



**Brookfield
Providence Hill
Bursledon
Hampshire**

**Ground Investigation
Report**





Geo-Environmental Report

Brookfield Providence Hill Bursledon Hampshire

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16-024 – 02 /Rev F	Site Plan Proposed

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Factual Information

1 Introduction

1.1 Instructions

Instructions were received from Triangle Property Developments Ltd to undertake a geo-environmental ground investigation report at a site known as Brookfields, Providence Hill, Hampshire.

It is understood that the site is to be redeveloped for approximately 19 residential properties including both detached and semi-detached houses with private gardens. The development will also include new access roads, parking areas, areas of soft landscaping with new planted trees. A large attenuation pond is also shown at the north east corner of the site.

A copy of the proposed draft development plan provided to Opus after the ground investigation site works were completed is included in the Drawings section of this report.

It is recommended that the reader of this report is also familiar with the Desk Study Report ref. E-E1663.00 DS/Rev A, issued by Opus alongside this report.

1.2 Report Objectives

The objective of the investigation was to carry out a Phase II Geo-environmental Survey of the site. The aim of the site investigation was to obtain information relating to the ground conditions in order to obtain:

- An initial assessment of potential contamination on the site.
- Soil, gas and groundwater data.
- Provide a preliminary appraisal of requirements for foundations and ground floor slab, and suitability of the existing ground conditions for potential soakaways.

1.3 Limitations

The client's attention is drawn to Appendix H to this report for the Conditions and Limitations.

This report has been prepared by Opus International Consultants (UK) Ltd (Opus) with all reasonable skill, care and diligence, within the terms of the Contract with The Client (Triangle Property Developments Ltd) and taking account of the information made available by The Client, as well as the manpower and resources devoted to it by agreement with The Client. Opus disclaims any responsibility to The Client and others with respect to any matters outside the scope of the above Contract.

This report has been produced on behalf of The Client, and no responsibility is accepted to any other Third Party for all or any part. This report should not be relied upon or transferred to any other parties without the express written authorisation of Opus. If any unauthorised Third Party comes

into possession of this report, they rely on it at their own risk and the authors owe them no duty of care or skill.

Whilst this report may express an opinion on the possible configuration of strata, contaminants or groundwater between or beyond exploratory hole positions, or on the possible presence of features based on visual, verbal or published evidence, this is for guidance only and no liability can be accepted for any inaccuracy.

This report has been prepared on the understanding that the development is to comprise of a residential end land use. Should the proposed site usage change significantly from the above, the contents of this report will require review and amendment as appropriate.

The comments on groundwater conditions are based on observations made at the time of the investigation and also the groundwater level monitoring data. It should be noted however, that groundwater levels may vary from those reported due to seasonal or other effects.

The site plans enclosed in this report should not be used for scaling purposes.

2 The Site

2.1 Location and Access

The site is situated immediately north east of Providence Hill (A27 carriageway) near Bursledon village and centred on National Grid Reference (NGR) 450590, 109690.

The site is a triangular shaped plot covering an approximate size of 1.0 Ha and comprises a mixture of both residential land associated with No. 4 Providence Hill and open grassed land that is currently not used.

The main access to the site is from Providence Hill via the driveway to property No. 4 at the south east corner of the site. A further gated access into the site is found further to the west off Providence Hill.

A site location plan is presented in the drawings section of this report.

2.2 Site Description

The site was noted to fall in level downwards from Providence Hill (A27) towards the northern site boundary. The site level at the higher west corner is at 53m AOD and the lower north east corner at 35m AOD.

A stream was located adjacent to the northern site boundary within which a steady trickle of water was noted flowing to the east during the site walkover survey (January 2017).

Mature trees were found along each of the site boundaries, with recently removed trees located in the western section of the site.

No. 4 Providence Hill was located on the higher ground near the south east corner of the site. The property had a large garden at its rear, which covered approximately 50% of the site, with the majority of this surfaced with grass. Approximately seven small to medium sized shed buildings

were noted across this area that were used for the storage of garden machinery, greenhouses and also for housing ducks and chickens. The garden was also used for typical recreational purposes with a small above ground swimming pool and children's swing noted near the north east corner. It is understood that a well was located within the garden at the rear of the residential building, however this was not identified during the site walkover.

The remaining section of the site located to the north west of No. 4 Providence Hill had been left unused and comprised a mixture of grasses, occasionally ivy clad on the surface and shrubs. A denser set of grasses more applicable to wetland was observed towards the North West site boundary. This area was found to be very soft underfoot with some 'ponding' of water noted near the surface. Close to this section of the site was evidence of what appeared to be recently felled trees with frequent medium sized tree stumps.

As a result of the sloping ground the main access driveway to No. 4 Providence Hill was supported by an approximately 1m high retaining wall. The wall was showing some signs of distress and cracking on its face. The land situated immediately inside the site next to the additional gated access off Providence Hill (further north) had also been built up to support vehicle access. The built up material was supported by a smaller approximately 0.50m high concrete blockwork wall which was also showing distress with cracking and some rotation noted.

3 Desk Study

3.1 Summary

A desk study report has been undertaken by Opus for the site (Reference EE1663.00 DS dated May 2017). A summary of the principal findings from the desk study is presented Table 3.1.

Table 3.1: Summary of Desk Study Report findings

Environmental Consideration	Comments
Site History	The historical map review revealed that the site appeared to have remained relatively similar in layout throughout the end of the 19th Century to present day. The site may have historically been used as arable land and it is understood that a part of the site was more recently used for growing strawberries and soft fruit bushes. The eastern half of the site appeared to have undergone development with the construction of a residential property, garden and outbuildings while the western half of the site was until recently an area of woodland. No significant evidence of contamination was observed during the site walkover survey. However, two small sections of the site had been used for bonfires. Partially burnt material can be a potential source of a range of contaminants including PAHs and metals.

Environmental Consideration	Comments
	The walls and roof of the sheds and outbuildings within the garden on site were observed to consist of visually suspected cement bonded asbestos sheeting. One of the current owners of the site had informed Opus that some of the land had been used for growing strawberries and soft fruit bushes previously and that pesticides were used during this operation. An inert landfill historically bordered the north of the site. The closest reported area of potentially infilled land is located approximately 264m to the south east of the site. The risk of ground gas impacting the site was therefore considered to be low.
Geology	Reference to the British Geological Survey's Geology of Britain viewer website indicates that the solid geology beneath the site consists of the Wittering Formation. No superficial geology is recorded as being present on site.
Hydrogeology	The solid geology underlying the site constitutes a Secondary A Aquifer. The site is not located within an Environment Agency designated Groundwater Source Protection Zone. No licensed water abstraction was reported within 1km of the site and the closest licensed discharge consent is located approximately 280m south east of the site.
Hydrology	The nearest surface water feature is a tertiary river that runs along the northern site boundary. An additional water feature (pond) is located approximately 75m north of the northern site boundary.
Environmental	Eight pollution incidents to controlled waters were reported to have occurred within 500m of the site. The closest incident occurred approximately 37m north of the site and involved the release of approximately 1000ltr of kerosene fuel oil from a tank. The Environment Agency recorded the severity of the incident as a Category 3 minor incident. The incident occurred in February 1997.

Environmental Consideration	Comments
	The other pollution incidents to controlled waters were reported to have taken place over 200m from the site, all of which occurred prior to 1999 and all were recorded as category 3 minor incidents. A historic inert landfill is located immediately north of the site.
Potential sources of Contamination	The following potential sources of contamination were identified within the conceptual site model: • Use of agrochemicals – pesticides • Asbestos Containing Materials (ACM) associated with workshop and outbuildings • Bonfire activities on site • Ground gas from neighbouring historic landfill

4 Investigation Methodology

4.1 Objectives

Given the findings of the desk study searches and with reference to the preliminary conceptual model for the site contained within the desk study report, the objectives of the intrusive investigation are as follows:

- To characterise the ground conditions across the proposed development area.
- To confirm potential pollutant linkages identified within the Preliminary Conceptual Site Model.
- To undertake a qualitative assessment of risks posed by any identified contaminants to the recognised receptors.
- To provide a preliminary geotechnical assessment of the proposed development area in the context of the proposed development.

The investigation does not include for a slope stability assessment for the site prior to or following the proposed construction.

The site work was carried out on the 26th and 27th January 2017 and included window sample drilling and trial pitting under the supervision of Chris Summers and David Crellin of Opus. The exploratory hole location plan ref. drawing number E-E1663.00 101/P1 is presented in the Drawings section of this report.

Table 4.1 below summarises the rationale behind the exploratory hole locations:

Operation	locations	Rationale
Window Sampling	WS1 to WS7	Assess geotechnical conditions of soil to a maximum depth of 4.45m begl using a windowless sampling rig. Establish density of the underlying strata by undertaking standard penetration tests (SPT's) at 1m centres in the window samples holes. Collect samples of near surface soils for laboratory environmental and geotechnical testing. Complete in all window sample holes dual purpose gas/groundwater installations to allow subsequent ground gas and water level monitoring.
Trial Pitting	TP1 to TP6	Excavations carried out using a JCB 3CX excavator to maximum depth of 2.20m begl. Assess geotechnical and environmental conditions of soil and collect samples of near surface soil for laboratory testing. Complete soil infiltration testing within 3No. trial pit locations across the site.
	SP1 to SP4	Shallow excavations carried out using a JCB 3CX excavator or hand tools to maximum depth of 0.1m begl through the stockpile material or surface veneer. Assess environmental conditions of soil and collect samples of near surface soil for laboratory testing.
	DCP 1 to DCP 7	Assess the California Bearing Ratio (CBR) value of the existing subgrade using DCP (Dynamic Cone Penetration). Testing carried out to maximum level of 0.85m begl.

4.2 Clearance of Underground Services

Prior to commencing ground investigations, statutory utility plans on record for the site were reviewed. Where underground services were suspected, exploratory positions were relocated in the interests of health and safety.

In addition to the above, the positions were scanned with a cable avoidance tool (CAT) and signal generator as a further precautionary measure prior to final positioning of each exploratory hole.

4.3 Site Works

All exploratory holes were logged by a qualified Opus Geo-Environmental Engineer, generally in accordance with BS EN 14688 'Geotechnical Investigation and Testing – Identification and Classification of Soil'. Disturbed samples were taken at selected intervals from the strata encountered, placed in appropriate containers and submitted for geotechnical and chemical testing.

On completion of the investigation the window sample holes were completed as dual purpose gas and groundwater monitoring wells. Trial pits were backfilled with arisings and any excess spoil left neatly mounded on the site.

In situ standard penetration testing (SPT) was carried out in the window sample boreholes to derive 'N' values, which can be used to assess the relative strength and density of encountered strata.

The exploratory hole logs are presented in Appendix A with selected site photographs of the soil arisings from exploratory holes in Appendix B. It should be noted that SPT 'N' values quoted within the exploratory hole logs presented in Appendix A and referred to within this report, are presented as uncorrected values. These do not take into account for the rig efficiency, borehole depth, overburden factors etc.

Selected soil samples were taken from each of the exploratory holes and placed in containers appropriate for the type of laboratory analysis to be undertaken. All samples were labelled following standard protocols to ensure the site location, exploratory hole location, sample depth, sample type, date and job reference were all clearly identifiable.

Once soil samples were collected for environmental purposes, they were stored in cool boxes containing chilled ice packs to preserve sample integrity as far as reasonably practicable. Subsequently the samples were transported to the laboratory under QA / QC controlled conditions employing a chain of custody system to ensure sample integrity prior to the laboratory testing.

4.4 Chemical Laboratory Testing (Soils)

A programme of chemical tests was undertaken on samples obtained from the intrusive investigation to assess the levels of contamination within the strata encountered on the site with regard to identified receptors, as detailed within the Conceptual Site Model. This analysis was carried out at the MCERTS accredited laboratory of SAL, for suites of determinands chosen bearing in mind the Conceptual Model for the site.

A sample of near surface soil consisting of Made Ground, Topsoil or natural underlying soils were selected in order to identify potential contaminants that may pose a risk to human health.

In summary, the following analyses were carried out:

- General Screening suite (including metals, pH, Water Soluble Sulphate, Phenols and PAH's).
(20 samples)
Targeted at samples of Topsoil (13), natural ground (4) and Made Ground (3)
- TPH CWG method including aliphatic and aromatic carbon banding with BTEX compounds and MTBE
(1 samples)

Targeted sample of Topsoil (1)

- PAH's
(20 samples)
Targeted at samples of Topsoil (13), natural ground (4) and Made Ground (3)
- Asbestos Identification
(13 samples including 1 bulk sample)
Targeted at samples of Topsoil (13)
- Multi-Residue Pesticide Screen
(11 Samples)
Targeted at samples of Topsoil (7) and natural ground (4)
- Soil Organic Matter
(8 samples)
Targeted at samples across the site to characterise mean soil organic matter content of the soils including Topsoil (5) and natural soil (3)
- Aggressive ground suite – pH, (Water Soluble) Sulphate expressed as SO₄, Sulphate (Total), Sulphur
(5 samples)
Targeted at samples of natural ground (5).

With regards to potential contamination, analysis was scheduled on separate soil types to allow a statistical analysis of results if required, with emphasis placed on analysis of near surface soil samples given the findings of the conceptual model and nature of the proposed redevelopment. The soil samples predominantly consisted of Made Ground topsoil or underlying natural ground deposits on site and have been assessed separately to allow a statistical analysis of results for the different material. Analysis was therefore targeted towards soil types.

Results of the chemical testing are presented in Appendix D along with a statistical assessment of the results, soil contamination criteria and methodology in Appendix F.

4.5 Geotechnical Laboratory Testing

Representative samples were submitted to the approved and accredited laboratory of K4 Soils and the following tests scheduled to determine soil properties as related to foundation design and construction.

- Plasticity Index Determinations – BS1377: Part 2: Clause 4.3 and 5.0 : 1990
(6 samples)
- Particle Size Distributions – BS1377: Part 2: Clause 9: 1990
(3 samples)

Results of the geotechnical testing are presented within Appendix E.

4.6 Gas and groundwater monitoring

Six ground gas and groundwater level monitoring visits have been undertaken between the 3rd February 2017 and 10th May 2017 and their results are presented within appendix G.

5 Results of the Investigation

5.1 Strata Encountered

Ground conditions encountered during the site investigation were similar to those identified in the published literature and the desk study report.

In summary the ground conditions comprised of a veneer of topsoil deposits overlying generally sandy silty Clay soils representative of the Wittering Formation. The Wittering Formation was proven to the final excavation/drill depths of 4.45m begl. A copy of the exploratory hole logs are presented in Appendix A.

The strata encountered are summarised below and variations in the strata and their thicknesses for the window samples and trial pits are summarised in Table 5.1 along with any groundwater observations during the drilling/excavation.

5.1.1 Made Ground/Topsoil

The veneer of Made Ground or topsoil was encountered in all exploratory hole across the site and generally described as a dark brown slight gravelly sandy clayey Silt. The observed thickness of the deposit varied across the site ranging between 0.10m and 0.80m depth (maximum depth in TP4). The gravel fraction comprised of flint and roots were occasionally observed within these soils.

There was a very thin veneer of anthropogenic material confirmed within the Made Ground topsoil deposits in TP5. The topsoil at this location was noted to include frequent ash, burnt paper, cloth and wood fragment to 0.40m depth. Shallow Made Ground was also encountered in the surface sample scrapes SP1 to SP4, which targeted former areas of bonfires and also within shed A. This was found to a depth ranging from 0.1 to >0.15m begl. The made ground in SP1 to SP3 contained the remnants from bonfires including burnt timber, remains of a burnt mattress, plastic and plasterboard and etc. In TP5 burnt products were also encountered and a single fragment of suspected asbestos cement sheet.

No visual / olfactory evidence of contamination was noted within the topsoil.

5.1.2 Wittering Formation

The underlying natural deposits recovered across the site were generally described as a sandy silty Clay. The sand fraction considered fine to coarse or fine to medium grained. The consistency of the clay deposits was described as firm or stiff however localised soft deposits was confirmed, notably in TP1, WS1 and WS6 within the top 1.0m depth.

Fine to medium sized flint gravel was noted within the silty sandy Clays in a number of locations. This was found within the top 3.00m of the deposit and typically found in a 200mm up to 1500mm thick band.

Below the upper clay deposit and with depths generally in excess of 1.50m the soil deposits were noted to be free from any larger gravel fraction and comprise of interlaminated silty Clay/Sand or laminated silty sandy Clay or silty clayey Sand soils. In all occurrences the laminations were described as extremely closely spaced or very closely spaced and thinly laminated.

It was evident that the soils deposits at the lower south east corner of the site were notably more granular compared to the remaining site. A more cohesionless silty Sand deposit was encountered at the lower north eastern corner of the site. This was confirmed in TP4 to the maximum excavation depth of 1.30m and in WS6 to the final drill depth of 4.25m.

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Table 5.1: Summary of Ground Conditions

Exploratory Hole ID	Soil Type and Depth Encountered m begl, (Unit Thickness (m))		Depth of Water Encountered (m begl)
	Topsoil	Wittering Formation	
TP1	GL – 0.20	0.2 – 1.00+ (>0.80)	0.50m
TP2	GL – 0.10	0.10 – 1.20+ (>1.10)	NE
TP3	GL – 0.28	0.28 – 1.30+ (>2.70)	NE
TP4	GL – 0.80	0.80 – 1.30+ (>0.50)	NE
TP5	GL – 0.40	0.40 – 1.50+ (>2.70)	2.10 (seepage)
TP6	GL – 0.40	0.30 – 1.80+ (>1.50)	NE
WS1	GL – 0.26	0.26 – 4.45+ (>4.19)	2.25
WS2	GL – 0.25	0.25 – 4.45+ (>4.20)	2.75
WS3	GL – 0.65	0.65 – 4.45+ (>3.80)	3.00
WS4	GL – 0.35	0.35 – 4.45+ (>4.10)	2.25
WS5	GL – 0.30	0.30 – 4.25+ (>3.95)	2.25
WS6	GL – 0.25	0.25 – 4.25+ (>4.00)	2.75
WS7	GL – 0.25	0.25 – 4.45+ (>3.50)	NE

>Depth not proven, NE – Not encountered

5.2 Groundwater Observations

5.2.1 Drilling and Excavations

Groundwater was confirmed across the site during the investigation works. In general seepages were confirmed below 2.00m depth (2.10m to 2.75m begl) in the deeper trial pit or window sample holes.

Exception to this rule includes a shallow medium inflow of water confirmed in TP1 at 0.50m begl in proximity to the potentially waterlogged ground at the north.

5.2.2 Groundwater level Monitoring Period

The subsequent monitoring period from the 3rd February 2017 to the 10th of May showed the groundwater levels have varied between 0.20m and levels greater than 3.50m depth. The highest ground water level was recorded within WS3 on the 3rd of February at 0.20m begl. Subsequent monitoring visits showed that the groundwater level had lowered to 1.30m depth at this location.

Full detailed ground water level monitoring results are presented in the Ground Gas and Groundwater Monitoring Data sheets in Appendix G.

An oil/water interface probe was used to measure the depth to groundwater and thickness of a floating layer of hydrocarbon product if present on the surface of the water table. No layer of light non-aqueous phase liquids (LNAPLs) was detected by the interface probe, which was used during each monitoring event.

It should be noted that groundwater levels may fluctuate for a number of reasons including seasonal variations etc.

5.3 In situ Testing

5.3.1 Hand Shear Vane Testing

Shear vane testing was carried with depth within the base and occasionally the sides of the trial pits as they progressed with depth. The test confirms the undrained shear strength value of the cohesive soils. Test results are presented on the trial pit logs as shown in appendix A.

In summary the results have confirmed undrained shear strengths (c_u) as

0.50m to 1.00m	36kN/m ² to 130kN/m ² (Low to High strength)
1.0m to 2.00m	80kN/m ² to 125kN/m ² (High strength)

In general the upper soils were considered to be high strength soils in excess of 80kN/m² below 1.0m depth.

The lower reading of 36kN/m² identified at 1.00m depth was localised to TP1 and consistent with the soft description of the soils at this location.

5.3.2 Standard Penetration Testing

Standard Penetration Testing (SPT) results were consistent six out of the seven locations. Results at 1m centres showed a steady increase with depth varying from N = 8 to N = 15 at 1.0m and from N = 12 to N = 16 at 4.00m depth (maximum test depth).

The one exception to this trend was recorded in WS4. At this position lower SPT N values were recorded equal to N = 6 at 2.0m begl and N = 9 at 4.00m begl.

5.3.3 Californian Bearing Ratio Testing (CBR)

Testing to assess the condition of the sub grade soils to assist with pavement designs (CBR value) were carried out using a DCP TRL probe.

A series of seven tests were carried out using the probe targeting areas for the new access roads and parking areas as shown on the layout plan provided.

Testing was carried out to a maximum depth of 0.75m to 0.85m depth at each location. Discounting the Topsoil overburden the results confirmed CBR of the silty clay subgrade ranging from 1.8% to 5% increasing to 2.6% to 7.5% for soils below 500mm depth (maximum 800mm).

5.3.4 Soil Infiltration Testing

Soil soakaway infiltration testing was carried within three shallow trial pits across the site, TP2, TP3 and TP4. After rapidly filling the trial pit with clean potable water from a roadside tanker, the fall in water level was monitored against time.

Full test results are presented in appendix C and summarised in table 5.3 below.

Trial Pit	Strata	Soil infiltration Rate (f) m/s	
		Run 1	Comments
TP2	Sandy silty Clay	NA	Did not fall to 25% fill depth during monitoring period (77%)
TP3	Sandy silty Clay	NA	Did not fall to 25% fill depth during monitoring period (94%)
TP4	Silty clayey gravelly Sand	NA	Did not fall to 25% fill depth during monitoring period (68%)

With testing failing to reach at least 50% fill depth during the course of the monitoring period the soils on site are considered to show poor soil infiltration characteristics.

5.4 Chemical Testing (Soils)

The procedure for assessing the risk to human health entails the initial comparison of results to the Environment Agency Soil Guideline Values (SGV's), DEFRA Category 4 Screening Levels, Opus In-House Tier 1 Screening Values (IHSV's) and Land Quality Management (LQM) & Chartered Institute for Environmental Health (CIEH) 'Suitable 4 Use Levels' (S4UL's) derived using CLEA 1.06 to be protective of human health. If any potentially significant concentrations are recorded, the results are subjected to statistical analysis in accordance with the CL:AIRE and CIEH document entitled 'Guidance on Comparing Soil Contamination with a Critical Concentration', published in May 2008.

TPHCWG, BTEX and VOC analysis cannot be assessed by statistical means due to the samples analysed being targeted and hence not being part of a general screen. Any elevated concentrations detected as a result of the targeted sampling and analysis would skew the statistical analysis and general distribution of the data set giving a false representation of the distribution of TPHCWG and BTEX contamination at the site.

The proposed end use of the site, which is residential with plant uptake, fits the residential with plant uptake CLEA end land use scenario. It has therefore been considered appropriate by Opus to compare the laboratory analysis results to the GAC for a residential land use at this stage to provide a preliminary assessment of any significant contamination given the intended end use of the site.

The statistical analysis model as outlined below is only undertaken where an exceedance of the Tier I Screening values has been reported. Where the objective is to demonstrate 'suitability for use', the Null and Alternative Hypotheses are as follows:

- Null Hypothesis: "Is the true mean concentration more than or equal to that of the critical concentration?"
- Alternative Hypothesis: "Is the true mean concentration less than the critical concentration?"

Should the nature of the proposed development change significantly, it may be necessary to re-evaluate the contamination results and recommendations presented within this report.

The type of contaminants e.g. metals and PAH results and soil type (Topsoil, Made Ground and natural deposits) have been screened against the Opus Tier 1 SSV's. The Human health generic screening assessment is contained in Appendix F.

Six No. soil samples were tested for soil organic matter (SOM). The SOM contents have been averaged to confirm their mean result for each strata type as shown in Table 5.2.

Table 5.2: Strata Type and SOM

Soil Type	Soil Organic Matter (%)	
	Mean Laboratory Result	GAC Assessment
Topsoil	3.96	2.5
Natural	0.50	0.25

5.4.1 Metals and Inorganics

Made Ground

Three samples of Made Ground were analysed for a standard metals and inorganics suite. The generic screen has identified a single exceedance for Arsenic and Lead within soil sample SP2/0.1m as detailed in Table 5.3.

Table 5.3 Exceedances of Screening Analysis for Arsenic and Lead

Determinand	Screening Value (mg/kg)	Elevated Concentration (mg/kg)	Sample Reference	Strata Type
Arsenic	37	62	SP2/0.1m	Made Ground
Lead	200	240	SP2/0.1m	Made Ground

The subsequent statistical analysis of the Arsenic and Lead data set within the Made Ground has confirmed the Null Hypothesis, as the true mean concentration is equal to/greater than the critical concentration. Therefore a potential risk to human health has been identified based on the elevated Arsenic and Lead levels present within the Made Ground.

However, the statistical assessment additionally indicates that the elevated contaminant concentrations represent outliers i.e. hotspots of contamination. Therefore, it is considered that the source of the Arsenic and Lead concentrations is associated with where bonfire activity has occurred on site. Some remediation of the soils underlying these areas of the site may be required depending upon the final development proposals, but it is likely that this will constitute a localised site scrape to remove the impacted soils from site.

These results are discussed further within Section 7 of this report.

Topsoil and Natural Ground

Thirteen samples of Topsoil and four samples of natural soil were analysed for a standard metals and inorganics suite. The generic screen has not identified any exceedances of the screening values; hence, no remedial action is considered necessary for metals and inorganics with respect to human health.

5.4.2 Speciated PAH's

Three samples of Made Ground, twelve samples of Topsoil and four samples of natural soil were analysed for the USEPA 16 most carcinogenic PAH congeners. The generic screen has not identified any exceedances of the screening values; hence, no remedial action is considered necessary for PAH with respect to human health.

5.4.3 Cyanide and Total Phenol

Three samples of Made Ground, twelve samples of Topsoil and four samples of natural soil were analysed for free Cyanide and total Phenol. None of the concentrations were recorded above the

lower laboratory detection limit. Hence, no remedial action is considered necessary for Cyanide or Total Phenol with respect to human health.

5.4.4 Speciated TPH, BTEX and MTBE

One sample of Made Ground was analysed for speciated TPH, BTEX and MTBE. The concentrations of Aliphatic and Aromatic TPH fractions did not exceed their applicable screening for the sample tested, hence, no remedial action is considered necessary for hydrocarbon compounds with respect to human health.

5.4.5 Pesticides

Seven Topsoil samples and four natural ground samples were analysed for the presence of a 'multi residue pesticide suite'. Generic assessment criteria is only currently available for Dieldrin, but the maximum concentrations reported for pesticide residues are summarised in Table 5.4.

Table 5.4 Screening Analysis for Residual Pesticides

Determinand	Screening Value (mg/kg) SOM 2.5%	Maximum Concentration (mg/kg)	Sample Reference	Strata Type
9,10-Anthraquinone	None	0.03	WS5/0.15	Topsoil
Dieldrin	2.00	0.05	WS1/0.1m	Topsoil
p,p-DDD	None	0.09	WS3/0.25	Topsoil
p,p-DDE	None	0.03	WS3/0.25	Topsoil
p,p-DDT	None	1.50	WS3/0.25	Topsoil

The GAC for Dieldrin indicates that this pesticide residue does not pose a risk to human health. No other UK based GAC is currently available for the other listed pesticides. However, if compared against the GAC for Dieldrin they are all below the concentration of 2.0mg/kg.

5.4.6 Asbestos Screen

Twelve samples of Topsoil and one bulk sample were analysed for the presence of asbestos fibres. None of the samples identified the presence of asbestos; hence, no remedial action is considered necessary for Asbestos with respect to human health.

5.5 Ground Gas Monitoring

Six ground gas monitoring visits were carried out by Opus between the 3rd February 2017 and the 10th May 2017 from the monitoring wells identified as WS1 to WS7.

The geological map indicates the site to be underlain by the Wittering Formation, which was confirmed by the site investigation. However, a landfill was historically located immediately north of

the site, which was reported to have accepted inert waste when active. The Environment Agency email advised that the landfill, site reference FEA31, East 7, took the following waste: 'earth spoils and builder's rubble'. The gas generation potential for inert landfill sites is very low but this has been upgraded to low owing to the lack of regulation in the past meaning that historic landfill sites may not have been entirely inert.

Based on the sensitivity of the development and the low generation potential of the source (presence of inert landfill adjacent to the site), a total of six visits over approximately 3 months has been undertaken to date to provide an initial characterisation of the general hazard at this site. The results of the ground gas monitoring are presented in Appendix G.

Monitoring was undertaken using a Gas Data Ltd GFM436 Gas Analyser calibrated in accordance with the manufacturer's instructions. During each monitoring visit, the following parameters were recorded:

- Methane;
- Carbon dioxide;
- Carbon monoxide;
- Oxygen;
- Hydrogen sulphide;
- Borehole gas flow rates;
- Ambient air pressure;
- Groundwater levels.

5.5.1 Gas Monitoring Results

The atmospheric pressure ranged between 989 and 1015mb during the monitoring period.

Groundwater depth was recorded between 0.20m (WS3) and 1.42m (WS2) on the first monitoring visit and generally the groundwater table fell over the monitoring period with the final water levels recorded between 1.34m (WS4) and 3.77m (WS6).

Hydrogen sulphide and carbon monoxide were not detected within any of the boreholes during the six monitoring events.

Flow rates were recorded at 0.0l/hr. during each monitoring visit for all monitoring wells.

Depleted oxygen levels were recorded within the majority of the monitoring wells, but particularly within monitoring well WS2, in which oxygen levels ranged between 1.6% and 12.2% v/v. Oxygen levels were recorded between 9.6% and 20.7% within the other monitoring wells.

A maximum carbon dioxide level of 11.3% v/v was recorded within monitoring well WS2 and the levels ranged between 4.2 and 11.3% v/v. Carbon dioxide levels within the other monitoring wells ranged between 0.0 and 4.2% v/v.

Methane was recorded in three of the monitoring wells WS1, WS4 and WS5, on the first monitoring visit only at 0.1%v/v.

5.5.2 Gas Risk Assessment

Guidance on the assessment of ground gas and the design of gas protection measures is detailed within the Construction Industry Research and Information Association (CIRIA) Report C665, entitled “Assessing Risks Posed by Hazardous Ground Gases to Buildings” which was published during December 2007 and British Standard BS8485:2015 entitled ‘Code of Practice for the Characterisation and Remediation from Ground Gas in Affected Developments’.

The CIRIA C665 guidance includes two methods for characterising a site with respect to gas regime:

- Situation A (Modified Wilson and Card) – All development types excluding low rise housing with gardens and a clear ventilated underfloor void;
- Situation B (NHBC Traffic Lights) – Specific to low-rise housing developments with a clear ventilated under floor void.

The guidance suggests that the calculations should be undertaken for both methane and carbon dioxide and then the worst case value adopted. The higher the classification the greater the risk posed by the presence of gas.

It is understood that the buildings proposed at the site will be for residential use therefore the results of the gas monitoring have been assessed in accordance with Situation B.

Although a risk of hazardous soil gases (Made Ground) has been identified for the site, given the nature of the identified potential source of gas (i.e. Made Ground with no visually observed degradable material and natural deposits with low volume of organic matter) the site is considered to be ‘low risk’, in accordance with Table 5.5 of C665.

To assess the risk, a Gas Screening Value (GSV – CIRIA C665) or hazardous gas flow rate (Q_{hg} – BS8485) needs to be determined for both methane and carbon dioxide by using the equation:

$$GSV/Q_{hg} = (\text{concentration}/100) \times \text{flow rate}$$

Where: concentration is measured in percent (%) and flow rate is measured in litres per hour (l/hr.).

In accordance with Section 8.3.1 of the CIRIA Guidelines, the worst case GSV derived for the available data should be used. Once a value for GSV is derived the Characteristic Situation for the site is determined in accordance with C665 Table 8.5.

As described in Table 2 of BS8485:2015, once the appropriate Characteristic Situation is determined, appropriate protective measures should be defined on the basis of a guidance value which reflects not only the soil-gas conditions but also the form of development.

In order to specify the protective measures that are required, this guidance value is compared with BS8485 Tables 5, 6 and 7 which lists a range of potential protective measures and associated protection system scores. A single protective measure or a range of measures from each of the categories can be selected provided that the combined protective system scores equals or exceeds the appropriate guidance value for the site.

The worst case GSV value obtained from the gas monitoring period can be derived from the highest carbon dioxide concentration of 11.3% v/v and a flow rate of 0.1l/hr (this has been chosen as a

conservative approach based on the minimum detection limit of the instrument). The corresponding worst case GSV is therefore 0.01/hr. This indicates that “Green classification” conditions prevail on site. However, based on the fact that Carbon Dioxide concentrations have been encountered above 5% over the majority of the monitoring period in WS2 the gas regime has been increased to “Amber 1 classification” and gas precautions will be required to be incorporated in the construction of the houses on site.

5.6 Geotechnical Testing

The results of geotechnical testing for pH and sulphate carried out during this investigation are included alongside the chemical testing data in Appendix C. All other geotechnical laboratory results are contained in Appendix D.

5.6.1 Aggressivity Testing

The water soluble sulphate content, total sulphate content, total sulphur content and pH values determined for selected samples taken from across the site have proved values in the following ranges:

Soils (Topsoil)

Water Soluble Sulphate (SO ₄)	<0.01 to 0.03 g/l
pH	4.2 to 7.5

Soils (Natural soil)

Water Soluble Sulphate (SO ₄)	<0.01 to 0.04 g/l
Total Sulphate (SO ₄)	0.01 to 0.16%
Total Sulphur	<0.01 to 0.06%
pH	4.6 to 6.0

Results from the stockpile samples SP1, SP2 and SP3 confirmed the following result:

Water Soluble Sulphate (SO ₄)	0.01 to 0.16 g/l
pH	8.1 to 8.8

5.6.2 Soil Moisture Content and Plasticity Index

The results of the Plasticity Index testing and moisture content determinations have been proved in the following ranges;

Plasticity Index 25 to 52% (Wittering Clay Formation)

Moisture Content 21 to 39% (Wittering Clay Formation)

When adjusted to account for the percentage of particles passing a 425µm sieve in accordance with NHBC standards, the Modified Plasticity Index (MPI) values range from 18% to 47%, indicating that the clays present on site can be considered to be classified as being low to high volume change potential, in accordance with NHBC standards.

5.6.3 Particle Size Distribution

Three particle size distribution tests were undertaken on samples retrieved from the Wittering Formation between 1.30m and 1.95m begl considered to have a higher granular content.

The testing confirmed the samples as cohesionless soils with variable matrix described as either a sandy Gravel, gravelly Sand or fine Sand character with high silt and clay content.

Geotechnical recommendations relating to the above results are included within Section 8 of this report.

Assessment & Recommendations

6 Introduction

This report has been prepared to provide preliminary information specific to the ground conditions at the site. It is understood that the proposed mixed development will comprise detached and semi-detached residential properties with, gardens, access roadways and parking areas.

Recommendations made within this report should be considered to be preliminary and are subject to confirmation once development proposals and structural details have been finalised. In particular the recommendations for foundation designs for the proposed development will be largely dependent on the nature and magnitude of imposed loads associated with the proposed structures and the interaction/relationship with adjacent buildings.

Given the nature of the proposed development, this investigation has been carried out on the assumption that the final development of the site will conform to the ‘residential with plant uptake’ land use scenario, in accordance with the Contaminated Land Exposure Assessment (CLEA) methodology.

Should the proposed site usage change significantly from the above, the contents of this report will require review and amendment as appropriate.

7 Environmental Assessment

7.1 Soil/ Ground Gas Contamination Summary

No exceedance of the screening criteria for PAH, TPH and BTEX has been reported for the soil samples analysed. It is therefore considered that the underlying shallow soils do not pose a significant risk of significant harm to the proposed redevelopment from these contaminants.

A single exceedance of both Arsenic and Lead was identified in SP2 at 0.10m bgl. Both of the elevated concentrations are considered to be representative of hotspots of contamination. The source of the contamination is considered to be from the residual material left over from bonfire activities on site.

It is considered that the Arsenic and Lead exceedance is unlikely to pose a risk to future site users if it is located below hard landscaping post site development such as the footprint of a building, access road or a driveway.

Should this area become an area of soft landscaping there might exist a direct exposure pathway in the form of dermal contact, soil ingestion and inhalation of potentially contaminated fugitive dust. In order to mitigate against this it is considered that a localised site scrape should be undertaken to remove the soils impacted by bonfire activities.

The Topsoil has proved positive for the presence of five separate pesticide residues. Only one generic assessment criteria is currently available for one of the pesticides in the UK, which is for Dieldrin. The maximum reported Dieldrin concentration and other positive pesticide concentrations have all been reported below the GAC for Dieldrin. The site is therefore not considered to be at a significant risk of significant harm from residual pesticide contamination.

Carbon Dioxide concentrations have been encountered above 5% over the majority of the monitoring period in WS2 the gas regime has been increased to “Amber 1 classification” and gas precautions will be required to be incorporated in the construction of the houses on site.

7.2 Revised Conceptual Site Model

The revised conceptual site model shows the likelihood of a potential risk being realised on site based on the site investigation data obtained to date and assuming the proposed future residential without plant uptake end use as shown in Table 7.2.

Table 7.1: Revised Conceptual Site Model

Source Material/Activity	Potential Contaminant	Pathways	Receptor	Risk
Ground Gas				
Wittering Formation	Carbon Dioxide	Inhalation (indoor air)	Future site users	Low to medium
Soil				
Made Ground (localised on site)	Arsenic	Ingestion, inhalation (contaminated dust), dermal contact.	Future site residents – soft landscaped areas	Low

Source Material/Activity	Potential Contaminant	Pathways	Receptor	Risk
Made Ground (localised on site)	Lead	Ingestion, inhalation (contaminated dust), dermal contact.	Future site residents – soft landscaped areas	Low

7.3 Contamination Assessment

7.3.1 Contaminants of Concern

Contaminants of concern have been identified within the Made Ground on site.

It is considered that some remediation of the soils will be required to protect future site users from these contaminants of concern. The greatest risk of exposure to future site residents is considered to be within soft landscaped areas, where direct contact could occur with contaminated soil and from soil tracked into the houses, which could pose an inhalation risk via breathing in contaminated dust/particulates.

The risk of construction workers coming into direct contact with contaminants during the ground works phase of development can be reduced by the appropriate use of PPE and having welfare facilities on site to allow for washing of hands etc.

7.3.2 Re Use of Arisings

The re-use of clean natural materials (from say foundations, basement construction etc.) on the site is generally acceptable provided that certain defined specific conditions are met. These conditions would include the material being “uncontaminated”; the material being suitable for use with no requirement for pre-treatment; there must be a certainty over the re-use and the quantities must be limited to those necessary for the specified works.

If re-use of arisings is envisaged, it will be essential to show that a material balance calculation has been carried out, to allow for the re-use of the arisings, rather than simply creating ‘landscape mounds’.

Additionally, there will be a requirement to show that there will be no environmental impact; this may well require a quantitative risk assessment with regards to Controlled Waters and Human Health depending on the nature of the contamination. A Waste Management Exemption or Material Management Plan is normally required where re-use of arisings or significant earthworks operations are envisaged.

With regard to the movement of materials between sites, the current Environment Agency policy is that any soil taken off a site and moved to another development site would be regarded as a waste. As such the re-use of this material on sites other than that on which it had been generated, would require a waste management license or a registered exemption at the site where it was proposed for re-use.

7.3.3 Managing Environmental Impacts

It would be advisable to carry out all construction work with due regard to the potential for environmental impacts during construction. Any fuels and chemicals used during construction should be stored in an appropriate manner to prevent leaks and / or spillages from impacting the local environment. Any surface water runoff during construction will need to be controlled to prevent silt from entering local drainage.

7.4 Health & Safety

During the construction of the development, a high standard of health and safety awareness should be maintained in order to protect construction workers from exposure to potentially contaminated soil. It is therefore recommended that the appropriate precautions given in Health and Safety Executive Report HS(G)66 'Protection of workers and the general public during the redevelopment of contaminated land' are adopted.

It is our judgement that The Construction Design and Management (CDM) Regulations 2015 (regulation 3) will apply to this project. As a designer, we have a responsibility to inform you of your duties to which you are subject by virtue of the Regulations as specified in regulation 11 (1).

We therefore draw your attention to the CDM Regulations 2015 and the Approved Codes of Practice contained therein.

The following basic health and safety measures should be adopted as a minimum during the site development works:

- Basic Personal Protective Equipment (PPE) including hard hats, gloves, coveralls and steel toe-capped boots to be worn at all times;
- Eating, drinking and smoking to be forbidden at all times except in designated mess areas; and
- Breathing equipment to be available for those working in confined or unventilated spaces.

If ground conditions should differ significantly from those encountered during the intrusive investigation, including the discovery of any visible or odorous contamination, site redevelopment works should be suspended until the suspect material has been inspected and assessed by a competent Geo-Environmental Engineer.

Depleted oxygen levels were recorded during the period of gas monitoring. Therefore, construction and maintenance workers who are required to work within manholes and other subsurface confined spaces should be made aware that a low oxygen environment could potentially exist with precautions taken to ensure their welfare.

7.5 Disposal of Waste Soil

Waste Acceptance Criteria (WAC) analysis is outside the scope of this report. It is recommended however that the general soil analysis laboratory certificates are forwarded to the selected landfill operator(s) to confirm waste classification. WAC analysis may be required in the future to facilitate the disposal of spoil from site and it is recommended that the selected landfill operator is contacted early in the construction programme to prevent delays during the construction phase.

7.6 Service Pipes

New water service pipes will be required for the proposed development. It is recommended that the water supply utility company is contacted for confirmation of pipe type prior to any construction work commencing on the site.

The use of recycled aggregate material made from road planning's and site Made Ground should be avoided for backfilling around services.

7.7 Remedial Measures

Based on the findings of the environmental assessment the following comments can be provided in terms of remedial requirements for the development of the site;

- Localised site scrapes to remove the Made Ground and near surface soils impacted by bonfire activity. Any imported topsoil/subsoil used on site to make up levels must be certified clean.
- Gas precautions will be required to be incorporated in the construction of the houses on site

7.8 Regulatory Liaison

It is recommended that agreement of the above assessment is sought from the Local Authority (Environmental Health and Planning) prior to commencing work on site, especially where planning conditions relating to environmental assessment apply.

8 Geotechnical Assessment

8.1 Geotechnical Issues

The most economic foundation solution for the proposed development will need to take account of a number of potential factors which could affect the economic viability and constructability of foundation solutions. The following issues will need to be considered:

- The change in site levels and the expected earthworks anticipated to accommodate each plot and access roads
- The potential for variation in soil type and their consolidating properties requiring differential settlement of the foundations to be limited;

Opus is not aware as to the precise details or form of construction that may be utilised for the proposed development and thus the precise loadings that may need to be carried by the foundations. Subject to review, as and when these details become available, as well as information on the existing foundations of the adjacent properties, a range of foundation options may therefore be appropriate. The following discussion of foundation options should therefore be regarded as preliminary and subject to review as and when the detail of the intended development and the associated foundation loadings are known.

8.1.1 General Earthworks

The current scheme design proposals assume that building construction shall, where possible reflect existing ground levels. Given that the site topography has a pronounced downwards gradient to the north east it is expected that there will be soil importation and cutting to provide both site access and level ground for the homes. Based upon the current development layout many of the building plots will possess potentially up to 1m fall across the building footprint. In addition a fall in level of up to 4m would need to be engineered for the proposed access road. There is therefore, expected to be local ground profiling to seat the buildings and access roads with the probability of using retaining structures to support the infill and cut ground. Therefore, there will be a volume of material won from the ground reprofiling exercise as well as excavations for service installation and foundations which may wish to be used to locally build up ground levels in certain areas of the site. Given the information from the ground investigation it is anticipated that:

- i. Topsoil material may be designated as Acceptable Class 5 Topsoil material for reuse within the works, where testing has proven the deposit to be uncontaminated.
- ii. Where the natural clay soils exhibit a firm to stiff consistency, then the soil testing would indicate a certain percentage of those materials won from excavations should be suitable for reuse as a Class 2a Wet Cohesive Fill. This material would be suitable for reuse as construction fill beneath areas of hard landscaping and general areas of construction make up. The material is not suitable for reuse beneath adoptable highway pavements, or for the backfilling of service trenches.
- iii. It is likely that a high percentage of material won from excavations shall be too wet of optimum to be suitable for reuse as a structural fill. During construction on site MCV testing should be undertaken to determine what material might be reused.
- iv. Any natural granular soils are expected to represent an acceptable Class 1b uniformly graded general granular fill and may be reused as general infilling below landscaping, general hardstand and backfill to service trenches.
- v. All materials won from the site strip and excavation works should be maintained in their “as-dug” condition and protected from excessive wetting or trafficking, which could increase their moisture content and reduce their strength. Poor treatment of the site won materials may, as a result, render them only suitable for use as Class 4 landscape fill.

8.2 Cuttings

The current scheme proposal would suggest the potential for permanent cutting slopes. Further details on the proposed cutting heights should be provided for engineering assessment prior to providing any recommendations on the necessary permanent gradient of such free standing slopes.

Unmanned temporary cut slopes for the installation foundations and service trenches are expected to be at best semi stable in the very short term. The degree of interbedded sand and clay horizons with the potential for perched water systems is likely to cause collapse of excavation slopes. Temporary pump and sump dewatering may also be required on occasion to remove perched groundwater from the short term excavations.

It is important that cuttings into the slope will need to take into consideration the stability of the material and appropriate temporary retaining solutions implemented in the design if required.

8.3 Embankments

It is not known whether the current scheme proposals indicate a requirement for permanent embankment slopes and therefore, the subject is not discussed further within the scope of this report. Generally where ground levels are required to be raised less than 500mm in height locally using site won structural fills it is advised that a maximum freestanding slope gradient of 1(v):2(h) should be used for design.

8.4 Road Pavements

The in-situ CBR values produced by the DCP provided values of 1.8% - 5.5% for the cohesive subgrade materials within the top 0.50m and values of 2.6% - 7.5% from 0.50m to 0.80m begl. Based upon the results from the various CBR test methodologies, it is recommended that a general CBR value of 2%% be used for pavement design for those soils found within the top 0.50m of existing site level and 2.5% below.

Accesses/estate roads, car parks and areas of hard landscaping shall require a capping layer to be included within the pavement design. To reduce the cost of pavement construction and to reduce the adverse effect of site working within predominately clay soils during wet weather conditions, consideration may be given to the use of lime/cement soil stabilisation. This would reduce both the degree of initial excavation for pavement construction and the disposal volume of excavated spoil material from the reduced level strip.

Lime/cement soil stabilization techniques might also be used to improve the won site soils which otherwise would be considered unsuitable for reuse as construction fill.

8.5 Foundation Design

The expected building development is for the construction of lightly loaded, 2 storey residential properties. From consideration of the final development proposals, it is expected that the site ground conditions will not allow for the installation of traditional simple concrete footings. Stepped foundations will be frequent across the site where the footprint of the building cross the sloping ground.

The variation in type and condition of the site soils is believed to require the use of thickened reinforced edge beam foundations tied into a ground bearing slab (where other factors such as depth of filling beneath the slab, the effect of over deepening of foundations to take account of trees, or any consideration for ground gas does not otherwise dictate the use of a 'tied in' suspended slab). The underside of foundations shall be seated on the natural ground soils, comprising firm clay or medium compact sand at a minimum installation depth of 900mm.

Foundation depths are likely to require over deepening in those areas either where softer consistency clay is identified near surface, or owing to the need to take account of the proximity of surrounding trees to meet NHBC standards and Building Regulations.

The depth of over deepening of foundations, where existing trees, recently removed trees or proposed tree planting lies within an influencing distance of those house units seated on clay foundation soils, will be dependent upon; the tree species; whether the trees are to remain or be removed; and the Volume Change Potential of the clay soil.

The immediate underlying natural cohesive superficial soils appear to show comparatively good strength. Lower bound hand vane testing has shown shear strength of the order of 80kN/m² at 1.0m depth or greater. A localised reduction in strength of the silty clay soil has occurred near TP1 with strength values significantly lower at 35kN/m². The latter reduction considered to be a result of the higher groundwater levels at this location and the subsequent softening of the clay soil.

When bearing into these natural silty Clay soils a safe ground resistance of 140kN/m² may be assumed at 1.00m begl for a traditional strip footing at which settlements are considered to remain within tolerable limits (<25mm). Over deepening is then subsequently required at those localised softer areas of the site.

The shallow foundations have the potential for the footprint to bear on both the clay soils and outcrops of more sandy/gravelly soils beneath. This should be taken into consideration in respect to potential differential settlements and suitable reinforcement should be adopted within the foundation.

The base of all formation surfaces should be vibro tamped, proof rolled or otherwise tested for the presence of soft ground. All soft areas of ground should be preferentially removed from the formation and infilled with an appropriate medium i.e. either concrete or compacted hardcore fill.

Given the expectation for a high degree of over excavation, caused through possible poor quality near surface site soils, perched groundwater seepages, or, the proximity to existing trees and a likely high degree of over break of temporary excavations consideration should be given to a range of alternative foundation options. Further foundation assessment on the likely choice of foundation type should be undertaken when a final housing development layout, with FFL information and an Arboricultural report is available.

As stated in section 6.2, temporary pump and sump dewatering is likely to be required to remove any ephemeral groundwater seepages during the excavation of foundation and service trenches.

Final designs for the foundations should be carried out by a suitably qualified Engineer, based on the findings of this investigation and with reference to the anticipated loadings and serviceability requirements for the structure.

8.6 Building near Trees

As noted in section 2.2 mature trees are found along each of the site boundaries and recently felled trees within the North West section of the site. In addition new trees are proposed within the development area and subsequently design should take into account both proposed and existing trees in respect the confirmed low to high volume change potential soils.

Reference should be made to guidance in NHBC standards, chapter 4.2 once final designs have been confirmed.

Heave precautions may be required for relevant structures, dependant on the proximity, size and species of any adjacent trees.

8.7 Floor Slab Design

Given the low to high volume change soils encountered on site a suspended ground floor slab may need to be incorporated for the proposed residential properties in accordance with current NHBC standards.

Final designs for the floor slabs should be carried out by a suitably qualified Engineer based on the findings of this investigation and with reference to the anticipated loadings and serviceability requirements for the structure.

8.8 Demolition and Construction

Where any significant obstructions (old foundations, drain runs etc.) are encountered during demolition works, these should be chased out and the position, extent and depth of any resultant voids should be recorded for future reference, as this could influence foundation designs for the proposed development. Where deep voids are to be in-filled, the advice of an Engineer should be sought to ensure that a suitable earthworks specification is achieved, so as to minimise impacts of designs for foundations / floor slabs etc.

It is generally anticipated that excavations within the near surface strata should be readily achieved using conventional plant (tracked excavator or similar). However, obstructions (old foundations, drain runs etc.) may be encountered, associated with previous phases of development and may require a higher specification of plant and /or breaking out.

Only occasional groundwater seepages were noted, lying at depths of between 2.1m and 2.75m begl. It was noted from ground water monitoring, carried out from February to May 2017 that the general groundwater level varied between 0.20 and 3.50m begl. Whilst it is unknown whether the water strikes represent perched water seepage or the main groundwater system, the predominately cohesive nature of the ground soils is expected to reduce groundwater discharge into excavations. However, groundwater levels can vary throughout the year and if groundwater is encountered appropriate, dewatering techniques should be adopted as necessary.

8.9 Buried Concrete

The results of the pH and water soluble sulphate, Sulphate and Total Sulphur analysis have been assessed for potential aggression to buried concrete in accordance with the Building Research Establishment: Special Digest 1: 2005 – Concrete in Aggressive Ground. With reference to the desk study review findings, we consider that the site can be classified as a 'Brownfield site'.

In accordance with Part C of BRE Special Digest 1:2005, based on the testing carried out to date on the Topsoil and natural ground deposits, we consider that the materials underlying the site are initially assigned a Design Sulphate Class DS-1 and ACEC (Aggressive Chemical Environment for Concrete) Class AC-4z. The higher ACEC class is attributed to the low pH recorded for the soil and a mobile groundwater condition for the site. Our assessment is based on soil testing only and does not account for any groundwater testing.

The specific concrete mixes for the Design Concrete Class (DCC) to be used on site will be determined by the site specific concrete requirements in terms of the required durability and structural performance. These are assessed in terms of the Structural Performance Level (SPL) and any need

for Additional Protective Measures (APM), detailed in Part 2 with further guidance in Parts 3 and 4 of BRE Special Digest 1.

8.10 Soakaways/Drainage

The soakage testing carried out within the trial pits confirmed a poor rate of infiltration within the upper silty clay soils. This was confirmed with water level only falling between 68% 94% of the fill depth during the monitoring period. The test results are applicable to the natural soils to depths of the order of 1.20m, i.e. above the anticipated groundwater levels at the time of the test.

Therefore results suggest traditional soakaway installation are not suitable for the infiltration of surface waters

8.11 Design Recommendations

Any design recommendations made within this report are considered the most appropriate considering a number of factors including investigation findings, financial and safety implications. All design recommendations are considered to be achievable within a safe system of work. During construction due consideration should be taken in relation to the safety implications inherent in the chosen construction method.

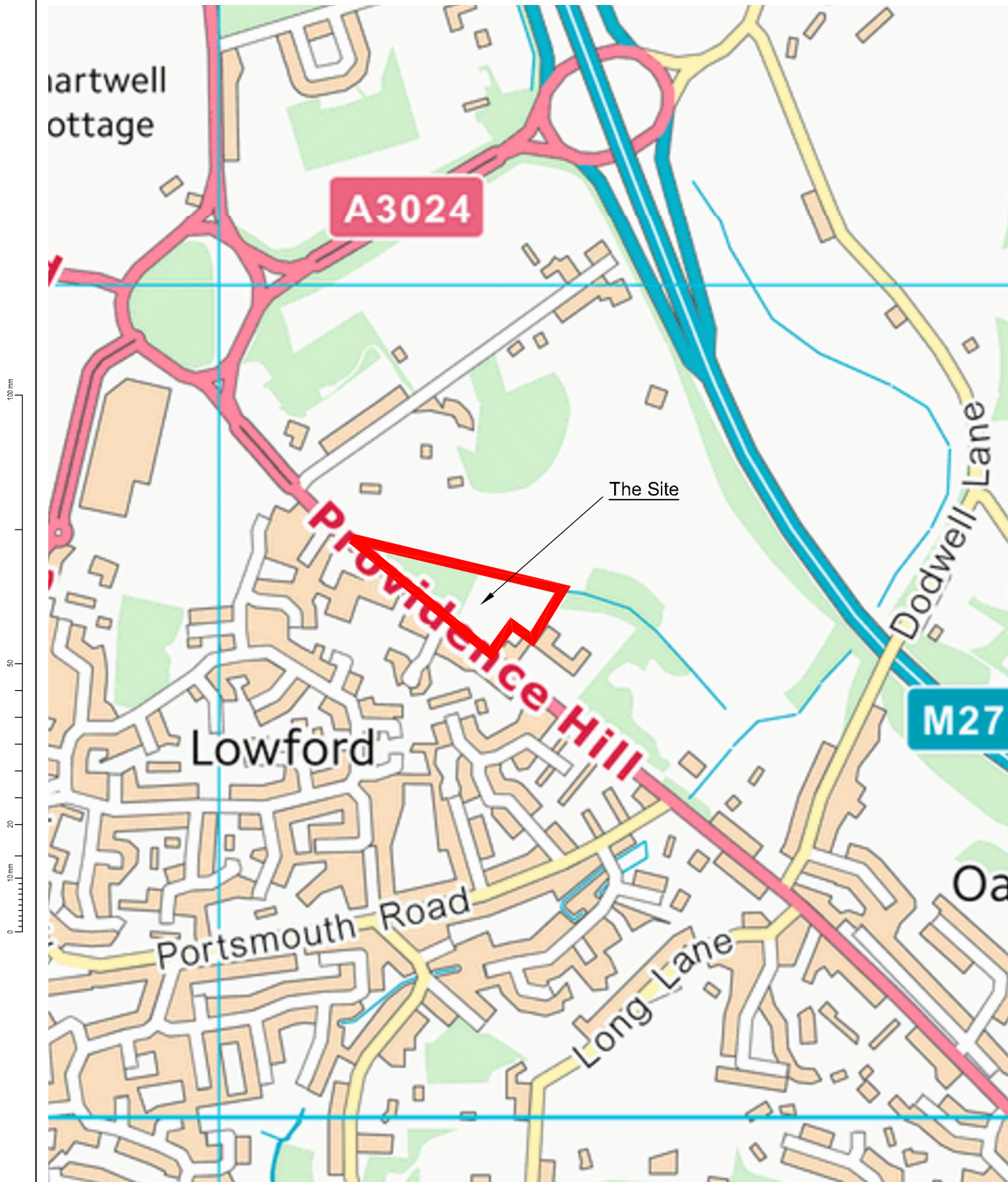
Any design recommendations suggested within this report should be carried out in line with current best practice and regulatory requirements. We consider that the contractor carrying out any recommendations contained within this report will be aware of the standard construction processes involved and have detailed knowledge of the relevant health and safety measures.

9 Further Recommendations

The following further works have been recommended prior to the development of the site:

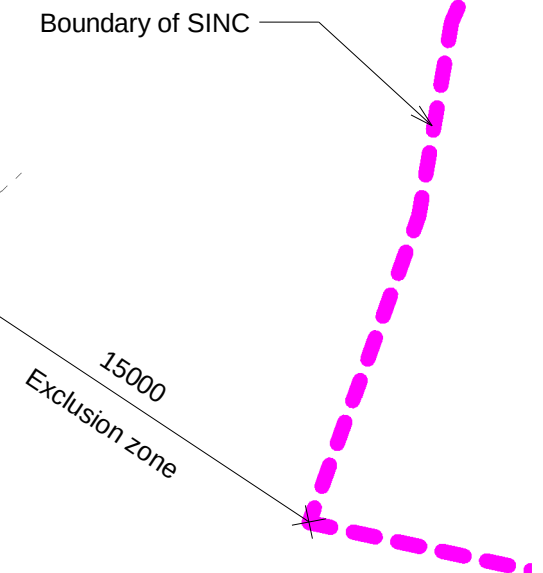
- Develop a remediation strategy to reduce the risk of exposure occurring between the Arsenic and Lead contaminant hotspots and future site users if these areas are to be left as soft landscaping post redevelopment. Also incorporate ground gas precautions into the construction of the houses on site.
- Finalisation of geotechnical designs for the proposed development, with reference to the finalised planning layout, dead and imposed structural loadings and serviceability limits.
- Further geotechnical site investigation and assessment of the soil slope stability with respect the proposed earthworks and designs.
- Full removal of any buried obstructions (such as footings, etc.) associated with the existing remaining structures on site.
- Confirmation of the water supply pipe specification with the appropriate authorities prior to construction.

DRAWINGS

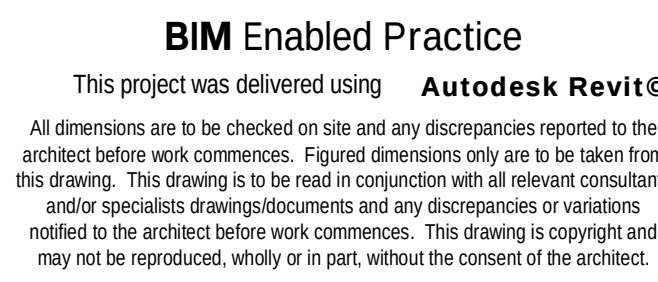


PRELIMINARY

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Revision				Amendment		Approved Date	
P1	PRELIMINARY ISSUE			CDS	20.02.2017	CGJ	
						CDS	
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				Drawn		Scale	
				CGJ	NTS		
				Project No.		Sheet No.	
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Revision	Date	Initials
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Site Plan - Proposed



Job Number & Drawing Number	Revision
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1 Site Plan - as proposed
1 : 250