Section 4 Discussion of Geotechnical Insitu and Laboratory Testing

4.1 Standard Penetration Tests (SPTs)

Standard Penetration Tests (SPTs) were undertaken in the Made Ground, Lynch Hill Gravel Member and the London Clay Formation.

Coarse (granular) soils of the Made Ground (MG) and Lynch Hill Gravel Member (LHGR) were classified using the same relationship as outlined in Table 4.1, using equivalent SPT "N" blow counts derived from the dynamic probe tests.

Table 4.1 - **Relative Density Classification**

Classification	S.P.T. "N" blow count (blows/300mm)
Very loose	0 to 4
Loose	4 to 10
Medium dense	10 to 30
Dense	30 to 50
Very dense	Greater than 50

(Ref: The Standard Penetration Test (SPT): Methods and Use, CIRIA Report 143, 1995)

The inferred undrained cohesion of the cohesive soils of the London Clay Formation (LC) was based on the SPT "N" blow counts. Table 4.2 outlines the classification, which was based on the relationship suggested by Stroud (1974) *(ref: Stroud, M. A. 1974, "The Standard Penetration Test – its application and interpretation", Proc. ICE Conf. on Penetration Testing in the UK, Birmingham. Thomas Telford, London.).*

Table 4.2 - **Cohesive Soil Classification**

Classification	Undrained Cohesive Strength C_u (KPa)
Extremely low	<10
Very low	10 – 20
Low	20 – 40
Medium	40 – 75
High	75 – 150
Very high	150 – 300
Extremely high	> 300

(Ref: EN ISO 14688-2:2004 Clause 5.3.)

The *UK National Annex to Eurocode 7: Geotechnical design – Part 2: Ground investigation and testing, NA 3.7 SPT test, BS EN 1997-2:2007, Annex F* states "Relative density descriptions on borehole records should also be based on uncorrected SPT N values, unless significantly disturbed, using the density classification in BS 5930:1999+A1, Table 13.

An interpretation of the S.P.T. "N" blow counts and soil classification is given in Table 4.3.

Table 4.3 - **Interpretation Of S.P.T."N" Blow Counts**				
Lithology	**"N" blow Range (uncorrected)**	**Soil Type**		**Borehole & Stratum Depth (m bbl)**
		Cohesive	**Granular**	
MG	6 – 31	-	Loose to dense	BH1/(1.50-4.50)
LHGR	14 – 22	-	Medium dense	BH1/(4.50-6.90)
LC	14 – 36	Medium to very high	-	BH1/(6.90-25.00)

(The Standard Penetration Tests were conducted in accordance with BS EN ISO 22476-3:2005)

4.1 Dynamic Probe Tests

Dynamic probing was undertaken at two locations (DP1-DP2) adjacent and prior to the drilling of the respective window sampler boreholes each to a depth of 8.00m and 10.00m blgl.

Dynamic probing involves the driving of a metal cone into the ground via a series of steel rods. These rods are driven from the surface by a hammer system that lifts and drops a 50.0kg hammer onto the top of the rods through a set height, thus ensuring a consistent energy input. The number of hammer blows that are required to drive the cone down by each 100mm increment are recorded. These blow counts then provide a comparative assessment from which correlations have been published, based on dynamic energy, which permit engineering parameters to be generated.

The dynamic probe results were converted to equivalent SPT "N" values based on dynamic energy using in-house computer software (Geostru).

Coarse (granular) soils of the Made Ground and Lynch Hill Gravel Member (LHGR) were classified using the same relationship as outlined in Table 4.1, using equivalent SPT "N" blow counts derived from the dynamic probe tests.

The inferred undrained cohesion of the cohesive soils of the London Clay Formation (LC) was based on the equivalent SPT "N" blow counts, derived from the dynamic probe tests. The same classification outlined in Table 4.2 was used to classify the cohesive soils.

An interpretation of the inferred SPT 'N' blow counts is given in Table 4.4.

Table 4.4 - **Interpretation Of Equivalent SPT 'N' Blow Counts**				
Lithology	**Equivalent SPT "N" Blow Counts**	**Soil Type**		**Trial Hole (m bgl)**
		Cohesive	**Granular**	
MG	2 - 31	-	Very loose to dense	DP1-DP2 (4.00-4.10)
LHGR	11 – >50	-	Medium dense	DP1 – DP2 (7.20-7.30)
LC	11 – 17	Medium to high	-	DP1 - DP2 (8.00-10.00)*

Note: *Full Depth of Probe

(The Dynamic Probe 'Supper Heavy' (DPSH-B) Test was conducted in accordance with BS EN ISO 22476-2:2005).

The test results are presented in Appendix A.

4.2 Quick Unconsolidated Undrained Triaxial Tests

QUU Triaxial Tests were made on four undisturbed cohesive soil samples of the London Clay Formation (LC), and a summary of the results is presented in Table 4.5.

Table 4.5 - **QUU Triaxial Test Results Summary**

Depth (m bgl)	Moisture Content (%)	Undrained Cohesion (kN/m^2)	Soil Strength
9.00	29	131	High
12.00	26	175	Very high
18.00*	25	105	High
24.00	21	294	Very high

Note: *It was noted in the Lab that the sample was disturbed, however, the reason for this was not established, but likely to be from the sampling process.

(The Triaxial Tests were made in accordance with B.S. 1377:Part 7:1990 Test 9.0)

The test results are presented in Appendix B.

4.3 Atterberg Limit Tests

Atterberg Limits Tests were made on two cohesive samples of the London Clay Formation (LC) and a précis of the results is given in Table 4.6.

Table 4.6 - **Atterberg Limit Test Interpretation**

Depth (m bgl)	Moisture Content (%)	Plasticity Index (%)	Passing 425 μm Sieve (%)	Modified Plasticity Index (%)	Soil Classification	Volume Change Potential	
						BRE	NHBC
6.90	29	44	100	44	CV	High	
9.00	29	55	100	55	CV	High	

NB: BRE Volume Change Potential refers to BRE Digest 240 (based on Atterberg results)
NHBC Volume Change Potential refers to NHBC Standards Chapter 4.2 (based on Atterberg results)
Soil Classification based on British Soil Classification System

The most common use of the term clay is to describe a soil that contains enough clay-sized material or clay minerals to exhibit cohesive properties. The fraction of clay-sized material required varies, but can be as low as 15%. Unless stated otherwise, this is the sense used in Digest 240.

The term can be used to denote the clay minerals. These are specific, naturally occurring chemical compounds, predominately silicates.

The term is often used as a particle size descriptor. Soil particles that have a nominal diameter of less than 2 μm are normally considered to be of clay size, but they are not necessarily clay minerals. Some clay minerals are larger than 2 μm and some particles, 'rock flour' for example, can be finer than 2 μm but are not clay minerals.

The test results are given in Appendix B.

(The Atterberg Limit Tests were undertaken in accordance with BS 1377:Part 2:1990 Clauses 3.2, 4.3 and 5).

4.4 Grading Analyses

Grading Analyses were made on one and two granular samples of the Made Ground and Lynch Hill Gravel Member respectively, and a précis of the results is given in Table 4.7.

Table 4.7 - **Grading Analysis Interpretation**

Stratum & Depth	Soil Description	Passing 63µm Sieve (%)	Volume Change Potential	
			BRE	NHBC
MG (2.5-3.0m)	Greenish grey clayey very gravelly SAND	18	Yes	No
LHGR (4.5-5.00m)	Pale brown very gravelly SAND	1	No	No
LHGR (6.0-6.5m)	Pale brown very gravelly SAND	1	No	No

NB: BRE Volume Change Potential refers to BRE Digest 240 (based on Atterberg results)
NHBC Volume Change Potential refers to NHBC Standards Chapter 4.2 (based on Atterberg results)
Soil Classification based on British Soil Classification System

Volume Change Potential – BRE 240 states that a soil has a volume change potential when the clay fraction exceeds 15%. Only the silt and clay combined fraction are determined by sieving therefore the volume change potential is estimated from the percentage passing the 63µm sieve.

NHBC Standards Chapter 4.2 states that a soil is shrinkable if the percentage of silt and clay passing the 63µm sieve is greater than 35% and the Plasticity Index is greater than 10%.

The test result is given in Appendix B.

(Grading Analyses were made in accordance with B.S.1377:Part 2:1990 Test 8).

4.5 One-Dimensional Consolidation Test

One-Dimensional Consolidation Test was made on one undisturbed cohesive soil sample of the London Clay Formation (LC) at 9.00m blgl.

(The One-Dimensional Test was made in accordance with B.S. 1377:Part 5:1990 Tests 3 & 4)

The test results are presented in Appendix B.

4.6 Sulphate and pH Tests

One sample of Lynch Hill Gravel Member (BH1/4.50m) and two samples of London Clay Formation (BH1/7.50-7.90m and BH1/18.50m) were submitted for water soluble sulphate (2:1) and pH testing in accordance with Building Research Establishment Special Digest 1, 2005, *'Concrete in Aggressive Ground'*.

The test results are given in Appendix B, and within the contamination results in Appendix C where six Made Ground samples were also analysed for pH and sulphate as part of the contamination testing.

The significance of the Sulphate and pH Test results are discussed in Section 5.4 in this report.

Section 5 Foundation Design

5.1 General

An engineering appraisal of the soil types encountered during the site investigation and likely to be encountered during the redevelopment of this site is presented. Soil descriptions are based on analysis of disturbed samples taken from the boreholes.

5.1.1 Topsoil or Made Ground

The terms *Fill* and *Made Ground* are used to describe material which has been placed by man either for a particular purpose e.g. to form an embankment, or to dispose of unwanted material. For the former use, the Fill and/or Made Ground may well have been selected for the purpose and placed and compacted in a controlled manner. With the latter, great variations in material type, thickness and degree of compaction invariably occur and there can be deleterious or harmful matter, as well as potentially methanogenic organic material.

The BSI Code of Practice for Foundations, BS 8004:1986, Clause 2.2.2.3.5 Made Ground and Fill, includes the caveat that *'all made ground should be treated as suspect, because of the likelihood of extreme variability'*.

A result of the inherent variability, particularly of uncontrolled Fill and/or Made Ground, is that it is usually unpredictable in terms of bearing capacity and settlement characteristics. Foundations should, therefore, be taken through any Fill and/or Made Ground and either into, or onto a suitable underlying natural stratum of adequate bearing characteristics.

Made Ground was encountered in each of the trial holes and comprised concrete over dark brown, dark grey and dark brown black slightly clayey to clayey sandy gravelly SILT, slightly sandy clayey GRAVEL, slightly sandy silty CLAY and gravelly silty SAND, with occasional to abundant brick fragment and concrete. Gravel is fine to coarse and sub-angular to sub-rounded.

The Made Ground was encountered to a depth of 4.50m blgl in BH1, and to the full depths of the remaining trial holes at depths of between 0.50m blgl in TP1 and 6.50m bgl in WS1.

The results of the SPT/dynamic probe blow counts showed the Made Ground to have relative density of **very loose to dense**.

The result of the Grading Analysis showed that the granular soils of the Made Ground fell into the ***no volume change potential*** classification according to the NHBC Standards Chapter 4.2 and a ***volume change potential*** classification according to the BRE Digest 240.

Made Ground may be present to similar, if not greater depth elsewhere across the site, such as in the vicinity of former foundations, infilled basement, services trenches, and the like which may be or are known to be present under the site.

5.1.2 Lynch Hill Gravel Member

Soils of the Lynch Hill Gravel Member were encountered underlying the Made Ground and comprised medium dense brown and pale brown very gravelly coarse SAND. Gravel is fine to coarse and angular to rounded.

The Lynch Hill Gravel Member was encountered to a depth of 6.90m blgl in BH1, and inferred in DP1 and DP1 to depths of 7.20m and 7.30m blgl respectively.

The results of the SPT/dynamic probe blow counts showed the Lynch Hill Gravel Member to have relative density of **medium dense**.

The result of the Grading Analysis showed that the granular soils of the Lynch Hill Gravel Member fell into the ***no volume change potential*** classification according to the NHBC Standards Chapter 4.2 and the BRE Digest 240.

The soils of the Lynch Hill Gravel Member are generally normally consolidated granular soils that are relatively recent granular deposits in geological terms, and as such generally have moderate bearing and settlement characteristics, and therefore were considered suitable as a bearing stratum for the proposed redevelopment conventional foundations.

5.1.3 London Clay Formation

Soils of the London Clay Formation were encountered underlying the Lynch Hill Gravel Member and comprised firm to stiff becoming very stiff medium to very high strength slightly fissured to fissured brown to dark grey silty CLAY.

The London Clay Formation was encountered to the full depths of the borehole at 25.00m blgl in BH1, and inferred in DP1 and DP2 at 10.00m blgl.

The results of the SPT/dynamic probe blow counts showed the London Clay Formation to have **medium to very high strength**.

The results of the Atterberg Limit testing showed that the **cohesive soils** of the London Clay Formation fell into the BRE Digest 240 and NHBC Standards Chapter 4.2 ***high volume change potential*** classification.

The soils of the London Clay Formation are overconsolidated soils and as such generally have moderate bearing and settlement characteristics and would be suitable as a bearing stratum for the proposed development.

5.1.4 Roots

No roots were observed in the samples recovered from the boreholes, and within the trial holes.

5.1.5 Groundwater

Groundwater was encountered during the intrusive investigation to a minimum depth of 1.90m and 3.94m blgl, these were considered to be perched and groundwater levels respective.

Given the groundwater level, it would not be possible to construct the basement without well pointing or some other form of dewatering, within the Made Ground and the granular soils. Groundwater control in the London Clay Formation should be controllable using shallow sumps and pumping.

5.1.6 Guidance on Shrinkage Soils

The Building Research Establishment (BRE) Digests 240, 241 and 242 provide guidance on 'best practice' for the design and construction of foundations on shrinkable soils.

The result of the Grading Analysis showed that the granular soils of the Made Ground fell into the ***no volume change potential*** classification according to the NHBC Standards Chapter 4.2 and a ***volume change potential*** classification according to the BRE Digest 240.

The result of the Grading Analysis showed that the granular soils of the Lynch Hill Gravel Member fell into the ***no volume change potential*** classification according to the NHBC Standards Chapter 4.2 and the BRE Digest 240.

The results of the Atterberg Limit testing showed that the **cohesive soils** of the London Clay Formation fell into the BRE Digest 240 and NHBC Standards Chapter 4.2 ***high volume change potential*** classification.

The BRE Digest 241 states: *"An increasingly common, potentially damaging situation is where trees or hedges have been cut down prior to building. The subsequent long-term swelling of the zone of clay desiccated by the roots, as moisture slowly returns to the ground, can be substantial. The rate at which the ground recovers is very difficult to predict and if there is any doubt that recovery is complete then bored pile foundations with suspended beams and floors should be used".*
The BRE Digest 240 suggests: *"Two courses of action are open:*

- *Estimate the potential for swelling or shrinkage and try to avoid large changes in the water content, for example by not planting trees near the foundations.*

- *Accept that swelling or shrinkage will occur and take account of it. The foundations can be designed to resist resulting ground movements or the superstructure can be designed to accommodate movement without damage."*

The design of foundations suitable to withstand movements is presented in BRE Digest 241 "Low-rise buildings on shrinkable clay soils: Part 2".

The BRE Digest 240 advises that a piled foundation must be used if there is any doubt regarding completion of soil moisture content following any tree removal. In predominantly clayey soils, moisture content recovery can take in excess of 20 years to complete.

The stated intention of the NHBC is to ensure that shrinkage and swelling of plastic soils does not adversely affect the structural integrity of foundations to such a degree that remedial works would be required to restore the serviceability of the building.

It must be borne in mind that adherence to the NHBC tables and design recommendations may not, in all cases, totally prevent foundation movement and cracking of brickwork might occur.

However, given the founding depth for the proposed double basement, to be of order 6m below existing lower ground level, it would be sufficiently deep to past through any desiccated soils.

5.2 Basement Scheme

The proposed redevelopment comprised the demolition of the existing building and construction of a new six storey building with a two level basement. The basement level was to be approximately 8m below existing ground (street) level or about 6m below existing lower ground level. The current proposal for the new building was to construct a concrete frame from the first floor slab down to the basement and a lightweight steel framed structure from first to roof level.

The slab of the new basement would take the proposed excavation to a depth of about 8.00 metres below street level. Support will be required on all faces, especially to the adjoining properties party walls.

The excavation of the basement must not affect the integrity of the adjacent structures beyond the boundaries.

According to MLM, the adjoining properties party walls would be underpinned and the construction sequences are given figures 5.1 and 5.2 for north and south boundaries respectively. Prior to the underpinning, the front and rear walls of the basement would be formed by contiguous piles. The details are given in the Basement Construction Impact Assessment prepared by MLM reference ARP/665721/AL dated 16 January 2015.

The underpinning must be excavated in short bays and sufficient time left prior to striking formwork. The bays must be excavated in a prescribed sequence to maintain stability.

The external excavation could be supported by a contiguous, secant or a sheet piled wall. Generally cantilevered piled walls have an open face to embedded ratio of about one to two ie. a supported face eight metres in height would require a penetration into the ground, below the base of the excavation, of about sixteen metres. Should the piled retaining wall be purely an unsupported cantilever then it is likely that quite deep section sheet piles or large diameter bored piles would be required.

Dewatering would be required to facilitate the construction and prevent the base of the excavation blowing before the slab was cast if the groundwater level rises or the construction undertaken in winter months. The advice of a reputable dewatering contractor, familiar with the type of ground and groundwater conditions encountered on this site, should be sought prior to finalising the design of the excavation for the basement.

Unsupported earth faces formed during excavation maybe liable to collapse without warning and suitable safety precautions must therefore be taken to ensure that such earth faces are adequately supported before excavations are entered by personnel.

Groundwater was encountered at a depth of 3.94m blgl on 16.01.15; this period is when groundwater should typically be increasing from its annual minimum (i.e. lowest) elevation.

Therefore the basement design must take into consideration a groundwater level rising potentially to surface i.e. full hydrostatic uplift and lateral forces, or worst credible scenario (EC7) unless long term monitoring is undertaken.

Heave would be anticipated within the base of excavations due to the reduction in the effective stress of the cohesive soils of the London Clay Formation. Immediate heave is likely to have a minimal effect as it would take place soon after excavation and any immediate heave is likely to be removed during the excavation of the basement slab in order to achieve the correct dig level prior to casting the slab. The long term heave would be anticipated to be less than 10mm.

Notes: For the calculations of the immediate heave, the Ey (Young's Modulus) for uploading was taken as equal to the Ey for loading, which is considered to be a conservative approach. For the calculations of the long term swelling, the ratio of swelling index (Cs) compression index (Cc) was taken as Cs=Cc/5 *(Reference: Simon & Menzies, Foundation Engineering).*

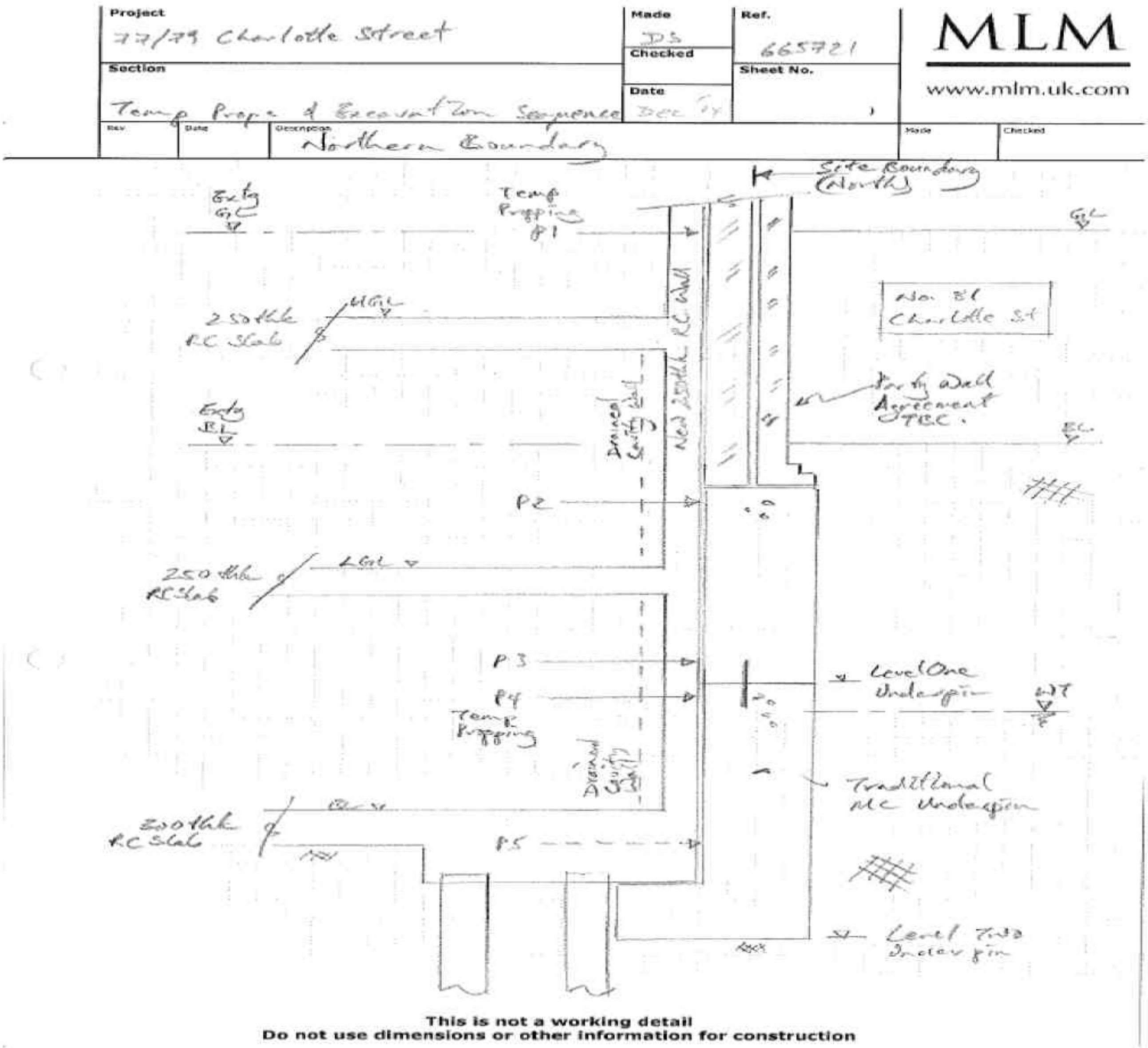


Figure 5.1 – Temporary Propping & Excavation Sequence (Northern Boundary)

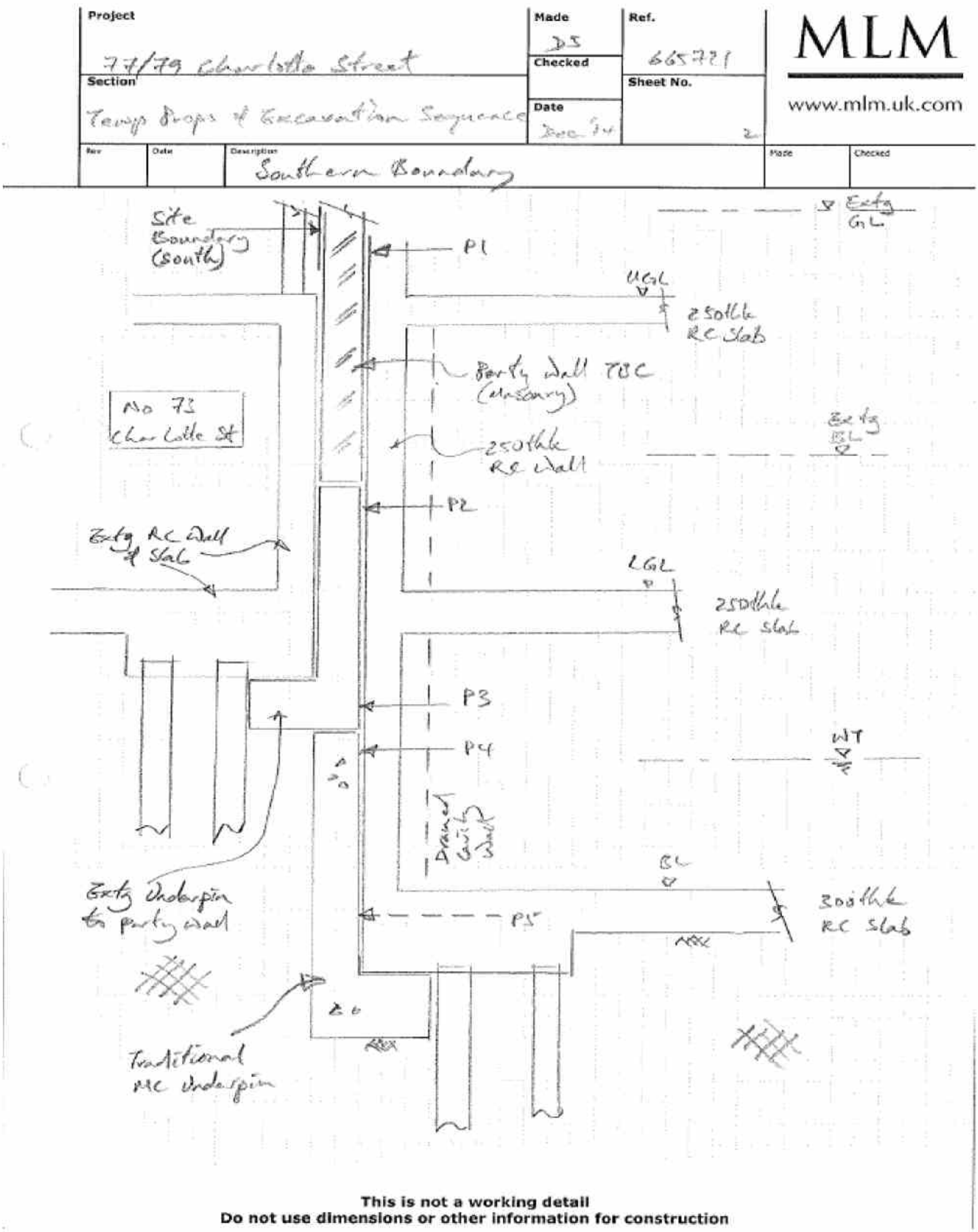


Figure 5.2 – Temporary Propping & Excavation Sequence (Southern Boundary)

5.3 Foundation Scheme

The proposed development comprises the demolition of the existing building and construction of a new six storey building with a two level basement. The basement level is to be approximately 8m below existing ground (street) level. The current proposal for the new building is to construct a concrete frame from the first floor slab down to the basement and a lightweight steel framed structure from first to roof level. It was intended to be of mix usage; with upper floors from roof to second for residential and first floor to basement for commercial/office usage, with no areas of soft landscaping.

The basement RC walls will be cast inside traditional underpinning to the flank walls and contiguous piles walls to the front, rear and return walls. The basement RC slab will be partially ground bearing with bearing and tension piles (to resist hydrostatic pressures).

The proposed building was to be supported by load bearing columns or walls within external walls. The axial load from these columns and walls at foundation level would be of order 1500kN and 120kN/m (gross) respectively.

The RC basement slab would be 25m long and 12m wide (front entrance) and 6m wide (rear entrance), and 0.30m thick was to be ground bearing slab of loads of order 15kN/m^2 (gross).

In compiling this report reliance was placed on drawing number 2128/L306 dated 9/12/14 prepared by Cove Burgess Architects LLP which was supplied by MLM, and other drawings by MLM without numbers and dates. Any change or deviation from the scheme outlined in the drawing could invalidate the recommendations presented within this report. Soils Limited must be notified about any such changes. The proposed layout and the sections are given on Figures 2.3-2.6.

From the engineering appraisal outlined in Section 5.1 the Made Ground was not considered suitable as a bearing stratum. Foundations must be taken through any Made Ground, Fill, live roots, disturbed or desiccated cohesive soils into the Lynch Hill Gravel Member for the basement slab and wall, and London Clay Formation for the piled foundations, which were considered suitable bearing stratum for the proposed redevelopment.

Recommendations for the foundation scheme are outlined below.

4.3.3 Raft/Strip Foundations

The basement RC walls would be cast inside traditional underpinning to the flank walls and contiguous piles walls to the front, rear and return walls. The basement RC slab will be partially ground bearing with bearing and tension piles (to resist hydrostatic pressures).

The proposed building was to be supported by load bearing columns or walls within external walls. The axial load from these columns and walls at foundation level would be of order 1500kN and 120kN/m (gross) respectively.

The RC basement slab would be 25m long and 12m wide (front entrance) and 6m wide (rear entrance), and 0.30m thick was to be ground bearing slab of loads of order 15kN/m^2 (gross).

Raft foundation for the basement slab and strip foundations for the underpinning walls were considered appropriate subject to the groundwater conditions found during the construction phase of the works and the depths of roots, with foundations taken through any Made Ground to a moisture stable depth and into the Lynch Hill Gravel Member.

Where foundations pass from one soil type to another, reinforcement must be incorporated into the foundation to reduce the risk of differential settlements affecting the structure.

A suitably qualified person must inspect all foundation excavations prior to the placing of any concrete or reinforcement.

All loose material must be removed from the base of the excavations, these excavations then being either concreted or blinded as soon after excavation as possible. Failure to do so could result in additional settlement.

Any groundwater or surface water ingress must be prevented from entering foundation excavations.

Based on the results of in-situ testing, geotechnical laboratory testing and an engineering appraisal of the soils encountered, allowable bearing value have been calculated for a strip and raft foundations taken into the Lynch Hill Gravel Member. The results are given in Table 5.1.

Table 5.1 - **Allowable Bearing Values in Lynch Hill Gravel Member**

Stratum	Foundation Dimensions (width x length) (m)	Foundation Depth (m blgl)	Net Allowable Bearing Values (kPa)	Anticipated Settlement (mm)
Strip				
Lynch Hill Gravel Member	0.75 x 5.0	6.00	150	25
Raft				
Lynch Hill Gravel Member	12.0 x 25.0	6.00	15	Long term heave (10mm)

For the allowable bearing values given, settlement should not exceed that given in the table above provided that excavation bases are carefully bottomed out and blinded, or concreted as soon after excavation as is possible and kept dry. Failure to do so could result in significantly high settlements.

The allowable bearing value given was calculated based on the SPT/dynamic probe blow counts analysed using foundation design software (Geostru).

Settlements may be taken as proportional to the applied foundation load for a given configuration of the foundation. In the example above if the allowable bearing pressure was halved then the anticipated settlement and settlement range would halve.

The bearing values given incorporated a factor of safety of at least three against general shear failure.

5.3.1 Piled Foundations

The piled foundations should be taken through any Topsoil, Topsoil/Made Ground or Made Ground, Lynch Hill Gravel Member, and disturbed and/or desiccated ground, below any roots and into the soils of the London Clay Formation.

The construction of a piled foundation is a specialist job, and the advice of a reputable contractor, familiar with the type of ground and groundwater conditions encountered on this site, should be sought prior to finalising the foundation design, as the actual pile working load will depend on the particular type of pile and method of installation.

In Table 5.2 load capacities calculated for varying diameters and lengths of bored piles taken into the London Clay Formation are given. These values have been calculated for the ground conditions found in the borehole and must be used for preliminary design purposes only. The plot of measured/inferred C_u against depth is given in Figure 5.1.

Temporary casing may be required where the pile passes through the Made Ground, Lynch Hill Gravel Member particularly below the groundwater table to prevent necking of the green concrete.

The upper 6.0 metres of the shaft of the pile (beneath existing lower ground level) has been ignored in the preliminary pile design given.

An adhesion value (α) of 0.45 was used to calculate the skin friction and a bearing capacity factor (N_c) of 9 was adopted in the calculation of the end bearing in the cohesive soils of the London Clay Formation.

The pile working loads given in the table incorporate a factor of safety of 3.0 on the ultimate skin bearing value and on the ultimate end bearing value.

The bearing values given in the table above are applicable to a single pile. Where piles are to be constructed in groups the bearing value of each individual pile should be reduced by a factor of about 0.8 and a calculation made to check the factor of safety against block failure.

No allowance has been made for negative skin friction that could be generated where piles pass through Made Ground underlying the site. The negative skin friction must be applied to the pile working load and must not be factored.

The design must accommodate uplift forces generated by recovery and subsequent heave.

Table 5.2 – **Preliminary Pile Working Loads**

Table 5.2

			Preliminary Pile Working Loads Single Vertically Loaded Pile (kN)			
Name:	RB	N_c value	9	Pile Start Depth:	7	FOS
Job No:	14653	α value:	0.45	Pile Final Depth:	24	Shaft: 3
Data:	5.2.15	Cu Ratio	5	Pile depth Increments:	1	Base: 3

Notes: Cu at 18.0m was ignored

Pile Depths (m bgl)	Shaft (0.30)	Base (0.30)	Total (0.30)	Shaft (0.45)	Base (0.45)	Total (0.45)	Shaft (0.60)	Base (0.60)	Total (0.60)
Column1	Column2	Column3	Column4	CoColumn5	Column6	Column7	Col Column8	Column9	Column10
7	0	0	0	0	0	0	0	0	0
8	15	25	40	25	55	80	30	95	125
9	30	25	55	50	55	105	60	100	160
10	45	25	70	75	60	135	95	110	205
11	65	30	95	105	65	170	130	115	245
12	85	30	115	135	70	205	170	120	290
13	105	30	135	165	70	235	210	130	340
14	125	35	160	200	75	275	255	135	390
15	150	35	185	235	80	315	300	140	440
16	175	35	210	270	85	355	350	150	500
17	200	40	240	310	85	395	400	155	555
18	225	40	265	350	90	440	455	160	615
19	255	40	295	390	95	485	510	170	680
20	285	45	330	435	100	535	565	175	740
21	315	45	360	480	100	580	625	180	805
22	345	45	390	525	105	630	685	190	875
23	375	50	425	575	110	685	750	195	945
24	410	50	460	625	115	740	815	200	1015

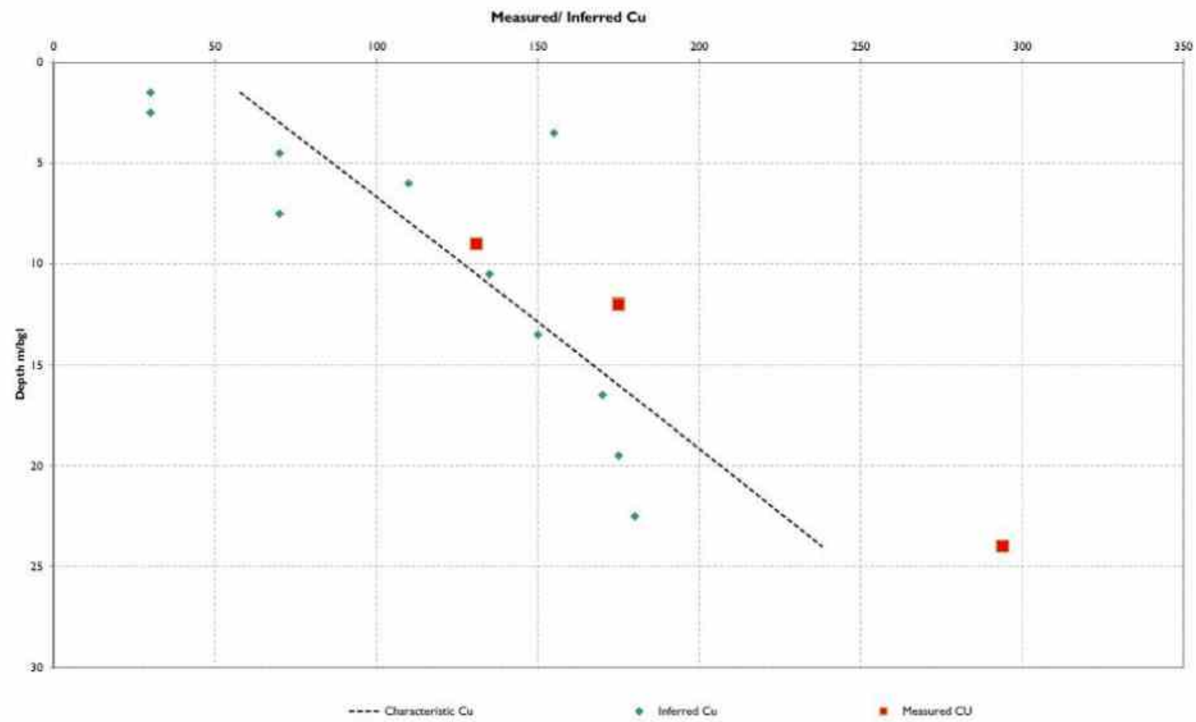


Figure 5.3 – Plot of Measured/Inferred C_u against Depth

soils LIMITED Geotechnical & Environmental Consultants

5.4 Excavations

Shallow short excavations in the Made Ground and Lynch Hill Gravel Member are unlikely to be stable in the short term. Long, deep excavations will become unstable as would be those excavated through significant thicknesses of Made Ground or those taken below the groundwater table.

Dewatering would be required to facilitate the construction and prevent the base of the excavation blowing before the slab was cast if the groundwater level rises or the construction undertaken in winter months. The advice of a reputable dewatering contractor, familiar with the type of ground and groundwater conditions encountered on this site, should be sought prior to finalising the design of the excavation for the basement.

Unsupported earth faces formed during excavation may be liable to collapse without warning and suitable safety precautions should be therefore be taken to ensure that such earth faces are adequately supported before excavations are entered by personnel.

5.5 Subsurface Concrete

Sulphate concentration measured in 2:1 water/soil extracts fell into Class DS-2 of the BRE Special Digest 1 2005, *'Concrete in Aggressive Ground'.* Table C2 of the Digest indicated ACEC (Aggressive Chemical Environment for Concrete) site classifications of AC-2. The pH of the soil was ranging between 6.8 and 8.4. For the classification given above, the mobile case was adopted for the natural soils as groundwater was encountered during the intrusive investigation and it would be mobile through Lynch Hill Gravel Member.

Concrete to be placed in contact with soil or groundwater must be designed in accordance with the recommendations of Building Research Establishment Special Digest 1 2005, *'Concrete in Aggressive Ground'* taking into account any possible exposure of potentially pyrite bearing natural ground and the pH of the soils.

Section 6 Introduction to Contaminated Land investigation

6.1 General

The site works were performed in accordance with the methods given in BS 5930+A2:2010 and BS EN ISO 22476-2&3:2005.

The chemical analyses were undertaken by QTS Environmental Limited in accordance with their UKAS and MCERTS accredited test methods or their documented in-house testing procedures. This investigation did not comprise an environmental audit of the site or its environs.

Trial-hole is a generic term used to describe a method of direct investigation. The term trial pit, borehole or window sample borehole implies the specific technique used to produce a trial-hole.

6.1.1 Objective of Investigation

The overall aim of the intrusive investigation was to investigate the infilled ground and assess potential pollutant linkages that may exist for further remediation actions. The objectives were defined as follows:

I. To investigate the likelihood that the site may have been contaminated as a result of infilled ground identified in during the intrusive site investigation carried out in November and December 2014.

II. To assess any soil contamination risk to potential receptors including human health and controlled waters.

III. To assess any soil gas risk to potential receptors.

IV. To use the result of intrusive site investigations to revise the initial conceptual site model designed by Soils Limited (Ref: 14653/DS, December 2014) and assess the need for suitable remediation measures or further monitoring.

V. To ultimate satisfy any pending conditions on the planning consent associated to the development planned.

6.1.2 Proposed Redevelopment

The proposed development comprises the demolition of the existing building and construction of a new six storey building with a two level basement. The basement level is to be approximately 8m below existing ground (street) level. The current proposal for the new building is to construct a concrete frame from the first floor slab down to the basement and a lightweight steel framed structure from first to roof level. It was intended to be of mix usage; with upper floors from roof to second for residential and first floor to basement for commercial/office usage, with no areas of soft landscaping.

In compiling this report reliance was placed on drawing number 2128/L306 dated 9/12/14 prepared by Cove Burgess Architects LLP which was supplied by MLM, and other drawings by MLM without numbers and dates. Any change or deviation from the scheme outlined in the drawing could invalidate the recommendations presented within this report. Soils Limited must be notified about any such changes. The proposed layout and the sections are given on Figures 2.3-2.6.

Section 7 Contamination Land Assessment

7.1 Preliminary Conceptual Site Model and Risk Assessment Estimation

The Made Ground (i.e. as revealed by the intrusive investigation at the site) may contain contaminants that could pose an unacceptable risk to identified receptors, requiring further investigation. It was agreed with the client that the proposed intrusive investigation would provide information to enable an assessment to be made of the nature and extent of contamination and any remediation actions or monitoring needed.

The 1:50,000 BGS map showed the site to be located on bedrock of the London Clay Formation that comprises primarily of clay, silt and sand. Furthermore, the CIRIA report pertaining to working within the Lambeth Group, indicates that the London Clay Formation is underlain by the Lambeth Group. The potential pathway for the contaminants to migrate through to the secondary aquifer is unlikely owing to the London Clay Formation deposits. The 'U' denotes the area to be urban where soil information was less reliable and based on fewer observations than in rural areas and thus the worst case vulnerability has been assumed by the Environment Agency in their classification. The superficial Lynch Hill Gravel Member is a pathway for water contamination until the London clay formations are encountered at depth. Migration of contaminants via superficial deposits is a pathway while migration of contaminations through the bedrock is unlikely.

No significant ecological features were present within 250m of the site therefore no pollutant linkage was considered.

The development was for an extension to the existing children centre therefore human health was considered at risk if significant pollutants were encountered in the made ground present at the site.

The installation of monitoring wells within the boreholes for soil gas monitoring and groundwater sampling (if encountered) was considered warranted if the initial site characterisation revealed significant made ground.

Table 7.1 presents the preliminary Conceptual Site Model (CSM) used to design the site investigation with all sources and pathways included.

The site investigation was designed, implemented and evaluated as presented in the following Sections.

Table 7.1 - **Preliminary Conceptual Site Model and Risk Assessment Methodology**

Linkage No	**Potential Contaminants Identified** (Table 8.3)	**Pathway** (See Tables 8.4 & 8.5)	**Receptor** (See Table 8.6)	**Risk Assessment Methodology (plus anticipated quantitative risk assessment methods)**	**Site specific settings**	**Risk Classification: Based on Desk Study**	**Pollutant Linkage & Action Required**
1	P2, P5, P7, P10 & P13	None	Ecological features (i.e. Flora and Fauna)	Presence of SSSI, Museum, Natural reserves and others within 0- 250m to the site. Use EA Science Report	No significant ecological feature within 250m of the site.	Likely to be none	**The view of the local council must be sought.**
2	P2, P5, P7, P10	None	Building structures/services	Soil testing & use BRE 2005 for risk assessment. Water UK (2014) for pipes. Use Anglian Water trigger for services risk assessment	Proposed foundations and services pipes	Likely to be medium	**No further actions needed**
3	P2, P5, P7-P10	e.g. Inhalation, ingestion and dermal contact	Human health Site users	Use CLEA for human risk assessment	Residential	Likely to be medium	**No further actions needed**
			Human Health Workers	Assessment not within the scope of this Desk study (responsibility of building contractor). Ground workers should follow regulations on health and safety during development (HSE, 1991)	Workers and the general public should follow regulation on health and safety during development (HSE, 1991)	Likely to be low	Follow HSE procedures
4	P2, P5, P7,P10	None	Shallow groundwater/ Surface Water	Assessment to be carried out based on distance from watercourse and direction of flow – Consider use of R&D 20 publication for risk assessment	There is no surface water within 250m of the site. There is no GSPZ on the site. The site is on secondary aquifer A therefore pollutant linkage exists.	Likely to be low	**No further actions needed**
5	P2, P5, P7,P10	None	Deep groundwater	Undertake groundwater or leachate testing depending on site specific ground conditions. – Consider use of R&D 20 publication for risk assessment if contamination is identified.	There is no GSPZ on the site. Site is on an Aquifer with soils of low permeability.	Likely to be very low	**No further actions needed**
6	None	None	Human, building Structures and the atmosphere	Current or former Landfill sites within 0-250m to the site. Assess nature/age/size of site for Risk Assessment. Use CIRIA 149 & 665 to assess need for gas protection measures where necessary following ground gas testing	No landfill site within 250m of the site. Very Low gas risk from potential infilled ground located onsite and within 250m of the site.	Likely to be very low	**No further actions needed**

Note: HSE= Health and Safety Executive, SPZ= Source Protection Zone and P=Property. P2= asbestos which is included anyway, P5=Metals and semi-metals (e.g. Arsenic, Chromium), P7=Organic compounds (e.g. PAHs and TPHs) and P10=Sulphate.

7.2 Investigation Design

The design was based on the preliminary conceptual site model presented in Table 7.1 as discussed in the previous section. The following sections deal with the Sampling Strategy and Risk Assessment Method.

7.2.1 Sampling strategy

CLR4 (DOE 1994) and EA R&D P5-066/TR were used to inform the decision regarding the number of sampling locations appropriate to the investigation.

A non-targeted sampling strategy is appropriate when there is:

- No adequate information available regarding the likely locations of contamination;
- No sensitive areas where there is a need for a high degree of confidence.

A targeted sampling strategy is appropriate when there is:

- Adequate information available regarding the likely locations of contamination;
- Sensitive areas where there is a need for a high degree of confidence.

Systematic (i.e. non target sampling) was adopted to identify the nature and extent of any soil contamination in the made ground at the site.

The planned site work (Figure 7.1) comprised the following items:

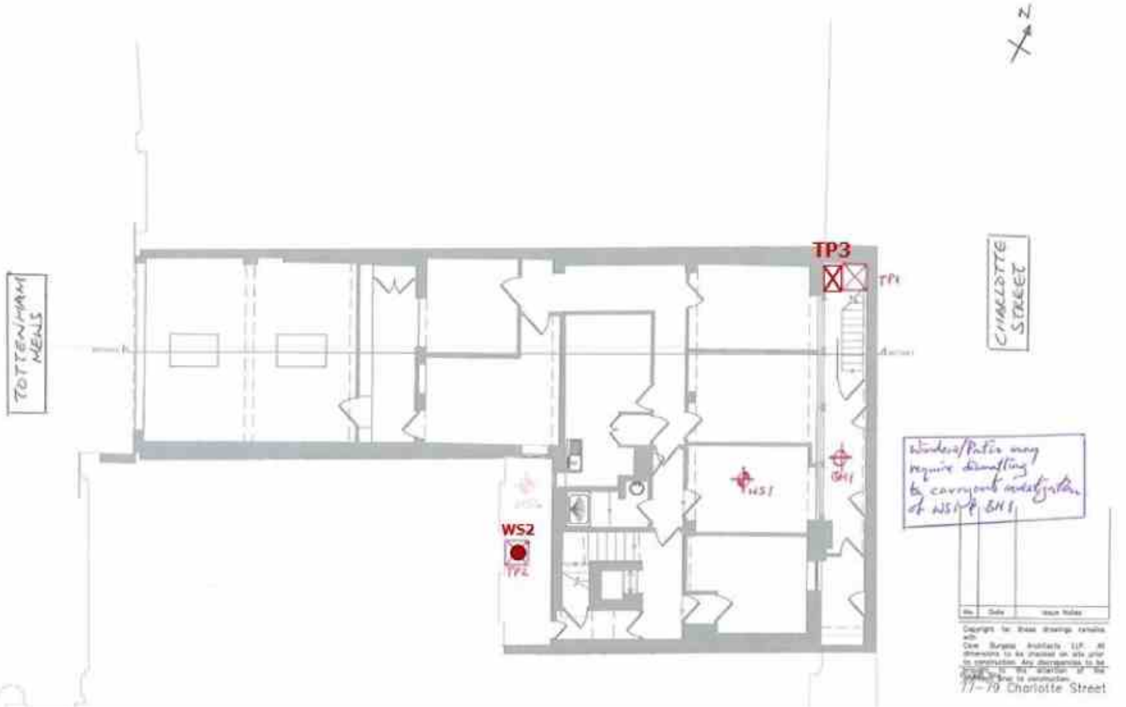
- **Trial Hole Samples:** The drilling of 1No cable percussive borehole (BH1) to a depth of 25.00m bgl, 2No window sampler boreholes (WS1-WS2) to depths of 6.50m and 6.00m blgl and 3No trial pits (TP1-TP3) to depths of 0.50-1.30m bgl, at locations across the site;
- **Groundwater/soil gas monitoring well:** The installation of 2No monitoring well within the WS2 and BH1 to depths of 3.60m and 7.00m blgl;
- **Groundwater monitoring well:** The installation of monitoring wells within two of the boreholes for groundwater monitoring was considered warranted if the initial site characterisation revealed soil contamination in the soil samples tested, and in addition if significant Made Ground is encountered on site.
- Logging of soils taken from the window sampler boreholes and trial holes.

Table 7.2 shows the receptors relevant to the planned sampling depths:

Table 7.2 - **Potential Receptors and Sampling Depths**

Receptors	Sampling Range (m bgl)
Human health: soils contamination	0.0-5.2
Human health: Soil gas	3.6-7.00

Table 7.2 - **Potential Receptors and Sampling Depths**	
Receptors	**Sampling Range (m bgl)**
Groundwater	0.30-7.0



KEY
BH1 = Cable Percussion Borehole to 25.0m blgl (below existing lower ground level) with 7m well;
WS = Window Samper Borehole; WS1=6.5m blgl, WS2=6.00m blgl with 3.5m well;
DP = Dynamic Probe Hole; DP1=8.0m blgl, DP2=10.00m blgl;
TP = Hand Excavated Trial Pit; TP1=0.60m blgl, TP2=0.90m blgl, TP3=1.30m blgl.

Note: BH1 (cable percussive borehole) to 25.00m blgl with 7m well, WS1-WS2 (window sampler borehole) to 6.0-6.5m deep with 3.60m well installed in WS2. TP1-TP3 (hand dug pits) to 0.5-1.3m blgl. DP1 and DP2 were dynamic probes carried out for geotechnical purposes.

Figure 7.1 – Planned Site Investigation Design

7.2.2 Risk assessment methods for human health

Model procedures (CLR 8) recommend a tiered approach to be taken to contaminated land risk assessment. Therefore, the interpretation of the site investigation results used Tier 1 Generic Assessment Criteria (GAC) and published soil guideline values (SGVs) for residential end-use, which was used as the most conservation value for residential home care which pollutant exposure characteristic are different.

It was therefore considered that values of contaminants tested were to be compared against Published United Kingdom SGVs where available and CLEA GAC to assess risk to human health Generated by third parties (e.g. ATRISK^{soil} assessment criteria or LQM GAC).

Published SGV's and GAC are used to assess long-term contamination risks to human health and are pre-calculated values derived from a given selection of contaminant pathways that will pose 'no significant threat to health'. The most sensitive exposure route is considered to be the oral route from contaminated soil by ingestion and inhalation. The assessment criteria used to determine risks to human health are derived and explained within Appendix D.

7.2.3 Risk to Controlled Water

Groundwater test results were assessed using a tiered approach as described in R&D 20 publication and EA Remedial Targets (2006). Leachate mean and individual values were to be compared against United Kingdom Drinking Water Standards where available and other authoritative guideline (i.e. WHO) where necessary and appropriate.

7.2.4 Soil Gas

The Soils Limited Phase I anticipated significant thickness of Made Ground on site, and Phase II intrusive investigation revealed the presence of Made Ground in each of the trial holes constructed on the site to depths of up to 6.50m bgl, indicating that the entire site area was potentially underlain by Made Ground. The NHBC document "Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present" Report edition No.: 04 dated March 2007, suggests that Made Ground could be considered as a potential source for soil gas such as methane and carbon dioxide.

Soil gas/VOC and groundwater monitoring well was installed in the boreholes WS2 and BH1 to depths of 3.50m and 7.00m blgl respectively, to allow for long term monitoring of soil gas and groundwater levels.

Given the nature of the Made Ground, slightly clayey to clayey sandy gravelly SILT, slightly sandy clayey GRAVEL, slightly sandy silty CLAY and gravelly silty SAND, with occasional to abundant brick fragment and concrete, with no putrescible material, it was considered unlikely to be a potential source of soil gas. Moreover, the entire Made Ground would be removed as part of the double basement construction.

However, the client requested soil gas monitoring to be undertaken on three occasions, and this has been done and the results are given below.

The details of the soil gas monitoring and the risk assessment is given in Section 9.3.

Section 8 Site Work

8.1 Work Undertaken

It was considered that if the results showed no soil or leachate contamination, the installation of groundwater wells would not be needed. The following works were carried out in November and December 2014.

I. The drilling cable percussive and windowless sampler boreholes and trial pits as planned.

II. The soils samples taken were logged and sent to the laboratory for testing as shown in Table 8.1.

III. The installation of 2No groundwater/soil gas monitoring well within BH1 and WS2 to depths of 7.00m and 3.60m blgl respectively.

8.2 Determination of Contaminants of Concern for Soil and Groundwater Samples

The driver for the determination of the analysis suite was the information obtained from the CSM framework.

Table 8.1 presents the number of samples recovered from the site and analysed.

Table 8.1 - **Chemical Analysis Samples**

Stratum	Trial Hole	Depth (m bgl)	Soil Suite 1	Soil Suite 2	Speciated PAH	Water Sample	WAC
MG	TP1	0.30	√	-	-	-	-
MG	WS1	5.20	√	-	-	-	-
MG	TP2	0.80	√	-	-	-	-
MG	WS2	2.50	√	-	-	-	-
MG	Sample A	0.30-2.0	√	-	-	-	√
MG	Sample B	2.0-6.1	√	-	-	-	√
W	WS2	1.90	-	-	-	√ (Metals)	-
W	WS2	1.80	-	-	-	√ (PAHs)	-
W	BH1	3.94	-	-	-	√ (SS1)	-

Notes: **Soils Suite 1:** Metals and semi metals and PAH - Speciated (EPA 16). **Soils Suite 2:** Metals and semi metals, Cyanide - Total, pH, Sulphate as SO4, Sulphide, Total Organic Carbon (TOC), PAHs, Phenols, and TPH CWG + BTEX (see Appendix C for full specification). MG= Made ground, W=Water, Sample A and B=Combined samples.

The results of the soil chemical testing are discussed in Sections 10 of this report.

The 1:50,000 BGS Map showed the site to be located on Lynch Hill Gravel Member overlying the London Clay Formation.

8.2.1 Made Ground (MG)

Made Ground was encountered in each of the trial holes and comprised concrete over dark brown, dark grey and dark brown black slightly clayey to clayey sandy gravelly SILT, slightly sandy clayey GRAVEL, slightly sandy silty CLAY and gravelly silty SAND, with occasional to abundant brick fragment and concrete. Gravel is fine to coarse and sub-angular to sub-rounded.

The Made Ground was encountered to a depth of 4.50m blgl in BH1, and to the full depths of the remaining trial holes at depths of between 0.50m blgl in TP1 and 6.50m bgl in WS1.

Section 9 Quantitative Risk Assessment

9.1 Human health quantitative risk assessment

The comparison of the representative contaminants concentration for human health receptor to the Soil Guideline Values (SGV), ATRISK^{soil}, Soil Screening Values (SSV) and General Assessment Criteria (GAC) are presented in Table 9.1. These results are assessed against the "Residential" land-use scenario as this was considered the worst case land-use scenario given the proposed landuse which is residential without soft landscaping areas. There were presence of lead and mercury in each of the samples tested and one of the samples (WS1/5.20m) tested. All other contaminants were either below laboratory detection limits or their authoritative soil guidelines (Appendix C).

Table 9.1 - Summary of Chemical Analysis of Soil Samples

Trial Pit	Sample A	Sample B	WS1	TP1	WS2	TP2	Mean	SGV/
Depth (m bgl)	0.30 - 2.00	2.00 - 6.10	5.20	0.30	2.50	0.80		GAC/DL
Asbestos Screen	ND	ND	ND	ND	ND	ND		na
pH	7.9	7.7	7.8	8.4	7.9	8	7.95	na
Total Cyanide	2	2	2	2	2	2	2.00	na
Sulphide	5	18	19	5	65	5	19.50	na
Organic Matter	3	1.9	2.1	2.6	2.8	2.8	2.53	na
Total Organic Carbon	1.7	1.1	1.2	1.5	1.6	1.6	1.45	na
Arsenic	35	12	15	27	12	11	18.67	37.00
Beryllium	0.5	0.5	0.5	0.5	0.5	0.5	0.50	51.00
Water Soluble Boron	1	1	1	1	1.6	1	1.10	291.00
Cadmium	0.6	0.5	0.5	0.6	0.5	0.5	0.53	26.00
Chromium	24	20	22	20	22	13	20.17	3000.00
Hexavalent Chromium	2	2	2	2	2	2	2.00	21.00
Copper	1060	108	511	166	87	61	332.17	2330.00
Lead	2040	422	733	917	387	248	791.17	200.00
Mercury	159	8.3	332	16.3	4.7	4.3	87.43	170.00
Nickel	28	18	21	18	24	14	20.50	130.00
Selenium	3	3	3	3	3	3	3.00	350.00
Vanadium	59	36	43	44	50	33	44.17	140.00
Zinc	404	88	123	232	82	76	167.50	3750.00
Monohydric Phenols	2	2	2	2	2	2	2.00	280.00
EPH (C10 - C40)								-
Naphthalene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	1.50
Acenaphthylene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	170.00
Acenaphthene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	210.00
Fluorene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	160.00
Phenanthrene	0.2	0.1	0.1	0.11	0.1	0.1	0.12	92.00
Anthracene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	2300.00
Fluoranthene	0.28	0.1	0.1	0.17	0.1	0.1	0.14	260.00
Pyrene	0.23	0.1	0.1	0.14	0.1	0.1	0.13	560.00
Benzo(a)anthracene	0.13	0.1	0.1	0.1	0.1	0.1	0.11	4.70
Chrysene	0.13	0.1	0.1	0.1	0.1	0.1	0.11	8.00
Benzo(b)fluoranthene	0.13	0.1	0.1	0.1	0.1	0.1	0.11	6.50
Benzo(k)fluoranthene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	9.60
Benzo(a)pyrene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	5.00
Indeno(1,2,3-cd)pyrene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	3.20
Di-benzo(a,h)anthracene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	0.86
Benzo(ghi)perylene	0.1	0.1	0.1	0.1	0.1	0.1	0.10	44.00
Total EPA-16 PAHs	1.6	1.6	1.6	1.6	1.6	1.6	1.60	none
		Value exceeds relevant Soil Guideline Value (SGV), Generic Assessment Criteria (GAC) or laboratory Detection Limit (DL)						
	Red	**Potentially contaminated samples ND= Not Detected, NA=Not Applicable**						

KEY
BH1 = Cable Percussion Borehole to 25.0m blgl (below existing lower ground level) with 7m well;
WS = Window Samper Borehole; WS1=6.5m blgl, WS2=6.00m blgl with 3.5m well;
DP = Dynamic Probe Hole; DP1=8.0m blgl, DP2=10.00m blgl;
TP = Hand Excavated Trial Pit; TP1=0.60m blgl, TP2=0.90m blgl, TP3=1.30m blgl.

Contaminated Area/All the tested areas **indicative NOT extent** — Lead detected in TP1/0.30m, WS1/5.20m, TP2/0.80m and WS2/2.50m, and Mercury detected in WS1/5.20m

Figure 9.1 – Area of Potential Contamination

9.2 Groundwater quantitative risk assessment

Given the site's environmental and hydrogeological setting, situated on a **Secondary A Aquifer** and soils with **high** leaching potential, the groundwater was considered a potential receptor.

Groundwater was encountered at a depth of 1.8-3.94m blgl during the intrusive investigation and groundwater monitoring to date.

To assess the potential risk to the groundwater receptor, a groundwater sample was recovered from site. The samples from boreholes WS2 and BH1 were sent off for chemical laboratory analysis. WS2 did not have sufficient sample, and it was sampled on two occasions, as a result the testing was divided into two Metals and PAHs.

All the relevant contaminants that were analysed in the samples were below laboratory detection limits or UK Drinking Water Standards (UKDWS) except lead in WS2. Given the groundwater was perched in WS2, and likely to be from a drain. However, the level of lead found was not unusual in an urban environment. As it was established that the groundwater in BH1 was the true groundwater underneath the site, the results of the analysis (Table 9.2) showed that groundwater has not been impacted by an onsite or offsite source.

Table 9.2 - **Summary of Chemical Analysis of Groundwater Samples**

Trial Pit	Unit	BH1	WS2	WS2	Mean	EQS
Depth (m bgl)		3.94	1.90	1.80		DL
Asbestos Screen		N/A	N/A	N/A		na
pH		6.8	7.1		6.95	10
Total Cyanide	ug/l	5	5		5.00	na
Sulphate as SO4	mg/l	0.1	0.1		0.10	na
Sulphide	mg/l					na
Total Organic Carbon (TOC)	mg/l	126	54.1		90.05	na
Arsenic (dissolved)	ug/l	9	5		7.00	10
Beryllium (dissolved)	ug/l	3	3		3.00	na
Boron (dissolved)	ug/l	326	348		337.00	1000
Cadmium (dissolved)	ug/l	0.4	0.4		0.40	5
Chromium (dissolved)	ug/l	5	5		5.00	50
Chromium (hexavalent)	ug/l	5	5		5.00	50
Copper (dissolved)	ug/l	5	12		8.50	2000
Lead (dissolved)	ug/l	5	15		10.00	10
Mercury (dissolved)	ug/l	0.05	0.05		0.05	1
Nickel (dissolved)	ug/l	5	5		5.00	20
Selenium (dissolved)	ug/l	5	5		5.00	10
Vanadium (dissolved)	ug/l	5	6		5.50	na
Zinc (dissolved)	ug/l	3	14		8.50	5000
Total Phenols	ug/l	0.5	0.5		0.50	na
Naphthalene	ug/l					
Acenaphthylene	ug/l	0.01		0.01	0.01	0.1
Acenaphthene	ug/l	0.01		0.01	0.01	0.1
Fluorene	ug/l	0.01		0.01	0.01	0.1
Phenanthrene	ug/l	0.01		0.01	0.01	0.1
Anthracene	ug/l	0.01		0.01	0.01	0.1
Fluoranthene	ug/l	0.01		0.01	0.01	0
Pyrene	ug/l	0.01		0.01	0.01	0.1
Benzo(a)anthracene	ug/l	0.01		0.01	0.01	0
Chrysene	ug/l	0.01		0.01	0.01	0.1
Benzo(b)fluoranthene	ug/l	0.01		0.01	0.01	0.1
Benzo(k)fluoranthene	ug/l	0.01		0.01	0.01	0.1
Benzo(a)pyrene	ug/l	0.01		0.01	0.01	0.1
Indeno(1,2,3-cd)pyrene	ug/l	0.01		0.01	0.01	0.1
Dibenz(a,h)anthracene	ug/l	0.01		0.01	0.01	0.1
Benzo(ghi)perylene	ug/l	0.01		0.01	0.01	0.1
Total EPA-16 PAHs	ug/l	0.01		0.01	0.01	0.1
Aliphatic >C5 - C6	ug/l	0.01		0.01	0.01	Na
Aliphatic >C6 - C8	ug/l	10			10.00	15000
Aliphatic >C8 - C10	ug/l	10			10.00	15000
Aliphatic >C10 - C12	ug/l	10			10.00	300
Aliphatic >C12 - C16	ug/l	10			10.00	300
Aliphatic >C16 - C21	ug/l	10			10.00	300
Aliphatic >C21 - C34	ug/l	10			10.00	300
Aliphatic (C5 - C34)	ug/l	10			10.00	300
Aromatic >C5 - C7	ug/l	70			70.00	300
Aromatic >C7 - C8	ug/l	10			10.00	10
Aromatic >C8 - C10	ug/l	10			10.00	700
Aromatic >C10 - C12	ug/l	10			10.00	300
Aromatic >C12 - C16	ug/l	10			10.00	100
Aromatic >C16 - C21	ug/l	10			10.00	100
Aromatic >C21 - C35	ug/l	10			10.00	90
Aromatic (C5 - C35)	ug/l	10			10.00	90
Total >C5 - C35	ug/l	70			70.00	300
Benzene	ug/l	1			1.00	1
Toluene	ug/l	5			5.00	50

Table 9.2 - **Summary of Chemical Analysis of Groundwater Samples**

Trial Pit	Unit	BH1	WS2	WS2	Mean	EQS
Depth (m bgl)		3.94	1.90	1.80		DL
Ethylbenzene	ug/l	5			5.00	300
m & p-xylene	ug/l	10			10.00	30
o-Xylene	ug/l	5			5.00	30
MTBE	ug/l	10			10.00	na
			Exceed EQS or Detection limit			
			No exceedance			
		EQS	*Environmental Quality Standard*			
		DL	*Detection Limit*			

9.3 Soil Gas Risk Assessment

The Soils Limited Phase I anticipated significant thickness of Made Ground on site, and Phase II intrusive investigation revealed the presence of Made Ground in each of the trial holes constructed on the site to depths of up to 6.50m bgl, indicating that the entire site area was potentially underlain by Made Ground. The NHBC document "Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present" Report edition No.: 04 dated March 2007, suggests that Made Ground could be considered as a potential source for soil gas such as methane and carbon dioxide.

Soil gas/VOC and groundwater monitoring well was installed in the boreholes WS2 and BH1 to depths of 3.50m and 7.00m blgl respectively, to allow for long term monitoring of soil gas and groundwater levels.

Given the nature of the Made Ground, slightly clayey to clayey sandy gravelly SILT, slightly sandy clayey GRAVEL, slightly sandy silty CLAY and gravelly silty SAND, with occasional to abundant brick fragment and concrete, with no putrescible material, it was considered unlikely to be a potential source of soil gas. Moreover, the entire Made Ground would be removed as part of the double basement construction.

However, the client requested soil gas monitoring to be undertaken on three occasions, and this has been done and the results are given below.

9.3.1 Soil Gas/VOC Monitoring Wells

Soil gas/VOC monitoring well was installed in boreholes WS2 and BH1.

The headworks comprised two gas taps, one of which was connected to an internal tube to draw gas from a point approximately one metre below ground level and the other tap to an internal tube terminating at a nominal depth of 300mm below ground level.

The taps were connected to the flow and return ports on the gas analyser to enable measurements of soil gas concentrations in the well to be taken without venting to the atmosphere.

9.3.2 Soil gas/VOC Monitoring

Field soil gas monitoring has been made on four occasions, since installation of the monitoring wells.

9.3.3 Soil Gas/VOC Measurements from Wells

The measurements of soil gas concentrations to date are given in Table 9.3.

Table 9.3 - **Soil Gas Readings**

Date	Pressure Trend	WS	CH_4 (%)	CO_2 (%)	O_2 (%)	H_2S (ppm)	CO (ppm)	LEL (%)	aP (mb)	Flow (l/h)	H_2O (m bgl)	BOH	VOC	DP
09/12/14	Falling	ATM	0.0	0.0	20.3	0.0	0.0	0.0	1023	0.0	-	-	0.0	-
		WS2	0.0	0.0	20.3	0.0	0.0	0.0		0.1	1.98	2.85	0.0	0.0
23/12/14	Rising	ATM	0.0	0.0	20.3	0.0	0.0	0.0	1023	0.0	-	-	0.0	-
		WS2	0.0	0.9	19.6	0.0	0.0	0.0		0.0	1.98	285	0.0	0.0
07/01/15	Falling	ATM	0.0	0.0	20.6	0.0	0.0	0.0	2018	0.0	-	-	0.0	-
		WS2	0.0	2.0	17.1	0.0	0.0	0.0	1021	0.0	2.40	2.87	0.0	0.0
		BH1	0.0	0.20	19.8	0.0	0.0	0.0	1020	0.0	3.95	6.21	0.0	-
16/01/15	Steady	ATM	0.0	0.0	20.6	0.0	0.0	0.0	2018	0.0	-	-	0.0	-
		WS2	0.0	**2.5**	15.0	0.0	0.0	0.0	998	0.0	2.18	2.87	0.0	0.0
		BH1	0.0	0.1	20.2	0.0	0.0	0.0	997	0.0	3.94	6.18	0.0	-

(Note 1: Zero reading = below machine detection). BOH=Base of hole

9.3.4 Soil Gas Protection

Methane is a flammable and asphyxiating gas, the flammable range being 5% to 15% under normal atmospheric conditions. If methane is within this range and atmospheric air are confined and ignited, the gas mixture will explode. Methane is a buoyant gas with a density of approximately two thirds that of atmospheric air.

The background concentrations of both methane and carbon dioxide in natural ground are not zero and they can be found in high concentrations in relatively innocuous environments. Under normal soil conditions the concentration of methane is very low. High concentrations of carbon dioxide can be produced by aerobic decay of organic matter and as a by-product of a reaction between soil and groundwater.

The soil gas concentration readings indicated no presence of methane (CH_4), hydrogen sulphide (H_2S) or carbon monoxide (CO). The maximum carbon dioxide (CO_2) concentration was 2.5% on 16.01.15. The oxygen concentrations were close to the atmospheric values except in WS2 on 16.01.15 when it was slightly depleted. No concentration of Volatile Organic Compounds (VOC) or flow rate was recorded. The atmospheric pressures were between 997 and 1023mb.

Based on the results to date, there are no potential issues relating to soil gas migration within the site.

9.4 Conclusions

Groundwater samples tested for metals, semi-metal and PAHs contaminants showed all the concentrations recorded were below their authoritative guidelines and where over the limit it was not considered to pose a risk, and therefore no further actions for controlled waters are required.

Remediation measures are recommended around each of the trial hole undertaken on site in order to break the pollutant linkage associated with lead and mercury contamination.

The results of the gas monitoring have shown that there was no risk from soil gas from the Made Ground encountered on site.

9.5 Revised Conceptual Site Model and recommendations

The results of the contamination assessment of risk to identified receptors have been used to revise the conceptual model. Based on the results of the chemical laboratory testing, Table 9.3 outlines the Revised Conceptual Site Model.