GeoDyne

Geotechnical &
Environmental
Consultants

Church Street
Holbeach

Combined Phase I Desk Study & Phase II Exploratory Investigation For Langwith Construction

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Project No: D34136		**Date: 17th February 2015**	
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EXECUTIVE SUMMARY

Ground Conditions	Made Ground was encountered across the site to depths ranging between 0.60m and 3.00m begl, and typically comprised surfacing materials over very loose to medium dense clayey/silty gravelly sand, compact sandy gravel or soft to firm slightly sandy gravelly clay. The gravel component locally included various anthropogenic materials. A possible buried topsoil layer was locally encountered between 0.80m and 1.25m begl. The Natural Strata typically comprised soft (becoming soft to firm) very sandy very silty CLAY or soft (becoming soft to firm) clayey very sandy SILT. Below depths ranging between 2.10m to 2.80m begl, very loose to medium dense wet very silty SAND, locally with pockets of Silt, was proven to depths of up to 5.00m begl.
Foundation Design	Due to the typically low strength near surface superficial deposits underlying the site and the presence of groundwater at depths of below 2.00m begl, the use of traditional foundations (i.e. pad, strip or trench fill) are unlikely to be suitable for a proposed commercial development. It is considered that a piled foundation represents the most likely solution for adoption at the site. An alternative foundation solution such as rafts may potentially be possible, subject to plot specific trial pitting during a post-demolition phase of exploratory works.
Floor Slab Design & Ground Gas Precautions	Based on the programme of ground gas monitoring undertaken, no specific precautions in relation to ground gases (i.e. methane and carbon dioxide) are required within the proposed redevelopment. However, given the potential for peat bands and horizons within the Terrington Beds strata, it may be considered good practice to include a lapped and taped ground gas resistant membrane within the foundation solution for the proposed development, with all service penetrations suitably sealed to the membrane. Ground bearing floor slabs may therefore be adopted at the site following geotechnical improvement of the Made Ground. However, consideration should be given to the low strength of the Terrington Beds strata, which may result in settlement issues for either the slabs or external levels where appropriate precautions are not taken. Alternatively, 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).
Building Near Trees	Foundation designs may require adjusting when building near existing, proposed or recently removed trees. We would recommend that a suitable arborist survey is undertaken (where not already completed) to assist in detailed foundation design.
Watching Brief	A well is historically indicated in the northeastern site area. We would therefore recommend that a general watching brief is maintained by the Contractor during enabling works at the site as a precautionary measure.
Coal Mining	No specific mitigation measures in relation to shallow coal mining are considered to be necessary at the site.
Radon	No radon precautions are required at the site.
Water	Dewatering of excavations (particularly deeper excavations for sewers construction etc.) should be anticipated to be required. Some dewatering may also be required where excavations are left open during periods of adverse weather.
Excavations / Stability	Excavations may require trench support for stability and health and safety reasons. The assessment of excavations and provision of support will be the responsibility of the contractor on site. Any softened soils should be removed from excavations prior to the pouring of concrete (where applicable).
Sulphate Classification	BRE Special Digest 1:2005 Design Sulfate Class DS-1 and ACEC classification AC-1.
CBRs	A CBR value of less than 2% may be anticipated in the Made Ground and a CBR value of around 2% to 3% may be anticipated within the shallow Natural Strata, subject to confirmation by in-situ testing.
Surface Water Drainage	The use of soakaways for surface water disposal is unlikely to be feasible at the site. It is recommended that alternative means of surface water disposal are investigated, at this stage.
Contamination Assessment	On the basis of the chemical contamination assessment undertaken, the Made Ground and Natural Strata may be considered to be uncontaminated for the proposed commercial end-use.
Remediation Proposals	Based on the findings of the soils testing undertaken to date, no general remediation requirements are considered to be required. However, it is recommended that this is confirmed by a programme of post demolition exploratory works, which should include exploratory positions advanced beneath the footprints of the existing buildings. In addition, the interceptor in the west of the site and the UST in the southeast of the site should be decommissioned and removed during the course of enabling works, together with any associated pipework.
Asbestos Survey	We would recommend that a suitable asbestos survey is undertaken prior to demolition of the existing buildings/structures, with any encountered/identified asbestos removed off-site by suitably qualified specialists.
Construction Workers	Construction personnel should 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.

Utilities	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 Limited to ensure that our recommendations continue to apply.
Licenses, Permits, Registrations, Plans and Approvals	The Contractor/Developer is responsible for, and must ensure that, all necessary licenses, permits, registrations, plans and approvals are in place prior to commencing with the earthworks at the site.
Further Works	• Advance a series of cable percussive boreholes to assist in the design of foundations for the proposed redevelopment. • A programme of post-demolition trial pitting and soil sampling to confirm the findings of the contamination assessment detailed herein, and to inform the requirement for any general remedial requirements necessary at the site. • The decommissioning and removal of the interceptor and UST identified at the site, together with appropriate validation works.

1.0 INTRODUCTION

1.1 Introduction

GeoDyne Limited has been appointed by the Client, Langwith Construction, to undertake a Combined Phase I Desk Study and Phase II Exploratory Investigation at a Langwith Construction depot facility located off Church Street, Holbeach.

1.2 Scope of Works

The scope of the Phase I Desk Study included the following:

- Detailed site walkover.
- Review of historical and contemporary Ordnance Survey publications.
- Review of the sites geology, hydrology and hydrogeology (including a visit to the British Geological Survey in Keyworth).
- Review of the sites coal mining status.
- Review of the sites radon status.
- Review of a commissioned Landmark Envirocheck Report.

Phase II Exploratory Investigation works comprised:

- A sub-contracted utility avoidance scan of proposed exploratory hole locations.
- A series of window sampling boreholes across the accessible external areas of the site.
- Geotechnical and environmental soils testing.
- A programme of ground gas and water monitoring.

1.3 Project Understanding

It is understood that the site is proposed to be redeveloped with a new medical centre, together with associated hardstanding and potentially soft landscaping (we understand that the layout of the development has yet to be finalised).

For the purposes of the assessments detailed herein, we have adopted a commercial end-use for the proposed development. If our understanding is incorrect (for example if a residential end-use was proposed), it would be necessary to review our report to ensure it continues to apply.

1.4 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, unless specifically stated.

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.

We would note that the scope of laboratory testing and our assessment of the chemical soil test results have been primarily focussed on potential risks to human health. Our scope of chemical testing and assessment has not been specifically designed to fulfil any landfill or waste disposal company's requirements to suitably characterise any waste soil arising during future redevelopment of the site, or accurately determine disposal costs for any waste soil, although it will assist in such an assessment.

GeoDyne Limited has prepared this report for the sole use and reliance of the Client, Langwith Construction, in accordance with our Standard Conditions and Limitations (included in Appendix XII). This report may not be used or relied upon by any unauthorised third party without the explicit written agreement of GeoDyne Limited.

1.5 Confidentiality

The risk assessment herein remains the intellectual property and trade secret of GeoDyne Limited. The information contained within this report must not be disclosed or divulged to any commercial Consultant or other third party without the prior written agreement of GeoDyne Limited.

2.0 SITE DESCRIPTION & HISTORY

2.1 Site Description

The main part of the site comprises an approximately rectangular shaped parcel of land, with an access route in the east of the site connecting it to Church Lane, Holbeach. The site may be located centred around approximate Ordnance Survey National Grid Reference 535760E 324610N, and extends to an area of approximately 0.49 hectares. A site location plan (Figure No. D34136/01) is included as Appendix I.

During the course of our works (December 2014), the site comprised a semi-derelict depot (utilised by the Client), with the yard area seemingly in use for the washing and maintenance of plant and locally as a car parking area.

A gated entry provided access into the site off Church Lane, with an adjacent small brick-built single-storey former office/gatehouse building. This building was noted to be partially dilapidated, with vegetation colonising the exterior. To the west of this structure, a weathered macadam surfaced road ran to an area utilised as a car park, with the northern half of the car park comprising a concrete slab (possibly associated with a former building/structure). Adjacent to the car parking area in the sites northeast, a small corrugated metal shed was present, with no discernible current usage.

The main area of the site was located to the west of the car parking area, and was surfaced with a mixture of gravel, macadam or concrete (primarily around the curtilage of the buidlings). A large portal frame type industrial warehouse was located in the northwestern part of the site, which appeared on inspection to be separated into three distinct areas accessed typically by roller-shutter doors; a derelict storage bay in the west (open-sided along the southern frontage), a workshop in the southeast and a storage area (containing racking units) in the northeast. At the southwestern corner of this building a vent pipe was evident, seemingly associated with a nearby (heavily silted) two-phase interceptor, which appeared to run off-site to the west.

Within the central-southern part of the site a former works building was present, with an open-plan workshop area in the central and western areas, and former offices and welfare facilities in the eastern extent of the building.

Both the workshop building and warehouse were observed to contain possible Asbestos Containing Materials (ACMs) as corrugated asbestos cement roofing, and further ACMs may be present within the construction materials.

A smaller block of offices was located in the southeastern part of the site, adjacent to which a fuel pump dispenser and diesel Underground fuel Storage Tank (UST) was situated. A bag of oil absorbent material was stored adjacent to the pump dispenser, and the recent use of this material was in evidence on the ground around the feature.

Topographically, the site appeared to be sensibly level, although small height variations were noted at the western edge of the car parking area and beyond the sites western boundary (where a drop of approximately 0.5m was observed). The boundaries of the site were defined with a mixture of mature trees and hedgerow (western boundary) and by fencing (either wooden or post and wire along the northern and southern boundaries).

The site was bounded to the north by existing residential dwellings (to the northeast), an Air Training Corps building (to the north) and a bowling green (to the northwest). A wooded copse was present to the west of the site, where a possible surface water drain was noted to run towards the site (the ditch appeared to be dry with no obvious flow direction) and seemingly disappearing at the sites northwestern boundary. Further residential dwellings were present to the sites southwest and south. Church Street was located to the east of the site, off which further residencies and commercial premises were accessed.

An annotated site plan (Figure No. D34136/02) showing the main features of the site is included within Appendix II of this report, with plans providing general site views (Figure Nos. D34136/03 & D34136/04) included in Appendix III. Plates showing notable features of the site are also included in Appendix XI (Plates 04 to 08).

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 IX of this report.

It should be noted that the site boundaries marked on the historical sheets within the Envirocheck Report appears to 'shift' on several of the maps. This is due to Envirocheck transposition and scaling algorithm inaccuracies.

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 site is shown to predominantly comprise an undeveloped field. • A building is indicated in the central-eastern part of the site, with a row of small structures leading off it to the east. • A further small structure is shown in the sites northeastern corner, which may be associated with a pump.	• The urbanised area of Holbeach is indicated around the general vicinity of the site. • A surface watercourse is shown to run to within approximately 70m of the sites southeastern corner, at which point it appears to become culverted beneath Church Street. • A possible large pond is indicated within the field adjacent to the north of the site. A further pond, situated within the grounds of '*Old Rectory House*', is indicated approximately 70m to the north. • Railway lines and Holbeach Station are indicated beyond approximately 200m to the south of the site.
1900s	• The site is labelled as comprising part of an '*Auction Yard*'.	• The possible pond to the north of the site is no longer indicated. • The watercourse to the sites south is annotated as an '*Old River*', which has become culverted further (or infilled) with an extension of the railway lines beyond approximately 180m to the sites south. • Various pumped wells are indicated in the sites general vicinity.
1930s	• A further small building is indicated at the eastern extent of the site, adjacent to Church Street. • No other significant changes identified.	• A surface water drain is indicated to lead into the sites northwestern corner (no longer shown at that point), connecting to '*Stukeley Hall*' located to the sites northwest.
1950s	• No significant changes to the site identified.	• No significant changes to the sites immediate surroundings identified.

TABLE 1 – HISTORICAL PUBLICATION DATA		
Date	**Features on Site**	**Features off Site**
1960s	• The site is indicated to contain a large square-shaped building in the northeastern area, with a further three buildings indicated in the western third. • The pump is no longer annotated at the site.	• A small rectangular shaped building has been constructed adjacent to the sites northern boundary, with a '*Garage*' indicated adjacent to the sites northeast and with a '*Caravan Site*' beyond. • A '*Bowling Green*' is indicated immediately adjacent to the sites northwest. • Residential dwellings are indicated to the sites southwest (to the south of the drain), with a heavily vegetated plantation shown immediately adjacent to the west of the site. • The old river is no longer indicated and has potentially been infilled. • The railway lines to the south of the site are shown as having been dismantled.
1970s	• No significant changes to the site identified.	• No significant changes to the sites immediate surroundings identified.
1980s	• The buildings in the western part of the site are no longer indicated, with a new larger building shown in the south of the site, together with a smaller building in the sites southeast. • A small extension is indicated on the western frontage to the large building in the northeast of the site.	• No significant changes to the sites immediate surroundings identified.
1990s	• Two very small structures are indicated in the northwestern area of the site until 1995. • By 1996 the large building in the northeast of the site is no longer indicated, with a further rectangular shaped building shown in the northwestern part of the site. The western part of the southern building is also no longer shown after this date.	• No significant changes to the sites immediate surroundings identified.
2006 to 2014	• No significant changes to the site are indicated.	• No significant changes to the sites immediate surroundings identified.

3.0 GEOLOGY & ENVIRONMENTAL SETTING

3.1 Geological References

The following geological publications were referred to:

- BGS 1:50000 Series Sheet 144 *'Spalding'* (1992) [no 1:10000 or 1:10560 geological map publications available at the BGS in Keyworth].
- The Coal Authority and The Law Society Publication *'Coal Mining and Brine Subsidence Claim Searches - Directory and Guidance'*, Sixth Edition (2006).
- Environment Agency website: www.environment-agency.gov.uk.
- British Geological Survey website: www.bgs.ac.uk.

3.2 Geology

Based on the reviewed geological map publications the site is indicated to be underlain by Terrington Beds dating from the Quaternary period (also identified as Tidal Flat Deposits on the BGS website), underlain at depth by solid geology comprising the West Walton Formation dating from the Jurassic. The West Walton Formation is indicated to be approximately 15m to 17m in thickness, below which the Oxford Clay Formation is indicated.

The Terrington Beds comprise younger marine alluvium, salt marsh, tidal creek and river deposits, typically consisting of sandy Silt, Sand and Clay. They are in turn typically underlain by the Barroway Drove Beds, comprising older marine alluvium or salt marsh deposits, and typically consisting of silty Clay, and may contain Peat either as a defined band (i.e. Nordelph or Lower Peat) or as impersistent horizons.

The West Walton Formation comprises *'silty mudstones and calcareous mudstones with minor nodular limestones'*.

It should be noted that superficial 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.

3.3 Faults

No 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 or Infilled Ground) are indicated on the reviewed geological map publications on, or within the general vicinity of, the site.

However, Made Ground is anticipated to be present beneath the site associated with the various phases of historical redevelopment noted in Section 2.2.

3.5 Coal Mining

The site does not lie within an area requiring the commission of a coal mining report in accordance with The Coal Authority and The Law Society publication *'Coal Mining and Brine Subsidence Claim Searches - Directory and Guidance'*, Sixth Edition (2006).

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 X and has revealed the following relevant information (details are only listed where they are within potential influencing distance, i.e. 250m, of the site).

3.6.1 Agency & Hydrological

Aquifer Status

Both the superficial deposits (Terrington Beds) and underlying bedrock geology (West Walton Formation and Oxford Clay Formation) are designated as Unproductive Strata by the Environment Agency.

Unproductive Strata is defined 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 EA. SPZs relate to the protection of groundwater used for public drinking water supply.

Surface Water

The closest surface water feature is indicated to be located 58m to the north of the site, seemingly located to a pond feature located within Rectory Park.

No other significant surface water features are indicated in the general vicinity of the site. We would note the presence of a surface water drain to the west of the site that appears to lead into the sites northwestern extent. No evidence of water flow was observed in the drain at the time of our works, and it is unclear whether the feature has been infilled, culverted or simply terminates at the site boundary.

Flood Risk

The majority of the site is shown to be located outside of an area at risk of flooding. However, the western third of the site is shown to be located within part of a larger area (that extends across Holbeach to the west) that is indicated to be at risk of flooding from rivers or seas without defences.

Local Authority Pollution Prevention and Controls

Two petrol filling stations are identified within the Landmark report, located 155m to the south of the site (the authorisation for which is listed as having been revoked) and 209m to the north of the site (license status not listed). Due to the distance from the site, together with the typically low permeability of the indicated underlying superficial deposits (i.e. Terrington Beds), it is considered unlikely at this stage that these features would have the potential to significantly impact upon the proposed redevelopment of the site (through the lateral migration of contaminants to the site).

Pollution Incidents to Controlled Waters

A single pollution incident is identified within the Landmark report located 183m to the south of the site and associated with the release of acid chemicals into the Holbeach River. The incident is listed as minor and occurred in 1996. This entry is therefore considered not to be relevant to the proposed development.

3.6.2 Waste

There are no sites associated with waste (e.g. historic landfills, transfer stations etc.) identified within 250m of the site.

3.6.3 Hazardous Substances

There are no sites associated with hazardous substances (e.g. explosives) identified within 250m of the site.

3.6.4 Geological & Radon

Geological Hazards

No potentially significant onerous geological issues have been identified within the Envirocheck report which relate to the site, although we would note that the site has been identified as being of moderate potential for compressible and running sand ground stability hazards.

BGS Estimated Soil Chemistry Data Maps

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.

BGS 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 of <150mg/kg and nickel of 15-30mg/kg.

Based on the information supplied within the Envirocheck report, the site is not shown to be located within an area where Natural Metal Enrichment of the underlying natural soils is likely to be present. However, this is only applicable to the specific determinands listed above.

Radon

The Envirocheck report states that '*The property is in a lower probability radon area, as less than 1% of homes are above the action level…No radon protective measures are necessary in the construction of new dwellings or extensions.*' No specific mitigation in relation to radon issues are therefore required at the site.

3.6.5 Industrial Land Use

A total of 12No. contemporary trade directory entries are listed between 34m and 238m from the site (none are identified on the site itself, albeit the site has previously been utilised as a Langwith Construction Depot facility), of which 5No. are identified as remaining active. The entries include activities associated with cleaning equipment, car dealers, joinery manufacturers, millers and printers; however, none of the entries are considered to have the potential to significantly impact upon the proposed redevelopment of the site.

A single active fuel station entry is listed 245m to the north of the site (presumably corresponding to the entry listed in Section 3.6.1 under Local Authority Pollution Prevention and Controls).

3.6.6 Sensitive Land Use

The site is not shown as being located within, or in close proximity to, a land use of sensitivity (i.e. conservation area, nitrate vulnerable zone etc.).

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 and the Chartered Institute of Environmental Health.

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). This document identifies key contaminants which may potentially be present at a site as a result of a given historical land use, and whilst formally withdrawn is still considered to be a useful desk based reference guide.

3.7.1 On Site Assessment

The site is indicated to have been utilised as part of an auction house in the early 1900s, prior to being developed with industrial premises in the 1960s. The site has subsequently been subjected to various phases of development, with the recent land use associated with a depot for Langwith Construction.

A fuel pump dispenser and UST (diesel) are located in the southeastern corner of the site, with a spill kit stored on site (and seemingly having recently been used based on observations during our works). An interceptor (heavily silted) and vent stack are located in the west of the site.

Historical maps suggest the presence of a pumped well in the early part of the Twentieth Century in the northeastern part of the site, although no evidence of such a feature was readily apparent during our walkover.

The site is indicated to be underlain by superficial deposits comprising the Terrington Beds (Tidal Flat Deposits), which can include discontinuous bands or pockets of Peat. At depth, the bedrock geology comprises the West Walton Formation.

Possible Asbestos Containing Materials (ACMs) were observed as roofing (possibly corrugated asbestos cement) to the main workshop/warehouse buildings, therefore previous development phases may have resulted in other ACMs having been deposited at the site.

Based on the Syms document, the general land use of a depot falls within the classification of '*Transport Depots, Road Haulage, Commercial Vehicle Refuelling, Local Authority Yards and Depots*', which is given a perceived risk classification of medium. The following salient information is provided by Syms:

'*...Many sites may include fuelling and vehicle maintenance facilities...historic contamination may remain on sites where these functions have been discontinued. Vehicle wash facilities are another potential source of contamination, unless waste water is disposed of via an effective interceptor.*

Raw materials for use in connection with vehicle operations include, diesel fuel, lubricating oils, cleaning materials, brake fluids and anti-freeze. Repair and maintenance facilities will generate wastes associated with operations such as welding, soldering and respraying, which may include body filler materials (e.g. glass fibre) solvents and paints. On some older sites waste oils, which can contain heavy metals such as lead and vanadium, may have been disposed of by simply pouring them on the ground, or into underground structures, such as redundant air raid shelters...Used tyres and other combustible wastes may have been burned on site, leaving behind PAH contamination.'

Based on the Desk Study information and our experience of similar sites, the following key contaminants could be present:

- Metals or metalloids associated with any Made Ground.
- Oil/fuel hydrocarbons associated with the diesel UST, vehicle maintenance or historical operations/spillages on site.
- Polycyclic Aromatic Hydrocarbons (PAHs) from any ashy inclusions and/or carbonaceous inclusions in the near surface soils.
- Asbestos from former buildings/structures.
- Potentially hazardous ground gases (i.e. methane and carbon dioxide) from the underlying potentially organic superficial soils.

3.7.2 Off Site Assessment

A garage has historically been present adjacent to the northeast of the site, with further industrial land uses identified in the sites general vicinity. However, due to the indicated underlying geology (i.e. typically cohesive and of low permeability), the risk of significant contaminant migration onto the site from these sources is considered to be low. On-site activities are therefore considered to represent the key risk drivers for potential risks to the proposed redevelopment.

We would additionally note the presence of potential Made Ground in the sites immediate vicinity, associated with the infilling of an old river. This is considered to represent a possible source of potentially hazardous ground gases (i.e. methane and carbon dioxide), which is a further reason to include ground gas monitoring within the scope of Phase II Exploratory Investigation works.

4.0 GROUND INVESTIGATION

4.1 Introduction

Sub-Surface Utility Avoidance Scan

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

Window Sampling Borehole Works

Window sampling borehole works were undertaken on 4th December 2014 and comprised the advancement of 6No. boreholes (designated WS1 to WS6) across the accessible external areas of the site, to depths ranging between 3.00m and 5.00m below existing ground level (begl). Standard Penetration Tests (SPTs) were undertaken at nominal 1m centres in selected boreholes in order to provide initial strength data for the near surface soils.

Exploratory Hole Locations/Logs

The approximate locations of the exploratory holes are shown on the plan presented in Appendix IV (Figure No. D34136/05). The exploratory hole logs are presented in Appendix V of this report.

4.2 Ground Conditions

Made Ground

Made Ground was encountered across the site to depths typically ranging between 0.60m and 0.90m begl, although a depth of 3.00m begl was recorded within WS1 (characterised by very poor sample recovery due to saturated ground conditions below approximately 1.00m begl).

The Made Ground typically comprised surfacing (variously concrete, macadam or gravel) over very loose to medium dense brown clayey/silty gravelly sand, compact yellow-brown sandy gravel (sub-base type materials) or soft to firm grey slightly sandy gravelly clay (visually comprising reworked natural soils). The gravel component locally included various anthropogenic materials, incorporating brick, concrete, coal, slate, ash, slag, timber and plastic. Within WS3 a possible buried topsoil layer was encountered between 0.80m and 1.25m begl.

A plan showing the depth to the base of the Made Ground at each borehole location is provided in Appendix VI (Figure No. D34136/06).

Natural Strata

Beneath the Made Ground, natural soils typically comprising soft (becoming soft to firm) very sandy very silty CLAY or soft (becoming soft to firm) clayey very sandy SILT were encountered to depths ranging between 2.10m to 2.80m begl. Below this depth, very loose to medium dense wet very silty SAND, locally with pockets of firm to stiff Silt, was encountered until termination of the boreholes at depths of up to 5.00m begl.

The Clay, Silt and Sand strata are anticipated to comprise part of the Terrington Beds, which are indicated from the geological maps to underlie the site.

4.3 Summary

The findings from the exploratory holes advanced within the site are summarised in Table 2.

TABLE 2 - SUMMARY OF FINDINGS IN EXPLORATORY HOLES

Stratum	Locations Encountered	Depth to base of stratum (m begl)	Typical Description
Made Ground	All	0.60m to 3.00m	Surfacing materials over very loose to medium dense clayey/silty gravelly sand, compact sandy gravel or soft to firm slightly sandy gravelly clay. The gravel locally included anthropogenic materials, including brick, concrete, ash, slag, timber and plastic. A possible buried topsoil layer was encountered between 0.80m and 1.25m begl in WS3.
CLAY / SILT / SAND (Terrington Beds)	All	5.00+ (base not proven)	Soft (becoming soft to firm) very sandy very silty CLAY or soft (becoming soft to firm) clayey very sandy SILT, progressing into very loose to medium dense wet very silty SAND with depth.

We would note that no obvious visual or olfactory evidence of significant soil contamination was identified during the course of the site works.

4.4 Water

Water was encountered at depths typically below around 2.00m begl, although water seepages were locally encountered at shallower depth (with the soils consistently wet below 1.00m begl within WS1).

4.5 Stability

The boreholes were typically cased to depths of 4.00m begl to prevent sidewall collapse. Where casing was not utilised, sidewall instability was noted within the Made Ground (particularly the deep Made Ground at WS1, which ultimately led to the requirement to adopt casing at this location) and the water-bearing granular natural soils at depth.

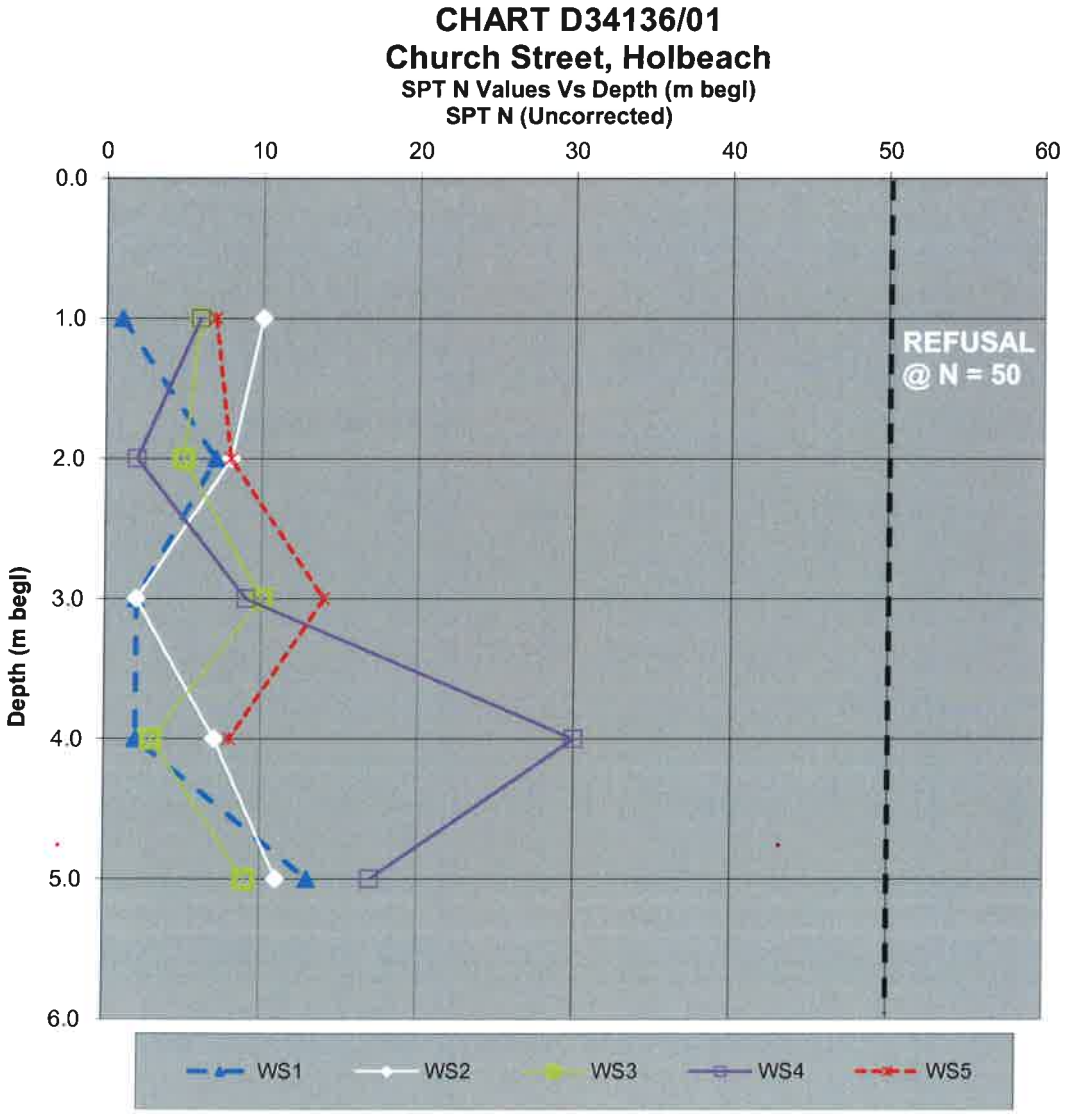
4.6 Plates

A photographic record of the exploratory investigation was obtained during the intrusive works. Photographs of the recovered cores from the boreholes are presented in the Plates included in Appendix XI of this report (Plates 01 to 03).

4.7 Standard Penetration Test (SPT) Data

In order to establish a strength/depth profile of the soils beneath the site, in-situ Standard Penetration Testing (SPT) was undertaken at one-metre nominal centres in selected boreholes. SPT 'N' values at 1m depth typically ranged between 1 and 10, with similar results obtained to depths of 4m. The soils were reported to become marginally more competent at 5m, with 'N' values of up to 17 revealed (although locally still <10).

A Chart (D34136/01) showing the SPT results with depth is provided below for information, with SPT results for each of the boreholes provided on the logs included in Appendix V.



4.8 On Site Photo-Ionisation Detector Screening

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

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

The selected soil samples were placed in sealed containers, agitated, and the headspace in each container aspirated into the PID for analysis.

Screening revealed values (ppm Isobutylene Equivalent Units) below background levels (assumed to be </=10ppm) in all soil samples obtained from within the subject site, which indicates the absence of any significant volatile contamination within the analysed soil samples (including from WS3 and WS6, targeted to locations around the existing UST).

5.0 GROUND GAS & WATER MONITORING RESULTS

5.1 Introduction

Based on the findings of the Desk Study works, it was considered necessary to install a series of monitoring points to facilitate a programme of ground gas monitoring at the site.

5.2 Monitoring Installations

Upon completion, three of the window sampling boreholes (WS1, WS3 & WS4) were installed with combined ground gas and water monitoring standpipes to depths of up to 5.00m begl to facilitate a programme of monitoring.

The full set of ground gas and water monitoring data is presented in Appendix VII of this report.

5.3 Results of the Ground Gas Monitoring

A total of six monitoring visits over an eight week period have been undertaken at the site as part of our works. The ground gas monitoring results are summarised in Table 3 below.

TABLE 3 – SUMMARY OF GROUND GAS MONITORING DATA

Parameter	Minimum % by volume (v/v)	Maximum % by volume (v/v)
Methane	0.0	0.1
Carbon Dioxide	0.4	4.1
Oxygen	10.3	21.3
Flow (l/h)	0.0	0.1

- Atmospheric pressure ranged between 974mb and 1010mb during the monitoring programme, and was at or below 1000mb (i.e. low pressure) on three of the monitoring visits.

- Water was recorded at depths ranging between 0.98m to 1.43m begl within the borehole installations during the course of the monitoring programme.

5.4 Appropriate Guidance

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

- CIRIA Report C665 *'Assessing risks posed by hazardous ground gases to buildings'* (2007).
- NHBC & RSK Group publication *'Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present'* (March 2007).

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

- GSV (l/hr) = maximum borehole flow rate (l/hr) x maximum gas concentration (expressed as a fraction).

The GSV should be used to assess the risks posed by gassing sites for both low-rise residential and commercial/industrial developments.

CIRIA Report C665 presents a total of six Characteristic Situations (CS) to assist with the relevant ground gas protection measures that should be installed to mitigate the risk posed by ground gases for a residential building (excluding low-rise housing) and commercial/industrial developments. The CS classifications represent a revised approach to the CS tables detailed within CIRA 149 *'Protecting development from methane'*.

The NHBC have developed a system of *'Traffic Lights'* to characterise gassing sites, which is specific to low-rise residential developments. Classification of the Traffic Lights provides the relevant ground gas protection measures that should be installed to mitigate the risk posed by ground gases for a low-rise residential development. The Traffic Light approach is based on *'Typical Maximum Concentrations'* of methane and carbon dioxide for initial screening purposes.

We understand that any potential future redevelopment of the site will be for a commercial/industrial end-use. Therefore the CIRIA report C665 'CS' classification has been adopted for the purpose of this assessment.

Table 8.5 (below) is reproduced from CIRIA C665 which indicates how a characteristic situation is determined.

	Characteristic situation (CIRIA R149)	Comparable classification in DETR *et al* (1999)	Risk classification	Gas screening value (GSV) (CH_4 or CO_2) (l/hr)[1] Threshold	Additional factors	Typical source of generation
	1	A	Very low risk	<0.07	Typically methane ≤1 % and/or carbon dioxide ≤5 %. Otherwise consider increase to Situation 2	Natural soils with low organic content "Typical" made ground
	2	B	Low risk	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to characteristic Situation 3	Natural soil, high peat/organic content, "Typical" made ground
	3	C	Moderate risk	<3.5		Old landfill, inert waste, mineworking flooded
	4	D	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures.	Mineworking - susceptible to flooding, completed landfill (WMP 26B criteria)
	5	E	High risk	<70		Mineworking unflooded inactive with shallow workings near surface
	6	F	Very high risk	>70		Recent landfill site

Table 8.6 (below) is also reproduced from CIRIA C665 which details typical protection measures associated with each Characteristic Situation.

Characteristic situation	Residential building (not those which belong to Situation B)[1]		Office/commercial/industrial development	
(From Table 8.5)	Number of levels of protection	Typical scope of protective measures	Number of levels of protection	Typical scope of protective measures
1	None	No special precautions	None	No special precautions
2	2	a. Reinforced concrete cast *in situ* floor slab (suspended, non-suspended or raft) with at least 1200 g DPM[2] and underfloor venting. b. Beam and block or pre-cast concrete and 2000 g DPM/ reinforced gas membrane and underfloor venting. All joints and penetrations sealed.	1 to 2	a) Reinforced concrete cast *in situ* floor slab (suspended, non-suspended or raft) with at least 1200 g DPM[2]. b) Beam and block or pre cast concrete slab and minimum 2000 g DPM/reinforced gas membrane. c) Possibly underfloor venting or pressurisation in combination with a) and b) depending on use. All joints and penetrations sealed.
3	2	All types of floor slab as above. All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated or positively pressurised underfloor sub-space.	1 to 2	All types of floor slab as above. All joints and penetrations sealed. Minimum 2000 g/reinforced gas proof membrane and passively ventilated underfloor sub-space or positively pressurised underfloor sub-space
	3	All types of floor slab as above. All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated underfloor subspace or positively pressurised underfloor sub-space, oversite capping or blinding and in-ground venting layer.	2 to 3	All types of floor slab as above. All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated or positively pressurised underfloor sub-space with monitoring facility.
	4	Reinforced concrete cast *in situ* floor slab (suspended, non-suspended or raft). All joints and penetrations sealed. Proprietary gas resistant membrane and ventilated or positively pressurised underfloor sub-space, oversite capping and in-ground venting layer and in-ground venting wells or barriers.	3 to 4	Reinforced concrete cast in-situ floor slab (suspended, non-suspended or raft). All joints and penetrations sealed. Proprietary gas resistant membrane and passively ventilated or positively pressurised underfloor sub-space with monitoring facility. In ground venting wells or barriers.
	5	Not suitable unless gas regime is reduced first and quantitative risk assessment carried out to assess design of protection measures in conjunction with foundation design.	4 to 5	Reinforced concrete cast in-situ floor slab (suspended, non-suspended or raft). All joints and penetrations sealed. Proprietary gas resistant membrane and actively ventilated or positively pressurised underfloor sub-space with monitoring facility, with monitoring. In ground venting wells and reduction of gas regime.

The GSV should be calculated for both methane and carbon dioxide and the worst case adopted in order to establish the appropriate protection measures for the site. The higher the classification the greater the risk posed by the presence of ground gas. Both the above guidance documents note that *'...the GSV is a guideline value and not an absolute threshold'.*

5.5 Ground Gas Analysis

The programme of ground gas monitoring has identified a maximum methane concentration of 0.1% v/v (expressed as 0.001 as a fraction), a maximum carbon dioxide concentration of 4.1% v/v (expressed as 0.041 as a fraction), and with a maximum flow rate of 0.1 l/hr.

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

- 0.001 x 0.1 = 0.0001 l/h

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

- 0.041 x 0.1 = 0.0041 l/h

Therefore, with a maximum GSV of 0.0041 l/h, negligible methane and a maximum carbon dioxide concentration of 4.1% v/v, it is considered appropriate to classify the site as Characteristic Situation CS1 in accordance with CIRIA guidance (i.e. no specific precautions are required at the site).

6.0 LABORATORY TESTING & CONTAMINATION ASSESSMENT

6.1 Introduction

The following environmental soil testing was carried out on visually representative samples recovered from the exploratory holes. The testing strategy was based on our land use assessment and was considered sufficient to enable an initial assessment of the chemical status of the soils at the site for a commercial/industrial end-use:

- 6No. Standard contamination suites (including metals, speciated PAH and TOC).
- 2No. Speciated Total Petroleum Hydrocarbon tests (TPHCWG criteria).
- 3No. asbestos screening tests.

Geotechnical soil testing comprised the following:

- 3No. Plasticity Index tests.
- 3No. Water soluble sulphate tests.
- 6No. pH tests.

All laboratory soil test results are included in Appendix VIII.

6.2 Geotechnical Soil Test Results

Water Soluble Sulphate/pH

Water soluble sulphate testing was undertaken on 3No. soil samples obtained from the Natural Strata during the site works, and revealed water soluble sulphate concentrations of <0.01g/l SO_4 or 0.03g/l SO_4 within the samples analysed. The pH values of the soil samples analysed ranged between 7.3 and 7.7.

In accordance with the Building Research Establishment publication Special Digest 1 '*Concrete in Aggressive Ground*' (2005) the highest sulphate concentration should be used to indicate the Design Sulphate Class (i.e. 0.03g/l SO_4), together with the lowest result for pH (7.3).

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 Brownfield location and the presence of potentially mobile groundwater conditions beneath the site (in the absence of long-term seasonal information).

Plasticity Index (PI) Testing

A total of 3No. Plasticity Index tests have been undertaken on selected samples of near surface Natural Strata obtained during the site works, including samples from the Clay and Silt strata. In accordance with BRE Digest 240, the reported PI value may be modified based on the portion of the sample passing a 425μm sieve.

The result of the PI analysis is summarised in Table 4.

TABLE 4 – SUMMARY OF PLASTICITY INDEX (PI) DATA				
Sample Ref.	**Reported PI Value (%)**	**Portion Passing 425µm Sieve (%)**	**Modified PI Value (%)**	**Volume Change Potential**
WS2, 0.60-1.00m (Clay)	14	100	14	Low
WS4, 1.50-2.00m (Silt)	NP	-	-	Non-Plastic
WS4, 0.70-1.00m (Clay/Silt)	11	100	11	Low

In accordance with Table 4, the soil samples analysed may typically be regarded as being of low volume change potential, and we would recommend that this classification is adopted for design purposes, where applicable.

6.3 Contamination Assessment Rationale

It is understood that it is proposed to redevelop the site with a new medical centre. We have therefore adopted a commercial end-use scenario for the purposes of a contamination assessment, which is considered to reflect the most appropriate end-use given the available land uses covered by the GAC.

6.4 Appropriate Guidance

Reference has been made to documents reflecting current good practice, including (but not limited to) the following:

- Environment Agency Contaminated Land Report 11 '*Model Procedures for the Management of Land Contamination*', September 2004, ISBN: 1844322955.
- British Standard BS10175:2011+A1:2013, '*Investigation of potentially contaminated sites. Code of practice*', March 2011.
- 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. "Copyright Land Quality Management Limited reproduced with permission; Publication Number S4UL3026. All rights reserved."*'
- DEFRA publication '*SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination*', Final Project Report (Revision 2), dated 24th September 2014 and Erratum dated December 2014.
- DEFRA publication '*SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination*' – Policy Companion Document, dated December 2014.
- EIC/AGS/CL:AIRE publication '*Soil Generic Assessment Criteria for Human Health Risk Assessment*', January 2010, ISBN 978-1-905046-20-1.
- Department of Environment, Food and Rural Affairs (DEFRA) and the Environment Agency publication – *'Contaminated Land Exposure Assessment (CLEA) model'* (March 2002).
- Environment Agency Science Report, *'Using Soil Guideline Values'*, SC050021/SGV, March 2009.
- R & D Draft Technical Report P5-079/TR1 *'Review of the Fate and Transport of Selected Contaminants in the Soil Environment'* dated 2003.
- CL:AIRE/CIEH *'Guidance on Comparing Soil Contamination Data with a Critical Concentration'* (May 2008).
- Environment Agency Science Report SC050021/SR7 *'Compilation of Data for Priority Organic Pollutants for Derivation of Soil Guideline Values'*, dated November 2008, ISBN 978-84432-964-9.
- Environment Agency Science Report Final SC050021/SR2 *'Human health toxicological assessment of contaminants in soil'*, dated January 2009, ISBN 978-84432-858-1.

- Environment Agency Science Report SC050021/SR3 *'Updated technical background to the CLEA model'*, dated January 2009, ISBN 978-84432-856-7.
- Environment Agency Science Report SC050021/SR4 *'CLEA Software (Version 1.05) Handbook'*, dated September 2009, ISBN 978-1-84911-105-8.

6.4.1 Selection of Appropriate Tier 1 Screening Values

Generic Assessment Criteria (GAC)

The assessment of contaminated land in the UK was historically undertaken with reference to ICRCL Guidance Note 59/83 together with successive versions of the CLEA model (inc. CLEA2002 (2002), CLEA UK (2005), CLEA V1.03 beta (2008), CLEA V1.04 (January 2009), CLEA V1.05 (September 2009) and CLEA V1.06 (October 2009)).

The CLEA V1.06 model is a deterministic quantitative risk assessment (QRA) model, which has historically been utilised by the Environment Agency to produce Soil Guideline Values (SGVs) for several contaminants, and has been used and modified by the authors of the LQM/CIEH S4UL publication and the authors of the DEFRA SP1010 series of documents in the derivation of their respective human health screening values.

Of key importance is the basis on which these two differing sets of commercially available screening criteria have been created, with the SP1010 values reflective of a '*Low Level of Toxicological Concern*' (LLTC) and the S4UL values based on a '*Minimal Risk Level*' (MRL).

Based on our understanding of current good practice within the contaminated land field, we have adopted the S4UL values (representing a compatible approach to risk assessments undertaken since the initial derivation of the CLEA model, and based on an established and fully justifiable methodology) as our initial Generic Assessment Criteria (GAC) values for human health. In the absence of a suitable S4UL value (such as lead), reference has been made to the relevant C4SL, and these have been adopted where considered justifiable and as appropriate (further consideration of their use is provided below).·

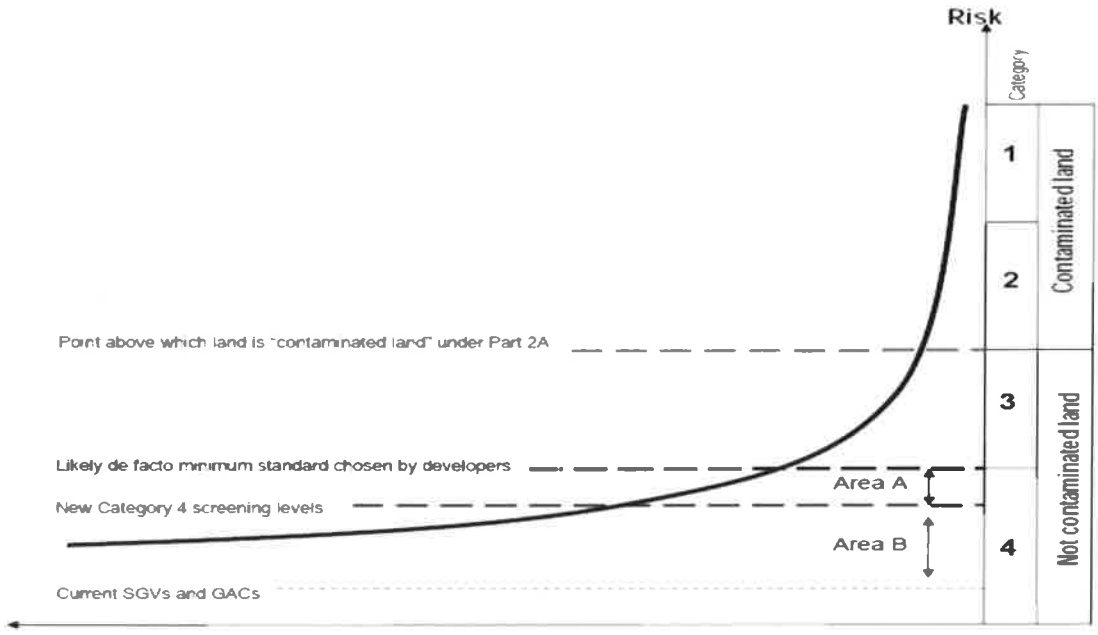
We would additionally note that other GAC values are commercially available, such as the Atkins ATRISKSOIL values (to which GeoDyne subscribe) and the EIC/AGS/CL:AIRE values for organic substances; and these have been referred to where relevant to the site.

Category 4 Screening Levels

Revised Statutory guidance for the assessment of land under Part 2A of the Environmental Protection Act 1990 was published by the Department for Environment, Food and Rural Affairs (Defra) in April 2012. The guidance introduced a new four-part category system for classifying land under Part 2A; Section 4.17 of the Guidance states:

'*In deciding whether or not land is contaminated land on grounds of significant possibility of significant harm to human health, the local authority should use the categorisations described in paragraphs 4.19 – 4.30...Categories 1 and 2 would encompass land which is capable of being determined as contaminated land on the grounds of significant possibility of harm to human health. Categories 3 and 4 would encompass land which is not capable of being determined on such grounds*'.

The foregoing categories are depicted in diagrammatical form in the following graph (taken from Defra publication SP1010):



Defra has subsequently commissioned the production of Category 4 Screening Levels (C4SLs) for a total of six substances (cadmium, benzo(a)pyrene, benzene, arsenic, lead and chromium VI), which are detailed within the SP1010 document titled '*Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination – Policy Companion Document*', dated March 2014. The C4SL values represent a level below which a contaminant concentration is considered to have a 'Low' risk to human health. The C4SL values are stated within the SP1010 document (page 7) as still remaining '*strongly precautionary*' and represent a more pragmatic approach to contaminated land risk assessment than the minimal risk values represented by the SGV/GAC levels.

In addition to the use of C4SLs in contaminated land risk assessment, the SP1010 document states the following with respect to background levels of contaminants:

'The outputs of Defra-funded research to determine 'normal' background concentrations of various contaminants in England and Wales and the outputs of this research project to develop new screening levels for contaminants in soil, are both designed as tools to be used by contaminated land risk assessors to inform decisions about whether or not it is necessary to proceed to a Detailed Quantitative Risk Assessment (DQRA) on a particular site taking into account the broad aims of the regime as set out in Section 1 of the Statutory Guidance. Questions have been raised about how these tools relate and interact.

41. Ultimately, it is up to individual risk assessors to make the most appropriate decisions on a site-by-site basis and to use the most appropriate tools in each case. However, with reference to the Part 2A Statutory Guidance, which states that 'normal' background concentrations should not be considered to cause a site to be determined as contaminated under Part 2A unless there is a reason to consider otherwise, it is envisaged that, where available, Category 4 Screening Levels should be the initial value against which site concentrations can be compared. Where a value on a particular site exceeds the Category 4 Screening Level for that substance, reference can then be made to the normal background concentration for that contaminant in that area. If concentrations are higher than the relevant Category 4 Screening Level but within 'normal' background concentrations for that area, it is not envisaged that a site

would be determined as contaminated under Part 2A (unless there was a reason to consider otherwise).

42. The British Geological Survey has derived 'normal' background concentrations for lead for England and Wales. In England, the 'normal' background concentrations of lead are 180 mg/kg for the 'principal' domain, 2,400 mg/kg for the 'mineralisation' domain and 820 mg/kg for the 'urban' domain (Defra, 2012) (see table below). In Wales the 'normal' background concentrations are 230 mg/kg for the 'principal' domain, 280 mg/kg for the 'mineralisation' domain and 890 - 1300 mg/kg for the 'urban' domain (Defra, 2013). Current advances in our understanding of the toxicology of lead have resulted in Category 4 Screening Levels for Residential, Allotments and Public Open Space 1 that are lower than the 'normal' background concentration of lead in ***urban*** *areas. This was also the case for the (now withdrawn) Soil Guideline Value for lead of 450 mg/kg.*

43. The report identifies other relevant considerations that may have a bearing on the final choice of Category 4 Screening Levels and the background level in soil is one of these. A pragmatic approach for lead would be to recommend the use of the 'normal' background concentration when the land use and domain permit (for example, providing other site and contaminant specific characteristics such as chemical form, bioavailability, soil depth, site use, etc. are comparable between the background and the site under investigation) so as not to disproportionately target land where there is widespread diffuse pollution of lead.

Normal background concentrations of contaminants in England

Substance	Principal domain	Urban domain	Mineralisation domain 1	Mineralisation domain 2	Ironstone	Chalk South
Arsenic	32 mg/kg		290 mg/kg		220 mg/kg	
Benzo-a-pyrene	0.5 mg/kg	3.6 mg/kg				
Cadmium	1.0 mg/kg	2.1 mg/kg	17 mg/kg	2.9 mg/kg		2.5 mg/kg
Lead	180 mg/kg	820 mg/kg	2400 mg/kg			

Where a valid Soil Guideline Value exists for a contaminant where a Category 4 Screening Level has also been derived, it is anticipated that risk assessors will use the Category 4 Screening Level in line with the Part 2A Statutory Guidance. In the absence of a suitable C4SL, risk assessors should identify and select appropriate generic assessment criteria in accordance with established good practice....'

The general approach indicated in the SP1010 document has been adopted in this report (as appropriate), although the C4SL values have been used as a second tier of risk assessment, due to the difference in the level of 'acceptable' risk between the various GACs (which we will adopt as the first tier of risk assessment) and the C4SLs.

National Planning Policy Framework (NPPF)

In relation to the requirements of a contaminated land risk assessment, the Department for Communities and Local Government publication titled '*National Planning Policy Framework*' (NPPF), dated March 2012, provides the following commentary:

'*121. Planning policies and decisions should also ensure that:*

- *the site is suitable for its new use taking account of ground conditions and land instability, including from natural hazards or former activities such as mining, pollution arising from previous uses and any proposals for mitigation including land remediation or impacts on the natural environment arising from that remediation;*

- *after remediation, as a minimum, land should not be capable of being determined as contaminated land under Part IIA of the Environmental Protection Act 1990; and*

- *adequate site investigation information, prepared by a competent person, is presented.*'

The Defra SP1010 document states: '***The Part 2A Statutory Guidance and accompanying Impact Assessment were developed on the basis that Category 4 Screening Levels could be used under the planning regime, as they would be in Part 2A investigations directly***' [GeoDyne emphasis added].

Summary

Taking account of the foregoing, we consider that industry good practice is currently best represented by GAC (variously LQM/CIEH, Atkins ATRISKSOIL or EIC/AGS/CL:AIRE) that adopt a MRL as the foundation for its derivation. In the case of Lead (which is modelled on blood lead concentrations rather than typical exposure scenarios applicable to other contaminants), the relevant C4SL value has been adopted, as this incorporates the most up-to-date toxicological information in the derivation of the various end-use specific screening criteria.

In relation to the remaining C4SL values, these have been adopted as a second tier of generic assessment criteria, and will be utilised where the GAC has been exceeded at a Tier 1 generic level and where justified in a site-specific context. Whilst representing a LLTC, the C4SL values are considered to represent a suitably conservative assessment tool, given that they fall comfortably within Category 4.

In the following sections, screening criteria have collectively been referred to as Generic Assessment Criteria (GAC). The C4SL values have been referenced as such. The GAC/C4SL adopted herein, i.e. commercial, are included in the tables provided in Section 6.8.

6.4.2 Selection of Soil Organic Matter (SOM) Content

The SOM content and soil type are used to provide an assessment of the applicability of the Tier 1 GAC adopted (the GAC are typically based upon SOM of 1%, 2.5% and 6%, as applicable, with Defra C4SL based on the default assumption of a UK Sandy Loam soil with 6% SOM).

Determinands have in the first instance, been compared to GAC adopting a conservative SOM of 1%, or, in the absence of one of the former, a relevant C4SL value. Where the determinand exceeds the relevant GAC at 1% SOM, a site specific SOM may be adopted as appropriate to derive new GAC and the dataset reassessed.

6.4.3 Assessment Methodology

Taking account of the foregoing, an initial qualitative Tier 1 Soil Assessment has been undertaken to assess the soils at the site. We have adopted a policy whereby determinands within the dataset are individually compared to the relevant screening values.

Where determinands within the dataset are less than the appropriate Tier 1 GAC value the determinand is considered to be present at an acceptable concentration and no further assessment is required. However, where a determinand exceeds the relevant Tier 1 GAC value on at least one occasion further assessment is required and will be undertaken in accordance with CL:AIRE/CIEH '*Guidance on Comparing Soil Contamination Data with a Critical Concentration*'.

Further assessment will comprise a quantitative Tier 1 assessment to examine the contamination data set in more detail. The methodology for undertaking the statistical assessment is provided in Section 6.5 below.

6.5 Statistical Considerations

Statistical tests relating to contaminated land, typically referred to as a Mean and Maximum Value Tests, were detailed in Department for Environment, Food and Rural Affairs and The Environment Agency publication CLR 7 *'Assessment of Risks to Human Health From Land Contamination: An Overview of the Development of Soil Guideline Values and Related Research'*, dated 2002, ISBN 1-857-05732-5.

This guidance was superseded by publication of CL:AIRE/CIEH *'Guidance on Comparing Soil Contamination Data with a Critical Concentration'* dated May 2008.

6.5.1 Null and Alternative Hypothesis

In consideration of statistical guidance jointly published by CL:AIRE/CIEH *'Guidance on Comparing Soil Contamination Data with a Critical Concentration'*, statistical convention requires consideration of the Null Hypothesis (expressed as H_o) or an Alternative Hypothesis (expressed as H_1). Appropriate statistical tests are then applied to the data to assess whether the strength of evidence favours the Null or the Alternative Hypothesis.

For the purpose of the following contamination assessments and in accordance with the CL:AIRE/CIEH guidance the key question for the site is as follows.

Question - *'Is there sufficient evidence that the true mean concentration of a contaminant in soil (μ) is less than some critical concentration (Cc)?'*

The Null and Alternative hypotheses are therefore defined as follows.

The Null Hypothesis (H_o)

$\mu \geq Cc$ (i.e. Tier 1 or 2 Assessment Criteria).

The Alternative Hypothesis (H_1) (the question the selected statistical test is designed to answer)

$\mu < Cc$ (i.e. Tier 1 or 2 Assessment Criteria).

6.5.2 95th Percentile Upper Confidence Level Mean Values

The selected relevant statistical assessment undertaken to evaluate the Null and Alternative Hypotheses requires consideration of the 95th Percentile Upper Confidence Level Mean value (this is abbreviated as the UCL).

The UCL value takes account the number of samples tested, the data set mean and the standard deviation of the data set and applies a correction factor to take account of the uncertainty of the data set.

CL:AIRE/CIEH guidance states that *'...since the 95% UCL is at most times greater than the true population mean, it follows that if the 95% UCL is less than Cc, the assessor will know (with a defined high level of confidence) that the true population mean (μ, the value which is not known) is also likely to be less than Cc'.*

6.5.3 Considerations for Appropriate Dataset(s)

The CL:AIRE/CIEH statistical guidance requires consideration of the appropriateness of the dataset being subjected to the statistical testing and notes the following three key elements to be considered.

- Consideration of any non-detects within the dataset.
- Consideration of potential outliers within the dataset.
- Consideration of the statistical distribution of the data (i.e. normality/non normality).

6.5.4 Consideration of Normality of Dataset

CL:AIRE/CIEH statistical guidance notes that the choice of statistical test to be applied to the dataset will depend on the assumptions about the distribution of the data being tested. The assumptions of the statistical test adopted therefore must be appropriate to the distribution assumptions of the data being considered.

The CL:AIRE/CIEH statistical guidance details the following two key statistical tests.

- **The one-sample t test** - assumes the data being assessed is approximately normally distributed.
- **The one-sided Chebychev Theorem** - assumes the data being assessed does not demonstrate normality (method makes no assumption about the shape of the distribution).

CL:AIRE/CIEH statistical guidance, however notes *'...with large datasets, minor deviations from normality may be flagged as statistically significant even though small deviations from a normal distribution will not affect the reliability of the one sample t-test'*. The guidance goes on to note *'Conversely, datasets with a small sample size more easily pass normality tests.* ***Failing, however to detect non-normality in a small dataset is unlikely to compromise the validity of the one sample t-test'*** [GeoDyne emphasis added].

CL:AIRE/CIEH statistical guidance further notes *'When considering which of the two tests to use, however, assessors should bear in mind that, in general, the one-sample t-test is more powerful that the method based on the Chebychev Theorem...****Given that the one sample t-test is also not sensitive to moderate departures from normality, it is recommended that assessors use the t-test unless there is good evidence that the dataset departs significantly from normality'*** [GeoDyne emphasis added].

On the basis of the above, an assumption of data normality has been made and the one-sample t-test adopted accordingly.

6.5.5 Consideration of Non-Detects within the Dataset.

The dataset may reveal the presence of non-detects for a number of the determinands tested. Where this occurs, we have adopted the LOD (i.e. 1.0LOD) as the chemical concentration, which provides a suitably conservative approach. However, please note that GACs have only been used for determinands where they are present at concentrations in excess of the LOD on at least one occasion.

6.5.6 Consideration of Outliers

The CL:AIRE/CIEH statistical guidance advises that *'...if outliers are identified, assessors have to decide whether they represent genuine soil concentrations or are the result of an error'*.

The guidance further notes that outliers should only be excluded from a dataset where they *'...are obviously and demonstrably the result of an error that can be identified and explained'* or *'...clearly indicate that more than one soil population exists within the dataset and this can be justified by (or informs the further development of) the conceptual model- in which case the different population expressed by the outlier(s) should be explored in more detail'*.

Taking account of the foregoing, we have adopted a policy of interrogating the relevant dataset to calculate the UCL and to ascertain the possible presence of statistical outliers (where relevant). At this point the possible relevance of statistical outliers to the interpretation of the data is considered, in accordance with the following matrix.

TABLE 5 – OUTLIER DECISION MATRIX

	UCL < GAC	UCL > GAC
Outlier Test reveals No Hotspot(s)	Determinand present at acceptable concentrations.	Pervasive contamination present in soil at unacceptable concentrations.
Outlier Test reveals Hotspot(s)	Determinand present at acceptable concentrations. Possible second population identified. Only of potential concern where outlier is at an individual concentration in excess of the Tier 1 GAC.	Pervasive contamination present in soil at unacceptable concentrations with possible hotspots of contamination identified.

6.5.7 CLEA Averaging Area

The CLEA Model requires consideration of an averaging area, i.e. an area within which the UCL is calculated and compared to the Tier 1 GAC. Within our assessments (where appropriate) the entire site has been adopted as the averaging area, in the first instance.

6.6 Sampling Strategy

Our sampling strategy is based on a review of the historical, geological and environmental information obtained as part of our Phase I Desk Study, together with the current site setting and the ground conditions encountered during our Phase II exploratory works, taking account of the proposed end-use.

The positions of the exploratory holes were typically chosen to provide general site coverage, although WS3 and WS6 were both targeted to the area immediately around the existing UST and pump dispenser situated in the southeast of the site.

Table 6 summarises the reasoning behind the exploratory hole positions.

TABLE 6 – REASONING FOR EXPLORATORY HOLE LOCATION

Exploratory Hole Reference	Reasoning Behind Location
WS3 & WS6	Targeted around the location of the existing diesel UST
WS1, WS2, WS4 & WS5	General site coverage avoiding known utilities
Key WS – Window Sample Borehole	

The ground conditions encountered during our Phase II works revealed the presence of two distinct types of material i) Made Ground and ii) Natural Strata comprising Terrington Beds.

Representative samples were obtained during our Phase II works and subjected to chemical analysis for a suite of contaminants deemed appropriate based on the land use assessment.

6.7 Contamination Analysis

A total of 6No. standard chemical contamination tests (including speciated PAH and TOC) were carried out on selected soil samples obtained during the site works, which comprised 3No. tests of the Made Ground (including one on the possible buried topsoil at WS3) and 3No. tests of the underlying Natural Strata.

For initial assessment purposes, we have combined the results into a single dataset, for individual comparison of the reported determinand concentrations against appropriate Tier 1 GAC.

6.8 Contamination Soil Test Results

6.8.1 Chemical Contamination Analysis

The contamination assessment for the Made Ground and Natural Strata analysed at the site is summarised in Table 7.

TABLE 7 – SUMMARY OF TIER 1 GENERIC ACCEPTANCE CRITERIA DATA ASSESSMENT COMMERCIAL END-USE

Contaminants – Potentially Harmful to Human Health	No. of Samples Tested	Concentration Range (mg/kg)	Tier 1 GAC (mg/kg)	C4SL (mg/kg)	UCL (mg/kg)	Tier 1 GAC Exceeded (Yes/No)
Metals						
Arsenic	6	4 - 19	640 S4UL	640	NA	No
Chromium III	6	9 - 23	8600 S4UL	-	NA	No
Copper	6	3 - 63	68000 S4UL	-	NA	No
Lead	6	6 - 340	2300 C4SL	2300	NA	No
Nickel	6	9 - 59	980 S4UL	-	NA	No
Zinc	6	23 - 310	730000 S4UL	-	NA	No
Speciated PAHs						
Phenanthrene	6	<0.1 - 0.6	22000 S4UL	-	NA	No
Anthracene	6	<0.1 - 0.2	520000 S4UL	-	NA	No
Fluoranthene	6	<0.1 - 2.0	23000 S4UL	-	NA	No
Pyrene	6	<0.1 - 1.8	54000 S4UL	-	NA	No
Benzo(a)anthracene	6	<0.1 - 1.0	170 S4UL	-	NA	No
Chrysene	6	<0.1 - 0.9	350 S4UL	-	NA	No
Benzo(b/k)fluoranthene	6	<0.1 - 1.7	44 S4UL	-	NA	No
Benzo(a)pyrene	6	<0.1 - 0.9	35 S4UL	77	NA	No
Indeno(123-cd)pyrene	6	<0.1 - 0.5	500 S4UL	-	NA	No
Dibenzo(ah)anthracene	6	<0.1 - 0.1	3.5 S4UL	-	NA	No
Benzo(ghi)perylene	6	<0.1 - 0.7	3900 S4UL	-	NA	No
Speciated TPHs						
Aliphatic C8-C10	2	<0.10 - 0.18	27 S4UL	-	NA	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 commercial end-use.
- See comments below table (where relevant).
NA – UCL not applicable as all individual concentrations are present at concentrations individually below the GAC.

All of the determinands assessed were present either 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 commercial end-use.

6.8.2 Asbestos Screening Tests

A total of 3No. soil samples (targeted to the Made Ground encountered) were screened by the laboratory under a microscope for the presence of asbestos fibres. No asbestos was revealed by the laboratory within any of the samples analysed.

6.9 Contamination Assessment Summary

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

Given the low contaminant concentrations revealed by the testing, together with the low groundwater sensitivity of the area and the absence of significant surface water features near to the site, there are considered to be no specific risks posed to Controlled Waters by the findings of the laboratory analysis undertaken.

7.0 CONCEPTUAL SITE MODEL

7.1 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 with respect to Part 2A.

'Under Part 2A, for a relevant risk to exist there needs to be one or more contaminant-pathway-receptor [CPR] *linkages – "contaminant linkage" – by which a relevant receptor might be affected by the contaminants in question. In other words, for a risk to exist there must be contaminants present in, on or under the land in a form and quantity that poses a hazard, and one or more pathways by which they might significantly harm people, the environment, or property; or significantly pollute controlled waters. For the purposes of this guidance:*

(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, an ecosystem, property, or controlled waters. The various types of receptors that are relevant under the Part 2A regime are explained in later sections.
(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. All three elements of a contaminant linkage must exist in relation to a particular land before the land can be considered potentially to be contaminated land under Part 2A, including evidence of the actual presence of contaminants. The term "significant contaminant linkage", as used in this Guidance, means a contaminant linkage which gives rise to a level of risk sufficient to justify a piece of land being determined as contaminated land. The term "significant contaminant" means the contaminant which forms part of a significant contaminant linkage.'

With respect to the presence of background levels of contaminants, section 3.21 to 3.23 states '*The Part 2A regime was introduced to help identify and deal with land which poses unacceptable levels of risk. It was not intended to apply to land with levels of contaminants in soil that are commonplace and widespread throughout England or parts of it, and for which in the very large majority of cases there is no reason to consider that there is an unacceptable risk.*

Normal levels of contaminants in soil should not be considered to cause land to qualify as contaminated land, unless there is a particular reason to consider otherwise. Therefore, if it is established that land is at or close to normal levels of particular contaminants, it should usually not be considered further in relation to the Part 2A regime...

For the purpose of this Guidance, "normal" levels of contaminants in soil may result from:

(a) The natural presence of contaminants (e.g. caused by soil formation processes and underlying geology) at levels that might reasonably be considered typical in a given area and have not been shown to pose an unacceptable risk to health or the environment.
(b) The presence of contaminants caused by low level diffuse pollution, and common human activity other than specific industrial processes. For example, this would include diffuse pollution caused by historic use of leaded petrol and the presence of benzo(a)pyrene from vehicle exhausts, and the spreading of domestic ash in gardens at levels that might reasonably be considered typical.'

In selecting appropriate generic assessment criteria Section 3.27 of the Guidance states:

'It is common practice in contaminated land risk assessment to use "generic assessment criteria" (GACs) as screening tools in generic quantitative human health risk assessment to help assessors decide when land can be excluded from the need for further inspection and assessment, or when further work would be warranted'.

With respect to assessing contaminated land, section 4.17 of the Guidance states:

'In deciding whether or not land is contaminated land on grounds of significant possibility of significant harm to human health, the local authority should use the categorisations described in paragraphs 4.19 – 4.30 below. Categories 1 and 2 would encompass land which is capable of being determined as contaminated land on the grounds of significant possibility of harm to human health. Categories 3 and 4 would encompass land which is not capable of being determined on such grounds.'

In relation to the use of GAC values in the assessment of contaminated land, section 3.29 of the Guidance states:

'GACs relating to human health risk assessment represent cautious estimates of levels of contaminants in soil at which there is considered to be no risk to health or, at most, a minimal risk to health. With regards to such GACs:

(a) They may be used to indicate when land is very unlikely to pose a significant possibility of significant harm to human health. This is on the basis that they are designed to estimate levels of contamination at which risks are likely to be negligible or minimal and far from posing a significant possibility of significant harm to human health.
(b) They should not be used as direct indicators of whether a significant possibility of significant harm to human health may exist. Also, the local authority should not view the degree by which the GACs are exceeded (in itself) as being particularly relevant to this consideration, given that the degree of risk posed by land would normally depend on many factors other than simply the amount of contaminants in soil.
(c) They should not be seen as screening levels which describe the boundary between Categories 3 and 4 in terms of Section 4 (i.e. the two Categories in which land would not be contaminated land on grounds of risk to human health). In the very large majority of cases, these SGVs/GACs describe levels of contamination from which risks should be considered to be comfortably within Category 4.

(d) They should not be viewed as indicators of levels of contamination above which detailed risk assessment would automatically be required under Part 2A.

(e) They should not be used as generic remediation targets under the Part 2A regime. Nor should they be used in this way under the planning system, for example in relation to ensuring that land affected by contamination does not meet the Part 2A definition of contaminated land after it has been developed.'

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 March 2012). Reference has also been made to the Contaminated Land Statutory Guidance (referenced above), although this is primarily concerned with Local Government determinations of Statutory '*Contaminated Land*', which is separate to planning framework requirements.

7.2 Contaminant-Pathway-Receptor [CPR] Considerations

The following CPR assessment has been undertaken based on the assumption of a commercial end-use for the proposed development.

7.3 Consideration of Potential Sources of Contamination [C]

Based on the findings of our works, the potential key sources of contamination at the site are considered to be the following:

- Metals or metalloids associated with any Made Ground.
- Oil/fuel hydrocarbons associated with the diesel UST, vehicle maintenance or historical operations/spillages on site.
- Polycyclic Aromatic Hydrocarbons (PAHs) from any ashy inclusions and/or carbonaceous inclusions in the near surface soils.
- Asbestos from former buildings/structures.
- Potentially hazardous ground gases (i.e. methane and carbon dioxide) from on- or off-site sources.

7.4 Consideration of Potential Pathways [P]

The potential pathways at the site are primarily:

- Direct ingestion of soil.
- Inhalation of dust and vapours.
- Direct skin contact with the ground.
- Direct contact with building materials.
- Vertical and lateral migration of contamination.
- Vertical and lateral migration of potentially hazardous ground gases/vapours.

7.5 Consideration of Potential Receptors [R]

The potential receptors at the site are:

- The construction personnel (i.e. site workers) involved with the development of the site (typically short term (acute) exposure).
- The final end users (i.e. employees - typically long term (chronic) exposure or site visitors (typically acute exposure).
- Neighbouring properties (i.e. off-site receptors).

- Controlled Waters (i.e. underlying groundwater).
- Buildings/construction materials.

7.6 Summary

GeoDyne Limited's conceptual site model of possible CPR pollutant linkages, applicable to the proposed site usage and based on the information currently available, is summarised in Table 8.

TABLE 8 – SUMMARY OF CPR ASSESSMENT

Contaminant	Pathway	Receptor	Comments	Plausible Pollutant Linkage	Possible Mitigation	Possible Statutory 'Contaminated Land' following mitigation
Contaminated Soils	***Direct Ingestion / Direct Contact*** ***Inhalation of Dust and Vapours***	***Site Workers***	The Made Ground and Natural Strata may be regarded as uncontaminated, based on a commercial end-use and the determinands analysed.	X	Site workers to wear appropriate PPE and conform to general health and safety requirements. Post-demolition works should be undertaken to confirm the findings of the contamination testing undertaken to date.	X
Contaminated Soils	***Direct Ingestion / Direct Contact*** ***Inhalation of Dust and Vapours***	***End Users (Employees& Site Visitors)***	The Made Ground and Natural Strata may be regarded as uncontaminated, based on a commercial end-use and the determinands analysed.	X	Post-demolition works should be undertaken to confirm the findings of the contamination testing undertaken to date. Tank removal and validation works will be required for the existing UST and pump dispenser in the southeast of the site.	X
Contaminated Soils	***Vertical and Lateral Migration***	***Neighbouring properties (off site receptors)***	The Made Ground and Natural Strata may be regarded as uncontaminated, based on a commercial end-use and the determinands analysed. No elevated hydrocarbon concentrations have been encountered within the boreholes targeted around the existing UST in the southeast of the site.	X	Post-demolition works should be undertaken to confirm the findings of the contamination testing undertaken to date. Tank removal and validation works will be required for the existing UST and pump dispenser in the southeast of the site.	X
Contaminated Soils	***Vertical and Lateral Migration***	***Controlled Waters***	The superficial and bedrock geologies beneath the site are classified as Unproductive Strata and the site does not lie within a SPZ.	X	No specific mitigation required, based on the findings of the works undertaken.	X

TABLE 8 – SUMMARY OF CPR ASSESSMENT						
Contaminant	**Pathway**	**Receptor**	**Comments**	**Plausible Pollutant Linkage**	**Possible Mitigation**	**Possible Statutory 'Contaminated Land' following mitigation**
			No significant Controlled Water receptors have been identified as part of the desk study works. In addition, no significant potentially mobile contamination has been revealed by the testing undertaken, at levels that are considered sufficient to pose a risk to Controlled Waters.		Post-demolition works should be undertaken to confirm the findings of the contamination testing undertaken to date. Tank removal and validation works will be required for the existing UST and pump dispenser in the southeast of the site.	
Water Soluble Sulphate/Acid Contaminated Soils	***Direct Contact***	***Building Materials***	Design Class DS-1/ACEC Class AC-1. (BRE Spec. Digest 1:2005).	X	Adopt appropriate concrete mix for all concrete in contact with the ground.	X
Radon	***Vertical and Lateral Migration***	***Site Users & Building Envelope***	Based on the Desk Study works, the site does not lie within an area affected by radon.	X	No specific precautions required in proposed dwellings.	X
Ground Gases	***Vertical and Lateral Migration***	***Site Users & Building Envelope***	Based on the ground gas monitoring undertaken, the site may be classified as 'CS1' in accordance with CIRIA C665 guidance.	X	No specific precautions required in proposed dwellings.	X

KEY

Where text is in ***Bold Italic*** item is potentially present. Where normal text is used item is not present/plausible.

X - Pollutant linkage not plausible.
✔ - Pollutant linkage plausible, mitigation required.
? - Insufficient information, further work necessary.
The requirement for mitigation is subject to review and confirmation by the appropriate regulatory authority.

In the foregoing CPR assessment, determinands identified by chemical analysis are only considered to be contaminated with respect to generic guidance where the determinand is present at concentrations above their respective screening criteria.

8.0 CONCLUSIONS & RECOMMENDATIONS

8.1 Site Summary

The site is indicated to have been utilised as part of an auction house in the early 1900s, prior to being developed with industrial premises in the 1960s. The site has subsequently been subjected to various phases of development, with the recent land use associated with a depot for Langwith Construction.

A fuel pump dispenser and UST (diesel) are located in the southeastern corner of the site, with a spill kit stored on site (and seemingly having recently been used based on observations during our works). An interceptor (heavily silted) and vent stack are located in the west of the site.

The site is indicated to be underlain by superficial deposits comprising the Terrington Beds (Tidal Flat Deposits), which can include discontinuous bands or pockets of Peat. At depth, the bedrock geology comprises the West Walton Formation.

8.2 Ground Conditions

Made Ground was encountered across the site to depths ranging between 0.60m and 3.00m begl, and typically comprised surfacing materials over very loose to medium dense clayey/silty gravelly sand, compact sandy gravel or soft to firm slightly sandy gravelly clay. The gravel component locally included various anthropogenic materials, incorporating brick, concrete, coal, slate, ash, slag, timber and plastic. A possible buried topsoil layer was locally encountered between 0.80m and 1.25m begl.

Beneath the Made Ground, natural soils typically comprising soft (becoming soft to firm) very sandy very silty CLAY or soft (becoming soft to firm) clayey very sandy SILT were encountered to depths ranging between 2.10m to 2.80m begl. Below this depth, very loose to medium dense wet very silty SAND, locally with pockets of firm to stiff Silt, was encountered until termination of the boreholes at depths of up to 5.00m begl.

8.3 Foundation Design

Due to the typically low strength near surface superficial deposits underlying the site (with nett allowable ground bearing pressures of around 40-50kN/m^2 applicable at depths of around 1.00m begl within the natural soils), together with the presence of groundwater at depths of below 2.00m begl, the use of traditional foundations (i.e. pad, strip or trench fill) are unlikely to be suitable for a proposed commercial development.

On the basis of the foregoing, it is considered that a piled foundation represents the most likely solution for adoption at the site. However, given the potential for low competency strata throughout the Terrington Beds soil profile (potentially to significant depths), it is recommended that a limited number of deeper cable percussive boreholes are advanced at the site. These boreholes will assist specialist piling contractors in selecting and designing the most appropriate type of pile to adopt at the site.

An alternative foundation solution such as rafts may potentially be possible, subject to plot specific trial pitting during a post-demolition phase of exploratory works.

8.4 Floor Slab Design & Ground Gas Precautions

Based on the programme of ground gas monitoring undertaken, the site may be classified as Characteristic Situation CS1 in accordance with CIRIA guidance; i.e. no specific precautions in relation to ground gas are required in the proposed development. However, given the potential for peat bands and horizons within the Terrington Beds strata, it may be considered good practice to include a lapped and taped ground gas resistant membrane (in accordance with the British Board of Agrément (BBA) certification) within the foundation solution for the proposed development, with all service penetrations suitably sealed to the membrane.

Ground bearing floor slabs may therefore be adopted at the site following geotechnical improvement of the Made Ground. However, consideration should be given to the low strength of the Terrington Beds strata, which may result in settlement issues for either the slabs or external levels where appropriate precautions are not taken.

Alternatively, 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).

8.5 Building Near Trees

Foundation designs may require adjusting when building near existing, proposed or recently removed trees, due to the presence of shrinkable soils underlying the site of low volume change potential (as confirmed by laboratory testing). This may include heave precautions for piles.

We would note the presence of many mature trees and hedgerows around the site, and we would therefore recommend that a suitable arborist survey is undertaken (where not already completed) where detailed foundation design needs to be considered.

8.6 Watching Brief

Historical maps suggest the presence of a pumped well in the early part of the Twentieth Century in the northeastern part of the site, although no evidence of such a feature was readily apparent during our walkover.

As a precautionary measure, we would recommend that a general watching brief is maintained by the Contractor during enabling works at the site. Where such a feature is encountered during the enabling works, it is recommended that the well is infilled with cement/grout to prevent future instability issues. Given the preliminary proposed layout of the redevelopment (i.e. with buildings located in the west of the site), and the indicated location of this feature (in the northeast), it is unlikely to affect foundation design for the proposed medical centre.

8.7 Coal Mining

No specific investigation or mitigation measures in relation to coal mining issues are considered to be necessary at the site.

8.8 Radon

No radon precautions are required at the site.

8.9 Water

Water was encountered at depths typically below around 2.00m begl during the course of the investigation works, although water seepages were locally encountered at shallower depth (with the soils consistently wet below 1.00m begl within WS1).

During the programme of groundwater monitoring, water levels were recorded within the wells at depths ranging between 0.98m and 1.43m begl, which appears to generally correspond to the water strikes observed during the site works.

On the basis of the foregoing, dewatering of excavations (particularly deeper excavations for sewers construction etc.) should be anticipated to be required. Some dewatering may also be required where excavations are left open during periods of adverse weather.

8.10 Excavations / Stability

The boreholes were typically cased to depths of 4.00m begl to prevent sidewall collapse. Where casing was not utilised, sidewall instability was noted within the Made Ground (particularly the deep Made Ground at WS1, which ultimately led to the requirement to adopt casing at this location) and the water-bearing granular natural soils at depth.

On the basis of the borehole works, excavations may require trench support for stability and health and safety reasons. The assessment of excavations and provision of support will be the responsibility of the contractor on site.

The natural cohesive soils may be subject to deterioration and softening if excavations are left open and exposed to wet weather. Any softened soils should be removed from excavations prior to the pouring of concrete (where applicable).

8.11 Sulphate Classification

In accordance with BRE 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, based on the assumption of a Brownfield location and the presence of potentially mobile groundwater conditions beneath the site.

Therefore, an appropriate concrete mix should be adopted in accordance with BRE Special Digest 1 for all buried concrete in contact with the ground.

8.12 California Bearing Ratios (CBRs)

A CBR value of less than 2% may be anticipated in the Made Ground and a CBR value of around 2% to 3% may be anticipated within the shallow Natural Strata, subject to confirmation by in-situ testing.

8.13 Surface Water Drainage

The use of soakaways for surface water disposal is considered unlikely to be feasible based on the presence of typically low permeability cohesive soils near surface (i.e. Clay and Silt) and the presence of water-bearing granular (Sand) deposits beneath. It is recommended that alternative methods of draining the site are investigated at this stage.

8.14 Contamination Assessment

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

Given the low contaminant concentrations revealed by the testing, together with the low groundwater sensitivity of the area and the absence of significant surface water features near to the site, there are considered to be no specific risks posed to Controlled Waters by the findings of the laboratory analysis undertaken.

We would additionally note that no visual or olfactory evidence of significant contamination was identified during the course of the exploratory investigation works.

8.15 Remediation Proposals

Based on the findings of the soils testing undertaken to date, no general remediation requirements (such as a remedial capping layer) are considered to be required.

However, it is recommended that this is confirmed by a programme of post demolition exploratory works, which should include exploratory positions advanced beneath the footprints of the existing buildings.

In addition, the interceptor in the west of the site and the UST in the southeast of the site (and any other such features uncovered during enabling works) should be decommissioned and removed during the course of enabling works, together with any associated pipework. It is recommended that these works are observed by a suitably qualified Engineer, with records of the excavations obtained. Where any potentially contaminated soils are encountered within the excavation, these should be removed pending off-site disposal, and a suitable programme of validation works undertaken (including obtaining soil samples for laboratory analysis).

8.16 Imported Soils

Any topsoil and subsoil proposed to be imported to site should be chemically tested at source to ensure it is suitably clean (prior to importation) in accordance with CLEA/generic guidance. Imported topsoil should ideally conform to BS3882: 2007 *'Specification for topsoil and requirements for use',* with respect to nutrient levels etc.

It is recommended that the results of the chemical analysis on the soils proposed for importation are forwarded to the Local Authority (Environmental Health Officer) for approval (prior to importation).

8.17 Off-Site Disposal

If off-site disposal is required the chemical testing regime can be different to the chemical testing required to assess the suitability of the soils for retention on site and the risks to Human Health 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.

8.18 Asbestos Survey

We would recommend that a suitable asbestos survey is undertaken prior to demolition of the existing buildings/structures, with any encountered/identified asbestos removed off-site by suitably qualified specialists.

8.19 Construction Workers

It is recommended that construction personnel involved with direct contact with the soils at the site use appropriate PPE equipment (i.e. boots, gloves and overalls) 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.

8.20 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.

8.21 Unforeseen Circumstances

Should any areas of potentially contaminated soil be encountered during site construction works we would recommend consultation with GeoDyne Limited to ensure that our recommendations continue to apply.

Any potentially contaminated soils should be left in-situ and subjected to further assessment, to potentially include further chemical testing and risk assessment.

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

i. Suspected contaminated material will remain in-situ.
ii. GeoDyne Limited to be notified. We will then undertake a visual assessment of the possible contamination, followed by appropriate sampling/testing (as necessary).
iii. If necessary, an appropriate strategy to remove/remediate the contamination will be submitted to the Local Authority.

8.22 Licences, Permits, Registrations, Plans & Approvals

The Contractor/Developer is responsible for, and must ensure that, all necessary licenses, permits, plans, registrations and approvals are in place prior to commencing with the earthworks at the site. These will include any Mobile Treatment Licenses (MTLs), Materials Management Plans (MMPs), Site Waste Management Plans (SWMPs) and/or Environmental Permits as necessary to enable the completion of the proposed works.

8.23 Further Works

The following further works are recommended at the site:

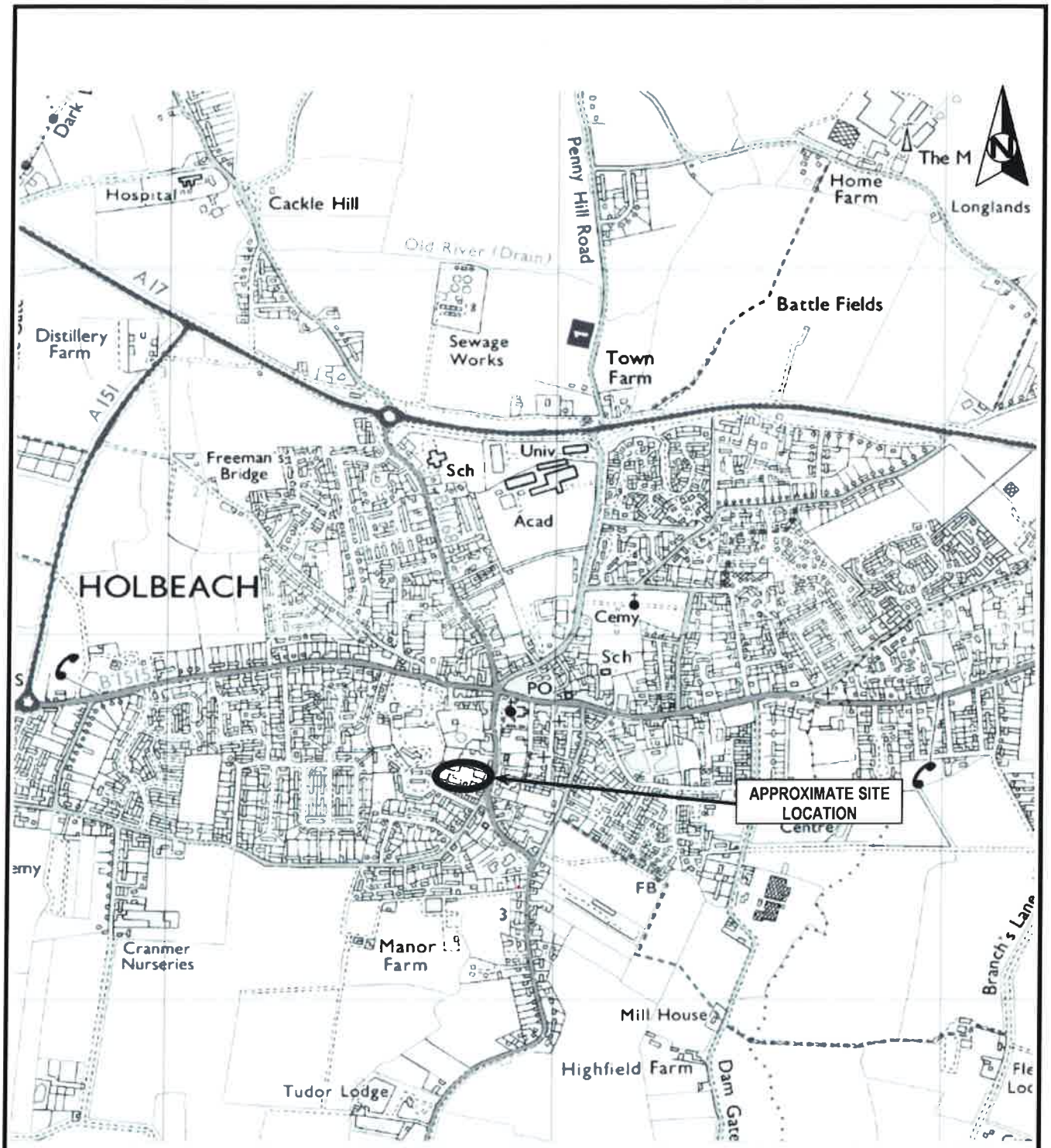
- Advance a series of cable percussive boreholes to assist in the design of foundations for the proposed redevelopment.

- A programme of post-demolition trial pitting and soil sampling to confirm the findings of the contamination assessment detailed herein, and to inform the requirement for any general remedial requirements necessary at the site.
- The decommissioning and removal of the interceptor and UST identified at the site, together with appropriate validation works.

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APPENDIX I

Site Location Plan
(Figure No. D34136/01)



REPRODUCED FROM THE ORDNANCE SURVEY MAP WITH THE PERMISSION OF THE CONTROLLER OF HER MAJESTY'S STATIONERY OFFICE.
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Project No.	D34136	Drawn	DJH
Client	Langwith Construction	Checked	PK
Project	Church Street Holbeach	Approved	PK
		Scale	NTS
		Date Drawn	03/02/2015
Title	Site Location Plan	Rev.	
		Figure No.	**D34136/01**

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