



Cala Homes (South Home Counties) Limited

West End Nursery, Roundstone Lane, Angmering BN16 4AX

Project no. 27621-R01 (01)

FEBRUARY 2015

RSK

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1 INTRODUCTION

RSK Environment Limited (RSK) was commissioned by Cala Homes (South Home Counties) Limited to carry out a geo-environmental assessment of West End Nursery Roundstone Lane, Angmering BN16 4AX hereafter referred to as 'the site'.

The site is currently occupied by two commercial greenhouses, associated warehouse, infrastructure and a boiler house.

It is understood that the site is being considered for redevelopment with 195 residential properties, with private gardens and some areas of communal soft landscaping.

This report is subject to the RSK service constraints given in Appendix A.

1.1 Objective

The objective of the work is to assess potential geo-environmental liabilities with site redevelopment, to provide information for geotechnical design and to support a planning application.

1.2 Scope

The scope of the investigation and layout of this report has been designed with consideration of CLR11 (Environment Agency, 2004a) BS 10175: 2011 (BSI, 2011) and guidance on land contamination reports issued by the Environment Agency (EA) (2010a). A summary of the contaminated land legislation and policy refer to in this report is given in Appendix B.

The project was carried out to an agreed brief as set out in RSK's proposal (ref: 27621T01(00) dated 15 December 2014). The scope of works for the assessment included:

- a preliminary risk assessment (PRA) to include a review of existing reports, geological, hydrogeological and hydrological information, a commercially available environmental database, and historical plans; correspondence with regulatory authorities; and a site walkover – this information is used to develop an initial conceptual site model to consider any potentially complete pollutant linkages;
- a review of published geological data to assess ground stability;
- an intrusive investigation consisting of 15 shallow drive in sampler boreholes and 18 hand auguring locations with laboratory analysis plus subsequent groundwater monitoring;

- development of a refined conceptual site model followed by generic quantitative risk assessment (GQRA) to assess complete pollutant linkages that may require the implementation of mitigation measures to facilitate redevelopment;
- identification of outline mitigation measures for complete pollutant linkages or recommendations for further work;
- interpretation of ground conditions and geotechnical data to provide recommendations with respect to foundations and infrastructure design;
- a factual and interpretative report with recommendations for further works (i.e. undertake a remedial options appraisal to identify appropriate mitigation measures/produce a remedial implementation and verification plan) and/or remediation as necessary; and,
- an assessment of the potential waste classification implications of soil arisings.

1.3 Existing reports

RSK was provided with a Phase 1 contaminated land assessment report by Hilson Moran (report reference 13829, dated 15th November 2012) pertaining to the site. The report identified a number of potential pollutant linkages associated with the site. The report has been reviewed and forms the basis of the PRA contained within this report.

1.4 Limitations

The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by the investigation and therefore could not be taken into account. In particular, it should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater levels may vary from those reported due to seasonal, or other, effects.

2 THE SITE

2.1 Site location and description

The site of West End Nursery Roundstone Lane, Angmering BN16 4AX is located at National Grid reference 507640, 103520 as shown on Figure 1. The current site layout is presented on Figure 2.

The site setting comprises a mix of residential, commercial and agricultural land as detailed in Table 1.

Table 1: Site setting

To the north:	Worthing Rugby Football Club is present. It is understood redevelopment is being considered for this area.
To the east:	immediately adjacent to the site boundary is a footpath and drainage channel with the A280 and agricultural land beyond.
To the south:	Haskins Garden Centre (formerly Roundstone Nursery and Garden Centre) is present, in addition residential properties are located immediately to the southwest of the site and beyond the garden centre.
To the west:	a mix of residential and commercial properties located beyond Roundabout Lane.

The site covers approximately 11ha at an elevation of approximately 11m above Ordnance Datum (AOD) although along some boundaries, there are bunds which rise up above general site levels.

2.2 Proposed development

The proposed layout of the site is shown on Figure 3.

3 PRELIMINARY RISK ASSESSMENT (PRA)

3.1 Site walkover

An engineer from RSK carried out a site walkover survey on the 13th January 2015. Photographs taken during the site walkover visit are presented in Appendix C. A summary of the site including potentially significant environmental and geotechnical issues arising from the survey are outlined below.

The site is accessed directly off Roundabout Lane. It predominately comprise occupied by two commercial greenhouses, a large greenhouse (approximately 5.2ha) in the north of the site and a smaller green house (approximately 0.8ha) in the southwest. In addition, in the southwest and central southern parts of the site there are site offices, fertiliser and chemical stores, external water and fuel storage tanks, boiler plant area, substations and a septic tank present. In the southeast, a large drainage pond is present.

The site is generally flat with exception to the pond area in the southeast, which is approximately 1-2m lower in elevation than the rest of the site. In addition it is noted that there is a drop in elevation of approximately 1.5m down to a public footpath adjacent to the eastern site boundary next to which a drainage channel approximately 2m deep was present and bunds approximately 2m high are present adjacent to the west and east site boundaries and in the southwest corner.

With respect to potential areas of contamination, above ground storage tanks (ASTs), an acid store, fertiliser storage area, boiler house, septic tank and, gas and electric substations were noted during the site walkover. Some waste materials were also observed within the bund along the north-western bund.

Japanese knotweed is a non-native, highly invasive species and spreads via rhizomes (underground 'stems') rather than seeds in the UK. It is found in a range of habitats across the UK including roadsides, riverbanks and derelict land.

Japanese knotweed was not identified during the site visit. However, Japanese knotweed is difficult to identify outside the growing season (March to September/October). As the site visit was conducted in October, it is unlikely that any Japanese knotweed present could be identified accurately and, as such, we recommend that the site be resurveyed during the growing season.

3.2 Ground conditions

3.2.1 Geology

Published geological records indicate the site to be underlain by superficial River Terrace Deposits (sand, silt and clay) overlying bedrock geology of the Lewes Nodular Chalk Formation, (BGS, 2015).

3.2.2 Radon

Information contained within an Envirocheck environmental database report (Ref. 63702396_1_1, dated January 2015) indicates that the site is located an area of intermediate probability of radon , with between 1 and 3% of the homes above the action level as defined by the Documents of the National Radiological Protection Board (Radon Atlas of England and Wales, HPA-RPD-033). As such, radon gas protection measures are not considered necessary in the construction of new dwellings or extensions.

To confirm this assertion, it is recommended that building control of the local authority be consulted.

3.2.3 Mining and quarrying

No evidence for mining or quarrying has been identified within a 500m radius of the site.

3.2.4 Landfilling and land reclamation

Evidence has been sought to identify any landfilling or land reclamation operations, past and present, which have taken place in the vicinity of the site. The sources of information referenced in this element of the desk study include:

- Envirocheck report;
- Old Ordnance Survey maps and plans; and
- Geological maps.

No Landfill sites have been identified within a 250m radius of the site.

3.2.5 Ground gas

Based on the observed presence of waste materials in the bund in the northwest of the site and the measured concentrations of total organic matter at 6% in one location, in accordance with BS8576 (2013) there is considered to be a low risk from potential ground gases associated with the site.

3.3 Hydrogeology

3.3.1 Aquifer characteristics

Based published hydrogeological data from Envirocheck report and the Environment Agency database, the hydrogeology of the site is likely to be characterised by a Secondary A Aquifer comprising the River Terrace Deposits. The underlying Lewes Nodular Chalk formation is designated as a Principal Aquifer. The groundwater regime is understood to be complex in this area. The Hilson Moran report details that groundwater is generally anticipated to flow in a southerly direction from the South Downs located to the north of the site towards the south coast. Furthermore, it is identified within the report that the site lies immediately to the south of a band of Palaeogene deposits running approximately east to west, which affect and impede the shallow groundwater flow of this area with some flows focused upwards forming springs.

Groundwater has previously been encountered resting in the Chalk aquifer below the site at a depth of 7.5m bgl, (Hilson Moran, 2012).

3.3.2 Vulnerability of groundwater resources

The soils beneath the site are classified as being located within high (HU) and intermediate (I) leaching potential areas, whereby soils are assumed until proven otherwise and can possibly transmit a wide range of pollutants.

In terms of aquifer protection, the EA generally adopts a three-fold classification of source protection zones (SPZ) for public supply abstraction wells. These are:

- Zone 1 or 'inner protection zone' is located immediately adjacent to the groundwater source and is based on a 50-day travel time from any point below the water table to the source. It is designed to protect against the effects of human activity and biological/chemical contaminants that may have an immediate effect on the source
- Zone 2 or 'outer protection zone' is defined by a 400-day travel time from a point below the water table to the source. The travel time is designed to provide delay and attenuation of slowly degrading pollutants.
- Zone 3 or 'total catchment' is the area around the source within which all groundwater recharge is presumed to be discharged at the source.

Information available on the EA website indicates that the site does not lie within a currently designated groundwater SPZ.

3.3.3 Licensed groundwater abstraction

It is understood that the site historically operated a licensed groundwater abstraction well (license no. 10/41/414002) which was drilled in 1938 according to the Hilson Moran (report reference 13829, dated 15th November 2012). The well is understood to have been located within the western area of the large greenhouse, to the north of the

entrances to the site offices and is believed to have been built over during redevelopment of the site by the current site operators circa 1988. The Envirocheck report (dated January 2015) does not include a permit end date for the abstraction licence pertaining to the site however it does document that the operator of abstraction license no. 10/41/414002 is Van Heyningen Bros. Ltd.

The Envirocheck report lists a further seven groundwater abstractions wells within a 2km radius of the site, the closest of which is located approximately 325m to the northwest for spray irrigation purposes. The abstractions are all associated with irrigation at nurseries, a golf club and for agricultural purposes with the exception of one abstraction detailed approximately 1025m to the northeast, which is also permitted for domestic use and as such the water abstracted may be associated with potable use. Given the regional flow of groundwater, this potential potable abstraction is considered to be located up-gradient of the site.

3.4 Hydrology

3.4.1 Surface watercourses

As previously mentioned, a large drainage pond is present in the south eastern corner of the site and a drainage ditch lies immediately adjacent to the eastern boundary of the site. This drain appears to flows in a southerly direction and be culverted beneath the A259 roundabout located approximately 200m southeast of the site. The site also lies within the River Basin Management Plans area for the River Arun and Western Streams, (Environment Agency, 2014).

3.4.2 Surface water abstractions

No surface water abstractions have been identified within a 1km radius of the site.

3.4.3 Preliminary flood risk assessment

The indicative floodplain map for the area, published by the EA, shows that the site does not lie within an area at risk from flooding.

It should be noted that a full flood risk assessment is outside of the scope of this report.

3.5 History of site and surrounding area

The history of the land-use and development of the site and surrounding area has been assessed based on the following sources:

- Historical maps within the Envirocheck report from 1876 to 2014; and,
- Aerial photography.

Copies of OS and County Series maps are included in the Envirocheck report in Appendix D. Reference to historical maps provides invaluable information regarding the land use history of the site, but historical evidence may be incomplete for the period pre-dating the first edition and between successive maps.

Table 2: Summary of historical development

Date	Land use/features on site	Land use/features in vicinity of site (of relevance to the assessment)
1876-1910	The site appeared to be occupied by arable land.	The area surrounding the site was predominately occupied by arable land. A railway line was located approximately 400m south of the site running east to west. In addition, a number of pits appeared to be present beyond 750m from the site.
1932	No significant change.	A small unnamed nursery was noted approximately 100m south of the site. The pits in the surrounding area generally appear to have become wooded.
1943	The western half of the site had been developed as West End Nursery comprising eight glasshouse type buildings. A chimney (likely boiler house) was noted.	Roundstone by-pass (now A259) had been developed approximately 200m south of the site.
1957	No significant change.	Buildings assumed to be glass houses had been developed neighbouring the south and west site boundary.
1970-1974	The nursery has extended into the eastern half of the site, comprising additional glasshouses.	The areas immediately to the south and west of the site have been developed as nurseries and farms. In addition, a residence labelled as West End Cottage had been constructed immediately adjacent to the southwest of the site.
1985	No significant change.	Worthing Rugby Football Club is present to the north of the site.
1994-2002	Former site buildings appear to have been demolished and the site redeveloped to house one large glasshouse plus a smaller glass house to its south. Tanks, a gas governor and laboratory are noted in the southwest of the site and a 'drainage pond' in the southeast.	No significant change.
2012-2014	The former laboratory is no longer present. No other significant	The new A280 by-pass has been constructed to the east.

	change.	
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From the earliest historic maps, in the late 1800s, the site appears to have been occupied by arable farmland. The land remained open and undeveloped until approximately 1943 by which time the western half of the site had been developed as West End Nursery comprising eight glasshouses, with a chimney (likely boiler house) noted. Several periods of redevelopment occurred between 1943 and 2014 however the current layout of the site has largely remained unchanged since 1994. In addition to the summary of historical development in the surrounding area as detailed in Table 2, the Envirocheck report (dated January 2014) identifies a number of potentially active and inactive contaminative activities in the surrounding area, including vehicle repairs, from 13m west and salvage dealers 75m southwest, with a wider range of activities beyond a 250m radius of the site.

3.6 Sensitive land uses

The South Downs located approximately 550m north of the site is designated as a National Park, however no other national or internationally designated sensitive land uses such as 'Sites of special scientific interest' (SSSI) were identified in the vicinity of the site.

There is a nitrate vulnerable zone located approximately 350m west of the site.

3.7 Initial conceptual site model

The information presented in Sections 2 and 3, has been used to compile an initial conceptual site model. The identified potential sources of contamination, associated contaminants and receptors have been considered with plausible pathways that may link them. The resulting potential pollutant linkages are considered in Section 3.7.5. The risk classification has been estimated in accordance with information in Appendix E.

3.7.1 Summary of potential contaminant sources

Potential sources and contaminants of concern are summarised in Table 3.

Table 3: Potential sources and types of contamination

Potential sources	Contaminants of concern
On-site	
Acid store, ASTs, fertiliser storage area, pesticides and herbicides used within the greenhouses, boiler house, septic tank and, gas and electric substations and made ground (waste materials identified within the north-western bund).	Fuels (hydrocarbons), PCBs, pesticides, herbicides, phenoxy acid, carbamate and urea, asbestos screen, metals, polycyclic aromatic hydrocarbons (PAHs) and ground gases.

Off-site	
Nurseries from immediately adjacent to the site.	Fuels (hydrocarbons), fertilisers and pesticides.
Vehicle repairs from 13m west.	Hydrocarbons and fuel additives.
Agricultural land	Pesticides and herbicides.

As detailed in Table 3, there is the potential for contamination to be present at the site in relation to the ASTs, acid store, pesticides and herbicides used within the greenhouses, fertiliser storage area, boiler house, septic tank, gas and electric substations and waste materials within the north-western bund.

Given the close proximity of the nurseries in the surrounding area and the former vehicle repair activities to the west, these activities have been considered as potential sources of contamination. However, based on the regional groundwater flow in this area, they are not considered to be hydraulically up-gradient of the site, therefore potential risks posed from these activities towards the site is considered low and therefore has not been assessed further.

The potential sources of contamination identified at the site and in relation to the surrounding agricultural land will be assessed further in the outline conceptual site model.

3.7.2 Sensitive receptors

Sensitive receptors that might be impacted by potential contaminants include:

- Future residents;
- Adjacent site users;
- Vegetation;
- Potable water supply pipes; and
- Buildings and infrastructure (e.g. foundations).

Please note that construction workers have not been identified in the conceptual site model as receptors because risks are considered to be managed through health and safety procedures including CDM regulations.

3.7.3 Summary of plausible pathways

The plausible pathways that might link potential contaminants and sensitive receptors are summarised below:

- Direct contact (soil, dust and vegetable ingestion, dermal contact, dust and fibre inhalation);
- Vertical and lateral migration including leaching;

- Root uptake; and
- Chemical attack of infrastructure (including water supply pipes) and buildings.

3.7.4 Data gaps and uncertainties

It should also be noted that whilst underground storage tanks (UST) were not identified within the Hilson Moran desk study report (November 2012), their presence cannot be discounted. A septic tank is known to exist. Such structures will have environmental and geotechnical implications.

There is the potential for contamination beneath existing structures including services trenches where potentially, asbestos containing materials and ash associated with former coal fired boilers may have been placed historically.

There is also the potential for asbestos containing materials associated with heating pipes etc.

3.7.5 Potentially complete pollutant linkages

An estimate of the risk associated with each linkage is summarised in Table 4 below. The risk classification has been undertaken in accordance with CIRIA C552 (Rudland et al., 2001), a summary of which is included in Appendix E.

Table 4: Risk estimation for potentially complete pollutant linkages

Potential Contaminant	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
Contaminants of concern within soil-Fuels (hydrocarbons), PCBs, pesticides, herbicides, phenoxy acid, carbamate and urea, asbestos screen, metals and polycyclic aromatic hydrocarbons (PAHs).	Future site occupants and adjacent site users	Direct contact (soil, dust and vegetable ingestion, dermal contact, dust and fibre inhalation) and inhalation pathways.	Low likelihood	Medium	Low to moderate risk Potential for significant impact within soil at the site is considered low, however if present, it is possible that future site users may come into contact through areas of soft landscaping.
	Vegetation	Plant uptake	Low likelihood	Mild	Low risk Potential for significant impact within soil at the site is considered low, however if present, it is possible that vegetation may be affected.
	Potable water supply pipes	Direct contact	Low likelihood	Medium	Low to moderate risk Potential for significant impact within soil at the site is considered low, however if present, it is possible that any future plastic utilities may be affected.
	Buildings and infrastructure (foundations)	Direct contact	Low likelihood	Mild	Low risk Potential for significant impact within soil at the site is considered low, however if present, it is possible that buried concrete may be affected.
	Groundwater (Secondary A and Principal Aquifers)	Vertical migration	Low likelihood	Medium	Low to moderate risk Potential for significant impact within soils at the site is considered low, however if present, based on the sensitive nature of the underlying aquifers there is considered to be a moderate to low risk that the underlying aquifers may be affected.

Potential Contaminant	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
Potential ground gases associated with Made Ground.	Future residents	Inhalation in indoor and outdoor air	Low likelihood	Medium	Low to moderate risk Potential for significant quantities of non inert Made Ground at the site is considered low, however if present, it is possible that future site users may be exposed to the ground gases in indoor and outdoor air.
	Buildings and infrastructure (foundations)	Migration and accumulation of gas within on-site buildings and services	Low likelihood	Mild	Low risk Potential for significant quantities of non inert Made Ground at the site is considered low, however if present, it is possible that onsite buildings and services may be affected by the accumulation of ground gases.

The potentially complete pollutant linkages with a risk of low to moderate or above that may drive site investigation works are:

- Risks from potential contaminants of concern within soils to human health receptors such as future site occupants and adjacent site users via direct contact and inhalation pathways;
- Risks for potential contaminants of concern within soils to potable water supply pipes via direct contact pathways;
- Risks for potential contaminants of concern within soils to migrate through the unsaturated zone towards the underlying Secondary A and Principal Aquifers; and,
- Risks from potential ground gases associated with Made Ground to human health receptors such as future site occupants and adjacent site users via inhalation pathways.

There is also a low risk of the following potentially complete pollutant linkages:

- Risks from potential contaminants of concern within soils to vegetation via direct contact pathways;
- Risks for potential contaminants of concern within soils to buildings and infrastructure via direct contact pathways; and,
- Risks from potential ground gases associated with Made Ground to buildings and infrastructure via migration and accumulation of ground gases.

4 SITE INVESTIGATION METHODOLOGY

RSK carried out intrusive investigation work and subsequent gas monitoring (3 visits conducted to date) and groundwater survey visits during January and February 2015 to further investigate the potentially complete pollutant linkages identified in the outline conceptual site model and to inform geotechnical constraints.

4.1 Sampling strategy and methodology

The techniques adopted for the investigation have been chosen considering the anticipated ground conditions, existing land use and the proposed development. Shallow boreholes were drilled using drive-in sampler percussive techniques. In addition shallow boreholes within the footprint of the greenhouses were advanced using hand augered techniques due to restrictions with in these areas in relation to fuel emissions. Selected soil samples were obtained for environmental and geotechnical assessment.

4.1.1 Health and safety considerations

Prior to intrusive investigation works, reference was made to existing service drawings for the site to prevent damage to underground utilities, in addition, each of the exploratory locations were cleared and marked out by a service clearance company.

4.1.2 The RSK supervising engineer carried out a scan of each exploratory hole location using a Cable Avoidance Tool (CAT) as a final check prior to commencement of drillingInvestigation locations

Intrusive site works were completed between the 26 and 28 January 2015.

The investigation and the soil descriptions were carried out in general accordance with 'BS 5930:1999. Code of Practice for Site Investigations' (BSI, 1999). The exploratory hole records are presented in Appendix F.

The locations of the intrusive investigations are shown in Figure 2. The rationale for these locations is given in Table 5. The investigation was targeted to identify impact from potential sources of contamination and also to provide information on geotechnical design parameters.

Table 5: Exploratory hole location rationale

Exploratory hole number	Location	Rationale
HA1-HA17	Northern and south-eastern areas of the development associated primarily with dwellings with gardens and communal landscaped areas.	General coverage within the greenhouses.
HA18 & HA18A	Located in the southwest of the site in an area proposed for dwellings with gardens.	To assess potential contamination from an above ground diesel storage tanks just to the north of these locations.
BH1	Centre of proposed development.	General site coverage and provide geotechnical design parameters
BH2	South-western corner of the development within an area of proposed communal landscaping.	General site coverage and investigate potential contamination within the bund materials.
BH3 & BH4	Along the southwest site boundary, within areas of proposed soft landscaping.	To investigate potential contamination within the bund materials, including in the immediate vicinity of the waste materials observed during the site walkover.
BH5	To the west of the large greenhouse, in an area proposed for dwellings with gardens.	General site coverage and provide geotechnical design parameters.
BH6	To the northwest of the large greenhouse, on the edge of an area proposed for dwellings in the vicinity of a proposed roadway.	To assess potential contamination from the greenhouse and general site coverage.
BH7	To the north of the large greenhouse, on the edge of an area proposed for dwellings in the vicinity of a proposed roadway.	General site coverage and to assess potential contamination from storage containers/sheds (contents unknown) near this location and provide geotechnical design parameters.
BH8	To the northeast of the large greenhouse, on the edge of an area proposed for dwellings in the vicinity of a proposed roadway.	To assess potential contamination from the greenhouse and general site coverage.
BH9 & BH10	To the east of the large greenhouse between a proposed roadway and soft landscaped area.	To assess potential contamination from the greenhouse and general site coverage, general site coverage and provide geotechnical design parameters

Exploratory hole number	Location	Rationale
BH11	Located between the small greenhouse and pond in the southeast of the site, on the edge of an area proposed for dwellings with gardens.	To assess potential contamination from the small greenhouse, general site coverage and provide geotechnical design parameters.
BH12	Located to the south of the small greenhouse on the edge of an area proposed for dwellings with gardens.	To assess potential contamination from the small greenhouse and general site coverage.
BH13	Located to the south of the small greenhouse in an area proposed for dwellings with gardens.	To assess potential contamination from an above ground storage tank just to the north of this location potential contamination from the CHP plant up-gradient of this location.
BH14 & BH14A	Located in the southwest of the site, in an area proposed for dwellings with gardens.	To assess potential contamination from the diesel tanks just to the east of these locations.
BH15	Located in the southwest of the site, in an area proposed for dwellings with gardens.	General site coverage.
Notes: Location HA18 had to be terminated at 0.25m bgl as it was suspected that a service may be present.		

The investigation points were located approximately by reference to physical features present on the site at the time of investigation in relation to a recent topographical survey.

4.1.3 Soil sampling, in-situ testing and laboratory analysis

Soils collected for laboratory analysis were collected in a variety of containers appropriate to the anticipated testing suite required. Samples were stored in accordance with the RSK quality procedures to maintain sample integrity and preservation and to minimise the chance of cross contamination.

Samples obtained are recorded together with their depths on the exploratory hole records in Appendix F. The samples were transported to the laboratory in chilled cool boxes. Chain of custody forms can be provided if required. The rationale for soil sample chemical analysis is presented in Table 6.

Table 6: Scheduled analysis – soil

Exploratory hole no. and sample depth (m bgl)	Analyte	Rationale
BH1 at 0.3-0.4m , BH2 at 1.2-1.6m, BH3 at 1.5-2.0m , BH4 at 0.6-0.9m, BH5 at 0.3-0.4m, BH6 at 0.0-0.1m, BH7 at 0.4-0.6m , BH8 at 0.3-0.4m, BH10 at 1.1-1.4m, BH11 at 0.3-0.4m, BH12 at 0.2-0.4m, BH13 at 0.1-0.3m, BH15 at 0.1-0.3m, HA1 at 0.3-0.4m, HA2 at 0.4-0.5m, HA3 at 0.4-0.5m, HA4 at 0.4-0.5m, HA5 at 0.4-0.6m, HA6 at 0.3-0.4m, HA7 at 0.6-0.9m, HA8 at 0.4-0.5m, HA9 at 0.4-0.5m, HA10 at 0.2-0.4m, HA11 at 0.3-0.4m, HA12 at 0.3-0.4m, HA13 at 0.4-0.5m, HA16 at 0.4-0.5m, HA17 at 0.3-0.4m.	EnviroLab Suite 2 : metals, PAH, TPH-CWG, BTEX	General suite of testing appropriate to site history.
BH1 at 0.5-0.5m, BH2 at 1.2-1.6m, BH3 at 1.5-2.0m , BH4 at 0.6-0.9m, BH4 at 2.6-3.0m, BH5 at 0.3-0.4m, BH6 at 0.0-0.1m, BH7 at 0.4-0.6m , BH8 at 0.3-0.4m, BH9 at 0.1-0.2m, BH10 at 1.1-1.4m, BH10 at 1.5m, BH11 at 0.3-0.4m, BH12 at 0.2m, BH12 at 0.2-0.4m, BH13 at 0.1-0.3m, BH14A at 0.2-0.6m, BH14A at 0.8-0.9m, BH15 at 0.5m, HA1 at 0.3-0.4m, HA2 at 0.4-0.5m, HA3 at 0.4-0.5m, HA4 at 0.4-0.5m, HA5 at 0.4-0.6m, HA6 at 0.3-0.4m, HA7 at 0.6-0.9m, HA8 at 0.4-0.5m, HA9 at 0.4-0.5m, HA10 at 0.2-0.4m, HA11 at 0.3-0.4m, HA12 at 0.3-0.4m, HA13 at 0.4-0.5m, HA16 at 0.4-0.5m, HA17 at 0.3-0.4m.	Asbestos screen	To assess for presence of asbestos fibres within soils.
BH14A at 0.2-0.6m, BH14A at 0.8-0.9m, HA18A at 0.3-0.5m	TPH CWG	To assess for presence of hydrocarbons in relation to the diesel tanks in the near vicinity of these locations.

HA4 at 0.4-0.5m, HA5 at 0.4-0.6m, HA9 at 0.4-0.5m, HA17 at 0.3-0.4m.	Pesticides	To assess for presence of pesticides in soil within the greenhouses.
HA2 at 0.4-0.5m, HA6 at 0.3-0.4m, HA12 at 0.3-0.4m.	Triazine herbicides	To assess for presence of herbicides in soil within the greenhouses.
HA3 at 0.4-0.5m, HA11 at 0.3-0.4m, HA17 at 0.3-0.4m	Phenoxy acid	To assess for presence of phenoxy acid in soil within the greenhouses.
HA7 at 0.6-0.9m, HA10 at 0.2-0.4m, HA17 at 0.3-0.4m	Carbanate and urea	To assess for presence of carbonate and urea in soil within the greenhouses.
BH2 at 1.2-1.6m, BH4 at 0.6-0.9m, BH6 at 0.0-0.1m, BH9 at 0.1-0.2m, HA1 at 0.3-0.4m	Total organic carbon (TOC)	To inform risk assessment.
BH1 at 1.4-1.6m, 2.4-2.6m and 2.5m, BH5 at 1.4-1.6m and 2.4-2.6m, BH7 at 1.4-1.6m, BH9 at 0.7-1.0m and 1.6-1.8m, BH11 at 1.0-1.2m, 1.6-1.8m and 2.4-2.6m.	Moisture content and liquid limits/plastic limits tests.	Geotechnical design parameters.
BH6 at 2.0m, BH9 at 1.6m.	Particle size distribution - sieve analysis	Geotechnical design parameters.
BH6 at 1.3-1.5, BH8 at 0.9-1.0 and 1.5-1.6, BH12 at 1.4-1.6, BH15 at 1.4-1.6 and 2.4-2.6.	BRE suite for non pyritic geology (% stones >10mm, pH BRE and sulphate BRE)	Geotechnical design parameters including to assess for buried concrete in potentially aggressive ground.

Standard penetration testing was undertaken typically at 1m intervals within some shallow borehole. Shear vane testing was carried out in cohesive soils where possible from shallow boreholes. Disturbed samples were obtained for geotechnical testing purposes. The samples obtained and results of in-situ testing is provided on the borehole records in Appendix F.

5 GROUND CONDITIONS

The results of the intrusive investigation and subsequent laboratory analysis undertaken are detailed below. The descriptions of the strata encountered, notes regarding visual or olfactory evidence of contamination, list of samples taken, field observations of soil and groundwater, in-situ testing and details of monitoring well installations are included on the exploratory hole records presented in Appendix F.

5.1 Soil

The exploratory holes revealed that the site is underlain by made ground in 25 of the 28 locations underlain by River Terrace Deposits. The River Terrace Deposits are anticipated to underlay the Lewes Nodular Chalk formation beneath the site, however the chalk formation was only encountered in BH8 during the intrusive investigation at 2.6m bgl.

This appears to generally confirm the stratigraphical succession described within the published geological records.

For the purpose of discussion, the ground conditions are summarised in Table 7 and the strata discussed in subsequent subsections.

Table 7: General succession of strata encountered

Strata	Exploratory holes encountered	Depth to top of stratum m bgl	Thickness (m)
Made ground	BH1-BH15, HA3, HA4, HA6, HA7, HA9, HA10, HA12, HA13, HA17, HA18 and HA18A	Surface Level	0.1 (BH8)-3.0m (BH2)
River Terrace Deposits	BH1-BH15, HA1, HA2, HA3, HA5, HA8, HA9, HA11, HA14, HA15 and HA16	Surface level - 3.0m	2.5 (BH8)-3.3m< (BH12)
Weathered Chalk	BH8 only	2.6 (BH8)	0.4m< (BH8)

5.1.1 Made ground

Made ground was encountered within all the machine drilled borehole locations located across the site and within 11 out of the 19 hand augured boreholes. The materials encountered in boreholes BH1-BH15 generally comprised clayey sandy gravels compacted limestone gravel overlying sandy gravelly clay, with brick, wood, charcoal, plastics, metal wire, clinker and ash fragments present. The materials encountered in the hand auger locations containing made ground generally comprised gravelly clay with

varying quantities of sand and silt and occasional concrete, mortar, glass, polystyrene, and charcoal fragments present.

5.1.2 River Terrace Deposits

This stratum was encountered beneath the made ground or directly from the ground surface as detailed in Table 8. The River Terrace Deposits generally comprised silty clays and sandy gravelly clays with occasional fine to coarse gravel layers. The thickness of the River Terrace Deposits was only proven in BH8 at 2.5m thick.

A summary of the in-situ and laboratory test results in this stratum is presented in Table 8 and the laboratory certificates can be found in Appendix H.

Table 8: Summary of in-situ and laboratory test results for River Terrace Deposits

Soil parameters	Range	Reference
Liquid limit (%)	37 - 44	Appendix H
Plastic limit (%)	18 - 23	
Modified plasticity index (%)	5 - 24	
Moisture content (%)	12 - 26	
Plasticity term	Intermediate	
Shrinkability	Low to Medium	NHBC
SPT 'N' values	0 - 34	Appendix F
Undrained shear strength (kN/m ²) from shear vane	32 - 73	
Undrained shear strength classification	Low to medium	BS EN ISO 14688-2:2004
Stiffness term	Soft to stiff	BS-EN 5930

5.1.3 Lewes Nodular Chalk Formation

Beneath the River Terrace Deposits, the Lewes Nodular Chalk was encountered in BH8 from a depth of 2.6m bgl to the full depth of boring of 3mbgl. The stratum comprised off white cream very gravelly clayey comminuted chalk (weathered chalk).

No in-situ or geotechnical laboratory tests were conducted in this stratum given that it was only encountered for 0.4m in a single location.

5.1.4 Groundwater

Groundwater was not encountered during the intrusive investigation, however, during the subsequent gas monitoring visits, groundwater was encountered at depths ranging between 1.79m (BH5 24/02/14) and 3.4m bgl (BH1 24/02/15) in boreholes BH1, BH5, BH11 and BH14A. It is noted that during the first gas monitoring visit all the boreholes

with exception to BH5 were found to be dry. It is noted that a large difference was observed in the groundwater level within BH1 between the second and third visit at 1.4m.

It should be noted that groundwater levels might fluctuate for a number of reasons including seasonal and tidal variations. A further gas monitoring visit is planned during which time groundwater levels will be taken to further establish the range of conditions and any trends in groundwater levels.

Depths to groundwater within installed monitoring wells were recorded using an electronic dip meter on 30 January 2015, 13 February 2015 and 24 February 2015. The monitoring results are given in Table 9.

Table 9: Groundwater monitoring results

Exploratory hole location	Visit No.	Depth to groundwater (mbgl)	Depth to base (mbgl)	Ground Level (mSTD)*	Water Table Elevation (mSTD)
BH1	1	Dry	3.74	11.57	Dry
	2	2.0	3.74		9.57
	3	3.4	3.73		8.17
BH5	1	2.80	2.93	11.49	8.69
	2	2.91	2.93		8.58
	3	1.79	2.93		9.70
BH7	1	Dry	1.90	11.40	Dry
	2	Dry	1.90		Dry
	3	Dry	1.90		Dry
BH9	1	Dry	2.93	11.56	Dry
	2	Dry	2.93		Dry
	3	Dry	2.93		Dry
BH11	1	Dry	2.93	11.30	Dry
	2	2.80	2.93		8.5
	3	Dry	2.93		Dry
BH14A	1	Dry	2.92	11.15	Dry
	2	2.92	2.93		8.23
	3	2.12	2.92		9.03
Notes :		* Denotes estimated level from topographic survey			

Based on the thickness of the water columns encountered within the monitoring wells during the three gas monitoring visits, it considered that insufficient quantities of groundwater water were present in order that representative samples could be collected. Therefore, no groundwater samples have been collected from the site to date.

Based on review of the above estimated groundwater elevations groundwater flow beneath the site is inferred in a southerly direction.

5.1.5 Visual/olfactory evidence of soil and groundwater contamination

Possible asbestos containing materials (ACM) were encountered in BH1 at 0.5-0.8m bgl, BH4 at 0.6-0.9m bgl and 2.6-3.0m bg, BH12 at 0.2m bgl and BH15 at 0.5m bgl. As previously reported, made ground was encountered in 26 of the 28 locations, of which charcoal fragments and ash were encountered in 16 of the locations. No other visual/olfactory evidence for gross soil or groundwater contamination was encountered during the intrusive works.

5.1.6 Ground gas monitoring

To date, three gas monitoring visits have been carried out on 30 January 2015, 13 February 2015 and 24 February 2015.

An infrared gas analyser was used to assess ground gas concentrations (methane, carbon dioxide, oxygen and Lower Explosive Limits), flow rates and atmospheric pressures. All monitoring results together with the temporal conditions are contained within Appendix I.

Depths to groundwater were recorded using an electronic dip meter on the same dates. Depths to groundwater are given in the monitoring data given in Appendix I.

5.1.7 Ground gas regime

The results of the three ground gas monitoring visits carried out are summarised in Table 10 and given in Appendix I. The gas risk assessment for the site is discussed in Section 6.2.3.

Table 10: Summary of ground gas monitoring data

Date	Methane (% by volume in air)		Carbon Dioxide (% by volume in air)		Oxygen (% by volume in air)		Flow Rate l/hr	
	Min	Max	Min	Max	Min	Max	Min	Max
Visit 1 30/01/15	<0.1	0.1	0.1	4.7	11.5	21.6	0.0	0.1
Visit 2	<0.1	0.1	<0.1	13.4	6.5	22.0	0.0	0.1
Visit 3	<0.1	0.1	0.1	7.8	11.5	21.9	0.0	0.1
Visit 4	Data not yet available							
Date	Temporal conditions during the monitoring round							
	Atmospheric Pressure				Rainfall		Other	
Visit 1	982				Dry and sunny			
Visit 2	1002				Heavy rain			
Visit 3	1009				Dry and sunny			
Visit 4	Data not yet available							

Methane: Methane concentrations have remained low with a maximum concentration of 1%v/v across the site;

Carbon Dioxide: Carbon dioxide concentrations have typically remained below 5%v/v across the site, with exception to BH1 within which a maximum concentration of 13.4%v/v was recorded; and

Flow Rates: Flow rates have remained typically low, with a peak rate of 1.0l/hr.

5.2 Refinement of the initial conceptual site model

Groundwater was encountered within the River Terrace Deposits, at depths ranging between 1.79m (BH5 24/02/14) and 3.4m bgl (BH1 24/02/15).

Possible asbestos containing materials (ACM) were encountered in BH1 at 0.5-0.8m bgl, BH4 at 0.6-0.9m bgl and 2.6-3.0m bg, BH12 at 0.2m bgl and BH15 at 0.5m bgl. As already mentioned, made ground was encountered in 26 of the 28 locations, of which charcoal fragments and ash were encountered in 16 of the locations. No other visual/olfactory evidence for gross soil or groundwater contamination was encountered during the intrusive works.

Based on the above, it is considered that the findings of the initial conceptual site model do not need revising. Chemical testing of soils and subsequent generic quantitative risk assessment will be undertaken to assess the extent of potential contaminants contained in soils at the site.

5.2.1 Uncertainty

Although every effort has been made to identify all potential sources of contamination and investigate areas of potential risk, the nature of site investigation is such that there may be areas of undiscovered contamination which have not been encountered, particularly directly beneath the CHP building, nitric acid store, substations and ASTs, which therefore have not been taken into account.

Based on the thickness of the water columns encountered within the monitoring wells during the three gas monitoring visits, it considered that insufficient quantities of groundwater water were present for representative samples to be collected from the existing monitoring well network. Therefore, potential risks posed to the underlying groundwater has not be assessed.

6 QUANTITATIVE RISK ASSESSMENT

In line with CLR11 (EA, 2004a), there are two stages of quantitative risk assessment, generic and detailed. The GQRA comprises the comparison of soil, groundwater, soil gas and ground gas results with generic assessment criteria (GAC) that are appropriate to the linkage being assessed. This comparison can be undertaken directly against the laboratory results or following statistical analysis depending upon the sampling procedure that was adopted.

6.1 Linkages for assessment

Section 5.2 presents the refined conceptual model which identified the linkages that required assessment after the findings of the site investigation had been considered. These linkages together with the method of assessment are presented in Table 11.

Table 11: Linkages for generic quantitative risk assessment

Potentially relevant pollutant linkage	Assessment method
Direct contact with impacted soil by future residents	Human health GAC (Appendix J) for a proposed residential end use with private gardens since proposed end use includes residential gardens. Statistical analysis was not undertaken owing to majority of sampling locations being targeted in the vicinity of previously un-investigated sources in the eastern portion of the site.
Uptake of contaminants by vegetation potentially impacting plant growth	Comparison of soil data to GAC in Appendix K.
Contaminants impacting building materials	Comparison of soil data to GAC in Appendix L for plastic water supply pipes and concrete assessment using UKWIR (2010) guidance.
Concentrations of methane and carbon dioxide in ground gas entering and accumulating in: Depressions and excavations during any site works and development that could affect site workers; and Enclosed spaces or small rooms in new buildings, which could affect future residents. In the case of methane, this could create a potentially explosive atmosphere, whilst death by asphyxiation could result from CO ² .	Gas screening values (GSV) have been calculated using the monitoring data collected by RSK. The GSV have been compared with the NHBC Traffic Light System (for low-rise houses) as presented within CIRIA Report C665.

6.2 Methodology and results

The methodology and results of the GQRA are presented for each relevant pollutant linkage in turn.

For the purposes of risk assessment, samples will be compared to GACs relevant to the typical Soil Organic Matter (SOM) for that stratum. Soil samples of topsoil and made ground were obtained for chemical laboratory testing. The three made ground samples analysed for Total Organic Carbon (TOC) reported values of between 1.40% and 6.43% and the two samples analysed from the River Terrace Deposits ranged between 0.43% and 0.49%. These results can be converted to give an SOM of between 0.73% and 11%. On this basis, the samples from the made ground and River Terrace Deposits will be compared to the GAC for SOM of 1%.

6.2.1 Direct contact with impacted soil by future residents

The measured concentrations of contaminants of potential concern in soil have been compared to the RSK GAC derived for the protection of human health in relation to a proposed residential end use with private gardens, as presented in Appendix J.

The comparison of the laboratory results to the applicable RSK human health GAC indicates that none of the measured concentrations of contaminants of potential concern in soil collected during this phase of works were found to be in excess of the GAC, with the exception of benzo(a)pyrene and zinc.

Four of the twenty eight samples analysed for benzo(a)pyrene were found to be in excess of the GAC, with a maximum concentration of 1.82mg/kg reported in BH2 at 1.2-1.6m bgl. This is considered to be marginally in excess of the GAC of 0.83mg/kg. However, this value is below the recently released LQM Suitable for Use Levels (S4UL) for benzo(a)pyrene of between 2.2 and 3.0mg/kg and the Category 4 Screening Level of 5mg/kg. Based on this the marginal exceedance of the RSK GAC, it is not considered to pose a potentially unacceptable risk to human health.

A single concentration of zinc (4430mg/kg) out of the twenty eight samples analysed for metals was found to be marginally (in the same order of magnitude) in excess of the GAC of 3800mg/kg. Based on this the marginal exceedance of the RSK GAC for zinc, it is not considered to pose a potentially unacceptable risk to human health.

It is noted that speciated chromium analysis was not conducted at the site. It is considered unlikely that chromium VI is present at the site and therefore the chromium results have been compared to the RSK GAC for chromium III.

Concentrations of the pesticides, dichlorodiphenyldichloroethylene (p,p-DDE), dichlorodiphenyltrichloroethane (p,p-DDT), Dichlorodiphenyldichloroethane (p,p-TDE (DDD)), 1,1,1-trichloro-2-(2-chlorophenyl)-2-(4-chlorophenyl)ethane (o,p-DDT) were measured above levels of detection in one or more of the four soil samples analysed for pesticides. No applicable RSK GAC, UK or European screening values are available for these compounds, as such screening levels from the United States Environmental

Protection Agency (US EPA, 2015) for residential end-use were compared to the measured concentrations of p,p-DDE, p,p-DDT and DDD. One of the four measured concentrations of p,p-DDE at 1.95mg/kg was found to be in excess of the screening value of 1.6mg/kg. No readily available screening value is available for o,p-DDT. Based on the frequency and magnitude of the pesticide compounds detected they cannot be discounted as posing a potentially unacceptable risk to human health.

6.2.2 Exposure to asbestos via inhalation pathways

Asbestos containing materials of cement and loose insulation were detected in six of the 27 samples submitted for chemical analysis and comprised chrysotile (BH2, BH3, BH5, BH10 and BH14) and amosite (BH13 and BH14). In addition the five samples of suspected asbestos materials from BH1, BH4, BH12 and BH15 were all confirmed to be asbestos cement comprises of chrysotile. The detections of asbestos pose a potentially unacceptable risk to the human health of construction workers and further residents via inhalation pathways.

6.2.3 Ground gas

In order to assess the significance of ground gases at the site, measured concentrations and flow rates have been used to generate Gas Screening Values (GSV's). These have then been compared with the NHBC Traffic Light System presented within CIRIA Report 665 as the site is to be developed with low-rise housing or apartments.

A summary of initial ground gas conditions, based upon the single round of monitoring carried out to date are:

- Methane – maximum concentration of 4.2%v/v;
- Carbon Dioxide – Maximum concentration 4.7%v/v; and
- Flow – Maximum positive steady rate 1.4l/hr.

Based on the above concentrations, GSV's may be calculated as follows:

$$GSV_{\text{METHANE}} = (0.1 / 100) * 0.1 = 0.0001 \text{ l/hr; and}$$

$$GSV_{\text{CARBON DIOXIDE}} = (13.4 / 100) * 1.4 = 0.19 \text{ /hr.}$$

Monitoring results from the three visits conducted at the site to date would characterise the site as being Characteristic Situation 'Amber 1' for traditional low-rise houses. On this basis, low level ground gas protection measures would be considered necessary at the site. Low-level gas protection measures would involve an appropriate membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into the buildings.

It is considered that the ground gas data collected is representative of worse case conditions at the site, given the low pressure recorded during monitoring visit 1 of 982mbars. Given this and the consistency of the results, further monitoring is not considered necessary at this time. However, it should be noted that the Local Authority

may require additional gas monitoring to be undertaken and that the relevant NHBC/CIRIA guidance recommends a minimum of six monitoring rounds over a 3 month period.

6.2.4 Uptake of contaminants by vegetation potentially inhibiting plant growth

The results have been directly compared with the GAC presented in Appendix K for this linkage. The results indicate that a relevant pollutant linkage is unlikely to exist associated with phytotoxic effects in relation to copper and nickel however five of the twenty eight soil samples analysed were in excess of the GAC for zinc. Given the physical nature of the Made Ground and the lack of topsoil at the site, there will be a requirement to provide a suitable growing medium in areas (cover layer comprising topsoil/subsoil) of soft landscaping/gardens as part of any redevelopment.

6.2.5 Impact of organic contaminants on potable water supply pipes

For initial assessment purposes, the results of the investigation have been compared with the GAC presented in Appendix L for this linkage, which are reproduced from *UKWIR Report 10/WM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites* (UKWIR, 2010).

Measured concentrations of hydrocarbons have been found to be in excess of the GAC for oils in the ranges >C11-C20 in relation to polyethylene water supply pipes in two locations BH4 and BH14.

Given that made ground was encountered in twenty six of the twenty eight investigation locations associated with this phase of works and that elevated concentrations of TPH compounds have been recorded, it is recommended that consultation be sought with the local water authority with respect to the design of buried water pipes. Given the presence of made ground, it is likely that barrier pipe will be required.

It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling/analytical strategy may be required at a later date once the routes of the supply pipes are known. In addition, it is recommended that the relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

6.3 Environmental assessment conclusions

Comparison of the laboratory data collected from the site to the screening criteria indicates potentially unacceptable risks exist in relation to:

- Future end-uses from measured concentrations of pesticides in excess of human health screening values in soil;

- Future end-uses and buildings from the accumulation of ground gases (based on the initial three monitoring visits only);
- Future end-users and construction workers from the presence of asbestos containing materials identified in soil;
- Construction workers from asbestos fibres associated with the potential disturbance of the asbestos containing materials;
- Vegetation in relation to phytotoxic effects from measured concentrations of zinc in soil; and
- Future water supply pipes.

Based on the absence of the groundwater monitoring data potential risks posed to the underlying aquifers cannot be quantified at this time. Based on the low magnitude of the measured concentrations of determinands encountered in soil to date and the low solubility of the pesticides detected above LOD, it is considered unlikely that these would result in significant impacts within the underlying aquifers.

6.3.1 Uncertainty

As previously reported in Section 5.2.1, although every effort has been made to identify all potential sources of contamination and investigate areas of potential risk, the nature of site investigation is such that there may be areas of undiscovered contamination which have not been encountered, particularly directly beneath the CHP building, nitric acid store, substations and ASTs. The uncertainty associated with the CHP building and the ASTs includes potential risks posed to the underlying aquifer which are yet to be quantified due to the limited presence of groundwater encountered during the monitoring visits to date.

7 GEOTECHNICAL SITE ASSESSMENT

7.1 Engineering considerations

It is understood that the proposed development is to involve the construction of 195 residential properties and associated infrastructure. At this stage no specific information relating to building loads has been provided and therefore a wall loading of 100kN/m has been considered..

7.2 Geotechnical hazards

A summary of commonly occurring geotechnical hazards is given in Table 12 together with an assessment of whether the site may be affected by each of the stated hazards.

Table 12: Summary of main potential geotechnical hazards that may affect site

Hazard category (excluding contamination issues)	Hazard status based on investigation findings and proposed development			Engineering considerations if hazard affects site
	Found to be present on site	Could be present but not found	Unlikely to be present and/or affect site	
Sudden lateral changes in ground conditions		√		Likely to affect ground engineering and foundation design and construction
Shrinkable clay soils	√	The clay soil have been assessed to be of low to medium shrinkage potential. For design purposes, medium shrinkage potential should be assumed		Design to NHBC Standards Chapter 4 or similar
Highly compressible and low bearing capacity soils, (including peat and soft clay)	√	In the vicinity of BH11, very soft clay was encountered at 3mbgl.		Likely to affect ground engineering and foundation design and construction
Silt-rich soils susceptible to rapid loss of strength in wet conditions	√			Likely to affect ground engineering and foundation design and construction
Running sand at and below water table		√		Likely to affect ground engineering and foundation design and construction

Hazard category (excluding contamination issues)	Hazard status based on investigation findings and proposed development			Engineering considerations if hazard affects site
	Found to be present on site	Could be present but not found	Unlikely to be present and/or affect site	
Karstic dissolution features (including 'swallow holes' in Chalk terrain)		√		May affect ground engineering and foundation design and construction – refer to Section 4.1.2
Ground subject to or at risk from coastal or river erosion			√	Likely to require special protection/stabilisation measures
High groundwater table (including waterlogged ground)			√	May affect temporary and permanent works
Existing sub-structures (e.g. tunnels, foundations, basements, and adjacent sub-structures)	√	Site currently occupied by offices, CHP building and glasshouses		Likely to affect ground engineering and foundation design and construction
Filled and made ground (including embankments, infilled ponds and quarries)	√			Likely to affect ground engineering and foundation design and construction
Adverse ground chemistry (including expansive slags and weathering of sulphides to sulphates)		√		May affect ground engineering and foundation design and construction
Note: Seismicity is not included in the above table as this is not normally a design consideration in the UK.				

7.3 Foundations

7.3.1 General suitability

Only associated with existing embankments, was significant made ground encountered. Elsewhere made ground generally extended to depths of <0.5mbgl. Subject to further assessment, the ground conditions are considered potentially suitable for the adoption of spread foundations taken down through any made ground and founded in the underlying River Terrace Deposits (silty clay) where a reduced bearing capacity can be assumed.

7.3.2 Spread foundations

The recommendations for the design and construction of spread foundations in relation to the ground conditions are set out in Table 13.

Table 13: Design and construction of spread foundations

Design/construction considerations	Design/construction recommendations
Founding stratum	River Terrace River Terrace Deposits (soft to firm silty clay)
Depth	Foundations should be taken to a minimum depth of 0.9m below finished ground level and at least 0.1m into the founding stratum below any overlying made ground or to any greater depth required in respect of the special design considerations given below.
Special design considerations	Evidence for desiccation was identified in shallow cohesive soils in the vicinity of BH5 and BH7. Desiccated clays are also lightly to exist elsewhere. Owing to the presence of shrinkable clay, foundations should be designed taking into account all the normal precautions, including minimum founding depths, to minimise the risk of future foundation movements in accordance with NHBC standards. The findings of the ground investigation indicate that foundations should be designed for shrinkable soils of medium volume change potential. Furthermore the site includes trees mainly along site boundaries which must be taken into consideration. Foundation design should be completed in line with guidance outlined in NHBC Standards Chapter 4.2 'Building Near Trees'.
Bearing capacity	Spread foundations with a width of up to 1m and constructed on the soft to firm clay at a minimum depth of 0.9m may be designed using a net allowable bearing pressure of 75. kN/m². The allowable bearing capacity includes an overall safety factor of 3 against bearing capacity failure and with total settlements associated with the bearing pressure estimated to be less than 25mm.
Dewatering	Groundwater was encountered in monitoring wells post investigation to depths typically between 1.8m and 3.4mbgl. Dewatering may therefore be required for deep excavations. The cohesive nature of the soils encountered suggests that pumping from open sumps should be sufficient to keep the excavations reasonably dry.
Construction considerations and recommendations	All foundation excavations should be inspected, and any made ground and soft, organic or otherwise unsuitable materials removed and replaced with mass concrete. To assess the suitability of the ground conditions for the adoption of spread foundations, it is recommended that trial pits are excavated across the site. The trial pits will also conform the practicality of foundation construction with respect to excavation stability and ground water ingress. It is recommended that a trial pit be excavated in the vicinity of BH11 to investigate the very soft clay encountered at 3m depth.

Should supplementary investigation reveal that trench fill foundations are not a viable proposition, then consideration should be given to the adoption of piled foundations. Piled foundations may also be the preferred option where spread are deep due to the thickness of made ground or construction in the vicinity of trees.

7.3.3 Piled foundations

To provide information for pile design, it is recommended that 3 boreholes are sunk using cable percussive drilling techniques to a provisional depth of 20m. The boreholes may be combined with the groundwater monitoring boreholes recommended in Section 9.1.2.

7.3.4 Foundation works risk assessment

Depending upon the foundation options, a foundation risk assessment may be required.

7.3.5 Floor slabs

Whilst the ground conditions are considered potentially suitable for the adoption of ground bearing floors, it is recommended that the ground floors be suspended throughout.

7.3.6 Roads, hardstanding and drainage

The results of in-situ testing indicate that the near surface soils have a CBR value that ranges from between 1% and 7%, the results are summarised in Table 14.

Table 14: Summary of CBR values derived from in-situ mexecone testing

Exploratory hole location	Test Depth	Mexecone Readings	CBR Result
BHA	0.40m	1.5, 1.5, 1.5, 1.5, 2, 2, 2.5, 2	1.5%
BHB	0.40m	5, 4, 3.5, 3, 4, 4, 4, 3	3%
PH1	0.40m	4.5, 7, 10, 10, 11, 15, 11, 12	4.5%
PH2	0.40m	5, 5, 8, 10, 10, 10, 12, 11	5%
PH3	0.00m	7, 7, 14, 14, 14, 12, 12, 7	7%
PH4	0.40m	2.5, 3, 1.5, 1, 1.5, 2, 2, 2	1%
PH5	0.40m	4, 4, 4, 4	Refusal
PH6	0.40m	2, 2, 2, 10	Refusal

The anticipated subgrade soils are likely to comprise River Terrace Deposits (silty clay) of medium shrinkage potential. Based upon the results of in-situ and laboratory tests, it is recommended that a CBR of 2% be assumed for preliminary design purposes at this time. Once the road layout has been finalised, it is recommended that in-situ CBR or plate bearing tests be undertaken on the proposed sub-grade to confirm pavement design thickness. Since the majority of results for Atterberg Limit testing on the River Terrace Deposits River Terracerevealed a plasticity index of >20%, the sub-grade soils can be regarded as being frost-susceptible, based upon the criteria given in Appendix 1 of TRRL (1970) Report Road Note 29. When the sub-grade is frost-susceptible the thickness of sub-base must be sufficient to give a total thickness of non-frost-susceptible pavement construction over the soil of not less than 450mm.

7.3.7 Chemical attack on buried concrete

This assessment of the potential for chemical attack on buried concrete is based on current BRE guidance. The desk study and site walkover indicate that, for the purposes of this assessment of the aggressive chemical environment, the site should be considered as a Brownfield development.

"Characteristic value" is the highest result, or mean of the two highest if you have 5 to 9 readings from one area. The mean maximum water-soluble sulphate content in soil of 2.2g/l has been taken as the characteristic value. As this value is below the limiting value of 3.0g/l consideration of magnesium is not required. Based on Table C1/C2 in the BRE guidance, Result one for Design Sulphate Class for the site is DS-3.

Although for the purposes of this assessment the site has been classified as brownfield, the pH is nowhere less than the limiting value of 5.5. The third assessment of Design Sulphate Class specific to brownfield sites is therefore not required in this case.

From consideration of results a Design Sulphate Class of DS-3, may be adopted for the site. Based on groundwater strikes of 5.50m and 12.50m bgl during the intrusive works, it has been assumed that groundwater conditions are static. From consideration of the characteristic pH value, an Aggressive Chemical Environment for Concrete classification of AC-2S may be assumed for design purposes.

8 REUSE OF MATERIALS AND WASTE

8.1 Reuse of suitable materials

In accordance with the *CL:AIRE Code of Practice* (2011) (CoP) materials are only considered waste if 'they are discarded, intended to be discarded or required to be discarded, by the holder'. Thus, contaminated material does not become waste until the aforementioned criteria are met.

Under the CoP, soils may be re-used on the site where they were produced provided they are:

- certain to be used
- are suitable for use both chemically and geotechnically
- only the required quantity is used.

The CoP requires the preparation of a materials management plan (MMP) that confirms the above factors will be met. This plan needs to be reviewed by a 'Qualified Person' (QP) who will then issue a declaration form to the EA. As the project progresses, data must be collated and on completion a verification report produced that shows the MMP was followed and describes any changes.

The MMP establishes whether specific materials are classified as waste and how excavated materials will be treated and/or re-used in line with the CoP. The MMP is likely to form part of the site waste management plan.

The site has been developed previously and the investigation has confirmed the presence of made ground. Therefore, before any excavation works begin on-site, an MMP will need to be prepared, reviewed by a QP; and a Declaration lodged with the EA.

As noted above, under the Waste Framework Directive naturally occurring soils are not considered waste and therefore arisings of clean natural soils, e.g. from foundation and drainage excavations, may be re-used on the site. However, it is important that these soils should be stockpiled separately and not become cross-contaminated with made ground / contaminated soils or construction wastes.

If it is proposed to import clean and naturally occurring soils direct from another site, the receiving site's MMP would need to be updated in advance of importation.

8.2 Treatment to meet suitable-for-use criteria

Where materials do not meet the suitable for use criteria it may be possible to treat them under an environmental permit (mobile treatment licence) to enable them to be reused onsite.

To enable the treatment options to be determined, an options appraisal and a remediation strategy document will be necessary to support discussion of the issues with regulators and third parties.

8.3 Reuse of waste materials

If material is discarded as waste then its reuse on site may still be possible. Waste soils and recycled aggregate can be reused on site under a standard rules environmental permit or a U1 waste exemption from the Environmental Permitting (England and Wales) Regulations 2010 provided that they are suitable for the proposed use, i.e. not cause harm to human health or the environment. However, it should be noted that these have strict limits on the quantity of material that can be reused.

8.4 Wastes for landfill disposal

Wastes require pre-treatment prior to disposal at landfill. Pre-treatment must be a physical, thermal, chemical or biological process (including sorting) that changes the characteristics of the waste to reduce its volume, reduce its hazardous nature, facilitate its handling and enhance its recovery.

The latest, edition of the EA's 'Technical Guidance WM2' (2013) Interpretation of the definition and classification of hazardous waste, requires that within a mixed waste* the separately identifiable wastes are assessed separately. Mixing of different types of hazardous waste and hazardous waste with other waste substances is prohibited under the Waste Framework Directive. Wastes that have been mixed must be separated whenever possible.

It is best practice to provide your waste carrier (or the disposal site) with details of how the waste has been treated. Your waste carrier may provide a pre-treatment confirmation form or space on the waste transfer note to detail the pre-treatment.

The classification of waste soil is a two-stage process, the first being an assessment of whether the soil is considered hazardous or not following the guidance within Technical Guidance WM2. For off-site disposal to landfill the results of Waste Acceptance Criteria (WAC) testing must then be reviewed to establish if the soil is acceptable at the relevant class of landfill or requires pre-treatment to reduce specific hazardous properties.

8.4.1 Waste acceptance criteria

All inert, stable non-reactive hazardous and hazardous wastes have limit values (waste acceptance criteria) set out in legislation that must be met before that class of landfill can accept the waste. Currently, no WAC are in place for non-hazardous waste.

Soil and other materials that are found not to be hazardous may be classified as either non hazardous or inert. In order to determine whether they can be classed as inert the soil must be tested and found to be below the inert waste acceptance criteria.

8.4.2 Waste sampling plan

Technical Guidance WM2 sets out in Appendix E requirements for waste sampling. It is a legal requirement to correctly assess and classify waste. The level of sampling should be proportionate to the volume of waste and its heterogeneity. At this stage RSK consider that the level of soil sampling is/is not sufficient to robustly/fully categorise the material.

RSK recommends that a Sampling Plan be prepared to support any waste classifications and hazardous waste assessments, prior to development.

8.4.3 Preliminary waste assessment

Given the level of data obtained, scale of the development and heterogeneity of the site soils the following assessment should be considered indicative and further assessment should be undertaken following the preparation of a Waste Sampling Plan.

EnviroLab (an RSK company) has developed a waste soils characterisation assessment tool (HASWASTE), which follows the guidance within Technical Guidance WM2. The analytical results have been assessed using this tool for potential off-site disposal of materials in the future. The results are presented in Appendix M.

Based upon the laboratory data it is considered that natural soils on site would likely to be classified as **inert** (River Terrace Deposits) and shallow 'made typical' ground as **non-hazardous**.

8.4.4 Asbestos within waste soils

The latest, edition of Technical Guidance WM2, requires that within a mixed waste the separately identifiable wastes be assessed separately.

For instance where waste soil contains identifiable pieces of asbestos (visible to the naked eye) the asbestos should, where feasible, be separated from the soil and classified separately.

Samples of potential asbestos containing material were collected from site and analysed for the presence of asbestos, the results of which are presented in Appendix E. Analysis confirmed that asbestos is present within soil samples from BH2, BH3, BH5, BH10 and BH14. In addition the five samples of suspected asbestos materials from BH1, BH4, BH12 and BH15 were all confirmed to be asbestos.

Visible asbestos containing material should, where feasible, be separated from soils and classified as stable, non-reactive hazardous waste, which can then be disposed of within a stable non-reactive hazardous waste landfill or a special cell in a non-hazardous waste landfill.

8.5 Landfill tax

Waste producers disposing of material to landfill are required to pay landfill tax by HM Revenue and Customs.

The tax is chargeable by weight (tonnage) and two rates apply, either standard or lower rate. The lower rate only applies to those less polluting wastes as set-out in the Landfill Tax (Qualifying Material) Order 2011 which include naturally occurring rock and soil, concrete, some minerals, some furnace slags and ash and some low activity organic compounds. Evidence confirming that the waste qualifies for the lower rate will be required and for any loads of mixed waste, standard rate tax will apply for the whole waste load.

Currently (since April 2014), standard rate landfill tax is £80 per tonne and the Treasury has confirmed that for five years thereafter the tax will not fall below £80.

The lower rate of landfill tax applicable to less polluting wastes (i.e. 'inert' wastes) remains at £2.50 per tonne.

Material disposed of at a soil treatment centre will not be subject to landfill tax.

8.6 Groundwater

When there is an intention to discard groundwater, chemical test results will indicate the appropriate disposal options. This could include disposal to treatment facility, via consent (issued by the water authority) to foul sewer or via consent (issued by the EA) to a watercourse.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Environmental

9.1.1 Conclusions

The results of the GQRA indicate that a risk exists for human health via direct contact pathways from measured concentrations of pesticides in soil due an exceedance of p,p-DDE in one of the four samples analysed and the presence o,p-DDT for which no readily available screening value is available.

Furthermore, comparison of chemical laboratory test results to RSK GACs has demonstrated that a potential pollutant linkages exists in relation to measured concentrations of zinc in soil associated with phytotoxic effects and to polyethylene water supply pipes in relation to measured concentrations of hydrocarbons in soil.

Asbestos containing materials of cement and loose insulation were detected in 6 of the 27 samples submitted for chemical analysis and comprised chrysotile and amosite. In addition the five samples of suspected asbestos containing materials were all confirmed to be asbestos cement comprising chrysotile. The detections of asbestos pose a potentially unacceptable risk to the human health of construction workers and further residents via inhalation pathways.

Monitoring results from the three visits conducted at the site to date would characterise the site as being Characteristic Situation 'Amber 1' for traditional low-rise houses. On this basis, low level ground gas protection measures would be considered necessary at the site. Low-level gas protection measures would involve an appropriate membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into the buildings.

It is considered that the ground gas data collected is representative of worse case conditions at the site, given the low pressure recorded during monitoring visit of 982mb. Given this and the consistency of the results, further monitoring is not considered necessary at this time. However, it should be noted that the Local Authority may require additional gas monitoring to be undertaken and that the relevant NHBC/CIRIA guidance recommends a minimum of six monitoring rounds over a 3 month period.

Based on the absence of the groundwater monitoring data potential risks posed to the underlying aquifers cannot be quantified at this time. Based on the low magnitude of the measured concentrations of determinands encountered in soil to date and the low solubility of the pesticides detected above LOD, it is considered unlikely that these results would result in significant impacts within the underlying aquifers.

9.1.2 Recommendations for further investigation and remedial work

Based on the conclusions summarised in Section 9.1.1, in order to manage risks associated with the potentially complete pollutant linkages identified, it is recommended that allowance be made for the implementation of the following:

- It is recommended that five deep light cable percussive (LCP) boreholes be drilled and installed at the site to a minimum depth of 5m bgl (or 1.5m below the groundwater strike if obvious) in order that groundwater samples can be collected to assess the groundwater quality beneath the site and determine whether groundwater remediation is required. Three of these boreholes could be deepened to provide information for pile design if required;
- Potential contamination may be present in soils directly beneath the CHP building, nitric acid store, substations and ASTs. Following decommissioning and demolition of these features it would be recommended that in the event that any visually impacted materials are observed, an Environmental Engineer be contacted so that appropriate sampling can be implemented to determine any additional remedial and validation requirements;
- It is recommended that garden areas and soft landscaping be constructed of clean soil. In view of the ground conditions encountered (i.e. absence of reusable topsoil and a thickness of at least 0.50m made ground across the majority of the site), it is recommended that a clean growth medium be placed in soft landscaped areas comprising:
 1. 450mm thickness of clean inert topsoil/subsoil in all private gardens; and
 2. 300mm thickness of clean inert topsoil/subsoil in all areas of communal soft landscaping, locally deepened (to the requirements of the Landscape Architect) in the proximity of any deep root-balled shrubs and/or trees proposed.
 3. Outside of garden and soft landscaped areas (i.e. beneath proposed buildings and roads), a plausible pathway (for human health) is unlikely to be present and therefore no specific remedial actions are considered necessary in these areas.
- Asbestos containing materials have been identified at the site within made ground, the importation of clean soil detailed above is considered appropriate in order to mitigate risks posed to future site users from the presence of asbestos. Asbestos containing materials are classified as being hazardous and must therefore be disposed off site at a suitably licensed waste facility should they be encountered during redevelopment. Following demolition of existing structures, prior to site development, it is recommended that an asbestos risk assessment is carried out to assess the liabilities associated with asbestos contamination and site development; and
- Low level ground gas protection measures are considered necessary at the site. Low-level gas protection measures would involve an appropriate membrane and ventilated sub-floor void to create a permeability contrast to limit the ingress of gas into the buildings.

In addition to the above, the following should also be noted:

- All imported material should be from a known source, preferably 'Greenfield', with haulage certification provided to confirm collection and delivery addresses. The material should be tested at source and on site to confirm it is suitable for placement in areas of soft landscaping. The topsoil/subsoil will provide a clean growth medium for proposed vegetation, whilst limiting the potential for contact with underlying made ground by future residents;

- The historical uses of the site should be noted and the potential for further contamination to be identified during demolition and site clearance works recognised. Any visual or olfactory evidence of contamination should be notified to an Environmental Engineer so that appropriate sampling can be implemented to determine any additional remedial requirements;
- Validation should be carried out for all remedial works and within soft landscaping areas to confirm that the topsoil and subsoil is of a suitable thickness and that it is suitable for its intended use. Validation of topsoil should be reported to the contaminated land officer for approval and sign off;
- A verification report should be submitted to the Local Planning Authority post remedial works;
- Risks to construction workers must be managed through the use of appropriate PPE and compliance with current guidance such as CDM and Construction on Brownfield Sites;
- During the construction phase, dust should be managed particularly during dry or windy periods to reduce risks to adjacent residents; and
- A copy of this report be provided to the following regulatory authorities for their comment and approval (i.e. The Local Authority Contaminated Land Officer, Environment Agency, and The National House Building Confederation (NHBC) (if appropriate).

9.2 Reuse of materials and waste

Based upon the laboratory data it is considered that natural soils on site would likely to be classified as inert (River Terrace Deposits) and shallow 'made typical' ground as non-hazardous.

All inert, stable non-reactive hazardous and hazardous wastes must be tested and found to be below the waste acceptance criteria (WAC) leaching limit values for the classification of landfill they are being disposed in. Currently, no WAC are in place for non-hazardous waste.

At present WAC testing has not been carried out on soil samples recovered from the site. Further assessment of the soils will be required to be undertaken once the development is underway.

9.3 Geotechnical

Subject to supplementary investigations, the ground conditions are potentially suitable for the adoption of spread foundations taken down through any made ground and founded in the underlying soft to firm silty Clay (medium shrinkage potential) where a net allowable bearing pressure of 75kN/m² can be assumed at this time.

To confirm the suitability for spread foundation, machine excavated trial pits are recommended, alternatively, piled foundations can be adopted.

Deep boreholes are recommended for pile design.

Based upon in-situ testing via Mexecon, CBR values of 1-7% were identified in the shallow subsoils. For preliminary design purposes at this time, a CBR of 2% can be assumed for the silty clay subgrade.

Suspended floor slabs are recommended throughout.

The underlying ground conditions were found to be unsuitable for drainage via soakaways.

With respect to aggressive ground at the site, a Design Sulphate Class for the site of DS-3 and Aggressive Chemical Environment for Concrete classification of AC-2S may be assumed for design purposes.

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FIGURES



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18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT
United Kingdom

Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info@rsk.co.uk
Web: www.rsk.co.uk

Client

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Project Title

WEST END NURSERY,
ANGMERING

Drawing Title

SITE LOCATION MAP

Rev	Drawn	Date	Checked	Date	Approved	Date
00	SAY	16.01.15	ARJ	16.01.15	ARJ	16.01.15

Dimensions	Scale	Original Size
m	1:25,000	A4

Project Number

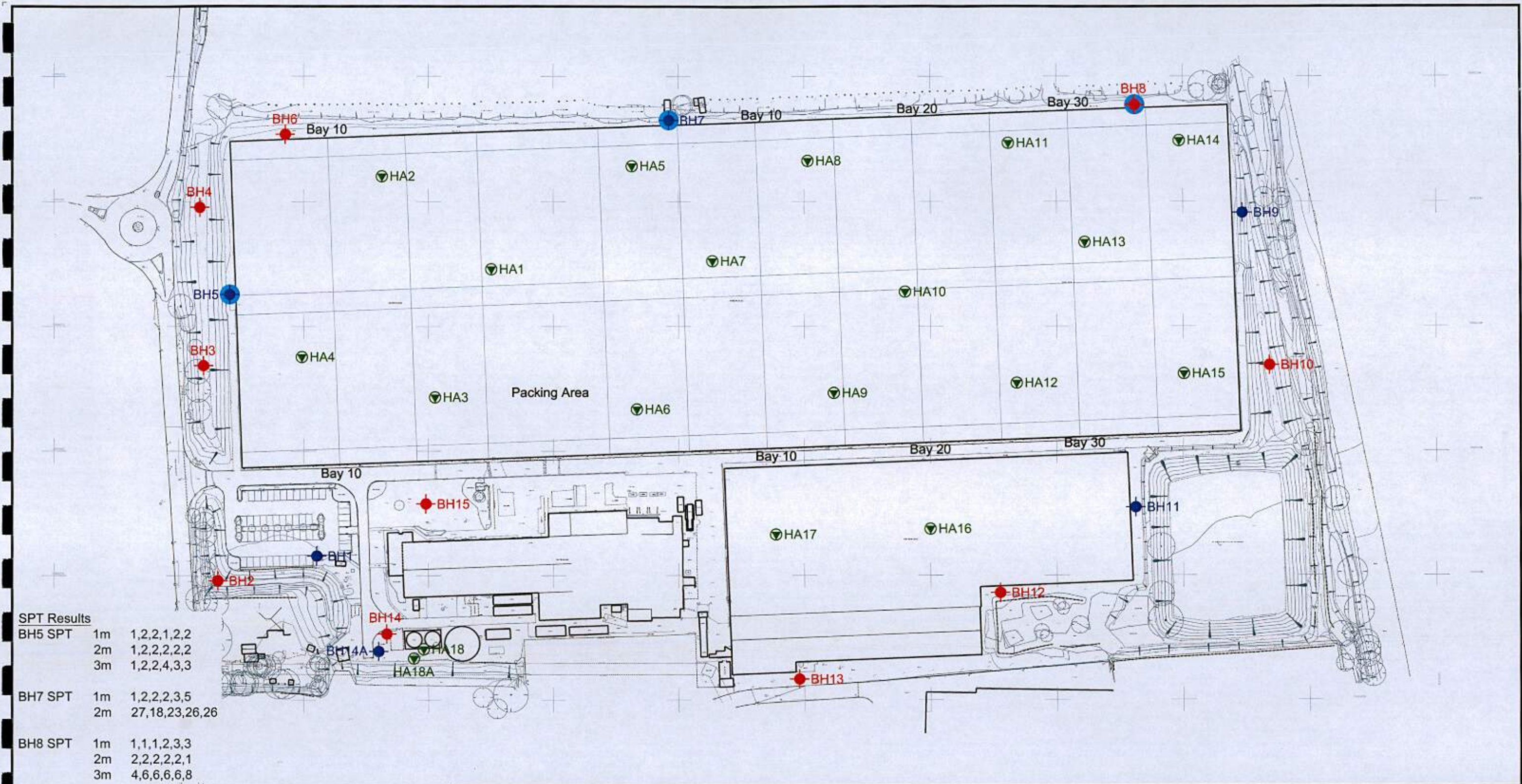
27621-01 (00)

Drawing File

27621 - SLP.dwg

Drawing Number

FIGURE 1



LEGEND

- Borehole Location
- Hand Auger Location
- Borehole Location with installation
- Standard Penetration Test (SPT)



18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT
United Kingdom

Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info@rsk.co.uk
Web: www.rsk.co.uk

Client
CALA HOMES (SOUTH HOME COUNTIES) LTD

Project Title
WEST END NURSERY,
ANGMERING

Drawing Title
EXPLORATORY HOLE
LOCATION PLAN

Project No.
27621-01 (00)

Drawing File
27621 (R01-00).dwg

Drawing No.
FIGURE 2

Rev.
P1

Rev.	Date	Amendment	Drawn	Chkd.	Appd.	Scale	Orig Size	Dimensions
						1:1500	A3	m

Drawn	Date	Checked	Date	Approved	Date
SAY	16.01.15	ARJ	16.01.15	ARJ	16.01.15



RSK

18 Frogmore Road
Hemel Hempstead
Hertfordshire
HP3 9RT
United Kingdom

Tel: +44 (0) 1442 437500
Fax: +44 (0) 1442 437550
Email: info@rsk.co.uk
Web: www.rsk.co.uk

Client
CALA HOMES (SOUTH HOME COUNTIES) LTD

Project Title
**WEST END NURSERY,
ANGMERING**

Drawing Title
PROPOSED DEVELOPMENT PLAN

Project No.
27621-01 (00)

Drawing File
27621 (R01-00).dwg

Drawing No.
FIGURE 3

Rev.
P1

Drawn	Date	Checked	Date	Approved	Date
SAY	16.01.15	ARJ	16.01.15	ARJ	16.01.15

Scale	Orig Size	Dimensions
1:1500	A3	m

Rev.	Date	Amendment	Drawn	Chkd.	Appd.