Smarter Building and
Construction Ltd

53 Fitzroy Park, Highgate, North West London

Geotechnical, Hydrogeological and Geoenvironmental Site Investigation Report

Project no. 241919-01 (01)

December 2010

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53 Fitzroy Park, Highgate, North West London

The Client: Smarter Building and Construction Ltd
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1. INTRODUCTION

1.1 Instructions

On the instructions of Elliott Wood Partnership LLP, on behalf of Smarter Building and Construction Ltd (the 'Client'), RSK STATS Geoconsult (RSK) has carried out a Phase 1 and Phase 2 geotechnical, hydrogeological, and geoenvironmental site investigation of 53 Fitzroy Park, located close to Highgate, North West London.

The project was commissioned in connection with the proposed redevelopment of 53 Fitzroy Park with a detached property and partial basement to replace the existing house on site. The site is located on the edge of Hampstead Heath, within an area of drainage which supports a chain of ponds (the Highgate Ponds), which lie topographically down-gradient of the subject site. An assessment of the hydrogeology of the site and the potential for the redevelopment to impact upon the groundwater regime is required to support the planning application. The project was also commissioned in order to identify the potential for hazardous substances or conditions to exist on, at or near the site and therefore, via the development of a Conceptual Site Model (CSM), identify the necessity for and extent of mitigation measures to be employed in relation to the proposed development of a residential property on the site.

By way of background to the project, a site investigation was previously undertaken at the site by Geotechnical & Environmental Associates (GEA), as presented in their report dated November 2009. Based on this report, Paulex Environmental Consulting developed a 'Site Investigation Plan' (Report no. 1067/R2), dated September 2010, which was updated by Elliot Wood Partnership LLP, who issued a 'Site Investigation Specification' in October 2010. The scope of work reported upon herein is based upon the above mentioned documents and subsequent agreed amendments following discussions with the above mentioned parties and the Client.

These reports and documents have been made available to RSK for review as part of this study.

1.2 Project Brief

The project was carried out to an agreed brief as set out in RSK's proposal letter of 27th October 2010.

The work undertaken included the following tasks:

(i) *Desk Study*

- A site walk-over reconnaissance survey;
- A study of the history of development and industry on the site, including reference to archival Ordnance Survey mapping and pre-OS maps of London;
- A search of Statutory Registers for potentially contaminative land uses and licences in the vicinity of the site, in the form of an environmental database report, and a search of the Environment Agency website;
- A study of the local geology, hydrology and hydrogeology of the site, including the identification of geological hazards and historic mining activities, and a search of the British Geological Survey database for relevant borehole logs; and
- A preliminary Conceptual Site Model (CSM) of contamination, identifying possible pollutant linkages.

(ii) Site Investigation

By means of:

- A Ground Penetration Radar survey;
- Light cable-percussive boreholes;
- Drive-in window sampler boreholes;
- *In situ* CBR testing;
- On-going monitoring of groundwater wells;
- Off-site analysis for geotechnical and geoenvironmental purposes; and
- Interpretative reporting (including development of the CSM).

1.3 Standards

The project was designed generally to meet the objectives of a Preliminary (Phase 1) Investigation and an Exploratory Investigation, as defined by BS 10175:2001 "Code of Practice for the Investigation of Potentially Contaminated Sites". Exploratory Investigations usually involve only limited intrusive/analytical work in which relatively few samples are collected for contamination identification/confirmation purposes. They play a role in establishing the potential for short-term exposure or other immediate risks to health and the environment, and they are used to generate initial gas, vapour and water quality data.

The intrusive aspects of the investigation were generally carried out following guidance given in BS 5930:1999 - Code of Practice for Site Investigations.

This report adopts the technical approach presented in Contaminated Land Report 11 "Model Procedures for the Management of Land Contamination" (Environment Agency 2004) for applying a risk management process when dealing with land affected by contamination.

The project and this report have been designed to fulfil the information requirements set out in the Environment Agency Guidance on Requirements for Land Contamination Reports (Environment Agency 2005).

1.4 Limitations

This report should be considered in the light of any changes in legislation, statutory requirement or industry practices that may have occurred subsequent to the date of issue.

The "vicinity" of the site for the purposes of this report, is defined as locations situated within an approximate 250m radius of the site, although certain sources of contamination and / or sensitive targets further than 250m may also have been considered.

The opinions and recommendations expressed in this report are based on the ground conditions encountered during the site work, the results of field and laboratory testing and interpretation between exploratory holes. The material encountered and samples obtained represent only a small proportion of the materials present on-site, therefore other conditions may prevail at the site which have not been revealed by this investigation.

The environmental reconnaissance survey consisted of a general external inspection of the site aimed at identifying any obvious signs of potential sources of ground contamination. A detailed internal inspection of the buildings was outside the brief for the study.

As an Exploratory Investigation, the results may not provide sufficient data to make detailed estimates of the quantities involved in any remediation work, if required.

The results of RSK laboratory tests are covered by UKAS accreditation, but opinions and interpretations expressed in the report and on the site work records are outside the scope of this accreditation. Where laboratory testing has been carried out at a sub-contractor laboratory, this laboratory is an approved sub-contractor in accordance with the requirements of the RSK quality management system and is UKAS accredited for the relevant range of tests undertaken.

2. SITE DETAILS

2.1 Description and Geographic Setting

The site is located at National Grid reference TQ 277 869, as shown on **Figure 1**. The site fronts onto Fitzroy Park, a private residential street, to the east, and is bordered by the gardens of neighbouring detached properties to the north, south and west, and by a pond within the neighbouring garden to the southwest.

The site currently comprises a large detached residential property set within mature, landscaped gardens (**Figure 2**).

2.2 Reconnaissance Survey

The site was visited on 15th November 2010. The characteristics of the site observed during the site reconnaissance visit and obtained from current Ordnance Survey maps are summarised in **Table 2.1**.

Table 2.1 – Site description

Feature	Description
Physical characteristics	
Area of site	Approximately 0.35 hectare.
Ground levels	The site lies on a westerly / southwesterly facing slope. Ground levels at the site range from an elevation of approximately 84mAOD at the site's eastern boundary to approximately 80.5mAOD to 80mAOD at the site's western and southwestern boundaries, respectively. Ground levels adjacent to the current property are level at approximately 82.5mAOD.
Depressions in the ground surface	None observed.
Waterlogged or marshy ground	None observed.
Surface water	There are no streams or drainage ditches on the site. There is a pond immediately adjacent to the site's southwestern boundary.
Trees	Numerous mature trees and shrubs are present on site.
Existing buildings on site	The current building on site comprises a three-storey detached property, built into the sloping ground, with two-storeys above ground level and one below ground level at the front of the property.
Basements on site	The current property has a semi-basement level.
External hardstanding	A small hardstanding for off-street parking is present to the east of the property adjacent to Fitzroy Park. There is a paved area surrounding the house at ground floor level to the rear of the property.
Retaining walls and adjacent buildings on or close to site boundary	The elevation of the site decreases by between 1.5m and 2.0m along its eastern boundary, stepping down from adjacent street level along Fitzroy Park. To the south of the house, there is a retaining brick wall, but to the north of the house the slope is unretained. There is an approximately 1m high retaining wall to the rear of the house, stepping down from ground floor level to the adjacent gardens. No buildings directly adjoin the site's boundaries.
Made ground and earthworks	The site appears to have been historically cut to allow development of the building currently occupying the site. Some garden areas of the site appear

Feature	Description
	to have been locally landscaped.
Potentially unstable slopes on or close to site	None observed. However, see **Section 4.1.2**.
Environmental characteristics	
Tank storage and dispensing facilities	None observed.
Potentially hazardous materials storage and use	None observed.
Asbestos-containing materials	No obvious asbestos construction materials were observed but a detailed survey of the buildings would be required to confirm the presence or otherwise of asbestos-containing materials.
Waste storage	None observed.
Evidence of possible land contamination on site	None observed.
Potential off-site sources of ground contamination	None observed.

No potentially significant ground contamination issues were identified during the site reconnaissance survey.

2.3 Information from Environmental Searches

2.3.1 Environmental Database Report and Environment Agency (EA) information

Details on the presence of industries with pollution-related licences, landfill sites and pollution incidents have been obtained via an environmental database report and from a search of information publicly available on the EA website. A copy of the environmental database report is included in **Appendix A**. Salient information from these sources is as follows:

- There are no records of landfill sites (former or current) within 250m of the site (i.e. within the Planning Consultation Zone). Furthermore, there are no records of landfills within a 1km radius of the site.

- There are no records of facilities currently operating under an Integrated Pollution Prevention and Control (IPPC) or a Local Authority Pollution Prevention and Control (LAPPC) authorisation within 500m of the site.

- There are no records of pollution incidents attributable to the site itself, and no records of prosecution or enforcement action against the site with respect to environmental issues.

- There are no Contemporary Trade Directory Entries or Fuel Station Entries within 250m of the site.

3. DEVELOPMENT HISTORY

3.1 Sources of Information

The history of the site's land-use and development from Victorian times onwards has been researched from:

- Early Ordnance Survey (OS) maps; and
- Pre-Ordnance Survey (County Series) maps.

Copies of OS and County Series maps are included in the environmental database report in **Appendix A**. 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.

The development history of the site and surrounding area from the above sources is summarised below.

3.2 Summary of Development History

3.2.1 The Site

From mid-Victorian times, the site lay within the wider Fitzroy Park, with Fitzroypark Farm to the west and the highways of Fitzroypark Road and Millfield Lane to the northeast and southwest, respectively. The site was covered by mixed woodland and heathland at this time. On the earliest map of 1870, the pond to the immediate southwest of the site is shown extending into the extreme southwest section of the site. On the 1894 map, the outline of the pond has changed, and no longer encroaches into the southwestern part of the site (i.e. it has been infilled in the site area).

From the mid-1910s, a small structure of unspecified usage was present in the southern area of the site, but this structure had been demolished by the mid-1930s. From the 1950s, there was another small building present close to the footprint of the building noted above. The site remained unchanged until the early 1970s, when the current property was constructed. By the late-1980s, the small structure to the south of the site had been removed. The site attained its current configuration at this time.

3.2.2 The Surrounding Area

From mid-Victorian times, the site lay within the wider Fitzroy Park, and was surrounded by open heathland to the east and south, with large detached residential properties ('Lodges') to the north and the west, set in large gardens and surrounded by fields / open land. Urban development was present 750m northeast (Highgate), 1km southwest (Hampstead), and 1km southeast (Dartmouth Park) of the site. The Highgate Ponds were present to the southwest of the site, the ponds being shown as the property of the 'New River Company's Water Works'. A large pond (No.55 Fitzroy Park) was also present to the immediate southwest of site boundary. Two smaller ponds, evidently lying along the same northeast-southwest axis through the topographic valley in this area were also present to the northeast of the site (see **Figure 3**).

No significant changes occurred in the site's vicinity, until the early-1910s, when the ponds to the northeast were no longer evident and a 'miniature rifle range' was present, located south of the site, adjacent to the Wildfowl Reserve Pond.

By the early-1930s, the ‘Water House’ residential property had been constructed adjacent to the site’s western boundary, as well as residential properties to the west (e.g. Fitzroy Farm Cottage). There are also new residential developments constructed across Fitzroy Park road. The ‘miniature rifle range’ was no longer present by this time.

By the early-1990s, some redevelopment of private residences including Fitzroy Close appears to have taken place to the immediate northeast of the site and the southeast of the site. No further significant changes appear to have occurred in the site vicinity to the present day.

4. GEOLOGY, HYDROGEOLOGY AND HYDROLOGY

4.1 Geology

4.1.1 General Characteristics

The published 1:50,000 scale geological map (Sheet No. 256 'North London') and 1:10,560 scale geological map (TQ28NE) of the area indicate that the immediate site area is underlain by the London Clay Formation (**Figure 3**).

The London Clay Formation is divided by the British Geological Survey (BGS) into five informal units. The lowest four, denoted A to D, are not mapped, whereas the top part of the formation is mapped as the Claygate Member. The site lies on the flank of, and topographically below, a dissected outlier comprising the Claygate Member and the overlying Bagshot Formation. These latter strata form the high ground on which Hampstead and Highgate are located, and comprise sandy lithologies, which give rise to the sandy soils of the heathlands. The geological boundary between the Claygate Member and the underlying Unit D of the London Clay Formation is mapped as lying close to the site's eastern boundary along Fitzroy Park. (**Figure 3**). It is therefore considered that the site area lies within Unit D of the London Clay Formation.

The BGS define the Claygate Member as "all the deposits above the base of the lowest fine-grained sandy bed that are thick enough to be distinguished from the underlying relatively homogenous clays". However, it notes in this regard that the criteria are "difficult to maintain in the mapping of outliers of Claygate Member in central London and westwards from there because of the increasing number of sand beds in the underlying Unit D of the London Clay".

In the west of the (London) district, the Claygate Member is described as a finely interbedded and thinly laminated sequence of clay, silt and fine-grained sand with numerous interbeds of planar and lenticular bedded fine-grained, finely laminated sand. The Hampstead Heath borehole (TQ28NE/198, **Appendix A**), reported by the BGS, indicates that the Claygate Member is dominated by mainly very fine-grained sand and silt in this area, whilst the underlying London Clay comprises silt, clay and silty clay. According to the BGS Memoir for London, beds of clayey silt grading to silty fine-grained sand increase in number and thickness within the London Clay across the London district from east to west. However, the Hampstead Heath borehole (TQ28NE/198) indicates that Unit D is dominated by silt, clay and silty clay in this area. Indeed, it should be noted that a recent BGS borehole recorded the base of the Claygate Member at an elevation of approximately 93mAOD, which is at a considerably higher elevation than the drawn boundary on the current published map of approximately 85mAOD in the site area. The 1:50,000 scale geological map indicates that the strata in this area are essentially horizontal, with the outcrop pattern parallel to the local topographic contours (see also Section **4.2.1**).

An intrusive site investigation was formerly undertaken at 53 Fitzroy Park by GEA, details of which were provided within their report no. J09196/RR/01, dated November 2009. Four boreholes were advanced to depths of 6m below ground level (bgl) across the site. The encountered ground conditions were described as 0.5m to 1.1m thickness of Made Ground, comprising brown gravelly sandy topsoil or mottled slightly sandy clay with rootlets and occasional fragments of brick and ash (reworked London Clay), overlying the London Clay Formation. The London Clay was described as firm brown fissured silty clay with occasional 'claystone' and selenite crystals, typical of weathered London Clay, locally becoming a firm to stiff grey silty clay below 5.5m bgl, more typical of 'fresh', unweathered London Clay.

No superficial deposits are shown in the site area, but the 1:50,000 scale geological map indicates that the site lies within an area of 'Head propensity', which is based on the geotechnical properties of the London Clay. These areas are most likely to be covered by Quaternary Head deposits as interpreted from digital slope analysis and confirmed by borehole data. These are not mapped deposits and not verified by fieldwork. However, the presence of Head deposits within this area may also contribute to placement of the Claygate Member/ London Clay boundary at too low an elevation on the geological map due to the effects of solifluction translating material to lower elevations and blurring geological boundaries.

4.1.2 Slope Stability Issues

The 1:50,000 scale geological map for the area indicates that the site lies within an 'Area of Significant Landslide Potential'.

The BGS' assessment of the potential for slope stability is given as follows:

"Due to a long history of intensive land use and urban development it has only been possible to recognise and map, with confidence, a few areas of past landslide activity. However, beyond the North London District, areas of similar bedrock geology and topography contain significant areas of mapped landslides. Therefore, a slope instability assessment has been made to act as a guide to where areas of significant landslide potential are present, but obscured, and where further information regarding their stability are needed before development or major changes in land use are made.

The assessment used a deterministic approach that looks at the presence at a site of landslide causative factors, such as slope angle, lithology and groundwater conditions that increase the susceptibility of a site to landslide activity. The causative factors were weighted according to their relative importance in promoting landslides and combined in a Geographical Information System to produce a computer generated map of the relative susceptibility to landslide activity across the area. It does not necessarily mean that landslides have happened in the past or will do so in the future, but if conditions change through natural or artificial means and a causative factor increases, then slope instability may be triggered."

The site reconnaissance survey did not reveal any obvious significant issues associated with the stability of slopes on the site or immediate surrounding area. Under the proposed development plan (see **Section 11.3**), slope stability issues are unlikely to affect the proposed residential structure, although it may need to be taken into consideration with regard to any landscaping proposals.

4.1.3 Radon

The environmental database report indicates that the site is not located within an 'Affected Area' as defined by the Documents of the National Radiological Protection Board (Radon Atlas of England and Wales, NRPB-W26-2002). Therefore the risk of significant ingress of radon into structures on-site is considered to be low and no radon protective measures are required within new dwellings at the site.

4.2 Hydrogeology

4.2.1 General Characteristics

The London Clay Formation (excluding the Claygate Member) is classified by the Environment Agency as a Non-aquifer (non-productive strata) (**Section 4.2.2**), reflecting its inability to store and transmit significant quantities of groundwater. Values for the coefficient of permeability for the London Clay Formation range from 3 x 10^{-9} m/s for clay with sand partings and silty clay to 3 x 10^{-11} m/s for intact clay, indicating the very low permeability of these materials.

In contrast, a perched water table may be present within the sandier lithologies of the overlying Claygate Member and Bagshot Formation, both of which are classified by the Environment Agency as Secondary Aquifers of variable permeability. Although no such features have been identified or reported from the subject site, springs / seepages / issues are indicated in the wider vicinity. These features are associated with geological boundaries between units of contrasting permeability, namely the junction between the Bagshot Formation and Claygate Member, and the Claygate Member and underlying argillaceous London Clay.

A spring-fed fountain, the Goodison Fountain, is located approximately 480m northwest of the site and is believed to be associated with the Claygate Member/argillaceous London Clay boundary. (It should be noted that this fountain appears to be at a higher elevation (approximately 91mAOD) than the traditionally mapped boundary between the Claygate Member and London Clay in this area, see **Figure 3**). The subject site is located topographically below (i.e. at a lower elevation), and hence down-gradient from, these spring lines, and is underlain by low permeability London Clay. It is therefore considered likely that any subsurface groundwater flow will be restricted to perched water within any Made Ground / reworked London Clay or weathered material at shallow depth.

During the previous site investigation undertaken by GEA, no groundwater was encountered during the site works. However, waters level could be measured within the borehole standpipes during a monitoring visit carried out two weeks after completion of the site work. Water levels were measured at depths between 1.04m bgl and 1.93m bgl (81.3mAOD and 78.4mAOD), the water levels decreasing in elevation towards the west, as would be expected from the topography. However, it should be noted that equilibrium conditions may not have been achieved within the timescale referred to above.

4.2.2 Vulnerability of Groundwater Resources

The London Clay Formation is classified by the Environment Agency (EA) as a Non-aquifer (non-productive strata) (as indicated on the Environment Agency Groundwater Vulnerability Map of the area, Sheet No.39 '*West London*').

The London Clay acts as an aquiclude, restricting the downwards migration of shallow groundwater (and mobile contaminants, if present) to deeper groundwater resources in the Thanet Sands / Lambeth Group (Minor Aquifers) and the Chalk Group (a Major Aquifer).

However, the presence of low permeability clay at relatively shallow depths beneath the site, whilst restricting downwards migration, may increase the potential for lateral migration of shallow groundwater (and therefore mobile contamination, if present).

4.2.3 Licensed Groundwater Abstraction

The environmental database report indicates that there are no current licensed groundwater abstractions and no public water supply boreholes within a 1km radius of the site.

Information provided by the Environmental Health Department of the London Borough of Camden indicates that there are a number of groundwater abstraction boreholes (recorded by the BGS) within 2km of the site. These appear to be historical (1833 – 1900), with the exception of one record for the Royal Free Hospital, Hampstead, dated 1999. The depths given relate to the abstraction of groundwater from the Chalk aquifer and overlying Thanet Sand Formation / Lambeth Group aquifers, which underlie the London Clay Formation.

In terms of aquifer protection, the EA generally adopts a three-fold classification of Source Protection Zones for public supply abstraction wells.

- *Zone I* - or 'Inner Protection Zone' is located immediately adjacent to the groundwater source and is based on a 50-day travel time. 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 II* - or 'Outer Protection Zone' is defined by a 400-day travel time to the source. The travel time is designed to provide delay and attenuation of slowly degrading pollutants.

- *Zone III* - or 'Total Catchment' is the total area needed to support removal of water from the borehole, and to support any discharge from the borehole.

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

4.3 Hydrology

The subject site lies within the catchment of the stream formerly known as the Highgate Brook, forming one of the tributaries of the River Fleet, which drains to the River Thames near Blackfriars. The Fleet rises on Hampstead Heath by two heads, separated by Parliament Hill. The eastern, or Highgate, source lies near to the subject site, and is fed via a series of springs in the grounds of Kenwood House, whence the stream flows southwards, via the Highgate Ponds (**Figure 3**). It is understood that this series of ponds was excavated in the 17th and 18th centuries for water supply purposes. The ponds currently serve a variety of leisure and recreational purposes, and are the subject of a number of conservation and management measures under the Corporation of London's Hampstead Heath Management Plan.

The ponds are formed in the channel of the Highgate Brook, which flows over impermeable London Clay. Flow in the stream is likely to be derived from direct surface runoff, and by drainage of groundwater from springs.

The topography and geological outcrop pattern shown on the 1:10,560 geological map (**Figure 3**) indicate that the subject site lies within a northeast to southwest orientated valley. There is no surface watercourse currently flowing within this valley and historical maps dating from the 1870s indicate that there was no overland flow (e.g. stream or drain) within the valley by at least that time. The map of 1896 shows two small ponds within the valley, up-gradient from the site, which were evidently dug to capture water, as it would also appear for the larger pond within the grounds of No.55 Fitzroy Park. These ponds lie on a northeast-southwest trend along the central axis of this small valley system. A drain is evident at the extreme southwestern end of this system where it enters the Wildfowl Reserve Pond within the chain of Highgate Ponds.

A second northeast to southwest orientated topographic valley is located approximately 220m to the northwest of the site, adjacent to Fitzroy Farm and the North London Bowls Club (**Figure 3**). A small surface watercourse flows within this valley, entering the Highgate chain of ponds at the northern end of the Ladies Bathing Pond.

Information provided by the Resident's Association suggests that drainage in this area is diverted through a culvert / buried channel beneath the residential properties in this area. Whilst it is possible that any watercourse occupying this valley is buried or culverted, given the scale of drainage in this area it is likely that any surface flow would be redirected through shallow pipework systems and it is possible that a system of land drains may have developed with time across this area.

It should be noted that the origins of these valleys lie at an elevation above the currently drawn Claygate Member/London Clay boundary and therefore unlikely to be related to spring lines associated with this geological boundary, at its currently drawn level (**Figure 3**).

4.3.1 Preliminary Flood Risk Assessment

The indicative floodplain map for the area, published by the EA, shows that the site does not lies within any designated fluvial floodplains.

4.4 Mining, Quarrying and Landfilling

Evidence has been sought to identify any mining, quarrying and landfilling 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:

- Environmental database report;
- Records held by Local Authority / Environment Agency;
- Old Ordnance Survey maps and plans (see **Section 3**); and
- Geological maps (see **Section 4.1**).

With reference to the above data there are no recorded mines, quarries or landfills within a 1km radius of the site, although ‘brick fields’ are known from the wider area. However, with regard to fill, and with reference to the historical data, there appears to have been some limited phases of construction and demolition on the site and therefore the presence of Made Ground should not be overlooked.

5. PRELIMINARY CONCEPTUAL SITE MODEL

5.1 Introduction

A CSM is a simplified written and/or visual/schematic description of the environmental conditions on a site and the surrounding area. It is developed from the individual components of the investigation at each stage to provide a depiction of likely contaminants, pathways and receptors, and highlights key areas of uncertainty.

Fundamental to the CSM is the principle of pollutant linkages, i.e. a source of contamination, a migration pathway and a receptor at risk from that contamination must all be present for a pollutant linkage to be complete. This approach is now accepted best practice in the industry but it does not take into account less scientific factors such as perceived risk, which frequently has a significant influence on land values.

The site is considered for the proposed future end use, which is understood to be a residential development with private gardens.

The preliminary CSM presented below is based on the findings of the Preliminary (Phase 1) investigation and information from previous intrusive investigations and therefore contains elements of conjecture and hypothesis. The exploratory investigation reported upon herein was designed to test those hypotheses and acquire data on the actual ground conditions beneath the site, enabling the CSM to be further refined.

In the following sections, the individual components of all identified possible pollutant linkages are assessed using the information identified during the course of the Preliminary (Phase 1) investigation described above.

5.2 Sources of Contamination

The study has identified no direct evidence of potentially contaminative land uses on or in the vicinity of the site. However, at least one limited phase of demolition and construction appears to have taken place locally on the site, and the pond to the southwest of the site appears to have been historically filled within the site area, which could have resulted in unknown Made Ground being present, with potential contaminants as identified in **Table 5.1**.

Table 5.1 – Potential Sources and Types of Contamination

Potential Sources	Contaminants of Concern
On-site	
Made Ground (i.e. fill material).	Unknown fill material (but potentially including heavy metals, ash, clinker, sulfates, polycyclic aromatic hydrocarbons (PAHs), asbestos etc.).

5.3 Receptors at Risk

The risk assessment identifies potential receptors within the following four categories:

i. end users of the site who may have acute exposure to sources of contamination on a regular and predictable basis;

ii. controlled waters, being defined as all surface water, groundwater or perched water;

iii. building structures and services placed in or on the ground;

iv. other targets such as the "environment", including any flora and fauna on or near the site and construction and maintenance workers who will have chronic but potentially higher levels of exposure than end users.

Table 5.2 below lists the main sensitive targets within these categories as follows:

Table 5.2 – Receptors at Risk

Category	Details of receptor
Current/End users	As detailed within the CLEA Model, this comprises a 0-6 year old female child with respect to the proposed residential end use.
Controlled waters	From the desk study/walkover information these comprise the water features of Highgate Ponds and associated surface drainage lines.
Buildings/services	Buried concrete and other material within the ground, including water supply pipes etc.
Other targets	Short term occupation by construction workers and long term but intermittent visits by maintenance workers. Vegetation may be present in the form of planting within private gardens.

5.4 Pathways for Migration

Based on the proposed end use of the site and the anticipated ground conditions at and in the vicinity of the site, the contaminant pathways identified within **Table 5.3** are considered potentially to be present.

Table 5.3 – Pathways for Migration

Category	Details of pathway
End users	Pathways relevant to the end user are identified in the CLEA Model as ingestion, inhalation of soil / dust particulates or contaminant vapours, dermal contact (absorption through skin), and consumption of garden vegetables and fruit.
Controlled waters	The presence of low permeability clay beneath the site, whilst restricting downwards migration, may increase the potential for migration of surface / perched water, and therefore mobile contamination, if present.
Buildings/services	Buried concrete and services will be susceptible to attack via contact with aggressive/contaminated ground, especially if mobile groundwater is present.
Other targets	Pathways towards construction and maintenance workers will relate to acute exposure and as such are outside the scope of chronic risk assessment methodologies. Vegetation and other ecological targets may be affected by contact with contaminated soils via plant uptake routes.

5.5 Preliminary CSM

Based on the assumptions above, a preliminary CSM of pollutant linkages on the site has been developed from the above information and is presented as **Table 5.4**, which combines and summarises the information contained within **Table 5.1** to **5.3**. The CSM includes a qualitative estimation of risk for each pollutant linkage, based on a comparison of the consequence of the event against the probability of its occurrence, in line with the risk classification methodology presented in CIRIA Report C552 (2001).

Table 5.4 – Preliminary Conceptual Model of Pollutant Linkages

Sources Potentially Present	Pathways	Receptors	Qualitative Assessment of Risk
Made Ground across site (may include heavy metals, PAH, sulphate, asbestos, etc.)	Ingestion of contaminated soil, dust, liquid Inhalation of contaminated dust and vapours/gases Contact with contaminated ground/liquid Migration via surface runoff / perched water flow	Human health (current and future site users) Human health (construction workers) Building materials Controlled waters Third Party land	**LOW** - Made Ground encountered by previous site investigation, although no direct evidence of contamination identified. No history of potentially contaminative land use.

To summarise, although the preliminary CSM has identified no direct evidence of ground contamination on the site, unknown Made Ground may be present and possible pathways for contamination to migrate and sensitive receptors potentially at risk have been identified. Possible pollutant linkages are therefore deemed to exist.

6. GROUND INVESTIGATION

6.1 Site Work

6.1.1 Rationale

The purpose of the intrusive investigation was to aid the confirmation of the ground conditions at the site with regard to the hydrogeological assessment, and to obtain geotechnical parameters for design purposes. With regard to contamination and environmental issues, the investigation was also designed to test the potential pollutant linkages identified within the Preliminary CSM. The techniques adopted for the investigation have been chosen considering the anticipated ground conditions and the proposed development.

6.1.2 Scope of Works

The intrusive site work was carried out by RSK in November and December 2010, and comprised the activities summarised in **Table 6.1**, below. The investigation and the soil descriptions were carried out in general accordance with BS5930:1999 - Code of Practice for Site Investigations. The exploratory hole logs are presented in **Appendix B**.

Table 6.1 – Summary of Ground Investigation Activities

Investigation Type	Number	Designation	Rationale
Boreholes - by light cable percussive methods	5	BH1A, BH2A, BH6A, BH8A & BH9A	To prove the geological succession beneath the site, obtain geotechnical data and install standpipes and piezometers.
Boreholes – by drive-in-sampler	4	BH3A, BH4A, BH5A & BH7A	To prove the geological succession beneath the site and install standpipes.
Californian Bearing Ratio (CBR) Tests	3	CBR1 to CBR3	To enable the design of hardstanding for vehicular access
Standpipe/Piezometer installations	9	All boreholes	Groundwater monitoring installations
Water level monitoring in piezometer/monitoring well installations	-	All boreholes	Measurement of depth to groundwater and establish groundwater conditions
Ground Penetrating Radar Survey	-	-	Determine the existence and location of any land drains draining the site into the large pond in the grounds of No.55 Fitzroy Park.
Rising Head Permeability Testing	3	BH2A, BH6A & BH9A	Determine the coefficient of permeability for encountered ground conditions
Soakage Testing	2	BH5A & BH7A	Establish suitability for SUDS-type drainage options

The investigation points were located approximately by reference to physical features present on the site at the time of investigation. An exploratory hole location plan is shown in **Figure 2**. The ground levels at the borehole locations have been determined by rigorous surveying techniques.

6.2 Laboratory Testing

6.2.1 Introduction

A programme of geotechnical and chemical laboratory testing, scheduled by RSK and as detailed below, was carried out on selected samples taken from various strata. The laboratory results are presented in **Appendices C** and **D**, respectively.

6.2.2 Geotechnical Testing

The programme of geotechnical tests undertaken on samples obtained from the intrusive investigation is presented in **Table 6.2**. Where appropriate, testing was undertaken in accordance with BS 1377:1990 Method of Tests for Soils for Civil Engineering Purposes within RSK's UKAS accredited laboratory.

Tests carried out in order to classify the concrete class required on site have been undertaken following the procedures within BRE SD1:2005 by a UKAS accredited laboratory (Envirolab).

Table 6.2 – Summary of Geotechnical Testing Programme

Strata	Tests undertaken	No of Tests
Made Ground	pH and sulfate	2
London Clay Formation	pH and sulfate	8
	Plasticity Index	20
	Natural Moisture Content	20
	Triaxial Compression	14
	Particle Size Distribution and Hydrometer Analysis	2

6.2.3 Chemical Testing

The programme of chemical tests was undertaken on samples obtained from the intrusive investigation as presented in **Table 6.3**. The scope of the testing undertaken is based on the findings of the Phase 1 study discussed above and includes the Contaminants of Concern listed within the Preliminary CSM in **Section 5.2**.

The testing was carried out to assess the levels of contamination within the Made Ground encountered on the site with regard to identified receptors as detailed within the Conceptual Model. Testing was undertaken by a UKAS accredited laboratory (Envirolab). MCERTS accredited test methods were specified where applicable.

Table 6.3 Summary of Chemical Testing Programme

Strata	Tests undertaken	No of Tests	Rationale
Made Ground	Metals Suite: As, Cd, tCr, Pb, Hg, Se, wsB, Cu, Ni, Zn, pH	5	**Non-Targeted** (representative Made Ground)
	Speciated Total Petroleum Hydrocarbons	3	**Non-Targeted** (representative Made Ground)
	Speciated Polyaromatic Hydrocarbons	5	**Non-Targeted** (representative Made Ground)

Strata	Tests undertaken	No of Tests	Rationale
	Asbestos Screen	5	**Non-Targeted** (representative Made Ground)
	Soil Organic Matter	3	**Non-Targeted** (representative Made Ground)
Groundwater	pH and sulfate	2	**Non-Targeted** (representative groundwater)
	Major Ion Analysis	1	**Non-Targeted** (representative groundwater)
	Lead and benzo(a)pyrene	1	**Targeted** (groundwater in BH2A)
Pond Water	Major Ion Analysis	1	**Non-Targeted** (representative pond water)

7. PHYSICAL GROUND CONDITIONS

7.1 Findings of Ground Investigation

7.1.1 General Succession of Strata

The exploratory holes revealed that the site is underlain by a variable thickness of Made Ground over weathered London Clay Formation, which becomes ‘fresh’ (unweathered) with depth. This confirms the stratigraphical succession described within the Preliminary CSM and confirms the ground conditions encountered by GEA during the previous phase of site investigation. For the purpose of discussion, the ground conditions are summarised in **Table 7.1** below.

Table 7.1 – General Succession of Strata Encountered

Strata	Exploratory Holes Encountered	Depth to top of stratum m.bgl (mAOD)	Thickness (m)
Made Ground (Infilled Pond)	All (BH3A & BH4A)	GL (80.16 – 82.43)	0.4 – 1.7 (2.0 – 2.3)
Weathered London Clay Formation	All	0.4 – 2.3 (77.88 – 82.40)	1.7+ - 4.6
London Clay Formation	BH1A, BH2A, BH6A, BH8A & BH9A	5.0 – 6.2 (75.02 – 77.43)	3.9+ - 8.8+

+ Thickness penetrated without proving full thickness of stratum

7.1.2 Made Ground

The exploratory holes encountered a variable thickness of Made Ground across the site, ranging from 0.4m to 1.7m thick. The thickest area of Made Ground (1.4m to 1.7m thick) was located in the south of the site.

In general, the Made Ground comprised brown, locally dry and friable, very silty / clayey slightly gravelly sand or sandy slightly gravelly reworked clay with roots. The gravel fraction generally comprised flint, with fragments of brick and concrete and occasional fragments of clay tile, metal and glass and occasional ash- and charcoal-type fragments.

Fine-grained alluvial-type sediments were encountered in BH3A and BH4A, adjacent to the site’s southwestern boundary, close to, and in line with, the large pond located in the grounds of No.55 Fitzroy Park. These sediments are located in the area identified as having been historically partly occupied by this pond (**Section 3.2**). In general, this material comprised water-bearing, soft and wet, dark-grey slightly sandy gravelly organic clay, with fine to coarse flint gravel. This layer contained rare fragments of man-made materials (i.e. glass and pottery), indicate reworked alluvial-type materials in this area, which appear to have accumulated / been utilised to infill this section of the historical pond. The base of this layer was between 77.9mAOD to 78.1mAOD. Beneath this layer, soft, becoming firm, brown and grey silty clay with occasional flint gravel was encountered and appears to be weathered, possibly partially reworked, London Clay. Boreholes BH7A and BH5A, located to the northwest and southest of BH3A and BH4A, respectively, encountered weathered London Clay lying at shallow depths.

No visual or olfactory evidence of contamination was encountered within the Made Ground.

7.1.3 Weathered London Clay Formation

The London Clay Formation was encountered across the site beneath the Made Ground. The upper part of the London Clay, which was encountered at depths ranging between 0.4m and 1.7m beneath Made Ground and depths of 2.0m to 2.3m beneath Alluvium, was deeply weathered, this horizon extending to depths of 5.5m to 6.2m bgl.

In general, the weathered London Clay comprised firm, locally soft in its uppermost part, fissured brown mottled grey-green silty clay. The clay was also locally slightly sandy (fine sand) with occasional partings of fine sand/coarse silt. Roots, rootlets and root traces were common. Selenite crystals were abundant, occurring throughout, predominantly as fine to coarse sand-sized aggregates. Powdery iron oxide and carbonate precipitate and discrete carbonate nodules were also locally present. Particle size distribution analyses between 1.0m and 3.0m bgl confirm that this material is a slightly sandy (fine) (5 – 10%) silty (45 – 47%) clay (45 – 48%) (**Appendix C**). Plasticity classification testing indicates that the clays are of high to very high plasticity.

Despite lying in an area of ‘Head propensity’, no deposits were encountered that could unambiguously be described as ‘Head’ although elements of the Made Ground (e.g. reworked sandy slightly gravelly clay) could represent reworked or disturbed Head deposits. Only in BH1A between 1.0m and 1.7m bgl were deposits encountered that could represent Head (sandy silty clay with flint gravel).

No visual or olfactory evidence of contamination was encountered within the weathered London Clay. The measured and inferred soil parameters for the weathered London Clay Formation are listed in **Table 7.2** below.

Table 7.2 – Summary of Soil Parameters for Weathered London Clay Formation

Soil Parameters	Range	Results
Liquid Limit (%)	65 – 86 (53)*	Appendix C
Plastic Limit (%)	24 – 31 (22)*	Appendix C
Plastic Index (%)	41 – 55 (31)*	Appendix C
Modified Plasticity Index (%)	41 – 55 (31)*	Figure 4
Plasticity Term	High - Very High (predominantly Very High)	Figure 4
Volume Change Potential (NHBC)	High	
Moisture Content (%)	29 – 39 (18)*	Figure 7
SPT ‘N’ Values	9 - 18	Figure 5
Undrained Shear Strength (kN/m2) measured by Triaxial Testing	48 - 78	Figure 6
Undrained Shear Strength (kN/m2) inferred from SPT ‘N’ values	38 - 76	Figure 6
Strength Term	Low to High	
Consistency Index	0.78 – 0.96 (1.13)*	
Consistency Term	Stiff**	

*Values in parantheses relate to possible ‘Head’ Deposits
** Field tests indicate a general firm consistency

7.1.4 London Clay Formation

Beneath the weathered London Clay, 'fresh' unweathered London Clay was encountered within the boreholes at depths of between 5.8m to 6.7m bgl (77.43 - 75.02mAOD), and extending to the base of the boreholes, to a maximum depth of 15m bgl (66.22mAOD). The 'fresh' London Clay generally comprised stiff fissured dark-brownish grey silty clay, locally slightly sandy (fine sand), with occasional thin partings of fine sand/coarse silt and rare shell fragments. Bands of 'claystone' (carbonate concretion) were encountered locally in BH1A and BH2A.

The measured and inferred soil parameters for the stratum are listed in **Table 7.3** below.

Table 7.3 – Summary of Soil Parameters for 'fresh' London Clay Formation

Soil Parameters	Range	Results
Liquid Limit (%)	69 - 77	Appendix C
Plastic Limit (%)	27 - 31	Appendix C
Plastic Index (%)	42 - 50	Appendix C
Modified Plasticity Index (%)	42 - 50	
Plasticity Term	High - Very High (predominantly Very High)	Figure 4
Volume Change Potential (NHBC)	High	
Moisture Content (%)	27 - 32	Figure 7
SPT 'N' Values	20 - 40	Figure 5
Undrained Shear Strength (kN/m2) measured by Triaxial Testing	50 – 200	Figure 6
Undrained Shear Strength (kN/m2) inferred from SPT 'N' values	84 - 168	Figure 6
Strength Term	High to Very High (generally High)	
Consistency Index	0.89 – 1.02	
Consistency Term	Stiff	

In general, no material distinction was discernible between the weathered London Clay and underlying 'fresh' London Clay, all analyses falling within the high to very high plasticity clay classification. No significant sand or silt dominated beds were encountered, and the principal lithologies encountered were clay dominated (i.e. the primary soil type was a clay). On the basis of this, it is considered that the encountered stratum is compatible with Unit D of the London Clay Formation.

The SPT 'N' Values versus elevation (**Figure 5**) and undrained shear strength versus elevation (**Figure 6)** plots both show consistent increases in values with decreasing elevation (i.e. with increasing depth below ground level), indicating a normal transition from lower strength materials at shallower levels to higher strength materials at depth, with no dramatic change in strength across the boundary of the weathered/unweathered London Clay.

7.2 Moisture Content and Desiccation Assessment

There are a number of mature trees present in the vicinity of the proposed new property. In order to assess whether the London Clay in these areas is currently desiccated, a comparison of the soil moisture profiles and soil index properties have been considered.

The following assessment is based on Driscoll criteria. This criteria indicates that onset of desiccation can be defined if the natural moisture content of the soil is less than 50% of its Liquid Limit and that significant desiccation can be defined if the natural moisture content is less than 40% of its Liquid Limit. The results of the assessment for samples showing desiccation are shown in **Table 7.4** below.

Table 7.4 Desiccation Assessment

BH Depth (m bgl)	Moisture Content (%)	Atterberg Limits			Driscoll Criteria[1]		Desiccation
		LL (%)	PL (%)	PI (%)	0.5 x LL (%)	0.4 x LL (%)	
Weathered London Clay							
BH1A (1.1m) (Head)	18	53	22	31	26.5	21.2	Significant
BH1A (2.2m)	39	86	31	55	43	34.5	Onset
BH1A (4.2m)	32	68	25	43	34	27.2	Onset
BH2A (2.1m)	34	75	27	48	37.5	30	Onset
BH2A (3.1m)	35	73	25	48	36.5	29.2	Onset
BH2A (4.3m)	36	80	29	51	40	32	Onset
BH6A (1.2m)	29	81	27	54	40.5	32.4	Significant
BH6A (2.2m)	33	73	27	46	36.5	29.2	Onset
BH8A (1.2m)	37	73	28	45	36.5	29.2	Not desiccated
BH8A (2.2m)	35	71	26	45	35.5	28.4	Not desiccated
BH9A (1.5m)	31	81	29	52	40.5	32.4	Significant
BH9A (2.5m)	33	65	24	41	32.5	26	Not desiccated

The assessment indicates the general widespread onset of desiccation, and locally significant desiccation, within the upper few metres of the weathered London Clay. The exception is borehole BH8A, in which no indication of desiccation was found. It should be noted that boreholes BH1A, BH2A and BH6A, from which desiccation is recorded, are located within the vicinity of mature trees.

7.3 Groundwater

Observations made during the initial site works and subsequent groundwater monitoring suggest that groundwater is present on the site in several distinct settings:

- Perched water was locally encountered during the site works as a minor seepage at the Made Ground/weathered London Clay interface in BH8A.

- Minor seepages were encountered at depth, within the London Clay (BH2A, BH6A, BH8A and BH9A). Three of these boreholes (within or close to the footprint of the proposed development) were pumped dry and rising head tests were undertaken to allow an assessment of recharge and determinations of the coefficient of permeability. Values for the coefficient of permeability within the range 1.83 to 1.98 x 10^{-7} m/s were obtained where seepages had been recorded (BH2A and BH6A), and values of 1.37 x 10^{-8} m/s were obtained for clay where seepages had not been recorded (BH9A). Both values are consistent with clay modified by the effects of weathering, desiccation and fissuring, which reflects the materials encountered on-site. Any groundwater movement within the London Clay is likely to be through the secondary effect of fissuring.

- Groundwater/perched water was encountered within alluvial-type sediments (Made Ground) in the southwest of the site (BH3A and BH4A) as strikes at depths between 1.38m bgl and 1.46m bgl, rising to approximately 1m bgl.

- Soakage Tests were undertaken in BH5A and BH7A to assess the soils beneath the site with regard to the suitability of SUDS-type drainage at the site. In BH7A, the water had not dissipated after 24 hours, and in BH5A, the water had not dissipated after three days. The obtained data preclude determination of permeability rates and indicate the general unsuitability for the use of SUDS-type drainage systems at the site.

Groundwater monitoring and testing sheets are presented in **Appendix B**.

A record of the groundwater monitoring programme and observations for each of the exploratory holes is summarised in **Table 7.5**.

Table 7.5 – Groundwater Results

BH	Strike / Seepage m.bgl (mAOD)	Standpipe / piezometer Response Zone	Monitoring Results Date m.bgl (mAOD)	Interpretation
BH1A	None	Standpipe in general WLCF	24/11/10 – 3.9 (77.83) 30/11/10 – 2.34 (79.39) (borehole pumped dry to assess recharge) 7/12/10 – 2.3 (79.43) 10/12/10 – 2.15 (79.58)	Completed and installed on 22/11/10; borehole dry. Very slow seepage over general weathered London Clay.
BH2A	4.2 (77.02) 6.05 (75.17)	Standpipe covering seepages within WLCF	30/11/10 – 1.41 (79.81) (borehole pumped dry and datalogger installed to allow recharge and permeability assessment) 10/12/10 – 1.5 (79.72)	Completed and installed on 25/11/10. Slow seepages within weathered London Clay. *K* value of 1.98 x 10^{-7} m/s.
BH3A	1.46 (78.70) (rose to 1.04 (79.12))	Standpipe in All / WLCF	10/12/10 – 1.06 (79.10)	Completed and installed on 7/12/10. Strike within localised water-bearing alluvial-type sediments
BH4A	1.38 (78.80) (rose to 1.06 (79.12))	Standpipe in All / WLCF	10/12/10 – 1.09 (79.09)	Completed and installed on 7/12/10. Strike within localised water-bearing alluvial-type sediments
BH5A	None	Standpipe in general WLCF	Soakage Test 10/12/10 – 1.22 (79.22)	Completed and installed on 7/12/10. Very poor soakage in low permeability clay. No value of *k* determinable.
BH6A	6.15 (76.25)	Piezometer at seepage within upper 'fresh' London Clay	24/11/10 – 1.58 (80.82) (borehole pumped dry and datalogger installed to allow recharge and permeability assessment) 10/12/10 – 0.86 (81.54)	Completed and installed on 18/11/10. Localised slow seepage within 'fresh' London Clay. *K* value of 1.83 x 10^{-7} m/s.

BH	Strike / Seepage m.bgl (mAOD)	Standpipe / piezometer Response Zone	Monitoring Results Date m.bgl (mAOD)	Interpretation
BH7A	None	Standpipe in general WLCF	Soakage Test 10/12/10 – 0.5 (80.15)	Completed and installed on 7/12/10. Very poor soakage in low permeability clay. No value of *k* determinable.
BH8A	1.1 (81.33) 7.8 (74.63)	Standpipe in 'fresh' London Clay	24/11/10 to 10/12/10 – 0.63 (81.80)	Completed and installed on 15/11/10. Localised seepage within upper 'fresh' London Clay.
BH9A	7.15 (75.15)	Piezometer within 'fresh' London Clay	24/11/10 – 2.5 (79.8) (borehole pumped dry and datalogger installed to allow recharge and permeability assessment) 10/12/10 – 2.29 (80.01)	Completed and installed on 17/11/10. Slow seepage from 'fresh' London Clay, recording pore water pressure. May not have reached equilibrium value. *K* value of 1.37 x 10^{-8} m/s.

7.4 Water Chemistry

In addition to the groundwater monitoring, a sample of groundwater was collected from BH2A and a sample of surface water was collected from the pond in the grounds of No.55 Fitzroy Park to allow a direct comparison of 'water types' within each setting. The results of chemical testing for dissolved major ions have been plotted as a Piper Diagram, which is shown in **Appendix B**.

The results of the chemical testing indicate two distinct water types; the groundwater has significantly higher concentrations of dissolved ions (e.g. sulafte values of 1753 mg/l and 66mg/l for the groundwater and pond water, respectively), and the samples clearly plot into distinct fields on the Piper Diagram. The higher dissolved ion load of the groundwater is consistent with the slow percolation of water through the weathered London Clay.

It is therefore considered that groundwater within the immediate site vicinity is unlikely to make any significant contribution to the pond in the grounds of No.55 Fitzroy Park, which is more likely to be fed by surface water.

8. GEOPHYSICAL SURVEY

8.1 GPR Survey

Given the location of the site within a northeast to southwest orientated valley, a geophysical survey was commissioned to seek to determine the location of field drainage channels, underground services and any other buried obstructions or anomalies in the ground conditions in a strip of land around the pond. The survey was carried out within the garden of No.55 Fitzroy Park along open ground immediately adjacent to the large pond and the site boundary with No.53 Fitzroy Park (the subject site).

The geophysical techniques employed were that of Ground Penetrating Radar (GPR). The geophysical fieldwork was conducted on 15th November 2010. The survey around the pond was conducted by collecting data along perpendicular directions at 0.5m spacing from east to west to ensure that as much ground as possible was covered.

8.2 GPR Application

A 400Mhz antenna was deployed in order to provide the appropriate depth penetration and resolution to identify the possible presence of drainage in the ground. From our experience, a 400Mhz antenna typically provides reliable reflection data up to 2.5m depth (dependant upon the conditions).

The presence of a drainage pipe or obstruction within the shallow subsurface can constitute a strong contrast in dielectric (electrical) properties, depending upon the pipe/obstruction diameter and material. Metallic pipes constitute the strongest contrast in dielectric properties and generate the strongest (highest amplitude) reflections. Plastic or ceramic pipes offer a reduced contrast, and subsequently generate lower amplitude reflections.

8.3 GPR Results

There were no anomalous GPR reflections in the data in the immediate vicinity of the boundary of the site and the pond in the grounds of No.55 Fitzroy Park that were indicative of buried pipes or services, and no areas of anomalous ground conditions indicative of preferential drainage pathways (i.e. significantly saturated ground) present in the GPR data.

However, the GPR data showed reflection anomalies consistent with the presence of buried pipes in the extreme west of the survey. At approximately 42m from the start of the survey line, a surface water inspection cover was noted. The GPR data showed two likely buried pipes leading from the cover; one leading off towards the pond, the other leading off towards the pond at an angle. The pipes generated strong hyperbolic reflections in the GPR data at depths of approximately 0.3m. A figure illustration the GPR data is included in **Appendix B**.

The surface water inspection cover was lifted and confirmed that two pipes exited the shallow inspection chamber, one heading directly to the pond, the second heading towards the southwest. The inspection also revealed a shallow pipe entering the inspection chamber from the adjacent site of ‘The Waterhouse’. However, this pipe was sealed with a pipe bung, which appeared to have been *in situ* for a considerable time. No water was flowing in the pipework at the time of this inspection.

9. GROUND CONTAMINATION CONDITIONS

9.1 Chemical Analysis of Soil Samples

9.1.1 Introduction

The findings of the investigation have been assessed in relation both to a combination of specific site characteristics, as identified within the Preliminary Conceptual Model, and the future site use proposals.

Chemical analyses have been performed on a total of five representative samples of Made Ground from across the site. In addition to the chemical analyses, the samples of the Made Ground were screened in the laboratory for the presence of asbestos fibres.

All soil samples scheduled for laboratory testing are also inspected visually on receipt at the laboratory for the presence of materials potentially containing asbestos, e.g. fragments of asbestos-cement products.

The full chemical results are presented within **Appendix D**. The results have been assessed with respect to human health, plant phytotoxicity, the performance of construction materials and water resources in the following sections.

9.1.2 Summary of Soil Results with Respect to Human Health

Assessment of risk is considered as a tiered approach. Assessment based on non-intrusive means is considered a Tier 1 assessment, comparison against Generic Assessment Criteria (GACs) is a Tier 2 assessment, and the generation of and comparison with Site Specific Assessment Criteria (SSACs) is a Tier 3 assessment and is conducted when deemed appropriate from the Tier 2 assessment.

The Tier 1 assessment is summarised in the CSM provided in **Chapter 5**. The following represents the Tier 2 assessment and an overview of the methodology applied is provided below. The Tier 2 Human Health Risk Assessment conducted on the results of the laboratory tests on soils sampled from the site were evaluated using Generic Assessment Criteria (GACs) calculated using the final updated CLEA framework, comprising the new CLEA Software (version 1.06), and supporting documents.

It should be noted that the new CLEA Software has not yet incorporated lead and therefore the former CLEA Soil Guideline Value (SGV) for lead, for a residential with plant uptake end use, has been used in this assessment.

It is proposed to redevelop the site with a large detached residential property. Initially the soil chemical results have been compared directly against the residential with plant uptake GACs calculated using the new CLEA software, as these are considered to be the most suitable guidelines to protect the most critical targets from contaminants via all possible exposure routes.

The CLEA software output reports for the site are presented in **Appendix E**.

For non-volatile contaminants the human health risk assessment has been conducted to a depth of 1m. At depths greater than 1m it is considered that no relevant pathway for human exposure to occur will be present. For volatile contaminants, the human health risk assessment may be conducted on samples collected at depths in excess of 1m as it is assumed that an inhalation pathway (i.e. from vapours) could potentially be present regardless of the depth of the contamination.

Non-volatile contaminants are considered to be those that have a Henry's Law Constant of less than 0.001 whilst volatile contaminants are considered to be those that have Henry's Law Constants greater than 0.001.

With regards to polycyclic aromatic hydrocarbons (PAHs) and metals, very marginal exceedances of the adopted assessment criteria were encountered only in BH2A at 0.45m, as detailed in **Table 9.1**, below.

Table 9.1 – Data Summary Table

Material	**Determinant**	**Total No of samples tested**	**Number of Non Detects**	**Adopted screening value**	**No of exceed-ances**	**Maximum concentration (mg/kg)**
						Value (Location and Depth in parentheses)
Made Ground	Benzo(a)-pyrene	5	2	0.94	1	1.43 (BH2A, 0.45m)
Made Ground	Lead	5	0	450	1	469 (BH2A, 0.45m)

However, under the proposed development scheme, BH2A is within the footprint of the proposed new building. Shallow soils in this area will therefore either be removed during construction or encapsulated beneath the new building, thus breaking any pathways towards human health.

With regards to petroleum hydrocarbons, no elevated concentrations were recorded in excess of the relevant assessment criteria.

With regards to asbestos, the visual inspection at the laboratory identified no materials suspected of potentially containing asbestos and the scheduled laboratory screening for asbestos found no detectable asbestos fibres within the samples of Made Ground.

In summary, with the exception of localised marginal exceedances of lead and benzo(a)pyrene in Made Ground within BH2A, no other potential risks associated with soil contamination have been identified and it is considered that the majority of the site may be regarded as free from contamination with respect to the end use.

9.1.3 *Summary of Soil Results with Respect to Plant Phytotoxicity Effects*

There are no substances present at concentrations above the relevant assessment values adopted from The Soil Code (1998) with respect to potential phytotoxic effects, with the exception of a single exceedance for zinc within Made Ground in BH1A. However, given that BH1A is within an area of mature garden on the site, it is considered that there is no significant risk to any proposed or retained areas of planting.

9.1.4 *Summary of Soil Results with Respect to Performance of Building Materials*

With respect to concrete and plastic water supply pipes, no determinants were present at concentrations in excess of the adopted assessment criteria. However, the pH of the soils locally marginally exceeds the upper threshold value of 8 for materials selection for water supply pipes. It is therefore recommended that service providers be consulted to discuss their requirements.

9.1.5 Summary of Soil Results with Respect to Water Resources

With respect to the chemical analyses conducted on soils, only lead and the PAH compound benzo(a)pyrene have been identified at marginally elevated concentrations, associated with the shallow Made Ground in BH2A. Therefore, a sample of groundwater was collected from BH2A and tested for these determinants to establish whether the encountered material presents a risk to nearby water resources.

The sample did not record any benzo(a)pyrene above the limits of detection of the laboratory equipment (<0.01 µg/l) and the concentration of lead (1 µg/l) was greatly below the UK Drinking Water Standard for lead (25 µg/l). Chemical test certificates are presented in **Appendix D**. It is therefore considered that the marginal exceedances, encountered locally in the soils, do not pose a risk to nearby water resources.

9.2 Ground Gas Monitoring

An assessment of ground gas was outside the scope of works for this investigation. However, the encountered ground conditions (Made Ground with very low degradable organic content overlying low permeability London Clay Formation) indicate very low ground gas generation potential and a negligible level of risk for on-site development.

9.3 Waste Classification of Soils

It is understood that the proposed development will include the localised excavation of Made Ground and natural soils to facilitate the formation of basements and foundations.

All excavated material and excess spoil must be classified for waste disposal purposes prior to disposal at landfill. Under the Landfill (England and Wales) Regulations 2002 (as amended) all wastes must be classified as inert, non-hazardous, stable non-reactive hazardous or hazardous wastes prior to disposal. The Environment Agency guidance document WM2 (interpretation of the definition and classification of hazardous waste) outlines the methodology for classifying wastes.

HASWASTE is a waste soils characterisation assessment tool, developed by Envirolab, which follows the guidance within WM2. The analytical results have been run the through this assessment tool for potential off-site disposal of materials. The results are presented in **Appendix F**.

The results indicate that the Made Ground across the site would not be classified as hazardous waste. Waste Acceptance Criteria testing will be required prior to off-site disposal to classify the soils into inert and non-hazardous categories.

It is important to note that the assessment given in this report is for guidance only and it is always necessary to confirm the actual classification with prospective landfill operators prior to disposal.

Further, all non-hazardous soils, if present, will require pre-treatment prior to disposal at landfill. Pre--treatment is defined as a physical, chemical or biological process that changes the characteristics of the waste in order to reduce its volume / reduce its hazardous nature / facilitate its handling or enhance its recovery. It should also be noted that as an alternative to landfill disposal, inert soils may potentially be suitable for re-use or disposal at an appropriate site, which is exempt from waste management licensing.

9.4 Site Waste Management Plans

It should be noted that the Site Waste Management Plans Regulations 2008 came into force in April 2008. The Regulations require the preparation of a Site Waste Management Plan (SWMP) for all construction projects in England with a value of more than £300,000 and a more detailed plan for projects with a value of more than £500,000. The purpose of the SWMPs is to encourage better resource utilisation and waste management practices in construction, improve environmental performance, minimise the landfilling of wastes, and reduce instances of fly-tipping.

A SWMP will therefore be required for the development and will need to consider all potential construction waste streams, including soils.

Some of the materials tested during this investigation appear to be suitable for re-use on site. In line with the principles of sustainable development and to reduce costs, it is recommended that the strategy for the site should attempt to minimise the volume of contaminated and uncontaminated soils removed off-site for disposal. Prior to commencing any excavation works on site, a Materials Management Plan (MMP) will need to be prepared to establish whether specific materials are classified as waste or not and how excavated materials will be treated and / or re-used, in line with *The Definition of Waste: Development Industry Code of Practice* (CL:AIRE, 2008). The MMP is likely to form part of the Site Waste Management Plan for the site.

10. CONCEPTUAL SITE MODEL AND CONTAMINATION ALLEVIATION MEASURES

10.1 Conceptual Site Model (CSM)

The findings of the site investigation and the above assessment of potential health and environmental risks from contamination has been used to refine a CSM of pollutant linkages. The findings of the investigations and the conceptual site model for the proposed type of development has identified no evidence of significant ground contamination on the site and hence pollutant linkages are deemed not to exist.

The only exception is some localised marginal lead and benzo(a)pyrene contamination within Made Ground in BH2A. However, under the proposed development plan this area of the site will either be excavated to form the new development or be encapsulated beneath the development, breaking any pollutant linkages towards human health. Groundwater from BH2A indicated no evidence of contamination with the above-mentioned contaminants, and therefore it is considered that there is no risk to nearby water resources.

10.2 Alleviation Measures in Respect of Ground Contamination

It is understood that the proposed development will comprise a large detached residential property over a basement, set within private gardens.

The CSM indicates that there is no evidence of significant ground contamination nor pollutant linkages on site in relation to the proposed end-use. Hence, no contamination alleviation measures are required, subject to ensuring that suitable topsoil/subsoil is present in garden and landscaped areas. Only validated sources of imported material should be used, and the imported materials from each source should be validated with appropriate chemical test certificates.

It should be noted that the above assessment is based on the ground conditions encountered during the investigation, the results of field and laboratory testing and interpretation between exploratory holes. The material encountered and samples obtained represent only a small proportion of the materials present on-site. Therefore other conditions may be encountered during ground works, which have not been revealed by this investigation. It is therefore recommended that the groundworks be monitored for previously undetected suspect materials and, if found, appropriate additional testing and advice is sought.

It is recommended that the Local Authority be contacted at an early stage to seek their views on the assessment of contamination at the site.

11. ENGINEERING CONSIDERATIONS

11.1 Details of the Proposed Development

The proposed development involves demolition of the existing property and construction of a new, larger, residential property over the existing footprint. This will comprise a partial basement excavation to form the lower ground floor level with a finished floor level (FFL) of 80.34mAOD. This basement is locally deepened in sub-basement areas to provide accommodation space for a lift pit (FFL 78.74mAOD). Lower ground floor level is at a FFL of 80.34mAOD. The lower ground floor level will be subterranean in the northeast of the development, but at the rear of the property will be at ground level, opening onto the garden to the rear. A ground floor FFL of 83.70mAOD will be at road level adjacent to Fitzroy Park in the east of the site, but will form a 1st floor level at the rear of the property.

A section through the proposed development is shown in **Figure 8**.

11.2 Geotechnical Hazards

A summary of commonly occurring geotechnical hazards is given in **Table 11.1** together with an assessment of whether the site may be affected by each of the stated hazards.

Table 11.1 – 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	✔	Infilled pond in southwest of site (not in development area)		Likely to affect ground engineering and foundation design and construction
Shrinkable clay soils	✔	High volume change potential London Clay		Design to NHBC Standards Chapter 4 or similar
Highly compressible and low bearing capacity soils, (including peat and soft clay)	✔	Locally soft weathered London Clay and infilled pond material (latter not in proposed development area)		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
Karstic dissolution features (including ‘swallow holes’ in Chalk terrain)			✔	May affect ground engineering and foundation design and construction – refer to **Section 4.1.2**
Evaporite dissolution features and/or subsidence			✔	May affect ground engineering and foundation design and construction
Ground subject to or at risk from landslides	✔	See **Section 4.1.2**		Likely to require special stabilisation measures
Ground subject to peri-glacial			✔	Likely to affect ground

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	
valley cambering with gulls possibly present				engineering and foundation design and construction
Ground subject to or at risk from coastal or river erosion			✔	Likely to require special protection/stabilisation measures
High groundwater table (including waterlogged ground)	✔	Shallow perched water present and seepage in London Clay		May affect temporary and permanent works
Rising groundwater table due to diminishing abstraction in urban area			✔	May affect deep foundations, basements and tunnels
Underground mining			✔	Likely to require special stabilisation measures
Existing sub-structures (e.g. tunnels, foundations, basements, and adjacent sub-structures)	✔	Foundations to existing structures on site		Likely to affect ground engineering and foundation design and construction
Filled and made ground (including embankments, infilled ponds and quarries)	✔	0.4m to 1.7m thickness of Made Ground encountered (up to 2.3m in infilled pond area)		Likely to affect ground engineering and foundation design and construction
Adverse ground chemistry (including expansive slags and weathering of sulphides to sulphates)	✔	See **Section 11.7**		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.

11.3 Foundations

11.3.1 General Suitability

In general, the ground conditions in the vicinity of the proposed new development comprised up to 1.7m of variable Made Ground, generally consisting of brown, locally dry and friable, very silty / clayey slightly gravelly sand or sandy slightly gravelly reworked clay with roots. The latter may have comprised an element of reworked 'Head' deposits. Weathered London Clay was encountered underlying the Made Ground and generally comprised firm, locally soft, fissured brown mottled, locally slightly sandy, silty clay. This material has a very high plasticity and high volume change potential and is locally desiccated within the upper few metres. The weathered horizon of London Clay extended to depths between 5.0m and 6.2m bgl and was underlain by 'fresh' London Clay, consisting of stiff fissured dark-brownish grey, locally slightly sandy, silty clay.

Perched water seepage was encountered at the junction between the Made Ground and low permeability weathered London Clay and slow seepage of water also appears to be present at deeper levels within the London Clay.

A piled foundation solution has been proposed for the redevelopment. It is understood that the permanent basement structure will be constructed in reinforced concrete with a piled raft to support the vertical load and deal with any tensile forces that might develop as a result of any heave or hydrostatic pressures.

11.3.2 Piled Foundations

The recommendations for the design and construction of piled foundations in relation to the ground conditions are set out in **Table 11.2**.

Table 11.2 – Design and Construction of Piled Foundations

Design/construction considerations	Design/construction recommendations	
Pile type	The construction of conventional bored and CFA piles is considered technically feasible at this site.	
Possible constraints on choice of pile type	Given the close proximity of the site to other properties and the proposed method of construction, the use of driven piles will not be acceptable due to ground heave, vibration and noise related problems.	
Temporary casing where groundwater is present	Bored piles are likely to require temporary casing throughout their depth due to the presence of groundwater. Alternatively, the use of continuous-flight-auger (CFA) injected bored piles usually overcomes this issue.	
Hard strata	An allowance should be made for the presence of thin ‘rock’ bands (claystone) within the London Clay.	
Made Ground and Desiccated soils	Due to the presence of Made Ground and the localised occurrence of desiccation within the weathered London Clay, the upper 3m of soils have been omitted from the calculations of shaft friction (i.e. only soils beneath proposed basement level of 78mAOD considered).	
Soil and pile design parameters for London Clay (cohesive soils)	Adhesion Factor (α)	0.6
	Bearing Capacity Factor (N_c)	9
	Undrained Shear Strength (c_u) (from basement level at 78mAOD)	57 + 9z kN/m^2 where z = depth into clay
	Global Safety Factor	3.0
	Limiting Shaft Friction	140 kN/m^2
	Limiting Concrete Stress	7.5N/mm^2
Bored pile shafts and bases	Bored pile concrete should be cast as soon after the completion of boring as possible and in any event the same day as boring. Prior to casting the base of the pile bore should be clean otherwise a reduced safe working load will be required. Similarly, if the pile bore is left open the shaft walls may relax/soften, leading to a reduced safe working load.	

The design procedure for piles varies considerably, depending on the proposed type of pile. However, for illustrative purposes **Table 11.3** gives likely working pile loads for traditional bored, cast-in-situ concrete piles of various diameters and lengths, based on the design parameters given in **Table 11.2**.

Table 11.3 – Illustration of Typical Pile Working Loads for Bored Cast-in-situ Piles

Typical Pile Working Loads (kN)				
Depth of pile below 78mAOD	Pile Diameter			
	300mm	350mm	400mm	450mm
10	223	267	312	359
12.5	303	360	420	481
15*	393	466	542	620

*Below maximum depth of investigation

A specialist piling contractor should be contacted at an early stage in the design to seek their advice on the most suitable pile type, depth and capacity for the ground and groundwater conditions encountered on site.

11.4 Retaining Wall Design Parameters

In order to facilitate basement construction, it will be necessary to construct a retaining wall around the perimeter. It is understood that the current proposal involves a temporary contiguous piled wall around the perimeter, within which will be constructed a permanent reinforced concrete basement box structure.

The construction of the partial basement is anticipated to involve excavations to approximately 80.34mAOD (locally 78.7mAOD for a lift pit). The ground conditions likely to be encountered include a variable thickness of Made Ground, up to 1.7m thick, overlying the weathered London Clay Formation and 'fresh' London Clay at depth.

On the basis of the ground investigation information, the soil parameters in **Table 11.4** are recommended for retaining wall design purposes.

Table 11.4 Retaining wall design parameters

Soil type	C_U (kN/m^3)	SPT 'N' value	Unit weight (kN/m^3)	Short Term Characteristics		Long Term Characteristics	
				C_U (kN/m^2)	φ (°)	c' (kN/m^3)	φ' (°)
Made Ground	N/A	4	17	0 1)	28 2)	0	28 2)
Weathered London Clay Formation	38 - 78	9 to 18	19.5	40 + 8z	0	0 2)	21 2)
London Clay Formation	50 - 200	20 to 40	19.5	76 + 9z	0	3 2)	25 2)

1) Assumed from field observation that the material is variable
2) Estimated values – no drained analysis undertaken

Perched water has been encountered at shallow levels and deeper seepages have been encountered within the London Clay Formation. Due to the proximity of the works to the pond in No.55 Fitzroy Park, and the wider hydrological system of the chain of Highgate Ponds, a main concern is protecting water flows near the surface of the site, although evidence from water chemistry (**Section 7.4**) indicates that the adjacent pond is not fed by groundwater. It is proposed that the temporary works retention would be formed using contiguous piles which have spaces between them and will allow the passage of water. In order to avoid loss of fines in the Made Ground, it is proposed that the Made Ground would be excavated immediately behind the upstream piled wall to allow the insertion of a geotextile membrane, which will allow water to continue to flow but would prevent fines from being washed out. Should water flows be high, which is considered unlikely, then a series of counterfort-type drains could also be incorporated within the porous layer.

The void between the temporary piles and the permanent basement structure will be backfilled with a free-draining material and the temporary piles would be left in place. This form of construction is likely to develop hydrostatic pressures around the basement structure. Provision should therefore be made for the build up of hydrostatic pressures behind the walls, and waterproofing of the basement structure.

It is, therefore, considered that temporary groundwater control will be necessary by a combination of gravity drainage and pumping from sumps to allow construction of the basement structure in relatively dry conditions.

Any retaining structures outwith the main basement structure that are to be constructed adjacent to natural or reworked clay soils should to be designed to withstand heave of the adjacent soils or constructed with a void former.

11.5 Ground Floor and Basement Slabs

The soils encountered during the investigation comprised very high plasticity clays of high volume change potential underlying variable Made ground at shallow depths. Soils in the vicinity of the proposed development also show signs of being desiccated. Therefore it is recommended that ground floor slabs should be suspended with a void former beneath.

The basement formation level is up to approximately 3.0m bgl within the weathered London Clay Formation. The proposed basement excavation and unloading caused by the removal of the overburden pressure will result in heave of the London Clay soils below formation level. The subsequent reloading from the building will reduce this heave, the final amount depending on the maximal total loads applied at the formation level. The ground movements resulting from heave of clay soils and the settlements from the building will depend on many factors including the stiffness of the underlying soils, the depth of excavation and the rate of construction. The basement slab will therefore have to be designed to withstand potential heave of the underlying clay soils resulting from unloading due to excavation. Alternatively, suspending the slab with a void former beneath will overcome this issue.

Given the presence of groundwater seepages within the London Clay, the basement slab design should allow for hydrostatic pressures in both the temporary and permanent cases.

All formation levels should be proof-rolled and all topsoil and any other loose, soft, organic or otherwise unsuitable materials should be removed and replaced with well compacted, suitable granular fill.

11.6 Roads and Hardstanding

In the 1m to 1.5m below the proposed finished ground level the exploratory holes have revealed a soil profile comprising variable Made Ground and weathered London Clay. The potentially poorest sub-grade material within this profile is the Made Ground.

In pavement design terms, the groundwater conditions are anticipated to comprise a low water table, i.e. least 1m below the pavement formation level.

The estimated minimum, equilibrium soil-suction, CBR value for the soils and groundwater conditions described above under a completed pavement is 2% to 3%, after Table C1 in TRRL Report LR1132 (1984).

The results of in situ CBR testing indicates that the near surface soils have a CBR value that ranges from between 3% and 7%, the results are summarised in **Table 11.5**.

Table 11.5 – Summary of CBR Values Derived from In Situ Tests

Test Location	Material Type	Minimum CBR value determined at or just below anticipated formation level
CBR1	Made Ground*	3% to 4.5%
CBR2	Made Ground*	6% to 7%
CBR3	Made Ground*	3.5% to 4.5%

* Sandy slightly gravelly silty clay

The sub-grade soils in the vicinity of test locations will not be susceptible to improvement by rolling with conventional compaction plant.

The recommended sub-grade soil CBR value for road pavement design is therefore 3%. This value assumes that during construction the formation level will be carefully compacted and any soft spots removed and replaced with well-compacted granular fill.

The sub-grade soils can be regarded as not frost-susceptible, after the criteria given in Appendix 1 of TRRL Report Road Note 29 (1970).

11.7 Chemical Attack on Buried Concrete

The results of chemical tests carried out on soil samples indicate 2:1 water soil extract sulfate contents of up to 470 mg/l, and with near neutral to slightly alkaline pH values. The results of chemical tests carried out on groundwater samples indicate soluble sulfate contents of up to 1753 mg/l, with near neutral pH values.

These results indicate that, in accordance with BRE Special Digest 1: 2005 *Concrete in aggressive ground*, the Aggressive Chemical Environment for Concrete (ACEC) Classification is ***AC-3*** with a Design Sulphate Class for the site of ***DS-3***. This assumes nominally mobile groundwater conditions and that no significantly disturbed clay comes into contact with concrete foundations or structures.

If significantly disturbed clay is likely to come into contact with concrete foundations or structures it will be necessary to carry out additional tests on the soil to investigate its total potential sulphate content. This will facilitate a re-evaluation of the ACEC Classification and Design Sulphate Class for the material, to take into consideration potential oxidation of available sulphides (e.g. pyrite), as defined in Table C1 (natural ground sites) or C2 (brownfield sites) BRE Special Digest 1: 2005.

11.8 Soakaways / SUDS-type Drainage Systems

The use of pit soakaways / SUDS-type drainage systems will not be appropriate given the encountered ground conditions and sensitive nature of the site area with regard to hydrology and hydrogeology (**Section 7.3**).

11.9 Earthworks Assessment

It is understood that, where possible, excavated soil from the basement and other areas of the scheme are to be re-used across the site.

For guidance on the re-use of materials as backfill, reference has been made to The Department of Transport (DOT), Manual of Contract Documents for Highway Works, Volume 1, Specification for Highway Works, 1998 incorporating November 2009 amendments.

On the basis of the investigation data, the soil type available for re-use from the basement excavation will consist of slightly sandy (5 – 10%) silty (45 – 47%) clay (45 – 48%).

The ground investigation indicates that in accordance with Table 6/1 and 6/2 of the Specification for Highway Works (SHW), Volume 1, the excavated material will predominantly be classed as Class 2A (wet cohesive material) for the purpose of general fill.

No compaction testing has been undertaken, however, the average maximum dry density is likely to be approximately 1.5Mg/m^3 and the optimum moisture content approximately 28%.

Natural moisture contents determined in the laboratory are generally slightly wet of this approximate optimum, indicating that with selective mixing the ‘as dug’ materials should be suitable for re-use as general fill.

12. HYDROGEOLOGICAL IMPACTS OF THE PROPOSED DEVELOPMENT

On the basis of the information presented herein, it is considered that the proposed development is unlikely to impact significantly upon the local hydrological / hydrogeological environment, for the following reasons:

- Perched water appears to be locally present in the Made Ground, overlying the weathered London Clay. In the vicinity of the proposed development, the Made Ground/London Clay boundary was encountered at a depth of 1m bgl, and at this level the proposed foundations and basement are likely to have no more effect on the perched water regime that the foundations to the existing property on site. It is proposed that the Made Ground would be excavated immediately behind the upstream piled wall to allow the insertion of a geotextile membrane which will allow water to continue to flow but would prevent fines from being washed out. Should water flows be high, which is considered unlikely, then a series of counterfort-type drains could also be incorporated within the porous layer. The void between the temporary piles and the permanent retaining wall will be backfilled with a free-draining material and the temporary piles would be left in place.

- The proposed partial basement level is up 3.0m below ground level within the weathered London Clay Formation. The site appears to be underlain by Unit D of the London Clay Formation, as no significant sand dominated beds have been encountered. Localised seepages were encountered within the London Clay Formation during the site works, and the results of a groundwater monitoring programme indicate that slow rates of water seepage are present within the London Clay. Local seepages have permeability in the order of 10^{-7} m/s and flow is likely to be fissure-dominated. The soils are therefore unlikely to hold significant quantities of groundwater, but it is anticipated that seepages will be encountered within the London Clay Formation during excavation for the construction of the basement. Temporary groundwater control will therefore be necessary in the form of gravity drainage and pumping from sumps. The short-term disadvantage of temporary groundwater control is outweighed by the long-term advantage of the proposed contiguous piled wall (with spaces between the piles), which will allow the free passage of groundwater, ensuring long-term drainage.

- Disturbance of the shallow water regime during construction is likely to be limited to the effects of severing existing land drainage networks. However, a GPR survey undertaken to the immediate southwest of the site in the vicinity of the pond in the grounds of No.55 Fitzroy Park did not reveal the presence of any shallow sub-surface land drains in this area directly draining the site. However, all efforts should be made to identify any possible land drains so that mitigation arrangements can be put in place before decommissioning the existing system and to avoid unexpected severance of drainage lines.

- An area of water-bearing alluvial-type sediments (Made Ground) was encountered in the southwest of the site (historical pond infill) adjacent to the site boundary with the pond in the grounds of No.55 Fitzroy Park. No redevelopment works are planned for this area of the site that would intrude into the groundwater environment.

- The results of chemical testing of groundwater from the site and pond water from the adjacent pond indicates distinct ‘water-types’ with significantly different concentrations of major ions. It is therefore considered that groundwater within the immediate site vicinity is unlikely to make any significant contribution to the pond in the grounds of No.55 Fitzroy Park, which is more likely to be fed by surface water.

- Surface run-off from the site may potentially be disturbed during construction by the removal of vegetation and changes to hardstanding, and run-off from stockpiles of excavated soils. However, any potential impacts may be effectively mitigated by on-site bunding of stockpiled materials and/or creation of retention basins to attenuate surface run-off.

In summary, it is considered that the impact of the proposed development on the local hydrogeological regime will be minimal and is considered unlikely to have any significant effect on the water supply to the Highgate Ponds. Any potential disturbances to drainage from the site may be effectively mitigated by the measures outlined above.

13. CONCLUSIONS

13.1 Geoenvironmental Conclusions

The findings of the site investigation, conceptual site model and the assessment of potential health and environmental risks from contamination for the proposed development has identified no evidence of significant ground contamination on the site and hence pollutant linkages are deemed not to exist.

The only exception is some localised marginal lead and benzo(a)pyrene contamination within Made Ground in BH2A. However, under the proposed development plan this area of the site will either be excavated to form the new development or be encapsulated beneath the development, breaking any pollutant linkages towards human health. Groundwater from BH2A indicated no evidence of contamination with the above-mentioned contaminants, and therefore it is considered that there is no risk to nearby water resources.

13.2 Geotechnical Conclusions

The soils encountered during the investigation comprised very high plasticity clays of high volume change potential underlying variable Made Ground at shallow depths. Soils in the vicinity of the proposed development also show evidence of desiccation within the upper few metres.

A piled foundation solution has been proposed for the redevelopment. It is understood that the permanent basement structure will be constructed in reinforced concrete with a piled raft to support the vertical load and deal with any tensile forces that might develop as a result of any heave or hydrostatic pressures.

Support for the proposed basement excavation will be provided by a temporary contiguous piled wall. Perched water has been encountered in the Made Ground and seepages within the London Clay Formation. Temporary groundwater control will be necessary for construction of the basement. Provision should also be made for the build up of hydrostatic pressures behind retaining walls and beneath the basement slab, and waterproofing of the basement structure.

The soils encountered during the investigation comprised very high plasticity clays of high volume change potential underlying variable Made Ground at shallow depths. Soils in the vicinity of the proposed development also show signs of being desiccated. Therefore, it is recommended that ground floor slabs should be suspended with a void former beneath.

The partial basement formation level is up to 3.0m bgl within the weathered London Clay Formation. The proposed basement excavation and unloading caused by the removal of the overburden pressure will result in heave of the London Clay soils below formation level. The basement slab should therefore be designed to resist this or be suspended with a void former beneath.

The recommended sub-grade soil CBR value for road pavement design is 3%.

Concrete (ACEC) Classification is AC-3 with a Design Sulphate Class for the site of DS-3.

The use of pit soakaways / SUDS-type drainage systems will not be appropriate given the encountered ground conditions and sensitive nature of the site area with regard to hydrology and hydrogeology

13.3 Hydrogeological Conclusions

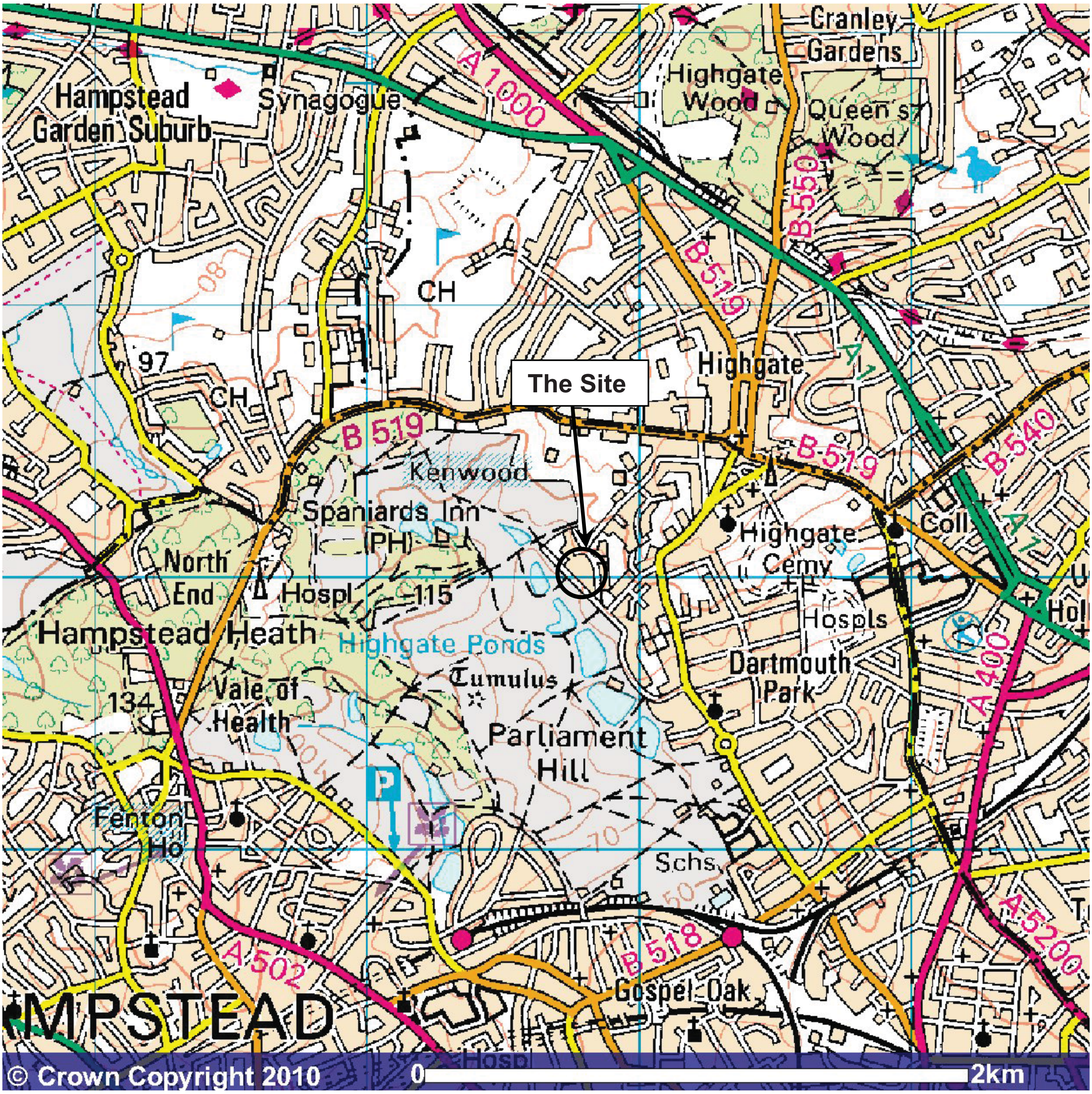
Perched water appears to be locally present in the Made Ground, overlying the weathered London Clay. It is proposed that the Made Ground would be excavated immediately behind the upstream piled wall to allow the insertion of a geotextile membrane which will allow water to continue to flow but would prevent fines from being washed out. Should water flows be high, which is considered unlikely, then a series of counterfort-type drains could also be incorporated within the porous layer. The void between the temporary piles and the permanent retaining wall will be backfilled with a free-draining material and the temporary piles would be left in place.

Groundwater monitoring indicates slow rates of water seepage within the London Clay, compatible with the anticipated low permeability of the encountered materials, and flow within the clay is likely to be fissure-dominated. In view of the proposal to support the basement excavation with a contiguous pile wall, t is considered that temporary groundwater control will be necessary in the form of gravity drainage and pumping from sumps. The short-term disadvantage of temporary groundwater control is outweighed by the long-term advantage of the proposed contiguous piled wall (with spaces between the piles), which will allow the free passage of groundwater, ensuring long-term drainage. This measure should effectively mitigate against damming of flows up-gradient of the basement structure.

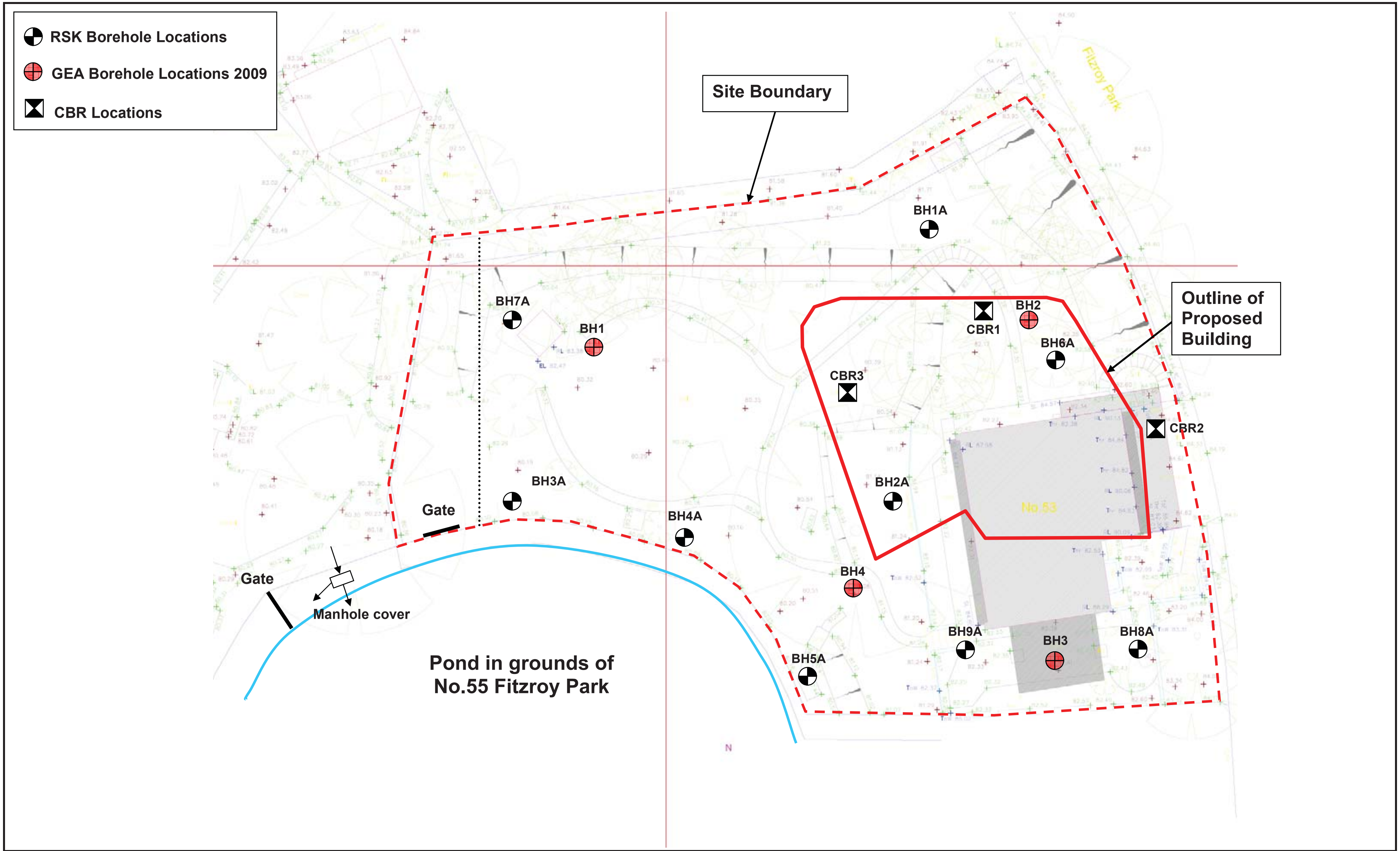
Disturbance of the shallow water regime during construction is likely to be limited to the effects of severing existing land drainage networks. However, a GPR survey undertaken to the immediate southwest of the site in the vicinity of the pond in the grounds of No.55 Fitzroy Park did not reveal the presence of any shallow sub-surface land drains in this area directly draining the site. However, all efforts should be made to identify any possible land drains so that mitigation arrangements can be put in place before decommissioning the existing system and to avoid unexpected severance of drainage lines.

An area of water-bearing alluvial-type sediments (Made Ground) was encountered in the southwest of the site (historical pond infill), adjacent to the site boundary with the pond in the grounds of No.55 Fitzroy Park. No redevelopment works are planned for this area of the site that would intrude into the groundwater environment. The results of chemical testing of groundwater from the site and pond water from the adjacent pond indicates distinct 'water-types' with significantly different concentrations of major ions. It is therefore considered that groundwater within the immediate site vicinity is unlikely to make any significant contribution to the pond in the grounds of No.55 Fitzroy Park, which is more likely to be fed by surface water.

FIGURES



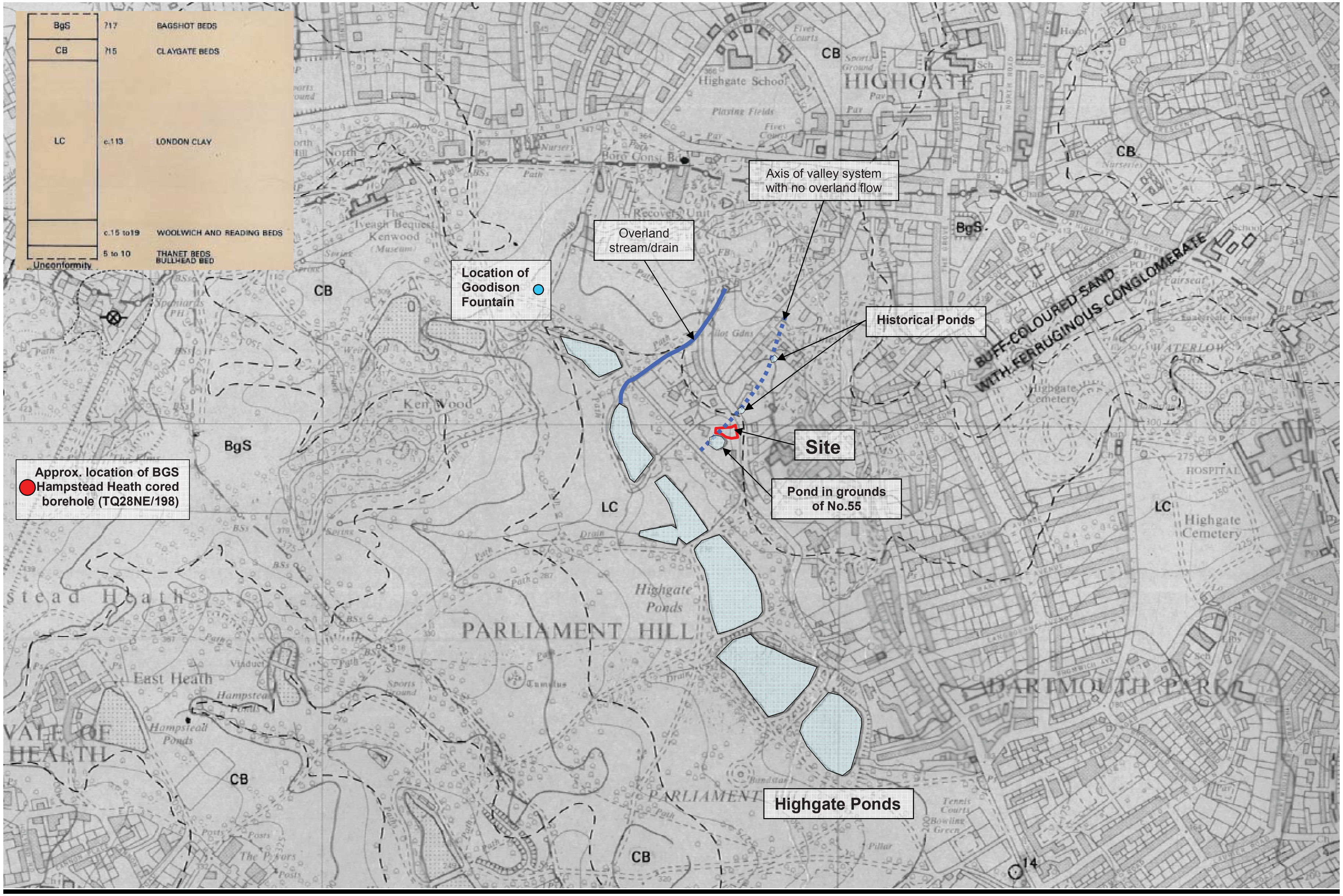
RSK GROUP PLC	SITE LOCATION PLAN	**Client:**	Smarter Building and Construction Ltd	**Figure:**	1
		Site:	53 Fitzroy Park	**Job No:**	241919
		Scale:	See scale bar	**Source:**	OS



RSK GROUP PLC

SITE LAYOUT AND EXPLORATORY POINT LOCATION PLAN

Client:	Smarter Building and Construction Ltd	**Figure No:**	2
Site:	53 Fitzroy Park	**Job No:**	241919
Scale:	NTS	**Source:**	Client



RSK GROUP PLC

GEOLOGICAL MAP EXTRACT

Client:	Smarter Building and Construction Limited	**Figure No:**	3
Site:	53 Fitzroy Park	**Job No:**	241919-01 (00)
Scale:	NTS	**Source:**	BGS 1:10560 Sheet TQ28NE

RSK GROUP PLC

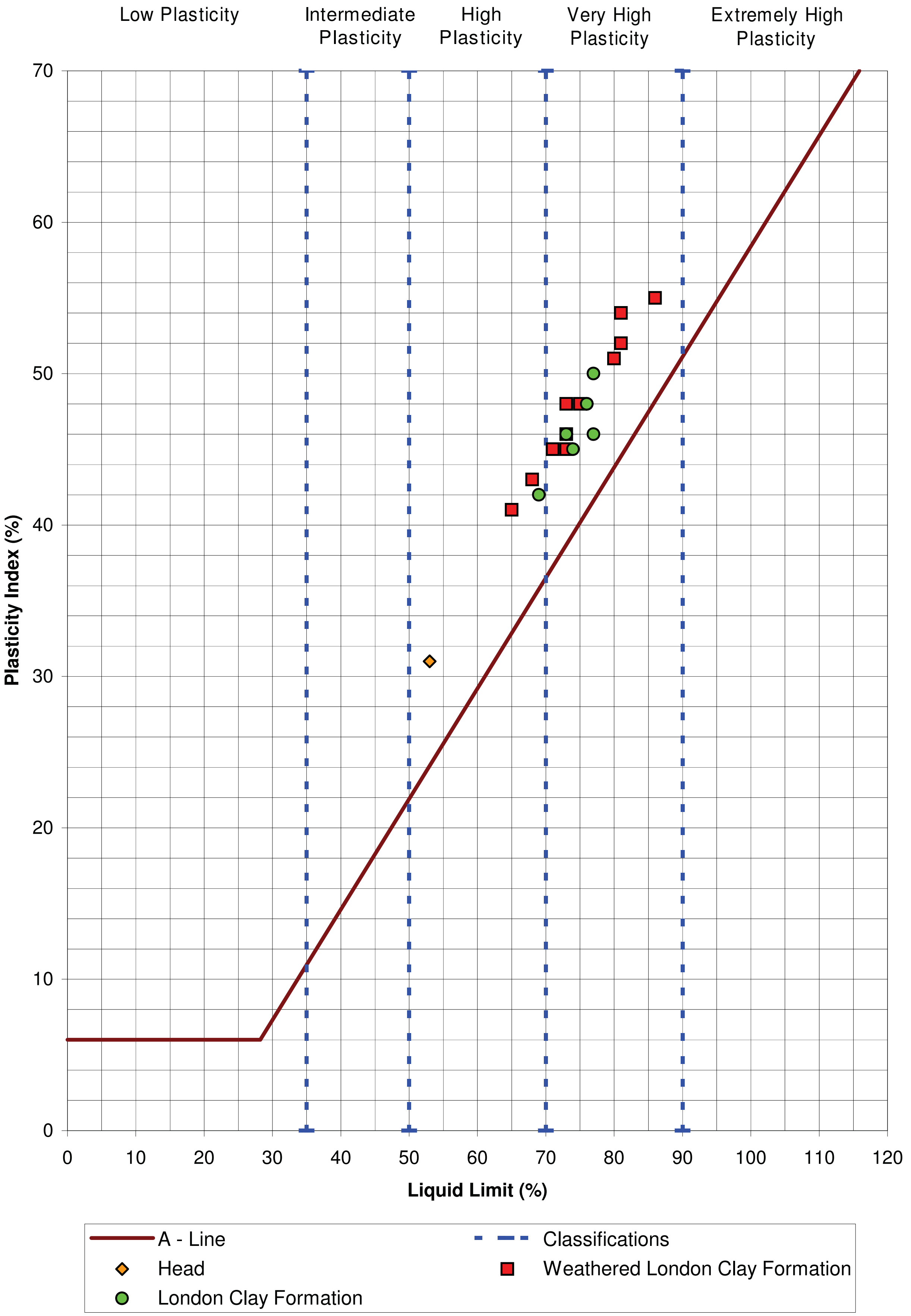
PLASTICITY CLASSIFICATION CHART

Site: 53 Fitzroy Park

Client: Smarter Building and Construction Ltd

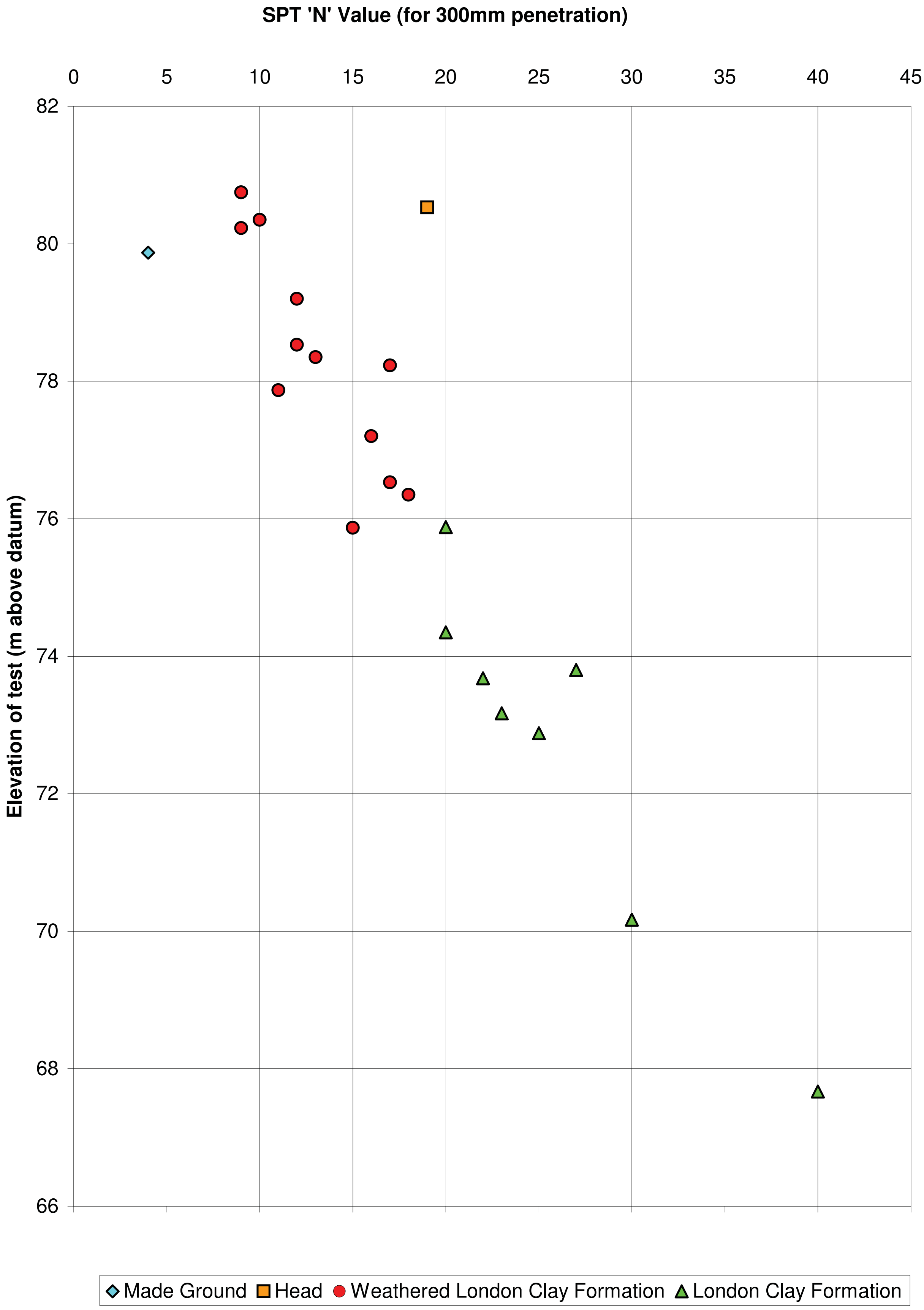
Job Number: 241919

Figure: 4

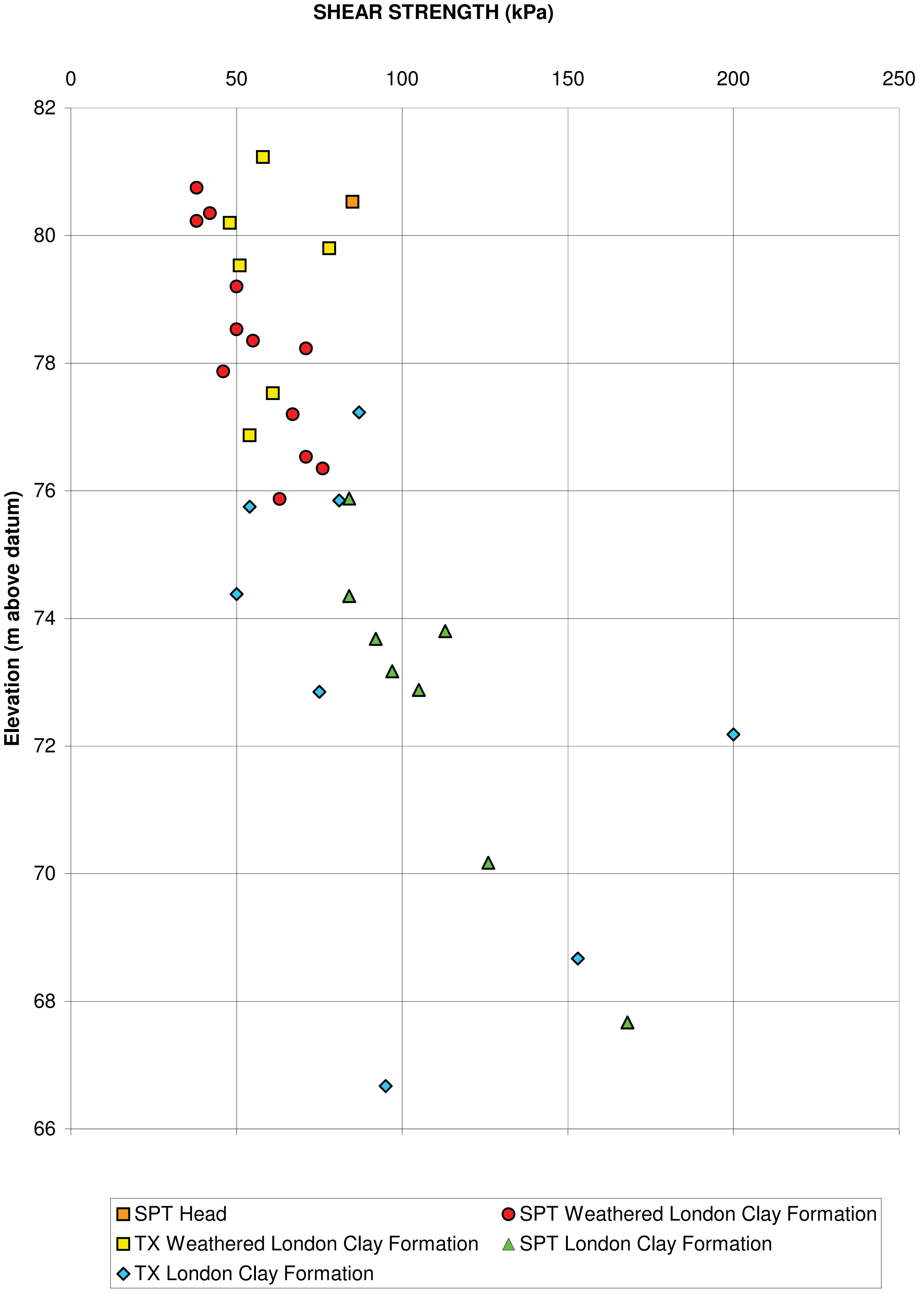


SPT 'N' VALUES vs Elevation

Site: 53 Fitzroy Park	**Client:** Smarter Building and Construction Ltd	**Job Number:**	241919
		Figure:	5



RSK GROUP PLC	SHEAR STRENGTH vs ELEVATION		
Site: 53 Fitzroy Park	**Client:** Smarter Building and Construction Ltd	**Job Number:**	241919
		Figure:	6



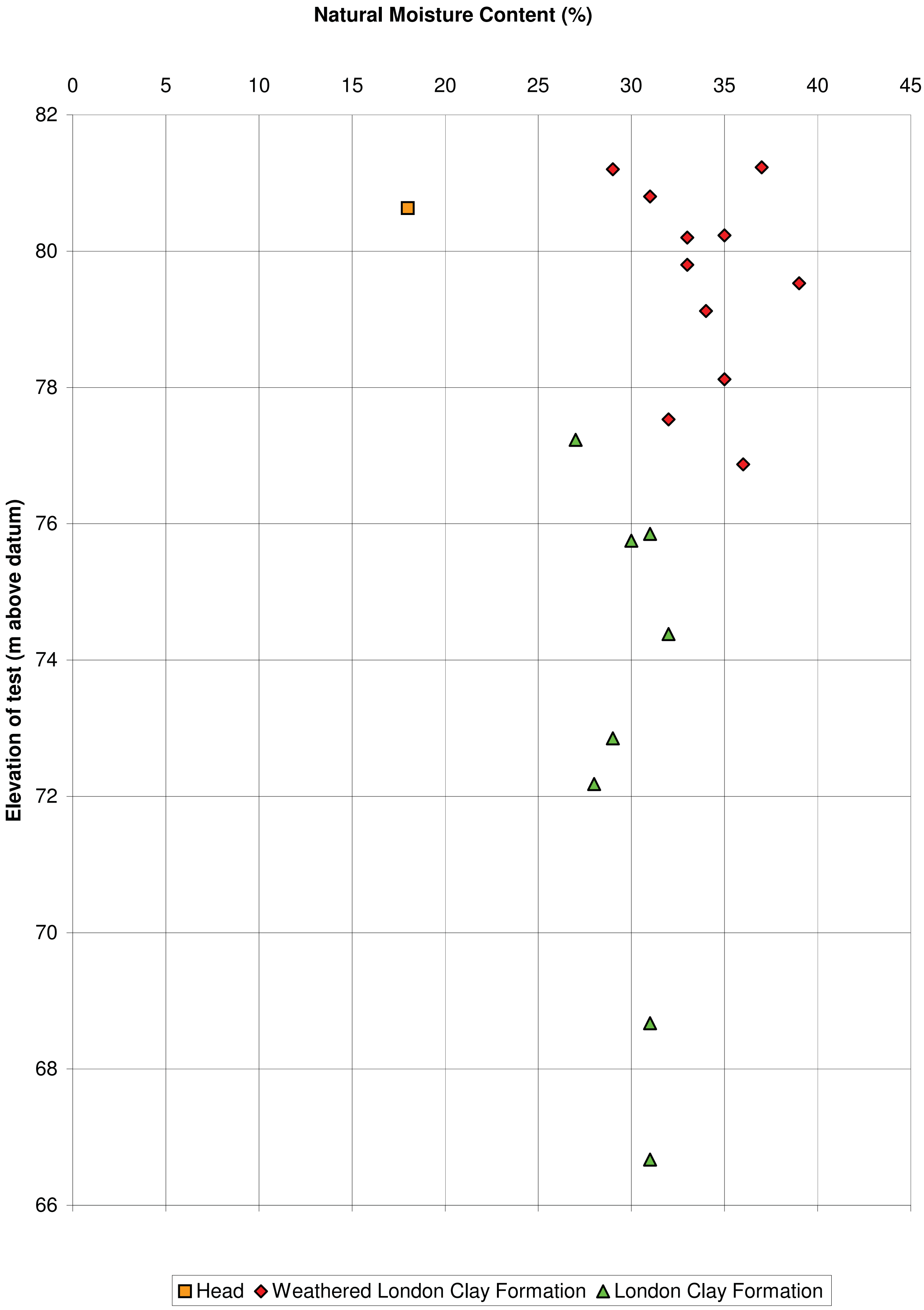
MOISTURE CONTENT vs ELEVATION

Site: 53 Fitzroy Park

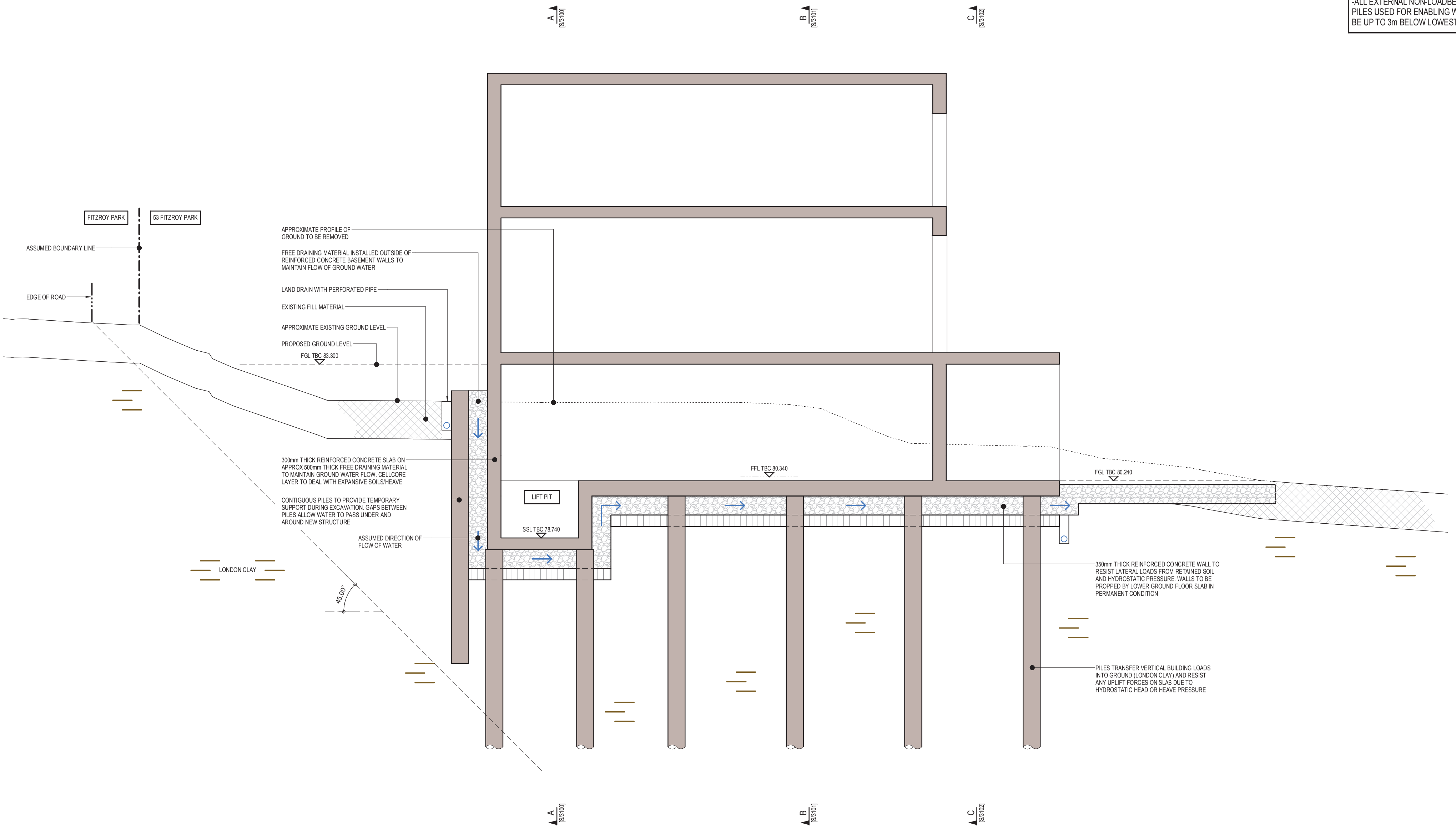
Client: Smarter Building and Construction Ltd

Job Number: 241919

Figure: 7



NOTE:
-ALL INTERNAL LOADBEARING PILES TO BE UP TO 15m BELOW LOWEST POINT.
-ALL EXTERNAL NON-LOADBEARING PILES USED FOR ENABLING WORKS TO BE UP TO 3m BELOW LOWEST POINT.



This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

Do not scale from this drawing.

0 500 1000 1500 2000 2500mm
SCALE 1:50 AT A1

NOT ALL INTERNAL COLUMNS AND WALLS SHOWN FOR CLARITY

WORK IN PROGRESS 06.02.17

NOT FOR CONSTRUCTION

rev	date	by	chk	description

drawing title
Building Sections F-F

scale (s)	date	drawn
1:50@A1; 1:100@A3	Oct 2014	BMC

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project
53 Fitzroy Park

project no.			drawing status.	
2160751			Preliminary	

originator.	zone.	level.	role.	drg no.	revision
EW	00	SEC	S	3105	-

APPENDIX A

Desk Study

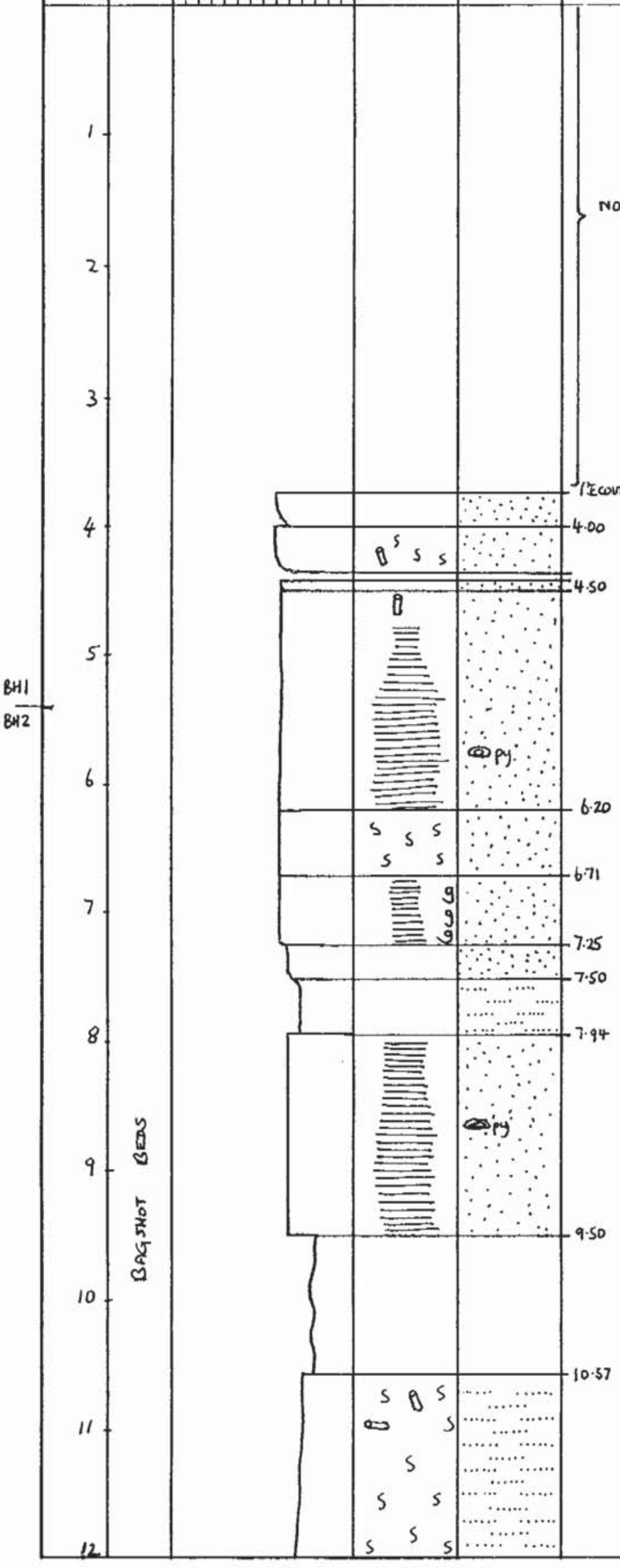
(this appendix contains 7 pages, including this one, and one CD)

BRITISH GEOLOGICAL SURVEY

Sheet 1 of 6

Borehole/Well No. TQ 28 NE/198	Location HAMPSTEAD HEATH	NGR/Lat. & Long. 26455 86890
	KB/Ground level +128.71m	Logged by P. J. STRANGE

Stratigraphy | Carbonates Calc. R Calc. A Calc. L / Average grain size C P G VC C M F VF SI C | Sedimentary structures | Graphic lithology | Lithological description



NO CORE RECOVERY

RECOVERY STARTS AT 3.76

SAND, fine-grained, dark yellow orange, 10YR 6/6, ferruginous streaks, silty at sharp base

SAND, fine-grained, dark yellow orange, 10YR 6/6, burrow prominent at 4.30; some bioturbation, pale brown clay lense at 4.38 - 4.44.

SAND fine-grained, yellowish olive grey, 5Y 5/3, Laminated, Very faint in part. Orange ferruginous patches to 3cm across around 4.70. Large vertical burrow at 4.60. Laminations becoming more distinct from 5.47 to base. Ferruginous nodule at 5.79

SAND, fine-grained, dark yellowish orange 10YR 6/6, variable colour patches, ? bioturbated with silty wisps.

SAND fine-grained brown, 7.5 YR - 5Y 5/3, faintly laminated scattered glauconite grains; orange-brown ferruginous patches.

SAND, Very fine-grained, brown 7.5 YR 5/8, ferruginous staining

SILT, clayey, light olive brown, 2.5Y 5/6, ferruginous staining at top

SAND, Very fine-grained, light olive brown, 2.5 Y 5/6, finely laminated. Scattered carbonaceous patches, one 'crab like' pyrite patch at 8.65. prominently laminated below 9.30. Very ferruginous near base.

CLAY, Silty and sandy, strongly coloured from orange to brown, yellow and grey. Highly disturbed, possibly by drilling

SILT, clayey coarsening downwards to sandy, yellowish olive grey, 10YR 5/3. Bioturbated and roughly horizontal burrows. Faintly laminated between 12.38 and 12.49 Orange wisps prominent between 12.76 and 12.86

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

BRITISH GEOLOGICAL SURVEY

Sheet 2 of 6

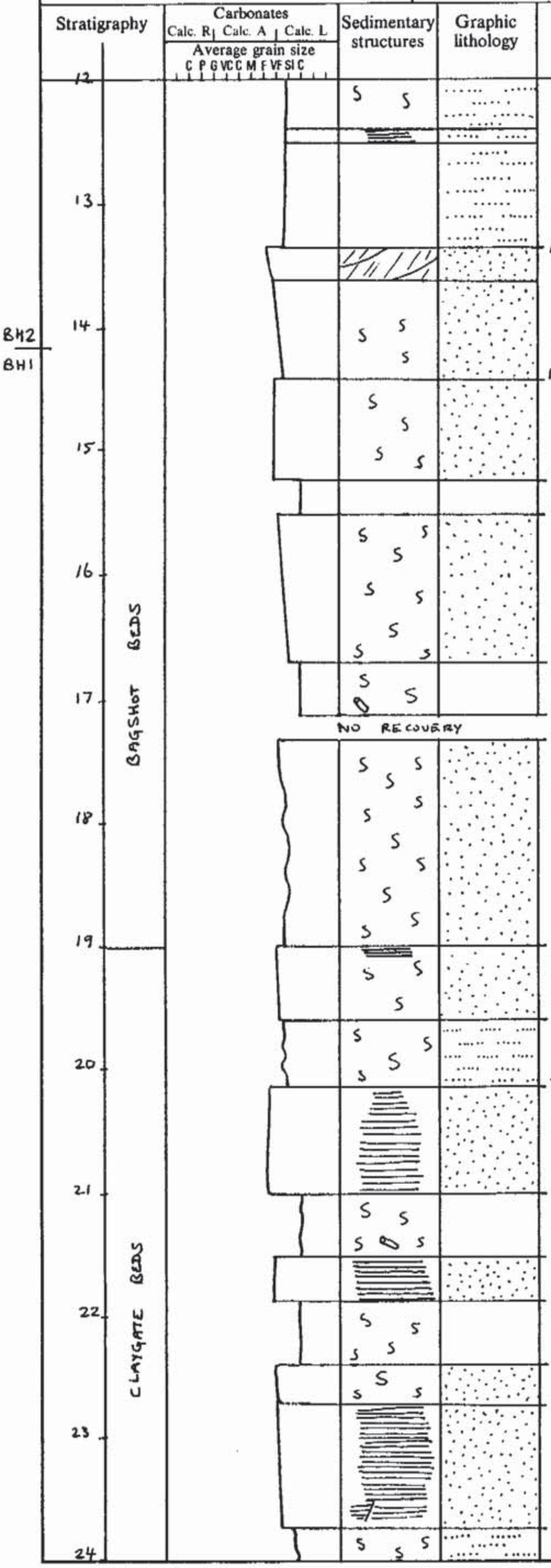
Borehole/Well No. TQ 28 NE /198

Location HAMPSTEAD HEATH

NGR/Lat. & Long. 26455 86890

KB/Ground level +128.71m

Logged by P J STRANGE



Lithological description

13.35	SAND, fine-grained, yellowish brown, 10YR 5/6, Crossbedded fining downwards
	SAND, Very fine-grained, yellowish brown, 10YR 5/6, ? bioturbated, fining downwards
14.42	SAND, very fine-grained, light olive brown, 2.5Y 5/4, bioturbated
15.25	CLAY, olive yellow, 2.5Y 6/8
15.50	SAND, Very fine grained, brownish yellow, 10YR 6/8, but grayish orange in top 10cm, fining downwards to silt size at base. Base is sharp and irregular, bioturbated throughout
16.70	CLAY, silty, medium gray to yellow brown, 10YR 5/6, Sandy filled burrows at 17.08
17.11	
17.33	SAND, Very fine-grained, light olive brown, 2.5 Y 5/4, with silty grayish brown patches, Ferruginous stained vertical joint, 18.30 to 18.90. fining downwards to base. Bioturbated.
19.00	SAND, Very fine grained, silty, olive, 5Y 4/3, laminated in top 10cm
19.63	SILT, light olive gray, 5Y 6/1, with darker clay patches and scattered sand lenses
20.15	SAND, Fine-grained, well laminated, particularly towards base, Sharp base of unit at 21.00.
21.00	CLAY, dark yellowish brown, 10YR 4/2, bioturbated, with sandy wisps and sand filled burrows.
21.50	SAND, Very fine-grained, light olive gray, 5Y 6/1, well laminated, roughly horizontal
21.86	CLAY, silty, dark yellow brown, 10YR 4/2, bioturbated
22.40	SAND, Very fine-grained, light olive gray, 5Y 6/1, fining downwards. Bioturbated
22.70	SAND, Very fine-grained, light olive gray, 5Y 6/1, well laminated, with colour contrast laminations. Small scale penecontemporaneous faulting displaying laminae at 23.10.
23.72	SILT, clayey with sandy patches, grayish brown, 5YR 3/2,