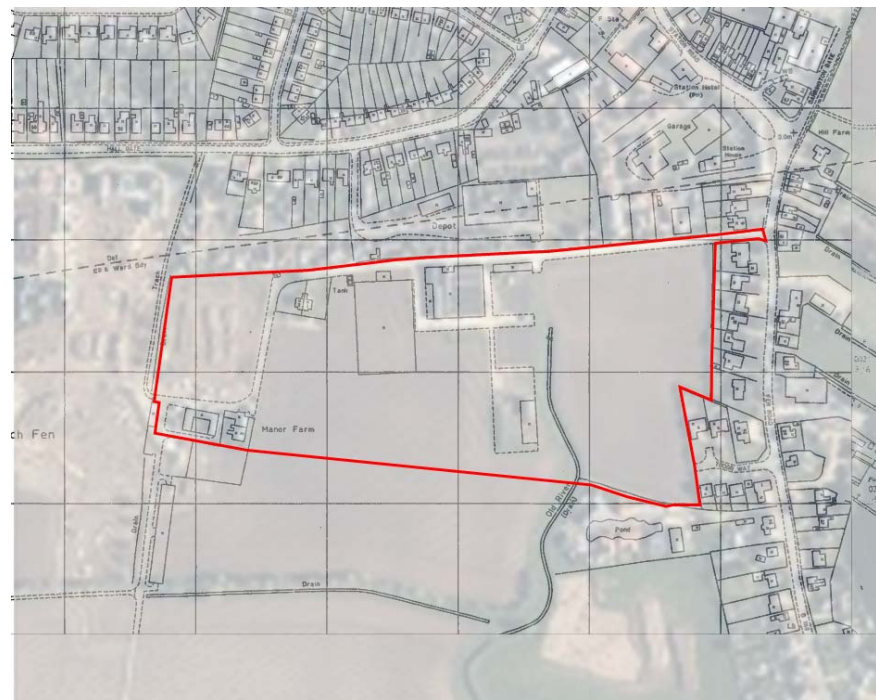


Figure 7 shows the eastern glasshouse to be no longer present. The open drain passing through the eastern area of the site is no longer present (presumed infilled).

3.0 GEOLOGY & ENVIRONMENTAL SETTING

3.1 Geological References

The following geological publications were referred to:

- BGS 1:50000 Series Sheet 144 'Spalding' (1992).
- BGS Publication 'Geology of the country around Kings Lynn and The Wash' (1994).
- The Coal Authority and The Law Society Publication 'Coal Mining and Brine Subsidence Claim Searches - Directory and Guidance', Sixth Edition (2006).
- Landmark Geological Maps (presented in Appendix VI).
- Environment Agency website: www.environment-agency.gov.uk.
- British Geological Survey website: www.bgs.ac.uk.

3.2 Geology

Superficial Drift Deposits

The geological maps reveal the entire site and immediate surrounding area to be underlain by Tidal Flat Deposits (formerly referred to as the Terrington Beds), which date from the Quaternary. These deposits are typically described as '*...marine alluvium comprising salt marsh, tidal creek and river deposits (i.e. sandy silt, sand and clay)*'.

Drift deposits have the potential to alter rapidly in character and geotechnical properties both laterally and vertically over relatively short distances and may also be water bearing. Tidal Flat Deposits may also contain peat as pockets, lenses or discrete layers.

Bedrock Geology

The drift deposits at the site and in the immediate surrounding area are indicated to be underlain by the West Walton Formation, dating from the Jurassic.

The West Walton Formation typically comprises '*...calcareous mudstone, silty mudstone and siltstone, with subordinate fine-grained sandstones and limestone or siltstone nodules*'.

3.3 Faults

No surface faults are indicated beneath the site or within the general vicinity of the site.

3.4 Man-Made Deposits

No man-made deposits (i.e. Made Ground, Worked Ground or Infilled Ground) are indicated on the reviewed geological map publications to be present at the site or within the area surrounding the site.

However, man-made deposits are indicated from historical information to be potentially present associated with on-site and off-site former ponds. The historical maps revealed the presence of three former on-site ponds, which appeared to become infilled c1930s. Historical information also revealed the presence of several infilled off-site former ponds in close proximity to the site to the north-west, south and south-east.

Man-made deposits may also be present associated with the infilled former open drain, which used to pass through the eastern area of the site.

The historical maps also revealed that man-made deposits may potentially be present associated with the brick works excavations located approximately 125m to the east of the site. The majority of these excavations appear to have been infilled by the 1930s with further infilling taking place by the 1950s.

3.5 Coal Mining Report

The site does not lie within an area requiring the commission of a coal mining report in accordance with The Coal Authority online interactive map viewer. No specific investigation or mitigation in relation to historical coal mining issues is therefore considered to be necessary at the site.

3.6 Landmark Envirocheck Report

A Landmark Envirocheck Report was commissioned to assist in ascertaining the environmental setting of the site. The full Envirocheck Report is presented in Appendix VII and has revealed the following key relevant information (details are only listed where they are within potential influencing distance of the site).

No comments have been made within our report with respect to potential flooding issues. Advice from a qualified drainage consultant should be sought by the Client with respect to this matter.

3.6.1 Agency & Hydrological

Aquifer Status

The aquifer designation maps are presented in Appendix VII and are based on geological mapping provided to Landmark by the British Geological Survey. Different aquifer classifications may be applied to superficial (drift) deposits (typically forming shallow perched groundwater units where present) and bedrock aquifers (which may contain regional groundwater units). Possible aquifer designations comprise Principal Aquifers, Secondary (A, B or Undifferentiated) Aquifers and Unproductive Strata.

The superficial deposits comprising the Tidal Flat Deposits and the underlying bedrock geology comprising the West Walton Formation are both designated as Unproductive Strata.

The Environment Agency describes Unproductive Strata as '*...rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow*'.

Source Protection Zones

The Envirocheck report indicates that the site does not lie within a Source Protection Zone (SPZ), as designated by the Environment Agency. SPZs relate to the protection of groundwater used for public drinking water supply.

Water Abstractions

There are no entries listed within the Envirocheck report.

Surface Water

The closest surface water feature is indicated to be the open drain, which passes through the central area of the site and a spur of the drain that defines part of the southern site boundary.

Pollution Prevention and Controls

There are three Local Authority entries listed within 250m of the site. The nearest entry (located 38m to the north-east) is revoked and relates to aluminium processes at '*Eric Ladbrook (Holbeach) Ltd*'. The entry located 73m to the east of the site relates to a petrol filling station off Fen Road. The third entry is revoked and is located 135m to the northeast of the site and relates to a garage/petrol filling station.

Pollution Incidents to Controlled Waters

There is one entry listed at the site relating to pollution by '*Other Oil*' '*Potential Sewage Works*' with an incident date of 15th March 1999. This entry appears to be indicated at the location of the existing on-site buried drainage facilities. Another entry is listed as being located 106m to the north-east of the site associated with acid pollution on 26th September 1996. Both these incidents have been classified as Minor Incidents and are considered not to affect the proposed development site.

Substantiated Pollutant Incident Register

One entry is listed associated with '*Smoke*' and '*Firefighting Run-off*', located 37m to the north-east of the site on 18th October 2002. The incident is detailed as '*Minor*' with respect to Water Impact, '*Significant*' with respect to Air Impact and '*No Impact*' in relation to Land Impact. This incident is considered not to affect the proposed development site.

3.6.2 Waste

Landfill Sites

There is a historical landfill site located 223m to the north-east of the site detailed as '*Barrington Gate*'. The specified waste at the landfill '*included Household Waste*'. The first and last input dates for the landfill are not provided. Based on a review of historical mapping, there does not appear to be any obvious feature on the maps relating to this landfill, which is now occupied by residential properties.

Waste Management & Waste Treatment / Disposal Facilities

There is one licensed waste management entry located 167m to the east of the site off Fen Road, relating to '*Nationwide Metal Recycling Ltd.*'. There is one registered waste treatment or disposal entry located 36m to the east of the site, relating to Eric Ladbrook (Holbeach) Ltd., off Fen Road. The entry is detailed as a '*Scrapyard*'.

Potentially Infilled Land

There are three on-site entries for Potentially Infilled Land (Water), which coincide with the locations of the former on-site ponds as identified from historical mapping. There are six off-site entries for Potentially Infilled Land (Water) within 250m of the site, the closest two entries being located to the south of the site coinciding with the location of former ponds as identified from historical mapping.

It should be noted that the off-site former ponds identified from historical mapping to the south-east of the site (in the area of former poultry houses now occupied by housing) and to the north-west of the site (in the area of the former plant nursery and now occupied by housing) are not listed within the Envirocheck report.

There is one entry for Potentially Infilled Land (Non-Water) located 124m to the east of the site. Based on a review of historical mapping, this entry coincides with the location of the former brick works excavations as identified on historical mapping.

3.6.3 Hazardous Substances

There are no sites associated with hazardous substances (i.e. sites dealing with explosives etc) identified on the site, or within a 250m radius of the site, in the Envirocheck report.

3.6.4 Geological Issues

BGS Soil Chemistry

The BGS has prepared estimated soil concentration maps for several metals (including Arsenic, Lead, Nickel, Chromium and Cadmium), which are extrapolated from records available for use within their assessments. Whilst potentially useful for the inference of Natural Metal Enrichment (NME) of the natural soils in a general locale, the data should not be used to inform any detailed decisions with regards to the chemistry of a particular site as it does not allow for anthropogenic effects. Estimates of the soil chemistry at the site indicate anticipated concentrations of Arsenic of <15mg/kg, Cadmium of <1.8mg/kg, Chromium of 60-90mg/kg, Lead <100mg/kg and Nickel of 15-30mg/kg.

Based on the information supplied in the Landmark Envirocheck Report, the site is indicated to be located in an area where significant NME of the underlying natural soils is not anticipated to be present. However, this is only applicable to the specific determinands listed above.

Ground Stability Hazards

No significant ground stability hazards have been identified by the Envirocheck report that relate to the site (including from collapsible, ground dissolution, landslide and shrinking or swelling clay ground stability hazards).

However, it should be noted that the site is listed as having a Moderate Hazard Potential associated with both Potential for Compressible Ground and Running Sand.

Radon

The Envirocheck report states that '*The property is in a lower probability radon area (less than 1% of homes are estimated to be at or above the Action Level)*', and further states that '*No radon protective measures are necessary in the construction of new dwellings or extensions*'.

BGS Borehole Records

There are no BGS records in the vicinity of the site.

Mining and Ground Stability Datasheet

The Landmark Mining & Ground Stability Datasheet (included within Appendix VII) does not identify the presence of any Extractive Industries or Potential Excavations at the site or within the vicinity of the site. The datasheet reveals the presence of a BGS Recorded Mineral Site located 141m to the east of the site, detailed as '*Holbeach Brick Works*'. The entry states that the mineral site was an opencast operation for '*Common Clay and Shale*'.

The location of this entry broadly coincides with the former brick works identified on historical maps and the Potentially Infilled Land (Non-Water) feature detailed in Section 3.6.2.

3.6.5 Industrial Land Use

Contemporary Trade Directory Entries

There are numerous entries listed within 250m of the site. The nearest active entry (located 38m to the north-east of the site) relates to scrap metal recycling, which appears to be associated with the facility discussed in Section 3.6.2. Several inactive entries are located to the north, north-east and east of the site including premises associated with former car body repairs, printers and car dealers.

The majority of the listed entries are in excess of 50m from the proposed development site.

Fuel Station Entries

An obsolete entry is listed 73m to the east of the site off Fen Road.

3.6.6 Sensitive Land Use

There are no sensitive land uses indicated on site or in the immediate vicinity of the site.

3.7 Land Use Assessment

As part of the land use assessment, reference has been made to the '*Desk Reference Guide to potentially Contaminative Land Uses*' produced by Mr P Syms and published jointly by the ISVA (The professional Society for Valuers and Auctioneers) in association with The Royal Institution of Chartered Surveyors (RICS) and the Chartered Institute of Environmental Health (CIEH).

We have also made reference to the Department for Environment, Food and Rural Affairs and the Environment Agency Contaminated Land Report CLR8 '*Potential Contaminants for the Assessment of Land*' (March 2002). Although now formally withdrawn, this document identifies key contaminants which may potentially be present at a site as a result of a given historical land use and is considered useful as a desk based ready reference guide.

3.7.1 On Site Assessment

At the time of our site works, the majority of the site comprised two cropped agricultural fields. The western extremity of the site (excluded from our intrusive investigation area as detailed in Section 1.2) comprised a series of disused farm buildings to the south of an area of exposed soils/scrub.

The agricultural fields were separated by a north to south trending drain and disused agricultural buildings and offices. The drain was culverted beneath the western extremity of the eastern field. A spur to the drain was also culverted through the central area of the eastern field, trending in an approximate west to east direction in close proximity to a former open section of the drain (now infilled).

Two vacant semi-detached residential properties with associated gardens were present to the north-west of the western agricultural field. One of the disused agricultural buildings incorporated a chimney. A disused external plastic above ground heating oil tank was present to the immediate south of this building.

Based on the reviewed historical information, buildings associated with a farm have been present in the south-western corner of the site since at least the 1880s. Buildings first appeared in the central northern area of the site by the 1930s together with the semi-detached residential properties.

By the 1960s, two large glasshouses were present in the central northern area of the site. A tank was also present adjacent to one of these glasshouses. The two glasshouses (and tank) were removed during and post 1990s.

The site is not identified in any of the land-use categories detailed within the publications referenced in Section 3.7. Based on the information obtained from the desk study and our walkover of the site, potential contamination that may be present could include:

- Metals or metalloids associated with any potential localised Made Ground in and around the area of the disused agricultural buildings, former glasshouses and infilled ponds.
- Polycyclic Aromatic Hydrocarbons (PAHs) from any ashy inclusions and / or carbonaceous inclusions in the near surface soils.
- Petroleum hydrocarbons (TPH) associated with potential leakages / spillages from i) the disused above ground heating oil tank, ii) the former tank located adjacent to one of the former glasshouses, iii) potential machinery used within the disused agricultural buildings and iv) vehicles parked in the former office car park area.
- Pesticides and herbicides associated with the agricultural use of the site including the existing fields, the area of the former glasshouses and the disused agricultural buildings.
- Asbestos Containing Materials (ACMs) associated with potential Made Ground in and around the disused agricultural buildings.
- Potentially hazardous ground gases (i.e. methane and carbon dioxide) associated with potentially organic superficial deposits beneath the site, in addition to potential man-made deposits in the area of the infilled ponds and infilled former open drain.

3.7.2 Off Site Assessment

Whilst the area to the immediate north of the site has had an industrial legacy (i.e. it has been formerly occupied by a railway line, railway sidings and a depot), this area has now been redeveloped with residential properties (including during the 2000s). Therefore, this area is considered not to represent a key risk driver in the environmental assessment of the site with the key risk drivers for the site considered to be the current and former on-site features, as detailed above.

No other significant sources of potential chemical contamination have been identified in close proximity to the site.

Based on the information obtained from the desk study, the following sources of potentially hazardous ground gas (i.e. carbon dioxide and methane) have been identified within potential influencing distance (i.e. <250m) of the site:

- Man-made deposits associated with the infilled brick works excavations to the east of the site, identified as a BGS Recorded Mineral Site.
- Man-made deposits potentially associated with the infill materials to several former ponds. Residential properties now occupy the location of some of these ponds, hence the risks associated with this potential off-site source of ground gas would appear to be low.
- Man-made deposits associated with the former landfill site to the north-east, which is now occupied by residential properties, hence the risks associated with this potential off-site source of ground gas would appear to be low.

4.0 PRELIMINARY CONCEPTUAL SITE MODEL

4.1 General

The DEFRA publication '*Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance*' (dated April 2012) states the following with regards to the production of a Conceptual Site Model (CSM) for a site:

'The process of risk assessment involves understanding the risks presented by land, and the associated uncertainties. In practice, this understanding is usually developed and communicated in the form of a "conceptual model"'. The development of a CSM is typically undertaken in an iterative process, reflecting the changes in understanding as more detailed site information becomes available.

In developing a CSM, and specifically in the context of land contamination, consideration needs to be given to three essential elements; which form the basis of any risk present. The statutory guidance sections 3.8 and 3.9 (April 2012) states the following:

- (a) *'A "contaminant" is a substance which is in, on or under the land and which has the potential to cause significant harm to a relevant receptor, or to cause significant pollution of controlled waters.*
- (b) *'A "receptor" is something that could be adversely affected by a contaminant, for example a person, an organism, and ecosystem, property, or controlled waters...*
- (c) *'A "pathway" is a route by which a receptor is or might be affected by a contaminant.*

The term "contaminant linkage" means the relationship between a contaminant, a pathway and a receptor.' For a contaminant linkage to be plausible, all three elements need to be present.

In undertaking a risk assessment and deriving a CSM for the purposes of the redevelopment of a site (i.e. planning and development control) reference has been made to both the Model Procedures for the Management of Land Contamination, as well as the National Planning Policy Framework (NPPF, dated July 2018).

The preliminary CSM should identify the hazards (source of potential contamination) and should set out the potential pollutant linkages with a view to identifying the nature and magnitude of the potential risks to receptors. In order to undertake the foregoing assessment, consideration is required with respect to the probability or likelihood of the linkage occurring and the severity and significance of the potential consequences; taking account the nature of the pollutant linkage and the potential severity of the hazard and the sensitivity of the receptor within the context of the proposed land use (in consideration of the planning regime).

Consideration of consequence/severity, probability/likelihood and risk has been based on the following guidance documentation:

- CIRIA C552 '*Contaminated Land Risk Assessment, A Guide to Good Practice*', 2001.
- EA R&D publication 66 '*Guidance for the Safe Development of Housing on Land Affected by Contamination*', 2008.

4.2 Classification of Consequences

In order to apply a consequence classification to a particular potential pollutant linkage, it is first necessary to define the terminology used within the classification system.

The following terminology and definitions detailed in Table 2 have been adopted within our assessment, based on the guidance referenced in Section 4.1.

TABLE 2 – CLASSIFICATION OF CONSEQUENCES	
Classification	Definition
Severe	- Acute risks to human health. - Short-term risk of pollution of controlled waters or significant impact on controlled waters; e.g. large-scale pollution or very high levels of contamination. - Catastrophic damage to buildings or property (such as building explosion causing collapse). - Ecological system effects – immediate risks of major damage which is likely to result in irreversible substantial adverse changes in the functioning of the ecosystem or harm to a species of special interest that endangers the long-term maintenance of the population.
Medium	- Chronic risks to human health. - Pollution of sensitive water resources (such as leaching of contaminants into controlled waters) causing a significant effect on water quality. - Ecological system effects – Immediate risks of significant damage which may result in substantial adverse changes to the ecosystems functioning or harm to a species of special interest that may endanger the long-term maintenance of the population. - Significant damage to buildings, structures and services (for example foundation damage or rendering the building unsuitable for habitation).
Mild	- Non-permanent health effects to human health (i.e. exposure is unlikely to lead to 'significant harm') in the context of Part 2A of the Environmental Protection Act 1990. - Pollution of controlled waters or non-sensitive water resources (for example non-classified groundwater) that results in a short-lived effect to water quality or a marginal effect on amenity value, agriculture or commerce. - Minor damage to buildings, structures and services. - Ecological system effects – Minor or short-term damage which is unlikely to result in substantial adverse changes to the ecosystems functioning or harm to a species of special interest. - Substantial damage to non-sensitive environments (such as arable farmland for example).
Minor	- No measurable effects on human health including non-permanent health effects to human health that are easily preventable by appropriate use of PPE/RPE. - Minor pollution of controlled waters including non-sensitive water resources with no discernible effects on water quality or ecosystems. - Minor damage to non-sensitive environments (including arable farmland for example). - Easily repairable effects of damage to buildings, structures, services or the environment (for example discolouration of concrete, loss of plants in a landscaping scheme etc.).

4.3 Classification of Probability

Once the possibility of a pollutant linkage has been established (noting that probability classification does not apply when there is no possibility of a linkage being present), the probability should be classified in accordance with Table 3.

TABLE 3 – CLASSIFICATION OF PROBABILITY		
Classification	Definition	Likelihood
High Likelihood	There is a pollutant linkage and an event is highly likely to occur in the short-term, and is almost inevitable over the long-term OR there is evidence at the receptor of harm or pollution occurring.	>95% likelihood of Consequence Occurring
Likely	There is a pollutant linkage and it is probable that an event will occur. It is not inevitable, but possible in the short-term and likely over the long-term.	50 – 95% likelihood of Consequence Occurring
Low Likelihood	There is a pollutant linkage and circumstances are possible under which an event could occur. It is by no means certain that even over a longer period such an event would take place, and less likely in the short-term.	5 – 49% likelihood of Consequence Occurring
Unlikely	There is a pollutant linkage and it is improbable that an event would occur even in the very long-term.	<5% likelihood of Consequence Occurring

4.4 Classification of Risk

In order to establish the relevant risk term applicable to the identified pollutant linkage, one of the risk phrases identified within Table 4 must be adopted, with the definitions of each risk term detailed within Table 5.

TABLE 4 - RISK CLASSIFICATION MATRIX (BASED ON C552 CIRIA, 2001)					
		Consequence of Risk			
		Severe	Medium	Mild	Minor
Probability (Likelihood)	High Likelihood	Very High	High	Moderate	Moderate/Low
	Likely	High	Moderate	Moderate/Low	Low
	Low Likelihood	Moderate	Moderate/Low	Low	Negligible
	Unlikely	Moderate/Low	Low	Negligible	Negligible or No Potential Risk

TABLE 5 - RISK CLASSIFICATION DEFINITIONS (BASED ON C552 CIRIA, 2001)	
Very High	There is a high probability that severe harm will arise to a designated receptor from an identified hazard OR there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability. Urgent investigation (if not undertaken already) and remediation are likely to be required.
High	Harm is likely to arise to a designated receptor from an identified hazard. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not undertaken already) is required and remedial works may be necessary in the short term and are likely over the longer term.
Moderate	It is possible that harm could arise to a designated receptor from an identified hazard. However, there is a low likelihood that such harm would be severe, or if any harm were to occur it is more likely that the harm would be mild. Investigation (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the longer term.
Moderate/Low	It is possible that harm could arise to a receptor. However, a combination of likelihood and consequence results in a risk that is above low but is not of sufficient concern to be classified as moderate. It can be driven by cases where there is an acute risk which carries a severe consequence, but where the exposure is unlikely. Such harm would at worst normally be mild. The risk is unlikely to present a substantial liability. Some limited further investigation may be required to clarify the risk and any associated liability. If subsequent remediation works are necessary, they are likely to be limited in extent.
Low	It is possible that harm could arise to a designated receptor from an identified hazard, but it is likely that this harm, if realised, would at worst normally be mild.
Negligible	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is unlikely to be any worse than mild. No liability would be associated with such risks.
No Potential Risk	There is no potential risk or liability where no pollutant linkage has been established.

4.5 Contaminant [C] - Pathway [P] - Receptor [R] Considerations

The following CPR assessment has been undertaken based on the assumption that the site will be developed for a residential end-use, including private gardens.

4.6 Consideration of Potential Sources of Contamination [C]

Based on the findings of our desk study works, the potential key sources of contamination at the site that would require consideration for the derivation of a preliminary CSM would be the following:

TABLE 6 – SUMMARY OF POTENTIAL CONTAMINANT SOURCES	
Areas of Potential Concern (APCs)	Associated Contaminants
Near Surface Soils (including potential localised Made Ground)	- Metals & Metalloids. - PAHs. - TPHs. - Pesticides & herbicides. - Asbestos. - Ground gases (including methane & carbon dioxide).
On-Site and Off-Site Features (including infilled ponds, open drain, excavations & landfill)	Ground gases (including methane & carbon dioxide).

4.7 Consideration of Potential Pathways [P]

The potential pathways at the site are primarily:

- Direct ingestion of soil (either directly or as soil particles attached to produce).
- Inhalation of fugitive dust and vapours.
- Direct skin contact with the ground.
- Direct ingestion of home-grown produce.
- Direct ground contact with construction materials (including supply pipes).
- Vertical and lateral migration of contamination.
- Vertical and lateral migration of potentially hazardous ground gases / vapours.

4.8 Consideration of Potential Receptors [R]

The potential receptors at the site are:

- The final end users (residents – typically long term (chronic) exposure) and site visitors – (typically short term (acute) exposure).
- The construction personnel (i.e. site workers) involved with the development of the site (typically short term (acute) exposure).
- Neighbouring properties (off-site receptors).
- Controlled Waters (i.e. underlying groundwater and nearby surface waters).
- Buildings and construction materials (including buried utilities).

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 conform to health and safety requirements of their site-specific Risk Assessments and Method Statements (RAMS). Site workers have therefore not been included within the following table, as the adoption of these appropriate mitigation measures will result in an overall low risk of exposure to the C-P-R linkages identified.

4.9 Preliminary Risk Assessment / Conceptual Site Model

Our preliminary conceptual model of possible pollutant linkages, applicable to the proposed site usage and based on our current understanding, is summarised in Table 7.

TABLE 7 – PRELIMINARY RISK ASSESSMENT SUMMARY TABLE DESK STUDY						
Potential Contaminant Source [C]	Potential Pathway(s) [P]	Potential Receptor [R]	Probability of CPR Linkage	Consequence of CPR Linkage	Risk Level	Comments / Justification
Near Surface Soils (including potential localised Made Ground)	Direct contact, ingestion or inhalation of fugitive dust and vapours	End users	Likely	Medium	Moderate	No Made Ground is indicated to be present on the site. Potential localised Made Ground may be present in and around the area of the disused agricultural buildings, former glasshouses, infilled ponds and infilled former open drain. No potentially significant historical contaminative land uses have been identified at the site. End users are likely to come into contact with the in-situ soils within garden areas. Further consideration of this potential linkage should be provided during the course of the Phase II Exploratory Investigation works.
	Plant uptake	End users	Likely	Medium	Moderate	No Made Ground is indicated to be present on the site. Potential localised Made Ground may be present in and around the area of the disused agricultural buildings, former glasshouses, infilled ponds and infilled former open drain. No potentially significant historical contaminative land uses have been identified at the site. Growing vegetables for private consumption may be anticipated at the site. Further consideration of this potential linkage should be provided during the course of the Phase II Exploratory Investigation works.
	Vertical and lateral migration	Neighbouring properties	Low Likelihood	Medium	Moderate/Low	No Made Ground is indicated to be present on the site. Potential localised Made Ground may be present in and around the area of the disused agricultural buildings, former glasshouses, infilled ponds and infilled former open drain. No potentially significant historical contaminative land uses have been identified at the site. Localised sources of potentially mobile contamination (e.g. hydrocarbons) have been identified, including the disused above ground heating oil tank and the former tank adjacent to one of the former glasshouses. Further consideration of this potential linkage should be provided during the course of the Phase II Exploratory Investigation works.

**TABLE 7 – PRELIMINARY RISK ASSESSMENT SUMMARY TABLE
DESK STUDY**

Potential Contaminant Source [C]	Potential Pathway(s) [P]	Potential Receptor [R]	Probability of CPR Linkage	Consequence of CPR Linkage	Risk Level	Comments / Justification
Near Surface Soils (including potential localised Made Ground)	Leaching of contaminants through unsaturated zone and / or vertical and lateral migration	Controlled Waters	Low Likelihood	Medium	Moderate/Low	No Made Ground is indicated to be present on the site. Potential localised Made Ground may be present in and around the area of the disused agricultural buildings, former glasshouses, infilled ponds and infilled former open drain. No potentially significant historical contaminative land uses have been identified at the site. Localised sources of potentially mobile contamination (e.g. hydrocarbons) have been identified, including the disused above ground heating oil tank and the former tank adjacent to one of the former glasshouses. The superficial deposits and bedrock underlying the site are classified as Unproductive Strata. The site does not lie within a Source Protection Zone. Drains are present within the site and in close proximity to the site. Further consideration of this potential linkage should be provided during the course of the Phase II Exploratory Investigation works.
	Direct contact or contact with vapours	Plastic buildings products (e.g. water supply pipes) and buried concrete	Low Likelihood	Medium	Moderate/Low	No Made Ground is indicated to be present on the site. Potential localised Made Ground may be present in and around the area of the disused agricultural buildings, former glasshouses, infilled ponds and infilled former open drain. No potentially significant historical contaminative land uses have been identified at the site. Localised sources of potentially mobile contamination (e.g. hydrocarbons) have been identified, including the disused above ground heating oil tank and the former tank adjacent to one of the former glasshouses. Made Ground may locally contain elevated levels of contaminants that may affect plastic building products. Further consideration of this potential linkage should be provided during the course of the Phase II Exploratory Investigation works.

**TABLE 7 – PRELIMINARY RISK ASSESSMENT SUMMARY TABLE
DESK STUDY**

Potential Contaminant Source [C]	Potential Pathway(s) [P]	Potential Receptor [R]	Probability of CPR Linkage	Consequence of CPR Linkage	Risk Level	Comments / Justification
On-Site and Off-Site Features (including ponds, open drain, excavations & landfill)	Vertical and lateral migration of ground gases to indoor air	End users of new buildings (asphyxiation) or new buildings (damage via explosion)	Low Likelihood	Severe	Moderate	Potential sources of hazardous ground gas have been identified at the site, including infilled former ponds and the infilled former open drain. Localised potential off-site sources of hazardous ground gas have also been identified, including infilled former ponds, excavations and a former landfill site. No radon precautions are required at the site. Further consideration of this potential linkage (including a programme of ground gas monitoring) should be provided during the course of the Phase II Exploratory Investigation works.

The foregoing preliminary conceptual model highlights the potential plausible pollutant linkages that may relate to the site and would therefore require addressing by appropriate Phase II Exploratory Works. The information contained within the conceptual model should be confirmed and revised upon completion of an appropriate intrusive investigation, as detailed in the following sections.

5.0 GROUND INVESTIGATION

5.1 Introduction

Sub-Surface Utility Avoidance Scan

Prior to the commencement of our intrusive works at the site, a sub-contracted sub-surface utility scan of proposed exploratory hole locations was undertaken to attempt to avoid buried services. Based on the results of the service scan, the exploratory holes were positioned in order to maximise the amount of information obtained during our site works, whilst avoiding known utilities.

Trial Pits

A total of twenty-six trial pits (TP1 to TP26) were excavated at the site on 19th and 20th April 2022. The trial pits were excavated to depths of between 2.50m and 3.80m below existing ground level (begl).

Window Sample Boreholes

Thirteen window sample boreholes (WS1 to WS13) were advanced at the site on 21st and 27th April 2022. The boreholes were advanced to depths of either 3.00m or 4.00m begl. Upon completion, three of the boreholes (WS9, WS11 and WS13) were installed with ground gas and water monitoring points to facilitate a programme of monitoring.

Exploratory Hole Locations / Logs

The approximate locations of the exploratory holes are shown on the plan presented in Appendix VIII (Figure No. D42030A/05). The exploratory hole logs are presented in Appendix IX of this report.

5.2 Ground Conditions

Made Ground

Made Ground was only encountered within the seven window sampling boreholes which were advanced within, and immediately around, the disused former agricultural buildings and offices in the central northern area of the site. It should be noted that no Made Ground was encountered in the trial pit targeted to the location of the on-site infilled former pond (TP5) or the trial pits targeted to the location of the infilled former open drain (TP16 and TP26).

Four of the seven boreholes were advanced through concrete surfacing, which was proven to be between 0.12m and 0.23m in thickness. The concrete was typically underlain by a gravel sub-base with brick and concrete fragments, to depths of between 0.25m and 0.50m begl.

The surface materials within the other three boreholes comprised loose stone surfacing (to a depth of 0.05m begl) or topsoil (to depths of 0.20m or 0.45m begl).

Beneath the surface materials, the Made Ground generally comprised loose to medium dense very silty sand with localised soft sandy clay, to depths of between 0.60m and 1.40m begl.

A plan showing the depth to the base of the Made Ground (where encountered) at each of the exploratory holes is presented in Appendix X of this report (Figure No. D42030A/06).

Topsoil

TOPSOIL was encountered at surface within the majority of the exploratory holes, to depths of between 0.30m and 0.70m begl, with an average thickness of 0.40m begl. It should be noted that the topsoil had been disturbed due to previous ploughing activities within the agricultural fields.

Natural Strata

The near surface Natural Strata generally comprised loose to medium dense very silty SAND. The Sand was noted to become loose, damp and locally wet with depth.

In the western portion of the site (i.e. to the west of the north to south trending open / partially culverted drain), the Sand was proven to the full depth of the exploratory holes. In the majority of the eastern portion of the site (i.e. to the east of the north to south trending open / partially culverted drain), the Sand was proven to depths of variable between 0.80m and 1.90m begl.

In the eastern portion of the site, the Sand was underlain by soft, soft to firm and firm sandy clayey SILT / silty sandy CLAY. These Silt / Clay soils become soft and very soft to soft with depth and locally graded into damp slightly peaty CLAY.

The near surface Sand was absent from the two exploratory holes advanced in the south-eastern corner of the site (TP21 and WS10). Within these two exploratory holes, firm sandy clayey SILT / silty sandy CLAY (which became very soft to soft with depth) was encountered directly beneath the topsoil.

The Natural Strata encountered are considered to be typical of the Tidal Flat Deposits, which are indicated to underlie the site on the reviewed geological mapping.

5.3 Visual & Olfactory Evidence of Soil Contamination

We would note that no obvious visual or olfactory evidence of significant soil contamination was identified during the course of the site works (such as hydrocarbons or asbestos fragments for example).

This included within the exploratory holes targeted to the potential sources of contamination as detailed in Section 3.7.1 (i.e. the disused above ground heating oil tank, the former tank located adjacent to one of the former glasshouses, the disused agricultural buildings, the former office car park area, the on-site infilled former pond and on-site infilled former open drain), as shown on Figure No. D42030A/05 in Appendix VIII.

5.4 Water

The soils within the exploratory holes advanced across the entire site were noted to become gradually damp with depth. However, water seepages (i.e. wet soils) were only locally encountered within the western portion of the site (i.e. to the west of the north to south trending open / partially culverted drain), generally from depths in excess of approximately 2m begl.

5.5 Stability

The sides of the trial pits advanced in the western portion of the site (i.e. to the west of the north to south trending open / partially culverted drain), were initially generally stable during excavation. However, the sides of the pits became unstable and began to slump / collapse when excavating generally in excess of 2m begl.

The sides of the trial pits advanced in the eastern portion of the site (i.e. to the east of the north to south trending open / partially culverted drain) remained stable throughout their excavation and for the short time the excavations remained open after completion.

The sides of the boreholes remained stable during their advancement.

5.6 Plates

A photographic record of the exploratory investigation was obtained during the intrusive works. Selected photographs are presented in the Plates included in Appendix XI of this report (Plate Nos. 1 to 29).

5.7 Shear Vane Values

Shear vane testing was undertaken on the visually cohesive soils encountered within the eastern portion of the site (i.e. to the east of the north to south trending open / partially culverted drain), at depths of between 1.00m and 3.00m begl. The majority of the recordings were taken ex-situ for health the safety reasons and given the presence of overlying visually granular soils.

A Chart showing the shear vane values in relation to depth recorded in the exploratory holes is provided below for information. The results generally confirm a reduction in soil shear strength with increased depth. Individual shear vane results are provided on the exploratory hole logs included in Appendix IX of this report.

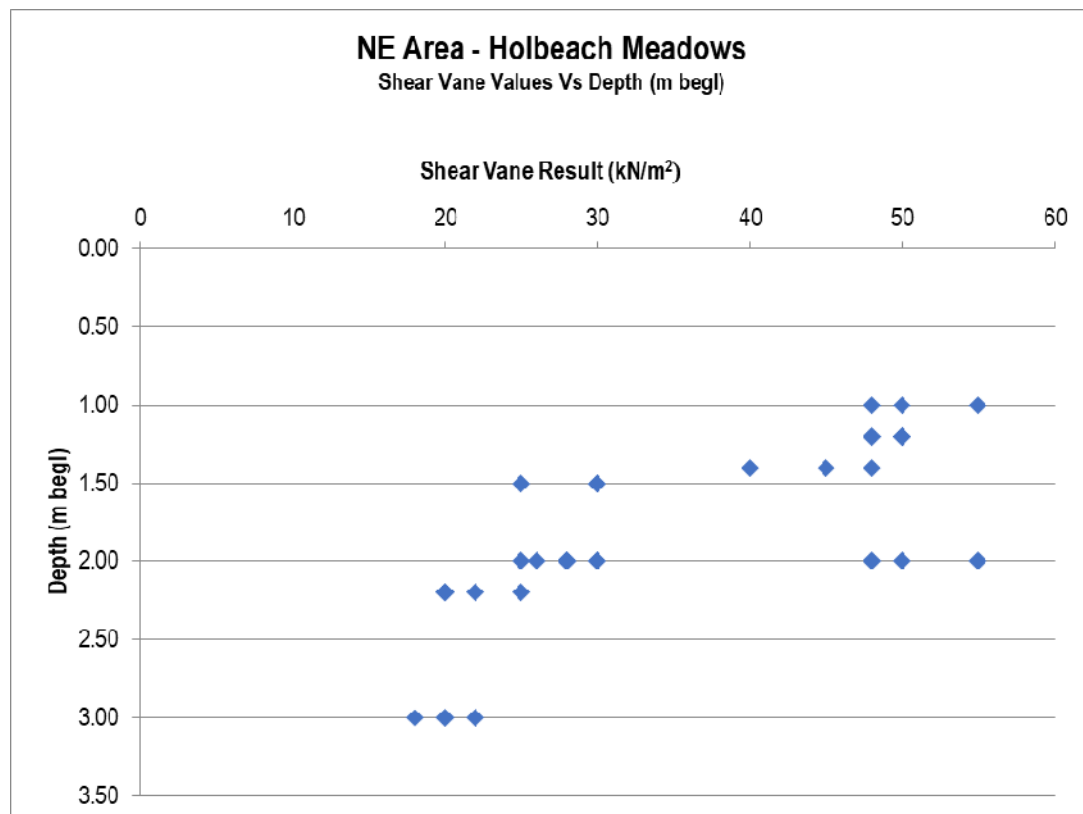


Table 8 shows a summary on the shear vane values between specific depth ranges.

TABLE 8 – SUMMARY OF SHEAR VANE RESULTS				
Depth (m begl)	Number of SV Readings	Minimum SV Reading (kN/m ²)	Maximum SV Reading (kN/m ²)	Average SV Reading (kN/m ²)
1.00 - 1.50	12	25	55	43
2.00 – 3.00	17	18	55	29

5.8 Standard Penetration Test (SPT) Data

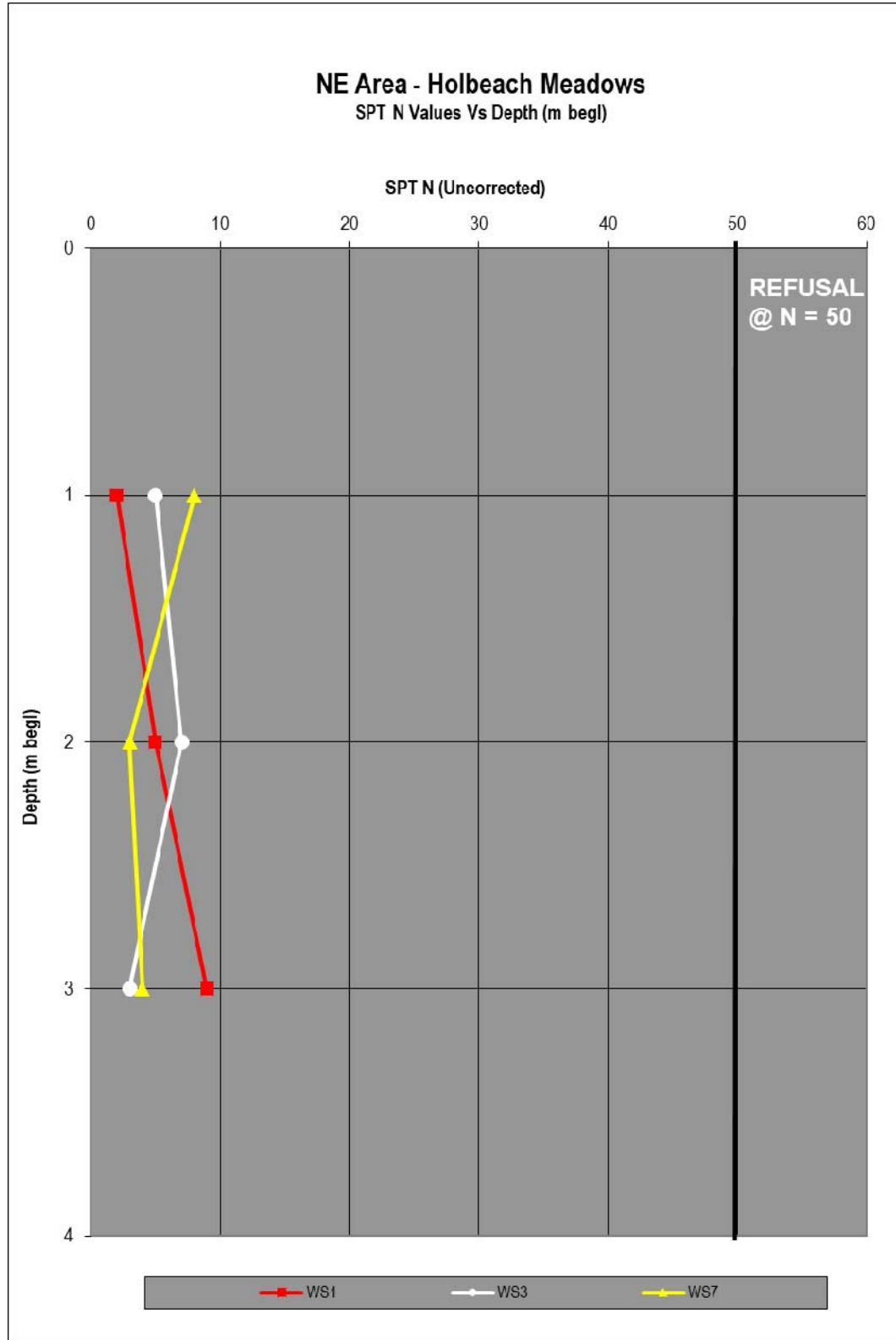
In order to establish a strength / depth profile of the strata beneath the site, SPT testing was undertaken at regular intervals within selected window sample boreholes.

The uncorrected SPT 'N' values within the Natural Strata at a depth of 1.00m begl ranged between 5 and 8.

The uncorrected SPT 'N' values within the Natural Strata at a depth of 2.00m begl ranged between 3 and 7.

The uncorrected SPT 'N' values within the Natural Strata at a depth of 3.00m begl ranged between 3 and 9.

A Chart showing the SPT results in relation to depth is provided on the next page, with the SPT results provided on the logs included in Appendix IX.



6.0 LABORATORY TESTING & CONTAMINATION ASSESSMENT

6.1 Introduction

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

- 9 No. Plasticity Index tests.
- 6 No. Particle Size Distribution tests.
- 9 No. Water soluble sulphate tests.
- 16 No. pH tests.
- 4 No. Remoulded CBR Tests.

In addition, environmental soil testing was carried out on visually representative samples recovered from the exploratory holes. The testing strategy was based on the land use assessment and preliminary CSM derived by the desk study works, and was considered sufficient to enable an assessment of the chemical status of the soils. The following testing has been undertaken as part of our works:

- 16 No. Contamination suites (including metals, speciated Polycyclic Aromatic Hydrocarbons and Total Organic Carbon).
- 9 No. Combined pesticide screens - Organochlorine & Organophosphate (OCP & OPP).
- 6 No. Total Petroleum Hydrocarbons (TPH) by Criteria Working Group (CWG) tests.
- 6 No. Asbestos screens.

All laboratory soil test results are included in Appendix XII.

6.2 Geotechnical Soil Test Results

Water Soluble Sulphate / pH

Water soluble sulphate testing was undertaken on 3No. samples of the Made Ground and 6No. samples of the Natural Strata obtained during the site works. The testing revealed water soluble sulphate concentrations of between <10mg/l and 130mg/l SO₄. The pH values of the samples of soils analysed (excluding topsoil) ranged between 7.02 and 8.68.

In accordance with the Building Research Establishment publication Special Digest 1 '*Concrete in Aggressive Ground*' (2005) the mean of the highest two sulphate concentrations should be used to indicate the Design Sulphate Class (i.e. 130mg/l SO₄), together with the mean of the lowest 20% of pH values (7.2).

Therefore, in accordance with Special Digest 1:2005 the site falls into Design Sulfate Class DS-1 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1. This classification has been made based on the assumption of a natural ground location with potentially mobile groundwater conditions beneath the site. It should be noted that the same classification applies if a brownfield location is assumed.

Plasticity Index Tests

A total of 9No. Plasticity Index tests have been undertaken on selected samples of the near surface Natural Strata obtained during the site works. 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 results of the PI analysis are summarised in Table 9.

TABLE 9 – SUMMARY OF PLASTICITY INDEX (PI) DATA				
Sample Ref.	Reported PI Value (%)	Portion <425µm (%)	Modified PI Value (%)	Volume Change Potential
TP2, 0.70 - 0.80m (SAND)	NA	NA	NA	Non-Plastic
TP4, 3.0 - 3.2m (SAND)	NA	NA	NA	Non-Plastic
TP6, 0.90 - 1.0m (SAND)	NA	NA	NA	Non-Plastic
TP11, 1.30 - 1.50m (SAND)	NA	NA	NA	Non-Plastic
TP13, 1.50 - 1.70m (SILT / CLAY)	18	93	17	Low
TP14, 0.70m (SAND)	NA	NA	NA	Non-Plastic
TP17, 0.60m, (SAND)	9	81	7	Non-Shrinkable
TP18, 1.50m (SILT / CLAY)	24	91	22	Medium
TP19, 3.30m (CLAY)	29	96	28	Medium

Table 8 reveals that the near surface Sand, which was encountered across the vast majority of the entire site area, has been proven to be Non-Plastic and / or Non-Shrinkable. This confirms the visual granular description of this soil type.

Table 8 also confirms that the Silt / Clay and Clay soils (encountered in the eastern portion of the site beneath the granular soils) may be regarded as being of low to medium volume change potential. Soils of a medium volume change potential should be assumed for design purposes where these soils are encountered.

Particle Size Distribution Tests

Particle Size Distribution (PSD) tests were undertaken on selected samples of the near surface Sand. The results revealed the granular (Sand) content of this soil type to be between 37% and 75% with a fine particles (Silt / Clay) content of between 25% and 63%. This confirms the visual granular description of this soil type.

It should be noted that two of the samples subjected to PSD testing (which recorded a fine particles content of 60% and 63%) were also subjected to PI testing. The PI testing revealed the two samples to be Non-Plastic.

A PSD test was also undertaken on a sample of the Silt / Clay (encountered in the eastern portion of the site beneath the granular soils), which revealed a fine particles content of 91%, which confirmed the cohesive description of this soil type and the results of the PI testing.

Remoulded Soaked California Bearing Ratio (CBR) Testing

Remoulded soaked California Bearing Ratio testing was undertaken on 4 No. samples of shallow Natural Strata across the site. The results of the remoulded CBR results are summarised in Table 10. CBR values for the top and bottom of the remoulded soaked sample are recorded.

TABLE 10 – SUMMARY OF LABORATORY CBR TEST RESULTS

Sample Ref.	Depth (m begl)	Initial Moisture Content (%)	CBR Value Sample Top (%)	CBR Value Sample Bottom (%)
TP1 (SAND)	0.50 – 0.90	28	0.3	0.4
TP8 (SAND)	0.50 – 0.90	26	0.3	0.4
TP16 (SAND)	0.70 – 1.10	31	0.2	0.3
TP25 (SAND)	0.40 – 0.80	28	0.3	0.4

6.3 Contamination Assessment Rationale

We understand that it is proposed to develop the site for a low-rise residential end-use incorporating private gardens, although the final site layout has yet to be confirmed. Based on these development proposals, we have adopted a residential with plant uptake end-use scenario for the purposes of the contamination assessment.

6.3.1 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 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.

6.3.2 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.

6.4 Sampling Strategy

The sampling strategy for the site was primarily to retrieve visually representative soil samples from a selection of locations that provide an initial coverage across the entire site area (where access allowed). The sampling strategy was based on a review of the historical, geological and environmental information obtained from the Desk Study enquiries and the current and proposed site setting together with the ground conditions encountered during our Phase II exploratory works.

Specific areas of concern were targeted during the investigation as highlighted in Sections 3.7.1 and 3.7.2. These included: the former glasshouses, the disused above ground heating oil tank, the former tank located adjacent to one of the former glasshouses, the disused agricultural buildings, the former office car park area, on and off-site infilled former ponds, the on-site infilled former open drain, off-site excavations and off-site landfill.

Exploratory holes were therefore advanced to target these specific features (using GPS co-ordinates, where appropriate) and also to provide general site coverage, taking account the presence of known buried services.

Table 11 summarises the reasoning behind the exploratory hole positions.

TABLE 11 – REASONING FOR EXPLORATORY HOLE LOCATION	
Exploratory Hole Reference	Reasoning Behind Location
TP1 – TP26 & WS9 – WS13	Targeted to the agricultural fields & general site coverage avoiding known utilities.
WS1 – WS7 & WS12	Targeted in and around the former agricultural buildings.
WS8	Targeted to the vacant semi-detached residential properties.
WS1	Targeted to the chimney within one of the former agricultural buildings.
WS5	Targeted to the former office car park.
WS6	Targeted to the disused above ground heating oil tank.
TP1	Targeted to the former tank located adjacent to one of the former glasshouses.
TP1, TP12, WS12, WS1 & WS5 - WS7	Targeted to the area of the two former glasshouses.
TP7, TP8 & WS11	Targeted to the area of the reported historic pollution incident.
TP5	Targeted to the on-site infilled former pond.
TP16 & TP26	Targeted to the route of the on-site infilled former open drain.
WS9	Targeted closest to the off-site former Brick Works excavations & former landfill (ground gas / water monitoring well installed)
WS11	General site coverage for the purposes of installing a ground gas / water monitoring well
WS13	Targeted closest to the off-site infilled former ponds (ground gas / water monitoring well installed)
Key TP – Trial Pit WS – Window Sampling Borehole	

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

Representative samples of the soil types were obtained during our Phase II works, and subjected to chemical analysis for a suite of contaminants deemed appropriate based on the findings of the Desk Study enquiries. It is noted that the suite of contaminants detailed in Section 3.7.1 and Table 6 were considered to remain applicable as an initial chemical screen of the encountered soils following completion of the site investigation works.

6.5 Contamination Analysis

A total of 16No. standard chemical contamination tests (including metals, speciated PAHs and TOC) were carried out on selected samples of the Made Ground (5No.), topsoil (4No.) and the underlying Natural Strata (7No.), obtained during the site works.

In addition, pesticide analysis was undertaken on samples of the Made Ground (2No), topsoil (5No.) and the underlying Natural Strata (2No.). Asbestos screening was undertaken on samples of the Made Ground (6No.). Speciated TPH analysis was undertaken on samples of the Made Ground (4No.) and the underlying Natural Strata (2No.).

For initial assessment purposes, we have collated the results into three datasets, for individual comparison of the reported determinand concentrations against appropriate Tier 1 GACs, namely the Made Ground, the topsoil and the underlying undisturbed Natural Strata.

6.6 Contamination Soil Test Results

6.6.1 Made Ground

The contamination assessment for the Made Ground analysed at the site is summarised in Table 12.

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

TABLE 12 – SUMMARY OF TIER 1 GAC ASSESSMENT (MADE GROUND – 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)
Metals				
Arsenic	5	4 – 8	37 S4UL	No
Cadmium	5	0.6 – 1.1	11 S4UL	No
Chromium III	5	19 – 24	910 S4UL	No
Copper	5	13 – 26	2400 S4UL	No
Lead	5	16 – 33	200 C4SL	No
Nickel	5	13 – 18	130 S4UL	No
Zinc	5	45 – 64	3700 S4UL	No
PAH				
Benzo(a)pyrene	5	<0.1 – 0.1	2.2 S4UL	No
Benzo(b)fluoranthene	5	<0.1 – 0.1	2.6 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. C4SL – value for Lead taken from DEFRA publication SP1010 and based on a residential (with home-grown produce) end-use.				

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

In addition to the foregoing contamination assessment, 6No. samples of the Made Ground were subject to asbestos screening and 4No. samples of the Made Ground were subjected to speciated TPH testing. No asbestos (loose fibres or bulk fragments) was detected in any of the samples analysed. The speciated TPH testing revealed all aliphatic and aromatic carbon fractions plus BTEX and MTBE to be below the Limit of Detection of the method of analysis adopted by the laboratory.

6.6.2 Topsoil

The contamination assessment for the topsoil analysed at the site is summarised in Table 13.

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

TABLE 13 – SUMMARY OF TIER 1 GAC ASSESSMENT (TOPSOIL – 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)
Metals				
Arsenic	4	11 – 16	37 S4UL	No
Cadmium	4	0.8 – 1.5	11 S4UL	No
Chromium III	4	16 – 34	910 S4UL	No
Copper	4	14 – 23	2400 S4UL	No
Lead	4	21 – 53	200 C4SL	No
Mercury	4	<0.17 – 0.19	40 S4UL	No
Nickel	4	12 – 21	130 S4UL	No
Zinc	4	46 – 72	3700 S4UL	No
PAH				
Benzo(a)anthracene	4	<0.1 – 0.4	7.2 S4UL	No
Benzo(a)pyrene	4	<0.1 – 0.5	2.2 S4UL	No
Benzo(b)fluoranthene	4	<0.1 – 0.5	2.6 S4UL	No
Benzo(ghi)perylene	4	<0.1 – 0.2	320 S4UL	No
Benzo(k)fluoranthene	4	<0.1 – 0.2	77 S4UL	No
Chrysene	4	<0.1 – 0.4	15 S4UL	No
Fluoranthene	4	<0.1 – 0.8	280 S4UL	No
Indeno(123-cd)pyrene	4	<0.1 – 0.4	27 S4UL	No
Phenanthrene	4	<0.1 – 0.4	95 S4UL	No
Pyrene	4	<0.1 – 0.7	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. C4SL – value for Lead taken from DEFRA publication SP1010 and based on a residential (with home-grown produce) end-use.				

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

6.6.3 Natural Strata

The contamination assessment for the Natural Strata analysed at the site is summarised in Table 14.

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

**TABLE 14 – SUMMARY OF TIER 1 GAC ASSESSMENT
(NATURAL STRATA – 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)
Metals				
Arsenic	7	3 – 6	37 S4UL	No
Cadmium	7	<0.5 – 0.9	11 S4UL	No
Chromium III	7	11 – 20	910 S4UL	No
Copper	7	3 – 9	2400 S4UL	No
Selenium	7	<1 – 4	250 S4UL	No
Lead	7	5 – 24	200 C4SL	No
Mercury	7	<0.17 – 0.62	40 S4UL	No
Nickel	7	8 – 14	130 S4UL	No
Zinc	7	20 – 54	3700 S4UL	No
Key S4UL – CIEH/LQM Sutable 4 Use Levels (2015). Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3026. All rights reserved. C4SL – value for Lead taken from DEFRA publication SP1010 and based on a residential (with home-grown produce) end-use.				

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

In addition to the foregoing contamination assessment, 2No. samples of the Natural Strata were subjected to speciated TPH testing. The speciated TPH testing revealed all aliphatic and aromatic fractions plus BTEX and MTBE to be below the Limit of Detection of the method of analysis adopted by the laboratory.

6.7 Pesticides

Pesticide analysis was undertaken on samples of the Made Ground (2No), topsoil (5No.) and the underlying Natural Strata (2No.).

The results typically revealed individual concentrations below the Limit of Detection of the method of analysis adopted by the laboratory (i.e. <0.01mg/kg, <0.10mg/kg or <0.50mg/kg depending upon the determinand), with the exception of the following:

- Pendimethalin within the topsoil at concentrations of 0.20mg/kg (TP1, 0.20m), 0.10mg/kg (TP10, 0.30m), 0.08mg/kg (TP14, 0.20m) and 0.07mg/kg (TP18, 0.20m).

We would note that there are presently no publicly available generic screening criteria for soils for Pendimethalin specific to the UK setting. We have therefore reviewed other sources of screening criteria for comparison purposes.

USEPA (United States Environmental Protection Agency) have co-operated to prepare Screening Levels (SLs) '*Regional Screening Level (RSL) Resident Soil Table May 2022*' for use within Superfund sites (i.e. contaminated land). USEPA have provided a screening level of 19000mg/kg for pendimethalin.

The contamination assessment for the soils analysed for pesticides at the site is summarised in Table 15.

TABLE 15 – SUMMARY OF TIER 1 GENERIC ACCEPTANCE CRITERIA DATA ASSESSMENT FOR PESTICIDES (RESIDENTIAL 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)
Pendimethalin	9	<0.01 – 0.20	19,000 USEPA	No
<u>Key</u> USEPA – November 2020 values; taken from Regional Screening Table for a residential soil.				

The concentrations of Pendimethalin are below the screening criteria reviewed. On this basis, the detected concentrations of the pesticide identified within the topsoil are considered not to represent a risk driver with respect to contamination at the site.

6.8 Contamination Assessment Summary

Human Health

Contamination testing was carried out on selected samples of the Made Ground, topsoil and underlying Natural Strata.

On the basis of the chemical contamination assessment undertaken, the soils may be considered to be uncontaminated for the proposed residential with plant uptake end-use.

Controlled Waters

There are considered to be no significant risks posed to Controlled Waters by the findings of the laboratory analysis undertaken.

7.0 GROUND GAS & WATER LEVEL MONITORING RESULTS

7.1 Introduction

Based on the potential presence of on and off-site sources of potentially harmful ground gas, monitoring points were installed in selected window sample boreholes to facilitate an initial programme of monitoring (i.e. for methane and carbon dioxide).

7.2 Monitoring Installations

Upon completion, WS9, WS11 and WS13 were installed with combined ground gas and water monitoring standpipes to a depth of 4.00m bgl, to facilitate an initial programme of monitoring. Installations were positioned to provide general site coverage and to target the off-site features (as detailed in Table 11). During the investigation works, no significant organic soils (such as peat deposits) were encountered within the exploratory holes advanced at the site and no evidence of the on-site infilled former pond and open drain were encountered during the exploratory works, as targeted by TP5 (pond) and TP16 & TP26 (drain).

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

7.3 Results of the Ground Gas Monitoring

A total of seven ground gas and water monitoring visits have been undertaken at the site over an eight-week period. The ground gas monitoring results are summarised in Table 16.

TABLE 16 – SUMMARY OF GROUND GAS MONITORING DATA		
Parameter	Minimum	Maximum
Methane (v/v)	0.0	0.5
Carbon Dioxide (v/v)	0.0	4.4
Oxygen (v/v)	16.1	21.1
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		

A maximum carbon dioxide concentration of 4.4% by volume was recorded during the monitoring programme. A maximum methane concentration of 0.5% by volume was recorded during the monitoring programme.

No discernible flow rates (positive or negative) in excess of +/-0.1 litres per hour were recorded during the monitoring programme.

Periods of falling atmospheric pressure are considered to be the optimum barometric conditions for gas emissions from the ground. Two of the gas monitoring visits were carried out falling a period of falling atmospheric pressure.

The atmospheric pressure trends over the 24hrs prior to monitoring are summarised below:

- 3rd May 2022 – Steady
- 12th May 2022 – Rise of 11mb
- 19th May 2022 – Fall of 3mb
- 24th May 2022 – Steady
- 1st June 2022 – Rise of 5mb
- 10th June 2022 – Rise of 4mb
- 21st June 2022 – Fall of 5mb

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 on any of the monitoring visits.

The highest recorded carbon dioxide concentrations were encountered in borehole WS11, with concentrations of between 3.8% by volume (steady atmospheric pressure) and 4.4% by volume (rising and falling atmospheric pressure) being recorded. The highest concentrations of methane were recorded when the atmospheric pressure was steady.

Water was recorded at depths of between 1.23m and 2.83m begl during the monitoring programme. No water was recorded in the well installed in borehole WS13 during the last four monitoring visits. Based on the general absence of water seepages during the advancement of the exploratory holes, it is considered likely that the water recorded within the installations during the monitoring visits represents both water that has seeped into the wells following periods of rainfall, as well as water which has seeped into the wells from the Tidal Flat Deposits at depth over a period of time.

7.4 Appropriate Guidance

7.4.1 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).

7.4.2 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:

- $GSV (l/h) = \text{maximum borehole flow rate (l/h)} \times (\text{maximum gas concentration}/100).$

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*'.

7.4.3 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].

7.4.4 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 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 below.

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.

7.4.5 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)}	$\boxed{A_1} \ 6 \ \langle A_1 \rangle$ ^{A)}	5.5	4.5
6	— ^{B)}	— ^{B)}	$\boxed{A_1} \text{ — } \langle A_1 \rangle$ ^{B)}	$\boxed{A_1} \ 6 \ \langle A_1 \rangle$

^{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.

7.4.6 Methods of Achieving Gas Protection Scores

The appropriate level of precautions, to be designed in accordance with the point scoring system of BS 8485:2019, 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 below.

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)}  ^{D)} 	2
Basement floor and walls conforming to BS 8102:2009, Grade 3 waterproofing ^{C)}  ^{D)} 	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  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). 

^{D)}  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. 

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 E. Passive ventilation should be designed to meet at least "good performance", see Annex E.
• 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 E.
(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 <i>Buildings Regulations 2000, Approved Document F [9]</i> .

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 $\langle A_1 \rangle$, 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; $\langle A_1 \rangle$ • sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions; • $\langle A_1 \rangle$ Text deleted $\langle A_1 \rangle$ • sufficiently strong $\langle A_1 \rangle$ ^{B)} $\langle A_1 \rangle$ 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); $\langle A_1 \rangle$ and to withstand in-service stresses (e.g. settlement if placed below a floor slab); $\langle A_1 \rangle$ • 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. $\langle A_1 \rangle$ Text deleted $\langle A_1 \rangle$ If a membrane is installed that does not meet all the criteria in column 1 then the score is zero.

^{A)} $\langle A_1 \rangle$ 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. $\langle A_1 \rangle$

7.5 Ground Gas Analysis

7.5.1 Gas Screening Value & Site Classification

The ground gas monitoring has identified a maximum methane concentration of 0.5% v/v and a maximum carbon dioxide concentration of 4.4% v/v. Measurable steady flow rates were not recorded during any of the monitoring visits. 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 GSV for methane at the site may be calculated as follows:

- $0.1 \times (0.5/100) = 0.0005 \text{ l/h}$

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

- $0.1 \times (4.4/100) = 0.0044 \text{ l/h}$

Therefore, with a maximum GSV of 0.0044 l/h, a maximum carbon dioxide concentration of 4.4% v/v, a maximum methane concentration of 0.5% v/v, and no measurable steady flow rate, this classifies the site as Characteristic Situation **CS1**, in accordance with Table 2 of BS 8485 (2015+A1:2019) and based on the visits undertaken.

7.5.2 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.

7.5.3 Gas Protection Score

On the basis of Characteristic Situation (CS1) and the development proposals with buildings 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 **0 points**.

7.5.4 Comments

The results of the gas monitoring carried out indicate that no ground gas precautions will be required for the site based on the gas protection score of zero in accordance with BS 8485:2015 (2015+A1:2019). It should be noted that this classification matches the classification given to the Client's ongoing first phase of development at Holbeach Meadows, which was subject to a ground investigation by others in 2016.

8.0 REVISED CONCEPTUAL SITE MODEL

8.1 Introduction

In accordance with the approach detailed within Section 4.0, the Conceptual Site Model (CSM) for the site should be refined following acquisition and collection of additional data following completion of the site investigation works.

Our revised assessment following the acquisition and collection of information from the site investigation works is provided in Table 17.

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 conform to health and safety requirements of their site-specific Risk Assessments and Method Statements (RAMS). Site workers have therefore not been included within the following table, as the adoption of these appropriate mitigation measures will result in an overall low risk of exposure to the C-P-R linkages identified.

TABLE 17 – REVISED RISK ASSESSMENT SUMMARY TABLE
PHASE II EXPLORATORY INVESTIGATION

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
Near Surface Soils (including localised Made Ground within, and immediately around, the disused former agricultural buildings and offices in the central northern area of the site).	Direct contact, ingestion or inhalation of fugitive dust	End users	Unlikely	Medium	Low	Phase II Exploratory Investigation works have revealed that the soils may be regarded as uncontaminated. This includes soils encountered within the exploratory holes targeted to the potential sources of contamination as detailed in Section 3.7.1 & Table 7.	Low – as per 'Risk Level' No remediation / mitigation measures required.
	Plant uptake / Soil Attached to Home Grown Produce	End users	Unlikely	Medium	Low	Phase II Exploratory Investigation works have revealed that the soils may be regarded as uncontaminated. This includes soils encountered within the exploratory holes targeted to the potential sources of contamination as detailed in Section 3.7.1 & Table 7.	Low – as per 'Risk Level' No remediation / mitigation measures required.
	Vertical and lateral migration	Neighbouring properties	Unlikely	Mild	Negligible	Phase II Exploratory Investigation works have revealed that the soils may be regarded as uncontaminated. There was no obvious visual or olfactory evidence of any significant contamination (i.e. hydrocarbon impacted soils, for example). This includes within the exploratory holes targeted to the sources of potential mobile hydrocarbon contamination (i.e. the disused above ground heating oil tank and the former tank located adjacent to one of the former glasshouses), as detailed in Section 3.7.1 & Table 7.	Negligible – as per 'Risk Level'. No remedial / mitigation measures required.

TABLE 17 – REVISED RISK ASSESSMENT SUMMARY TABLE
PHASE II EXPLORATORY INVESTIGATION

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
Near Surface Soils (including localised Made Ground within, and immediately around, the disused former agricultural buildings and offices in the central northern area of the site).	Leaching of Contaminants through unsaturated zone and/or vertical and lateral migration	Controlled Waters	Unlikely	Mild	Negligible	The soil test results are considered to be not sufficiently elevated to represent a significant risk to Controlled Waters. There was no obvious visual or olfactory evidence of any significant contamination (i.e. hydrocarbon impacted soils, for example). This includes within the exploratory holes targeted to the sources of potential mobile hydrocarbon contamination (i.e. the disused above ground heating oil tank and the former tank located adjacent to one of the former glasshouses), as detailed in Section 3.7.1 & Table 7.	Negligible – as per 'Risk Level'. No remedial / mitigation measures required.
	Direct contact or contact with vapours	Plastic buildings products (i.e. water supply pipes) and buried concrete	Unlikely	Mild	Negligible	Contamination testing has not revealed concentrations of contaminants which may pose a risk to buried services. Design Class DS-1/ACEC Class AC-1 (BRE Spec. Digest 1:2005).	Negligible – as per 'Risk Level'. No remedial / mitigation measures required.
Off-Site Features (including ponds, excavations & landfill)	Vertical and lateral migration of ground gases to indoor air	End users of new buildings (asphyxiation) or new buildings (damage via explosion)	Unlikely	Medium	Low	No evidence of the on-site infilled former pond and infilled former open drain were encountered during the exploratory works, as targeted by TP5, TP16 & TP26. No ground gas protection measures are recommended for the site based on the results of the programme of monitoring undertaken. No radon precautions are required at the site.	Low – as per 'Risk Level'. No remedial / mitigation measures required.

9.0 CONCLUSIONS & RECOMMENDATIONS

9.1 Site Summary

At the time of our site works (April 2022), the majority of the site comprised two cropped agricultural fields. The western extremity of the site (excluded from our intrusive investigation area) comprised a series of disused farm buildings to the south of an area of exposed soils/scrub.

The agricultural fields were separated by a north to south trending drain and disused agricultural buildings and offices. The drain was culverted beneath the western extremity of the eastern field. A spur to the drain was also culverted through the central area of the eastern field, trending in an approximate west to east direction.

Two vacant semi-detached residential properties with associated gardens were present to the north-west of the western agricultural field.

Based on the reviewed historical information, buildings associated with a farm have been present in the south-western corner of the site since at least the 1880s. Buildings first appeared in the central northern area of the site by the 1930s together with the semi-detached residential properties. By the 1960s, two large glasshouses were present in the central northern area of the site. The two glasshouses were removed during and post 1990s.

The site is indicated to be underlain by superficial drift comprising Tidal Flat Deposits. The underlying bedrock is indicated to comprise the West Walton Formation.

9.2 Geotechnical Information

9.2.1 Ground Conditions

Made Ground was only encountered within the window sampling boreholes advanced within, and immediately around, the disused former agricultural buildings and offices in the central northern area of the site. The Made Ground surfacing comprised concrete (underlain by a gravel sub-base with brick and concrete fragments), loose stone surfacing and topsoil.

Beneath the surface materials, the Made Ground generally comprised loose to medium dense very silty sand with localised soft sandy clay, to depths of between 0.60m and 1.40m begl.

A plan showing the depth to the base of the Made Ground (where encountered) at each of the exploratory holes is presented in Appendix X of this report (Figure No. D42030A/06).

TOPSOIL was encountered at surface within the majority of the exploratory holes, with an average thickness of 0.40m begl.

The near surface Natural Strata generally comprised loose to medium dense very silty SAND. The Sand was noted to become loose, damp and locally wet with depth.

In the western portion of the site (i.e. to the west of the north to south trending open / partially culverted drain), the Sand was proven to the full depth of the exploratory holes. In the majority of the eastern portion of the site (i.e. to the east of the north to south trending open / partially culverted drain), the Sand was proven to depths of variable between 0.80m and 1.90m begl.

In the eastern portion of the site, the Sand was underlain by soft, soft to firm and firm sandy clayey SILT / silty sandy CLAY. These Silt / Clay soils become soft and very soft to soft with depth and locally graded into damp slightly peaty CLAY.

The near surface Sand was absent from the south-eastern corner of the site where firm sandy clayey SILT / silty sandy CLAY (which became very soft to soft with depth) was encountered directly beneath the topsoil.

9.2.2 Foundation Design

Reference should be made to the Foundation Zoning Plan (Figure No. D42030A/07), which is presented in Appendix XIV of this report.

Zone 1

Foundations for the proposed dwellings within Zone 1 are likely to comprise Structural Engineer designed strip or raft foundations to suit the loading characteristics of the proposed structures. The natural near surface Sand soils underlying Zone 1 at shallow depth appear suitable to support a nett allowable ground bearing pressure of up to 75kN/m². This bearing pressure is considered appropriate due to the presence of underlying Tidal Flat Deposits, which have the potential to alter rapidly in character and geotechnical properties both laterally and vertically over relatively short distances.

Due to the variability of the Tidal Flat Deposits encountered at the site, we would recommend that an allowance is made for suitable mesh reinforcement to all foundations within Zone 1 to minimise the potential for localised differential settlement.

Foundations within Zone 1 should be advanced to a minimum depth of 0.60m below existing or proposed ground level (whichever being the deeper) and founded within undisturbed suitably competent natural soils. It is important to ensure that all foundation excavations are kept as shallow as possible to avoid potential decreases in soil strength with depth from affecting foundation integrity.

Should any localised Made Ground or soft spots be encountered at founding depth, rafts or potentially piles (rather than strips) are anticipated to comprise the more appropriate foundation solution.

The proposed site layout will need to take into account the route of the culverted drain, which is present in the eastern area of the site.

The use of a deeper founding solution (i.e. piles, for example) may need to be considered within Zone 1 if there is a need to raise site levels and / or where excessive loads from buildings are present and shallow foundations are not deemed appropriate, subject to advice from a Structural Engineer.

Zone 2

Foundations for the proposed dwellings within Zone 2 are likely to comprise Structural Engineer designed strip or raft foundations to suit the loading characteristics of the proposed structures. The natural near surface Clay / Silt soils underlying Zone 2 at shallow depth appear suitable to support a nett allowable ground bearing pressure of up to 75kN/m². This bearing pressure is considered appropriate due to the presence of underlying Tidal Flat Deposits, which have the potential to alter rapidly in character and geotechnical properties both laterally and vertically over relatively short distances.

Due to the variability of the Tidal Flat Deposits encountered at the site, we would recommend that an allowance is made for suitable mesh reinforcement to all foundations within Zone 2 to minimise the potential for localised differential settlement.

Foundations within Zone 2 should be designed assuming soils of medium volume change potential based on the results of the laboratory testing. Therefore, foundations should be advanced to a minimum depth of 0.90m below existing or proposed ground level (whichever being the deeper) and founded within undisturbed suitably competent natural soils. It is important to ensure that all foundation excavations are kept as shallow as possible to avoid potential decreases in soil strength with depth from affecting foundation integrity.

Should any localised Made Ground or soft spots be encountered at founding depth, rafts or potentially piles (rather than strips) are anticipated to comprise the more appropriate foundation solution.

Some foundations within Zone 2 may require locally deepening in accordance with NHBC Standards, due to the effects of trees (see Section 9.2.6). To avoid excessive deepening into the geotechnically less competent soils at depth, it is anticipated that arboreally affected foundations are likely to comprise rafts rather than strips, or potentially piles.

The use of a deeper founding solution (i.e. piles, for example) may need to be considered within Zone 2 if there is a need to raise site levels and / or where excessive loads from buildings are present and shallow foundations are not deemed appropriate, subject to advice from a Structural Engineer.

Zone 3

Made Ground was encountered within Zone 3 within, and immediately around, the disused former agricultural buildings and offices. The presence of Made Ground within this zone is likely to preclude the use of traditional shallow foundations in this part of the site.

It is anticipated that further potentially increased thicknesses of Made Ground may ultimately be present in this zone once the foundations associated with the existing buildings are exposed and grubbed out in due course.

Based on the findings of the exploratory holes, deepening of potential shallow foundations through Made Ground is considered more likely to encounter the less geotechnically competent soils at depth, which were observed during the exploratory works. Therefore, at this stage, it is recommended that piles are adopted for the proposed dwellings within Zone 3 (see comments below).

Comments Regarding Piles

The use of piles at the site (within any of the indicated zones) would be subject to advice from a specialist piling contractor to confirm the depths of the piles and the most feasible and cost efficient type of pile to be used at the site. It would be necessary to undertake further intrusive works at the site, involving cable percussive boreholes, to assess the deeper ground conditions to assist with a piled foundation solution for the proposed development.

A further consideration as an alternative to strips / rafts may be the use of ground improvement by vibro-stone columns. However, the soft / loose nature of the soils may preclude the use of this technique. Advice from a specialist contractor should be sought to confirm the feasibility of ground improvement at the site, if necessary.

9.2.3 Floor Slab Design

Where strip foundations are considered appropriate, ground bearing floor slabs may be adopted provided that there is less than 0.60m of suitably compacted geotechnically competent sub-slab fill beneath proposed slabs. Where in excess of 0.60m of sub-slab fill is present, a suspended slab may be adopted, which may be either cast in-situ or a pre-cast suspended floor with a clear ventilated void (i.e. beam and block).

9.2.4 Ground Gases

Based on the programme of ground gas monitoring undertaken, no ground gas precautions (in relation to methane and carbon dioxide) are considered to be necessary at the site.

9.2.5 Radon

No radon precautions are required at the site.

9.2.6 Building Near Trees

Foundation designs are unlikely to require adjusting for existing trees and / or hedgerows based on the predominant presence of granular / non-plastic soils at typical founding depths beneath the site and the absence of existing trees / hedgerows within likely influencing distance of foundations.

If proposed trees are to be planted within the eastern portion of the site (i.e. to the east of the north to south trending open / partially culverted drain), foundation designs should take into account the recommendations within NHBC Standards Chapter 4.2.9 '*Strip and trench fill foundations in non-shrinkable soils overlying shrinkable soil*'. Cohesive soils of medium volume change potential should be assumed for design purposes.

9.2.7 Water

The soils within the exploratory holes advanced across the entire site were noted to become gradually damp with depth. However, water seepages (i.e. wet soils) were only locally encountered within the western portion of the site (i.e. to the west of the north to south trending open / partially culverted drain), generally from depths in excess of approximately 2m begl.

On the basis of the water levels observed during the exploratory works, water is unlikely to be encountered within foundation excavations. Deeper excavations (i.e. for sewers) may encounter water seepages and dewatering of deeper excavations may be necessary.

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. 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.

9.2.8 Excavations / Stability

The sides of the trial pits advanced in the western portion of the site (i.e. to the west of the north to south trending open / partially culverted drain), were initially generally stable during excavation. However, the sides of the pits became unstable and began to slump / collapse when excavating generally in excess of 2m begl.

The sides of the trial pits advanced in the eastern portion of the site (i.e. to the east of the north to south trending open / partially culverted drain) remained stable throughout their excavation and for the short time the excavations remained open after completion.

On the basis of the exploratory works, excavations deeper than approximately 2m begl within the western portion of the site are likely to require trench support for health and safety reasons. The assessment of excavations and provision of support across the entire site will be the responsibility of the contractor on site.

The natural soils are likely to 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 and foundation construction.

9.2.9 Sulphate Classification

In accordance with BRE Special Digest 1 (2005), the site falls into Design Sulphate Class DS-1 and an Aggressive Chemical Environment for Concrete (ACEC) classification of AC-1. Therefore, an appropriate concrete mix should be adopted in accordance with BRE Special Digest 1 for all buried concrete in contact with the ground.

9.2.10 Coal Mining

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

9.2.11 California Bearing Ratios (CBRs)

The remoulded soaked CBR testing has revealed CBR values for the Natural Strata ranging between 0.2% and 0.4%. No frost susceptible material should be within 450mm of the ground surface in road construction.

9.2.12 Surface Water Drainage

The use of traditional soakaways is not recommended due to the anticipated relatively low permeability of the near surface Natural Strata across the site. Therefore, at this stage, it is recommended that alternative methods of surface water drainage should be investigated.

9.3 Environmental Considerations

9.3.1 Soil Contamination Assessment

Human Health

On the basis of the chemical contamination assessment undertaken, the soils may be considered to be uncontaminated for the proposed end-use (i.e. in relation to human health).

We would note that no obvious visual or olfactory evidence of significant soil contamination was identified during the course of the site works (such as hydrocarbons or asbestos fragments for example). This included within the exploratory holes targeted to the potential sources of contamination as detailed in Section 3.7.1 and Table 7.

Controlled Waters

Given the low contaminant concentrations revealed by the testing, there are considered to be no specific risks posed to Controlled Waters by the findings of the laboratory analysis undertaken.

9.3.2 Remediation Proposals / Re-Use of Soils

Human Health

No specific remediation works will be required other than the provision of suitable topsoil in proposed gardens to provide a suitable growing media for plants. As the existing topsoil is considered suitable for re-use at the site (based on laboratory testing), it is considered unlikely that there will be a requirement to import topsoil. Should there be a requirement to import topsoil to the site, all topsoil should be tested 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 for any topsoil proposed for importation should be forwarded to the Local Authority (Environmental Health Officer) for approval (prior to importation).

Controlled Waters

No specific remediation in relation to Controlled Waters is considered to be necessary at the site on the basis of the available information.

Off-Site Disposal

Excess uncontaminated soils (for example underlying Natural Strata) should be regarded as a potential asset and we would recommend that the re-use of excess uncontaminated soils on site or off-site is investigated in the first instance (subject to appropriate permits, plans and registrations etc).

The Natural Strata may be regarded as suitable for re-use within proposed garden areas as subsoil (to raise levels, as appropriate) or for landscaping / capping on alternative developments (subject to regulatory approval and the production of any necessary plans or permits) where surplus arisings are generated from the site and adequate control measures are in place.

Should off-site disposal be 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 and Controlled Waters. Therefore, Waste Acceptance Criteria [WAC] testing may be required to confirm disposal costs, although in the first instance, the test results from this investigation should be supplied to landfill operators to determine likely disposal costs before any further testing is carried out.

9.4 Construction Workers

No contamination has been identified at the site that would require specific PPE. However, it is recommended that construction personnel involved with direct contact with the soils at the site use appropriate PPE equipment together with hygiene facilities in accordance with general health and safety guidelines.

A copy of this report should be included in the site health and safety file, and site workers should be made fully aware of the sites setting.

9.5 Asbestos Survey

The existing structures at the site have the potential to include asbestos containing materials (ACMs). It is recommended that a suitable asbestos survey is undertaken on all site buildings prior to demolition. Any ACMs encountered should be removed off-site by a suitably qualified contractor prior to redevelopment / refurbishment.

The demolition rubble generated from the existing buildings may be suitable for use to raise levels (if necessary), subject to confirmatory testing. If demolition rubble is placed in proposed areas of soft landscape, it should be subject to confirmatory testing.

9.6 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.

9.7 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.

A careful watch should be maintained during removal of the concrete surfacing, including the floor slabs to the former agricultural buildings.

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.

9.8 Licences, Permits, Registrations, Plans and Approvals

The Contractor / Developer is responsible for, and must ensure that, all necessary licences, 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.

9.9 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 NHBC or other Warranty Provider, if necessary) for review / comment and approval prior to commencing with the development of the site.