Chelmer
Consultancy Services
'Groundbreaking Services'

Basement Impact Assessment

Site	76 Fleet Road London NW3 2QT
Client	Mr M Godfrey
Date	January 2016
Our Ref	BIA/5839

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Report Status: **FINAL**		
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Foreword

This report has been prepared in accordance with the scope and terms agreed with the Client, and the resources available, using all reasonable professional skill and care. The report is for the exclusive use of the client and shall not be relied upon by any third party without explicit written agreement from Chelmer Site Investigation Laboratories Ltd.

This report is specific to the proposed site use or development, as appropriate, and as described in the report; Chelmer Site Investigation Laboratories Ltd accept no liability for any use of the report or its contents for any purpose other than the development or proposed site use described herein.

This assessment has involved consideration, using normal professional skill and care, of the findings of ground investigation data obtained from the Client and other sources. Ground investigations involve sampling a very small proportion of the ground of interest as a result of which it is inevitable that variations in ground conditions, including groundwater, will remain unrecorded around and between the exploratory hole locations; groundwater levels/pressures will also vary seasonally and with other man-induced influences; no liability can be accepted for any adverse consequences of such variations.

This report must be read in its entirety in order to obtain a full understanding of our recommendations and conclusions.

1.0 INTRODUCTION

1.1 This Basement Impact Assessment (BIA) has been prepared in support of a planning application to be submitted to the London Borough of Camden (LBC) for the construction of a single-storey basement beneath No.76 Fleet Road, NW3 2QT. The assessment is in accordance with the requirements of the London Borough of Camden (LBC) Development Policy DP27 in relation to basement construction, and follows the requirements set out in LBC's guidance document CPG4 'Basements and Lightwells' (July 2015).

1.2 This assessment has been prepared by Keith Gabriel, a Chartered Geologist with an MSc degree in Engineering Geology (who has specialised in slope stability and hydrogeology), and Mike Summersgill, a Chartered Civil Engineer and Chartered Water and Environmental Manager with an MSc degree in Soil Mechanics (geotechnical and hydrology specialist). Both authors have previously undertaken assessments of basements in several London Boroughs.

1.3 A preliminary site inspection (walk-over survey) of the house was undertaken on Tuesday 3rd November 2015. Photos from that visit are presented in Appendix A. Desk study data have been collected from various sources including borehole records (Appendix B) and geological data, environmental data and historic maps from GroundSure which are presented in Appendices E, F and G. Relevant information from the desk study and site inspections is presented in Sections 2–6, followed by the Basement Impact Assessment in accordance with CPG4 Stages 1–4 in Sections 7–10 respectively. The factual report on the ground investigation is included in Appendix C and the findings are summarised in Section 9.

1.4 The following site-specific documents in relation to the proposed new basement and planning application have been considered:

Tal Arc Ltd (Architects):

- Drg No. 76FR-PP1-01 Existing Plans
- Drg No. 76FR-PP1-02 Existing Section
- Drg No. 76FR-PP1-03 (Existing) Elevations Sections
- Drg No. 76FR-PP1-04 Proposed Plans
- Drg No. 76FR-PP1-05 Proposed Section
- Drg No. 76FR-PP1-06 Proposed Elevations

Fridum Ltd (Design & Build and Structural Engineering Consultants):

- Drg No. FR0343-FR-STRU-1001 Proposed Basement Plan & Section A-A
- Drg No. FR0343-FR-STRU-1002 Section B-B & Details
- Drg No. FR0343-FR-TMP-1001 Construction Sequence for Underpin Section
- Drg No. FR0343-FR-TMP-1002 3D Illustration of Construction Sequence

This report should be read in conjunction with all the documents and drawings listed above.

1.5 Instructions to prepare this Basement Impact Assessment (BIA) were confirmed by signed order on the 9th September 2015.

2.0 THE PROPERTY, TOPOGRAPHIC SETTINGAND PLANNING SEARCHES

2.1 No.76 Fleet Road is a three-storey terraced house (see cover photo) within the Mansfield Conservation Area, in the London Borough of Camden (LBC). Fleet Road is located between South End Road to the north-west, and Mansfield Road to the east. Junctions with Lawn Road and Cressy Road are close to the west of the site. No.76 is situated on the north side of Fleet Road, between No.74 to the east, No.78 to the west, and the plot is bounded to the north by the Camden Ambulance Station, as shown in Figure 1 below and Photos 1 & 2 in Appendix A. A search of planning applications revealed that the single-storey rear extension which adjoins the rear projection to No.76 is a later addition, and was granted planning permission on 28th October 1983 (planning application F9/2/A/36938) (see Photo 4 and paragraph 2.8).

Figure 1: Extract from 1:1,250 OS map (not to scale) with the site outlined in red.

2.2 Reference to the first available historic Ordnance Survey (OS) maps dated 1871 and 1872 (presented in Appendix G) shows that No.76, along with ten adjoining properties on the north side of Fleet Road, were built prior to that date. These maps also show a row of terraced houses on the south side of Fleet Road; however, other than these houses, the surrounding area appeared largely undeveloped. The former course of the western branch of the River Fleet passed through the rear gardens of these houses (see Section 5 for more details).

2.3 Development of the surrounding area occurred between publication of the 1872 and 1896 OS maps, during which time a school, paper mill, and a building labelled 'laundry' were constructed just to the north of the site; the remainder of the terrace along the north side of Fleet Road was also completed. The River Fleet was not shown on the 1896 OS map, however the rear (northern) boundaries to No.76 and the adjoining properties which form the terrace on the north side of Fleet Road, still followed the alignment of the original boundary on the north bank of the river (Photo 6). Between publication of the 1916 and 1936 OS maps, the paper mill to the north of the property expanded, to include the adjacent building labelled 'laundry', and by the time the 1953 OS map was published, this single large building was labelled 'Paper Goods Works'. A number of small buildings thought to be associated with the 'Paper Goods Works' were also constructed along the northern boundary to No's 70-78, between publication of the 1953 and 1965 OS maps, during which time major redevelopment occurred on the south side of Fleet Road, including the demolition of the row of terraced houses, and the construction of several blocks of flats. Significant re-development of the area immediately to the north of No.76 then occurred between publication of the 1966 and 1985 OS maps, during which time the 'Paper Goods Works' and various school buildings were demolished, and the Camden Ambulance Station, Fleet Primary School, and what is currently labelled as Agincourt House were built.

2.4 Externally, there is a very small amenity area at the front of the property (Photo 3), which is surfaced with concrete, contains a sewer chamber, and is bounded by kerb stones. The internal ground floor level is 0.3m below the level of the external amenity area, and 0.25m below the path to the front door. To the rear of the house, there is a small garden, which is surfaced with paving slabs alongside the rear projection and concrete beyond it (Photo 5). A perimeter raised flower bed formed from 'railway sleepers' surrounds the rear part of the garden, adjoining high brick walls which form the site's northern and western boundaries, between the Camden Ambulance Station and No.78 Fleet Road respectively (Photo 6). To the east, the perimeter raised flower bed adjoins a low, partially demolished brick wall, which forms the boundary between No's 76 and 74 Fleet Road (Photos 5 & 6). The ground level within the rear garden and rear projection to No.76 is similar to that of the adjoining No.74, however this level is approximately 0.9-1.0m below the level of the footway and small amenity area at the front of the house.

2.5 The London County Council Bomb Damage Map for this area indicates that No.76, along with the adjoining houses on the north side of Fleet Road suffered only 'Blast damage, minor in nature'. The closest building to have suffered more serious damage was located to the south-west of No.76, on the west side of Lawn Road, which is recorded as having been totally destroyed.

<u>Topographic Setting:</u>

2.6 Fleet Road is located in the valley of the former western branch of the River Fleet, one of the 'lost' rivers of London, on a generally south-east-facing slope, which leads down from Hampstead Heath (see Figure 2). The course of the River Fleet was within the rear garden of the site, however it has since been filled in and probably culverted (see paragraph 5.1). As a result, the ground level within the rear garden is thought to have been raised artificially, although it is still at a reduced level relative to the carriageway at the front of the property (see paragraph 2.4).

2.7 No.76 is located at approximately 53m above Ordnance Datum (AOD). The contours on Figure 2 indicate an overall slope across the site of approximately 1.1° towards the south-east, calculated between the 50m and 55m contour lines, increasing to 2.4° between the 55m and 60m contour lines further up-slope. Using the spot heights on Figure 1, a slope angle of around 0.75° towards the south-east was calculated for this part of Fleet Road.

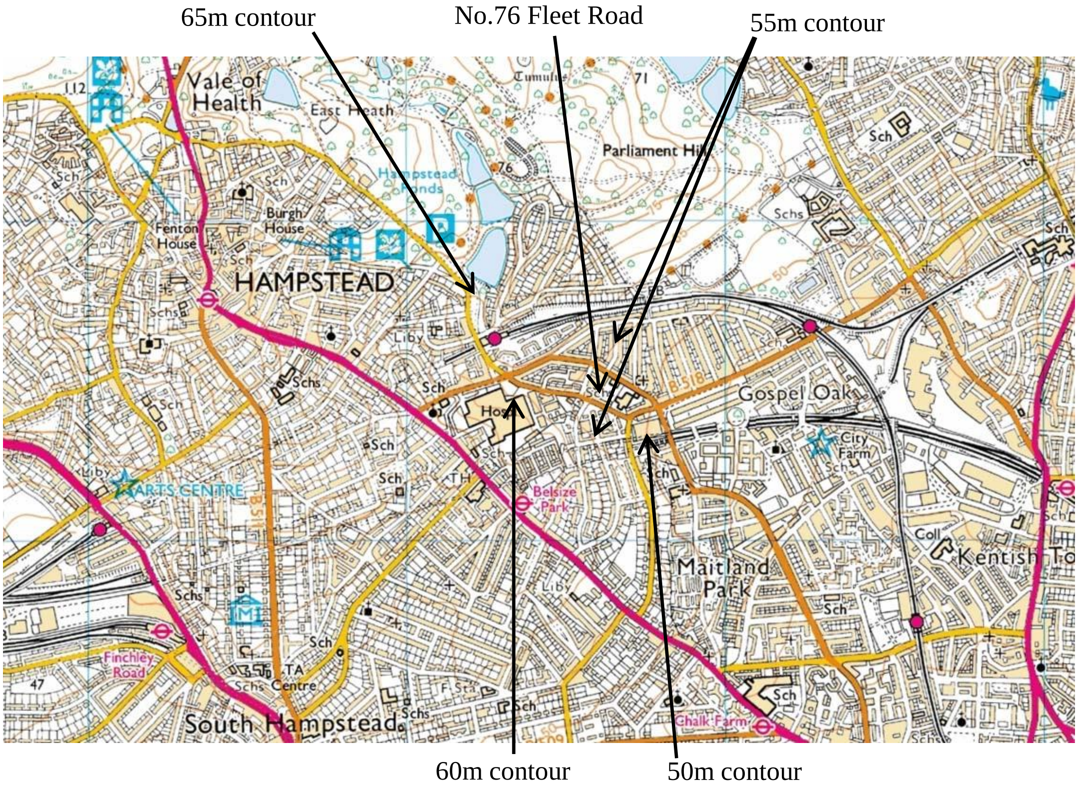

Figure 2: Extract from 1:25,000 scale Ordnance Survey map showing site location.

Planning Searches:

2.8 A search was made of planning applications on Camden council's website in order to obtain details of any other basements which have been constructed, or are planned, in the vicinity of the property. This search found:

- **No. 76 Fleet Road:** Application (F9/2/A/36938) involving the "*Change of use and works of conversion, including the erection of a single-storey rear extension, to provide a self-contained flat and a self-contained maisonette*" was granted conditional planning permission on 28th October 1983. A drawing of the proposed extension was found on the website.
- **No. 78 Fleet Road:** Application (9500769) involving "*The erection of a mansard roof extension and enlargement of the extension at the rear first floor level and works of conversion to provide 1 x 1-bedroom flat and 1 x 2-bedroom maisonette as shown on drawing nos. CN/78/5/6 7A 8A 9A. Revised on 31.07.95 and 16.08.95*" was granted conditional planning permission on 7th September 1995. With the exception of a decision notice, no documents related to this application were found on the website.
- **No. 86 Fleet Road:** Application (9401919) involving "*the erection of a roof extension to provide a one-bedroom flat the erection of a two-storey rear extension to provide staircase access the enlargement of the **rear lightwells** and alterations to the rear fenestration as shown on drawing nos. 95-S-0 1 2 3 4 5 6 7 95-P-1A 2A 3B 4B 5A 7 8B 9 10. Revised on 03.04.95*" was granted conditional planning permission on 3rd August 1995. With the exception of a decision notice, no documents related to this application were found on the website.

3.0 PROPOSED BASEMENT

3.1 The proposed works at No.76 Fleet Road for which planning permission will be sought, as shown in the scheme drawings by Tal Arc Ltd and Fridum Ltd (see paragraph 1.4), will comprise:

- Widening of the existing two-storey rear projection and single-storey rear extension to cover the full width of the plot, and the formation of two private terraces at the roof level of these new two-storey and single-storey extensions.
- A single-storey basement beneath the entire footprint of the existing house, as well as beneath the proposed new two-storey and single-storey extensions. The proposed basement will be split into two levels, with the finished floor level of the front part of the basement set 1.1m above that of the rear of the basement (see 'Proposed Section' Drg No.76FR-PP1-05 and Fridum's Drg No.FR-STRU-1001).
- This basement will also include two lightwells, at the front and rear of the property, with a bridge over the rear lightwell, enabling access to the rear garden. The rear lightwell will be full depth and full width; the front lightwell will not extend below the path to the front door and its base level will be just below sill level to the basement's front window.
- The addition of a mansard roof, similar to that of the adjoining No.78 Fleet Road, in order to create additional living space.
- A new ground floor in the front part of the house, raised by approximately 0.28m in order to lift it slightly above the external footway level, and lowering the ground floor in the rear part of the house by about 0.18m (both scaled from Fridum's section).
- Major internal alterations.

3.2 Both Tal Arc's and Fridum's section drawings show a headroom of 2.43m within the front part of the basement, and 2.5m within the rear part. Fridum's sections show that the underpin bases will be 400mm thick, with a further 200mm for insulation, cavity drainage and floor structure. The new ground floor structure scales at 0.25m thick, so the founding level (formation) of the front part of the proposed basement will be approximately 3.3m below the level of the footway at the front of the house. Within the rear part of the basement, the founding level will be about 3.35m below the level of the existing rear garden and proposed new lower ground floor level.

3.3 Although the existing FFL in the front part of the house is approximately 0.58m above that of the existing rear projection and garden, this floor is suspended, with an underfloor void of 0.58m/0.8m depth (see Factual Report on Ground Investigation in Appendix C). As a result, the depth of excavation required to achieve the founding level of the front part of the basement will be around 2.22m/2.44m. Fridum's section shows that the founding level and excavation depth for the lightwell at the front of the property will be 2.4m below the level of the footway.

4.0 GEOLOGICAL SETTING

4.1 Mapping by the British Geological Survey (BGS) indicates that the site is underlain by the London Clay Formation. Figure 3 shows an extract from Figure 16 of the Camden GHHS (Camden Geological, Hydrogeological and Hydrological Study by Arup, November 2010) which illustrates the site geology of the Hampstead area. It is possible that Alluvium will also be present within the site, given that the western branch of the river Fleet used to run through the rear garden of this property.

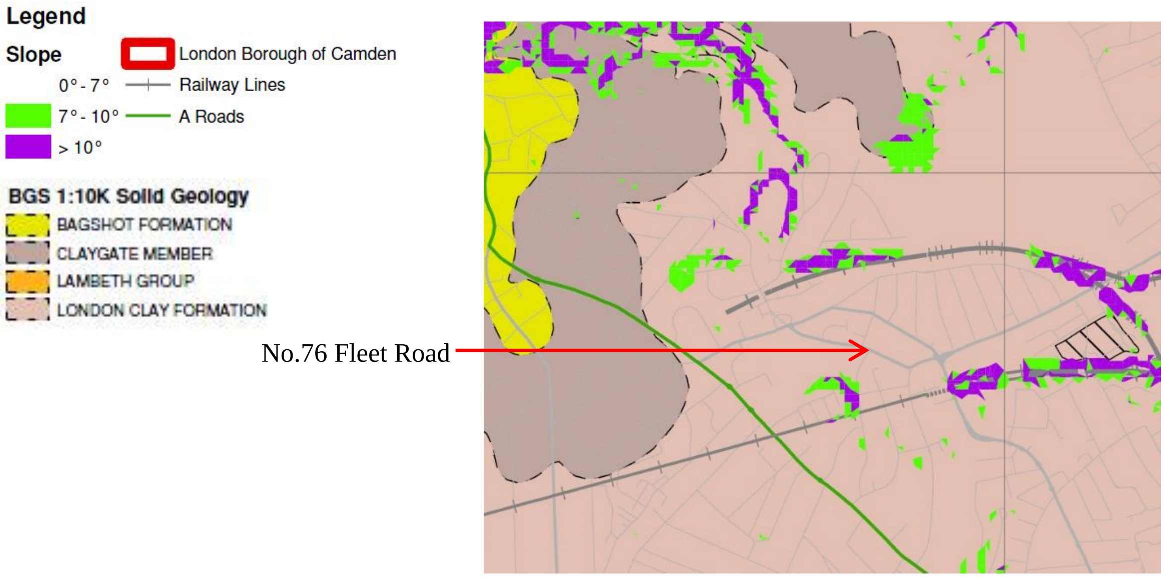

Figure 3: Extract from Figure 16 of the Camden GHHS showing geology and slope angles >7° (Arup, 2010)

4.2 In urban parts of London, the London Clay is typically overlain by Made Ground. A thin superficial layer of natural, locally-derived re-worked soils called Head deposits may also be present (because these are not mapped by the British Geological Survey where they are expected to be less than 1.0m thick). In the areas which have been excavated, some or all of these deposits may have been removed.

4.3 The London Clay is well documented as being a firm to very stiff over-consolidated clay which is typically of high or very high plasticity and high volume change potential. As a result, it undergoes considerable volume changes in response to variations in its natural moisture content (the clay shrinks on drying and swells on subsequent rehydration). These changes can occur seasonally, in response to normal climatic variations, to depths of up to 1.50m and to much greater depths in the presence of the trees whose roots abstract moisture from the clay. The clay will also swell when unloaded by excavations such as those required for the construction of basements.

4.4 The results of the BGS natural ground subsidence hazard classifications are provided in the GroundSure GeoInsight report (Appendix E); all indicated 'Negligible' or 'Very Low' hazard ratings with the exception of 'Shrink – Swell Clay' for which a 'Moderate' hazard rating was given, which reflects the outcrop of the London Clay Formation at surface.

4.5 The GroundSure GeoInsight report (Appendix E, Sections 2, 3 & 7) records:

- Historic underground workings, the closest of which are tunnels located 131-137m and 170-175m to the south of the site, which are thought to form part of National Rail's Midland Main Line (see App.E, map on page 15, Section 2.2 and Sections 7.1 & 7.2).
- A number of Historic 'mining' features within 1000m of the site, the closest of which are 'Air Shafts' located 198m & 205m to the south-west of the site (see App.E, Section 3.1).
- Historical surface ground working features, the closest of which are an 'Unspecified Heap' located 217m to the north-west of the site, and 'Cuttings' located 235m to 246m to the north and north-west of the site (see App.E, Section 2.1).

It should be noted that these databases are based on mapping evidence so inevitably will provide an incomplete record of underground workings.

4.6 A search of the BGS borehole database was undertaken for information on previous ground investigations and any wells in the vicinity of the site, the locations of which are presented on the location plan in Appendix B. The strata depths in a selection of these boreholes are summarised in Table 1. For full strata descriptions, reference should be made to the logs in Appendix B. General points of note from these boreholes were:

- TQ28NE/277 is a deep borehole (177m bgl), and does not provide a detailed description of the London Clay, therefore it is unclear if the upper parts of the London Clay appeared weathered at this location, as is commonly found within this unit.

Table 1: Summary of Strata in BGS and other Boreholes

Strata (abbreviated descriptions)	**Depths (m) and levels (m AOD) to base of strata in BGS Boreholes**							
	TQ28NE/277 aka TQ28/198 (177m deep)		**TQ28NE/77**		**TQ28NE/78**		**TQ28NE/79**	
GL (mAOD)	Depth	**Level 59.28**	Depth	**Level 52.30**	Depth	**Level 54.61**	Depth	**Level 54.54**
Surfacing/ Made Ground	-	**-**	0.3	**52.0**	3.05	**51.56**	0.90	**53.64**
Firm-stiff, brown and grey/orange brown, silty to sandy CLAY with stones (Head deposits?)	-	**-**	-	**-**	-	**-**	2.15	**52.39**
Stiff (mottled in TQ28NE/79) brown and blue CLAY with crystals (Weathered London Clay Fm?)	-	**-**	3.35	**48.95**	4.90	**49.71**	7.00	**47.54**
Firm-very stiff fissured brown silty CLAY with crystals (Weathered London Clay Fm)	-	**-**	4.25	**48.05**	8.55	**46.06**	9.15	**45.39**
Firm-very Stiff, fissured dark brown/grey silty CLAY with crystals (London Clay Fm)	69.00	**-9.72**	>15.25		>12.20		>12.20	
Seepage/Strike	-	**-**	-	**-**	-	-	-	-
Groundwater standing level	95.65	**-36.37**	12.20	**40.10**	2.20	**49.56**	1.50	**53.04**

5.0 HYDROLOGICAL SETTING (SURFACE WATER)

Approximate location of No.76 Fleet Road

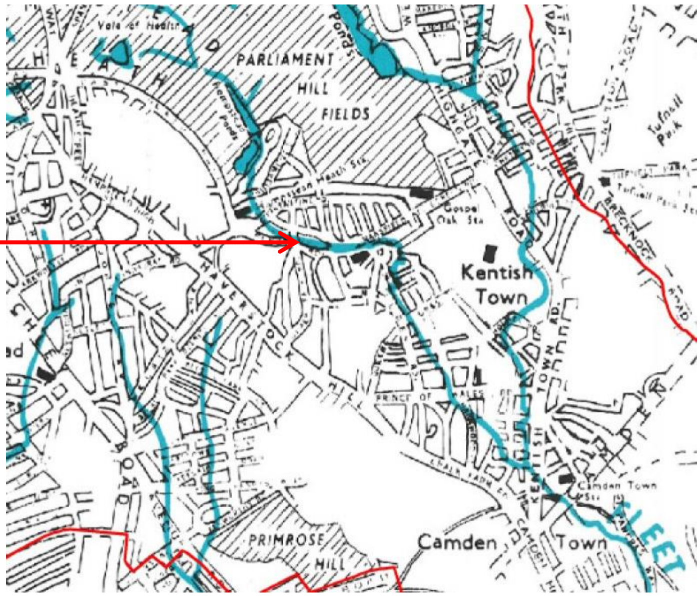

Figure 4: Extract from Figure 11 of the Camden GHHS (Arup, 2010) showing former watercourses, based on Barton (1992).

5.1 Figure 4 shows that Fleet Road is located adjacent to the former western branch of the River Fleet, one of the 'lost' rivers of London which now run in dedicated culverts or the sewer system. As shown on the more detailed 1871 and 1872 historic OS maps (see Appendix G), the river channel was located within the rear gardens of No.76 and the adjoining properties on this terrace. The rear boundaries to these properties were sited on the north bank of the river and followed the course of the river, which was responsible for the irregular pattern of this boundary. Between publication of the 1872 and 1896 OS maps, this area was subject to major development, and the River Fleet can no longer be seen by the time the 1896 OS map was published. As a result, it is considered likely that this tributary was either culverted on-line, or directed into the sewer system when the area was developed. A deep tunnelled culvert now carries this branch of the river Fleet from Hampstead No.1 Pond to the Serpentine; that culvert passes 368m to the west of the site (see paragraph 5.5 and App.F, Section 6.10 & map on page 43). However it is still considered likely that a separate smaller culvert was constructed closer to the site, prior to the construction of the deep culvert. If a smaller dedicated culvert does exist, then it is likely to be located either along the northern boundary to the site, close to the location of the original tributary, or beneath the Fleet Road carriageway.

5.2 The gentle fall of the footway away from the front of the property (Photo 3), together with the slightly raised amenity area and the south-eastwards fall of Fleet Road, are likely to ensure that most surface (rain)water drains away from the property under normal conditions. The small amenity area at the front of the property is surfaced with concrete and bounded by kerb stones (Photo 3), thus its surface water catchment will be limited to direct rainfall only, and there will be no infiltration. The high brick boundary walls which form the site's northern and eastern boundaries, between the Camden Ambulance Station and No.78 Fleet Road respectively, will prevent surface water run-off from or to these areas (Photos 5 & 6). Between No's 76 and 74 Fleet Road however, the low brick boundary wall which adjoins the perimeter raised flower bed is in poor condition, with large sections missing altogether (Photo 5), therefore the surface water catchment for the rear garden is expected to be restricted to the site itself, plus any surplus overland run-off water seeping from the adjoining No.74's back garden. Most of the rear garden is surfaced with paving slabs or concrete, so infiltration will be limited or nil in that 'central' area, whereas infiltration will occur within the perimeter raised flower beds (though that would be nil when the ground is saturated or frozen).

5.3 Figure 5 shows that Fleet Road was subject to surface water flooding in 2002, but not in the 1975 floods; however, the adjoining Parkhill Road flooded in both of these events. The implications of those historical events are addressed in Section 10.8. While the whole length of the road is recorded as having flooded, the floods generally affected only a short length of these roads.

No.76 Fleet Road

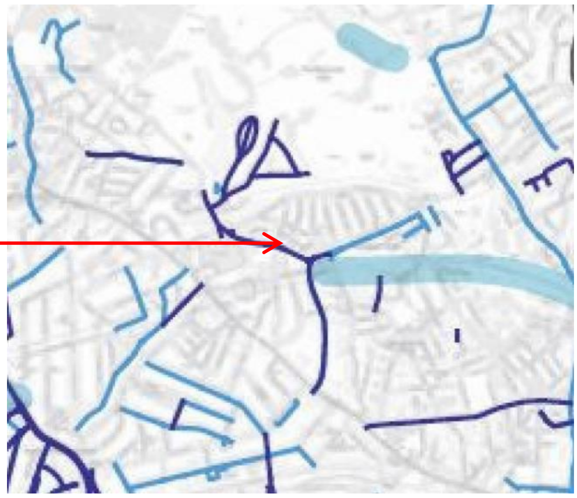

Figure 5: Extract from Figure 15 of the Camden GHHS (Arup, 2010) showing roads which flooded in 1975 (light blue), in 2002 (dark blue), and 'Areas with potential to be at risk of surface water flooding' (wide light blue bands).

5.4 Maps on the website of the Environment Agency (EA) show that the site lies within Flood Zone 1, which is defined as areas where flooding from rivers and the sea is very unlikely, with less than a 0.1 per cent (1 in 1000) chance of such flooding occurring each year. The EA's website also shows that immediately to the north of the site is an area at risk of flooding from reservoirs, with flooding from a failure of the Hampstead No.1 Pond shown as almost reaching the northern boundary to the site.

5.5 The following hydrological data for the site has been obtained from the GroundSure EnviroInsight report (see Appendix F), including:

- The closest 'river' (or more specifically "Detailed River Network" entry) is a culvert, 368m to the west of the site (see App.F, Section 6.10). This is the culverted western branch of the River Fleet. It should be noted however, that a separate smaller culvert may be located much closer to the site, possibly within the site or along the northern boundary to the site, or beneath the Fleet Road carriageway (see paragraph 5.1).
- There are no surface water features within 250m of the site (see App.F, Section 6.11).
- The closest surface water abstraction licences are 1675m and 1681m to the south-east of the property, at the Grand Union Canal (App.F, Section 6.4).
- There are no flood defences, no areas benefitting from flood defences, and no flood storage areas within 250m of the site (App.F, Sections 7.4, 7.5 & 7.6).

5.6 Further flood modelling has been undertaken by the Environment Agency and was published on its website in early 2014, an extract from which is presented in Figure 6. While this map identifies four levels of risk (high, medium, low and very low) it is understood that it is based at least in part on depths of flooding as well as flow routes. This modelling shows areas at a 'Low' to 'High' risk of flooding from surface water directly in-front of the property, within the Fleet Road carriageway, and extending south-eastwards (downslope) along Park Dwellings. An area at 'Low' risk of flooding from surface water is also shown immediately to the north/north-east of the site, within the south-east corner of the Camden Ambulance Station (where the ground levels are lower than the vehicular access into the building - Photo 6). This area extends southwards into the rear gardens to No's 74 and 76 Fleet Road; however, due to the high brick boundary wall which separates these properties from the Camden Ambulance Station, this must be either coincidental or incorrect (the height of the boundary wall made it impossible to assess the relative ground levels on either side of the wall).

Figure 6: Extract from the Environment Agency's 'Risk of Flooding from Surface Water'.
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5.7 More recently, surface water flood modeling has been undertaken by URS as part of a Strategic Flood Risk Assessment for the London Borough of Camden, and was published in July 2014; an extract from their model is presented in Figure 7. As per the Environment Agency's modeling, this map identifies the same four levels of risk (high, medium, low and very low). This modeling shows broadly similar areas at a 'Low' to 'High' risk of flooding from surface water in front of No.76, within the Fleet Road carriageway, and a localized area at a 'Low' risk of flooding from surface water within the south-east corner of the Camden Ambulance Station, similar to that shown by the Environment Agency's modeling (Figure 6). Once again this area appears to extend southwards into the rear gardens to No's 74 and 76 Fleet Road.

5.8 Figure 7 also shows that Fleet Road falls just outside of the Group3_003 Critical Drainage Area, located to the south-east of the site.

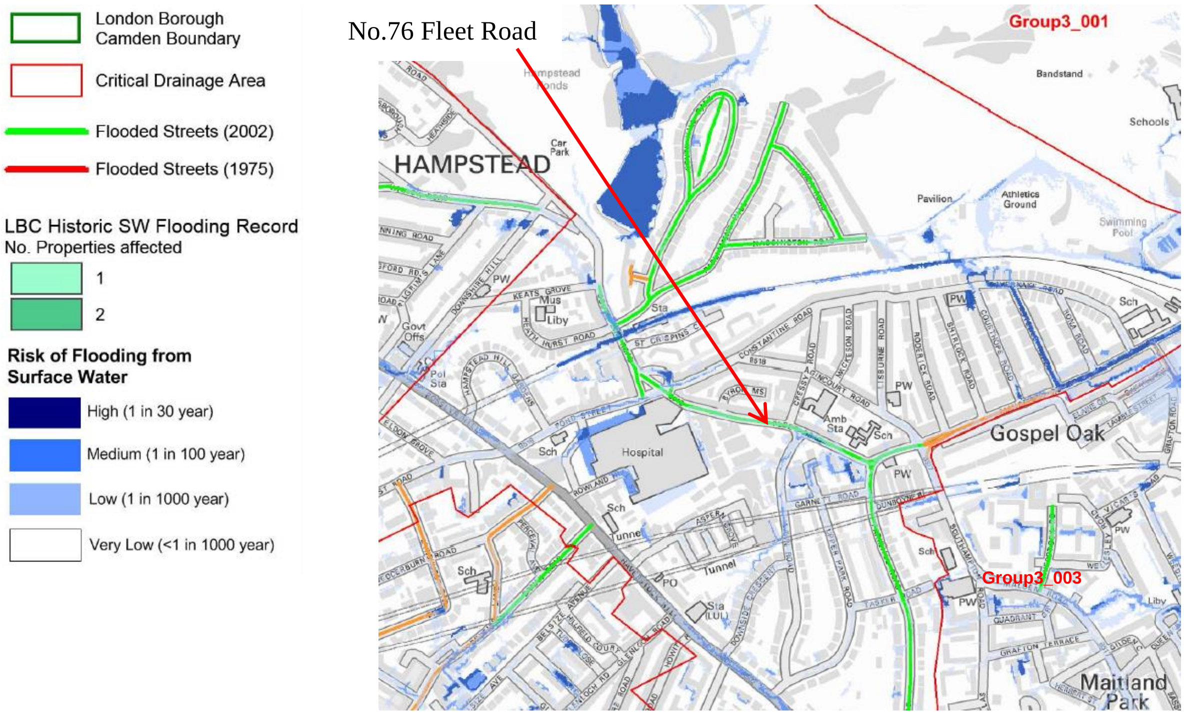

Figure 7: Extract from Figure 3v of the Camden Strategic Flood Risk Assessment (SFRA) (URS, July 2014) showing risk of flooding from surface water.

5.9 The implications from these flood models are discussed in Section 10.8. Dual gullies have been installed on the opposite side of Fleet Road, on each side of the turnout from Lawn Road, probably in response to past flooding (the 2002 event perhaps).

5.10 Figures 5a & 5b of the Camden Strategic Flood Risk Assessment present historic records of internal and external sewer flooding respectively, based on Thames Water's DG5 Flood Register. These figures show that, when the Camden Strategic Flood Risk Assessment was written (July 2014), none of the properties within this postcode were recorded by Thames Water as having been affected by internal or external sewer flooding in the previous 10 years.

6.0 HYDROGEOLOGICAL SETTING (GROUNDWATER)

6.1 The London Clay Formation is classified by the Environment Agency as an 'Unproductive Stratum', as indicated by Figure 8. Under the old groundwater vulnerability classification scheme, which now applies only to superficial soils, the area is unclassified.

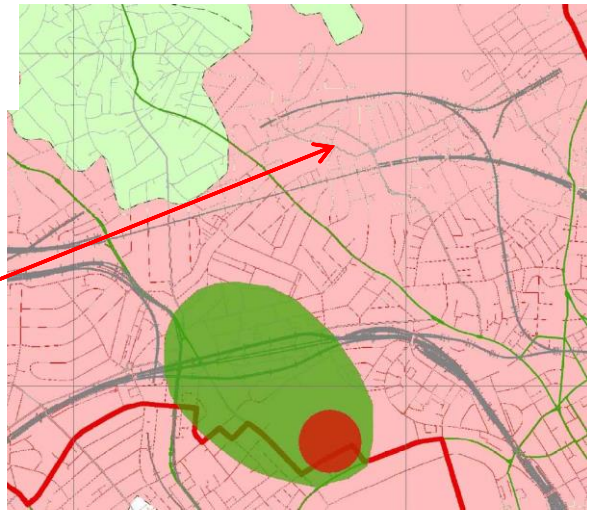

Figure 8: Extract from Figure 8 of the Camden GHHS (Arup, 2010) showing aquifer designations and SPZs. (Red = Zone I, Dark Green = Zone II).

6.2 The Chalk Principal Aquifer which occurs at depth beneath the London Clay is not considered relevant to the proposed basement, so is not considered further.

6.3 While the London Clay Formation is classified as an 'Unproductive Stratum', it can still be water-bearing. The water pressures within the clay in the depths of current interest are likely to be hydrostatic, which means they increase linearly with depth, except where they are modified by tree root activity or the influence of man-made changes such as utility trenches (which can act either as land drains or as sources of water and high groundwater pressures). Any silt or sand partings, laminations or thicker beds are likely to contain free groundwater and, where these are laterally continuous, they can give rise to moderate water entries into excavations. In most cases there will be only very limited or no natural flow in these silt/sand horizons.

6.4 Perched groundwater would typically be expected in any Made Ground, and possibly also in any Head deposits which overlie the London Clay, in at least the winter and early spring seasons. Variations in groundwater levels and pressures will occur in response to seasonal climatic changes and with other man-induced influences.

6.5 Details of what was found by the site-specific ground investigation in September 2015 are presented in Section 9.

6.6 The groundwater catchment areas upslope of No.76 are likely to differ for each of the main stratigraphic units:

- Made Ground: The catchment for any perched groundwater in the Made Ground is probably limited to the immediately adjoining areas of Made Ground, except where the trenches for drains and other services provide greater interconnection.
- London Clay Formation: The catchment for the underlying London Clay will comprise recharge from the overlying soils in the vicinity of the site, plus potentially a wider area determined by the lateral extent of any interconnected silt/sand horizons.

6.7 Other hydrogeological data obtained from the GroundSure EnviroInsight report (Appendix F) include:

- There are no Source Protection Zones (SPZs) within 500m of the site (App.E, Sections 6.6 & 6.7, and Figure 8 above).
- The nearest groundwater abstraction licences are 1401m to the south-west of the site at the Swiss Cottage Open Space Borehole (TQ28SE1769), and 1413m to the south-east of the site, at the Kentish Town Sports Centre (App.E, Section 6.3). The Swiss Cottage Open Space Borehole is 159m deep with 6" steel casing grouted into the London Clay and abstracts water from the Chalk below -56mOD, so it will have no effect on the proposed basement.
- The closest abstraction licences for potable water are 1413m to the south-east of the site at the Kentish Town Sports Centre (App.E, Section 6.5).
- The BGS has classified the area within 50m of the site as 'Not Prone' to groundwater flooding, based on the presence of London Clay to surface (App.E, Section 7.7).

6.8 Details of what was found by the site-specific ground investigation in September 2015 are presented in Section 9.

7.0 STAGE 1 - SCREENING

7.1 The screening has been undertaken in accordance with the three screening flowcharts presented in LBC's CPG4 guidance document. Information to assist with answering these screening questions has been obtained from various sources including the site-specific ground investigation, the Camden geological, hydrogeological and hydrological study (Arup, 2010), historic maps and data obtained from GroundSure (see Appendices E, F & G) and other sources as referenced.

7.2 Subterranean (groundwater) flow screening flowchart:

Question		**Response, with justification of 'No' answers**	**Clauses where considered further**
1a	Is the site located directly above an aquifer?	No – Site underlain by London Clay	4.1 & Figure 3
1b	Will the proposed basement extend beneath the water table surface?	No, not beneath the water table in an aquifer, though it will extend below the phreatic surface of the groundwater in the London Clay.	8.2, 9.8, and Sections 10.2 & 10.3
2	Is the site within 100m of a watercourse?	No – There are no surface water features within 250m of site, however there may be a culverted tributary to the River Fleet close to the northern boundary to the site, or beneath the Fleet Road carriageway.	5.1 & 5.5
3	Is the site within the catchment of the pond chains on Hampstead Heath?	No – Site is approx 450m to the south–east of the nearest pond chain catchment (Hampstead Pond Chain).	
4	Will the proposed basement development result in a change in the proportion of hard surfaced/ paved areas?	No – the small front amenity space is already fully paved. The rear lightwell will overlap the front ends of the perimeter flower bed at the rear, but this will be mitigated by a new flower bed alongside the rear lightwell.	5.2
5	As part of the site drainage, will more surface water (eg: rainfall and run-off) than at present be discharged to the ground (eg: via soakaways and/or SUDS)?	No – Soakaways would be inappropriate in London Clay.	
6	Is the lowest point of the proposed excavation (allowing for any drainage and foundation space under the basement floor) close to, or lower than, the mean water level in any local pond (not just the pond chains on Hampstead Heath) or spring line?	No – There are no surface water features within 250m of the site. Nearest springs are likely to be 600+m to the west (at the London Clay-Claygate Member interface).	5.5 & Figure 3

While the answer to question Q1b above was no, the design of the basement must allow for the presence of groundwater in the Made Ground, which was found to be predominantly clayey, and the London Clay. The temporary works during construction must also allow for the presence of groundwater. These matters are considered in Sections 10.1 to 10.3.

7.3 Slope/ground stability screening flowchart:

Question		**Response, with justification of 'No' answers**	**Clauses where considered further**
1	Does the existing site include slopes, natural or man-made, greater than 7°? (approximately 1 in 8)	No – The site is broadly level, with an overall slope angle from front to rear of around 1.0°.	2.7 and Figure 3
2	Will the proposed re-profiling of landscaping at site change slopes at the property boundary to more than 7°?	No – No re-profiling is proposed.	
3	Does the development neighbour land, including railway cuttings and the like, with a slope greater than 7°?	No – Figure 16 in the Camden GHHS shows no land greater than 7° in the vicinity of this property.	2.6, 2.7 & Figure 3
4	Is the site in a wider hillside setting in which the general slope is greater than 7°?	No – The slope angle upslope of No.76 is around 2.4° and reduces to around 1° within the vicinity of No.76.	2.7 & Figure 3
5	Is the London Clay the shallowest strata at the site?	Yes, it is the shallowest strata mapped by the BGS (though it may be overlain by Head Deposits).	Carried forward to Scoping: 4.1, 8.2, Section 9
6	Will any tree/s be felled as part of the proposed development and/or are any works proposed within any tree root protection zones where trees are to be retained?	Unknown – No trees will be felled, but root zone of silver birch tree on adjacent public footway needs to be assessed.	Carried forward to Scoping: 8.2, Section 10.4
7	Is there a history of seasonal shrink/swell subsidence in the local area, and/or evidence of such effects at the site?	Yes, in No.76, although no evidence of damage consistent with differential foundation movement was seen in the front walls of the other houses in this terrace.	Carried forward to Scoping: 8.2, Section 10.4
8	Is the site within 100m of a watercourse or potential spring line?	No – see Q2 & Q6 in subterranean flow screening above. No springs in the vicinity.	
9	Is the site within an area of previously worked ground?	No – See BGS map extract (Figure 3 herein) and maps on pages 8 & 15 of the GeoInsight report (in Appendix E).	4.1 & Figure 3
10	Is the site within an aquifer? If so, will the proposed basement extend beneath the	No – London Clay Formation is classified as an	6.1

	water table such that dewatering may be required during construction?	'Unproductive Strata'.	
11	Is the site within 50m of the Hampstead Heath ponds?	No – Site is approx 450m to the south –east of the Hampstead No.1 Pond.	
12	Is the site within 5m of a highway or a pedestrian right of way?	Yes.	Carried forward to Scoping: 8.2, Section 10.4
13	Will the proposed basement substantially increase the differential depth of foundations relative to neighbouring properties?	Yes	Carried forward to Scoping: 8.2, Section 10.4
14	Is the site over or within the exclusion zone of any tunnels, eg railway lines.	No – Re railway tunnels. Unknown re other tunnels.	Carried forward to Scoping: 8.2, 10.1.3

7.4 Surface flow and flooding screening flowchart:

Question		**Response, with justification of 'No' answers**	**Clauses where considered further**
1	Is the site within the catchment of the pond chains on Hampstead Heath?	No – Site is approx 450m to the south-east of the nearest pond chain catchment (Hampstead Pond Chain).	
2	As part of the proposed site drainage, will surface water flows (eg volume of rainfall and peak run-off) be materially changed from the existing route?	No – Flow routes at surface should be unchanged. Only change to surface water flow route will be the front and rear lightwells (from where the surface water will have to be pumped into the drainage system)	
3	Will the proposed basement development result in a change in the proportion of hard surfaced / paved external areas?	No – see answer to Groundwater screening Q4.	5.2
4	Will the proposed basement result in changes to the profile of the inflows (instantaneous and long-term) of surface water being received by the adjacent properties or downstream watercourses?	No – The lightwells will not affect surface water run-off to adjacent properties. The historic natural watercourse along the northern boundary to the site is thought to have been culverted since the late 1800's.	5.1, 5.2
5	Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?	No – There should be no significant change in surfaces generating run-off. None of the run-off from this property goes directly to a surface watercourse.	5.2
6	Is the site in an area known to be at risk from surface water flooding, such as South Hampstead, West Hampstead,	Yes – Fleet Road did flood in 2002 (though probably only a small part of the road).	5.3 & Figure 5. Carried forward to Scoping:

	Gospel Oak and King's Cross, or is it at risk from flooding, for example because the proposed basement is below the static water level of a nearby surface water feature?		8.3 & Section 10.7

7.5 Non-technical Summary – Stage 1:

The screening exercise in accordance with CPG4 has identified seven issues which need to be taken forward to Scoping (Stage 2); six are related to ground stability and one is related to flooding potential. None are related to groundwater, but the presence of perched groundwater in the clays of the Made Ground must also be allowed for in the design of the basement and the associated temporary works; these matters are considered in Sections 10.2 and 10.3.

8.0 STAGE 2 - SCOPING

8.1 The scoping stage is required to identify the potential impacts from the aspects of the proposed basement which have been shown by the screening process to need further investigation. A conceptual ground model is usually compiled at the scoping stage, however, because the ground investigation has already been undertaken for this project, the conceptual ground model including the findings of the ground investigation is described under Stage 4 (see Section 10.1).

8.2 Slope/ground stability scoping:

Issue (= Screening Question)		Potential impact and actions
5	Is the London Clay the shallowest strata at the site?	**Potential impact:** Heave in response to the unloading caused by the basement excavations, and as Q6 and Q7 below. **Action:** Ground investigation required, followed by appropriate design.
6	Will any tree/s be felled as part of the proposed development and/or are any works proposed within any tree root protection zones where trees are to be retained?	**Potential impact:** Heave from removal of trees; slope(s) become less stable; damage to trees. **Action:** Arboricultural assessment and review of potential impact on stability of buildings and/or slopes and/or the trees as relevant.
7	Is there a history of seasonal shrink/swell subsidence in the local area, and/or evidence of such effects at the site?	**Potential impact:** Weakened structures from past movement would be more susceptible to damage during works. Future differential movement between the building above the basement and the adjoining structures. **Action:** Review potential impact of future vegetation growth. Designer and contractor to take account of any weakening of the structure caused by past movements.
12	Is the site within 5m of a highway or a pedestrian right of way?	**Potential impact:** Construction of basement causes loss of support to footway/highway and damage to the services beneath them. **Action:** Ensure adequate temporary and permanent support by use of best practice underpinning methods.
13	Will the proposed basement substantially increase the differential depth of foundations relative to neighbouring properties?	**Potential impact:** Loss of support to the ground beneath the foundations to No's 74 & 78 Fleet Road if basement excavations are inadequately supported. Possible long term differential movement. **Action:** Ensure adequate temporary and permanent support by use of best practice underpinning methods. Consider the need for transition underpinning.
14	Is the site over or within the exclusion zone of any tunnels, eg railway lines.	**Potential impact:** Stress changes on any tunnel lining. Piles or boreholes penetrating the tunnel. **Action:** Undertake services search to check that there are no tunnels / deep services in the vicinity.

8.3 Surface flow and flooding scoping:

Issue (= Screening Question)		Potential impact and actions
6	Is the site in an area known to be at risk from surface water flooding, such as South Hampstead, West Hampstead, Gospel Oak and King's Cross, or is it at risk from flooding, for example because the proposed basement is below the static water level of a nearby surface water feature?	**Potential impact:** Flooding of the basement. **Action:** Review flood risk and provide flood resistance measures as appropriate**.**

8.4 Non-technical Summary – Stage 2:

The scoping exercise has reviewed the potential impacts for each of the items carried forward from Stage 1 screening, and has identified the following actions to be undertaken:

- A ground investigation is required (which has already been undertaken).
- An arboricultural assessment regarding the root zone of the Silver Birch tree on the public footway, followed by a review of the potential impact of the proposed basement extension on that tree.
- Designer and contractor to take account of the weakening of the structure caused by past movements.
- Ensure adequate temporary and permanent support by use of best practice underpinning methods.
- Consider the need for transition underpinning to mitigate differential foundation depths, subject to Party Wall Act protocols.
- Undertake a services search to check whether there are any deep services/ tunnels which might be affected by the basement.
- Review flood risk and include appropriate flood resistance and mitigation measures in the scheme's design.

All these actions are covered in Stage 4, or Stage 3 for the ground investigation.

9.0 STAGE 3 – GROUND INVESTIGATION

9.1 The ground investigation site work was carried out by Chelmer Site Investigations (CSI) in September 2015, and consisted of two continuous flight auger boreholes (BH1 & BH2) drilled to depths of 5.1m and 8.0m bgl respectively, and three hand dug trial pits (TP1 - TP3). It should be noted that BH1 had to be terminated within the Weathered London Clay at 5.1m, due to ground conditions being "too dense for drill to penetrate" (this was suspected to have been caused by a claystone nodule/horizon). The factual findings from the investigation are presented in Appendix C, including a site plan, borehole logs, trial pit logs and laboratory test results.

9.2 Trial pits TP1 - TP3 were dug in order to investigate the foundations to No.76, and the soils beneath the footings, at their respective locations.

- TP1 was dug to a depth of 1125mm within the lounge at the front of the house, in order to investigate the foundations beneath the 76/78 party wall. It revealed brickwork with three corbels at its base, founded at 925mm bgl. At this location, in the front of the house, the floor was found to be suspended timber, supported off brickwork sleeper walls, with the ground surface at 585mm beneath the finished floor level (FFL).
- TP2 was dug within the rear garden, opposite the rear projection, in order to investigate the foundations beneath the 76/78 party wall, where that was formed by the flank wall of No.78's rear projection. It was dug to a depth of 650mm bgl, and revealed brickwork with three corbels at its base, resting on a 300mm thick concrete footing, founded at 450mm bgl. A 100mm diameter clay pipe was also recorded alongside this footing.
- TP3 was dug within the single-storey rear extension, in order to investigate the foundations beneath the eastern flank wall of this later addition to the house. The pit was dug to a depth of 1450mm bgl, and revealed brickwork, resting on a 900mm thick concrete footing, founded at 1250mm bgl. The floor within this rear extension, was recorded as 250mm thick reinforced concrete, with 5mm rebar.

9.3 In all three trial pits, Made Ground was described from directly beneath the floor structure, or the 80mm lean mix concrete surfacing in TP2, to the maximum depths excavated; however its composition was found to vary across the site. In TP1, Made Ground consisting of "medium compact, grey, slightly gravelly silty fine **sand** with brick, concrete and clinker fragments and pieces" was recorded, overlying "medium compact, brown/orange, slightly sandy silty **clay** with brick and concrete fragments". In TP2, the Made Ground was described as "soft to firm, moist, brown stained grey, slightly pungent, slightly sandy silty **clay** with brick, concrete and clinker pieces and fragments and occasional gravel", whereas in TP3 similar material (though described as "medium compact" and dark brown/orange) was found to the base of the footing, underlying which the Made Ground became gravelly and brown in colour.

9.4 The site's geology as found by the two boreholes may be summarised as follows: (It should be noted that the ground level at the position of BH2 was approximately 0.6m below the level of BH1.)

- Made Ground: Found immediately beneath a 0.8m underfloor void in BH1, and beneath 0.05m of concrete in BH2; the Made Ground was proved to depths of 1.8m and 2.9m below ground level (bgl) in BH1 and BH2 respectively. In BH1, a 0.6m horizon of "medium compact, brown/grey, slightly gravelly very clayey **silt**, with occasional brick and concrete fragments", was recorded, over 0.4m of "medium compact, brown/grey, silty sandy fine to coarse **gravel**, with brick and concrete fragments", whereas in BH2, 0.95m of "medium compact, moist, brown/orange, sandy silty **clay** with gravel and numerous brick, concrete and clinker fragments and pieces" was recorded, over 1.9m of "firm, moist, brown, stained grey, slightly pungent slightly sandy very silty **clay**, with occasional gravel, brick and clinker fragments and pieces".

- GRAVEL (River Terrace Deposits?): In BH1 only, a 0.6m thick horizon of "medium dense, brown/orange, silty very sandy fine to medium GRAVEL" was recorded directly beneath the Made Ground.
- Weathered London Clay Formation: Recorded from the base of the GRAVEL to the base of BH1 at 5.1m bgl, and from the base of the Made Ground to a depth of 5.8m bgl in BH2, the Weathered London Clay Formation was generally described as "Stiff (becoming very stiff from 3.7m bgl in BH1), brown (brown/grey in BH1), slightly sandy silty CLAY (with occasional fine gravel in BH2 only)". In BH2, the lower 0.6m of Weathered London Clay was recorded as "Stiff, brown/grey, slightly sandy silty CLAY, with partings of brown and orange silt and fine sand".
- Un-weathered London Clay Formation: Described from the base of the overlying Weathered London Clay at 5.8m bgl to the base of BH2 at 8.0m bgl, the London Clay was recorded as "Very stiff, grey, slightly sandy silty CLAY, with partings of brown and orange silt and fine sand".

9.5 Hand vane measurements of shear strength were taken in-situ in the boreholes. In the upper part of the Weathered London Clay, these tests gave averaged values of 106kPa and 89kPa at 3.0m bgl, in BH1 and BH2 respectively. Below 4.0m, all readings in BH1 were >120kPa, whereas in BH2, an averaged value of 99kPa was recorded at 4.0m bgl, rising to 111kPa at 5.0m. Below 6.0m in BH2, all readings were >120kPa. These values do not allow for the clay's fabric such as fissures, so typically over-estimate the soil's strength and should NOT be used for design.

9.6 No roots were observed in either of the boreholes or TP1 & TP3, however roots of live and dead appearance were recorded in TP2.

9.7 No groundwater entries were recorded in BH1 or BH2, and they were both described as 'dry' and open (ie: stable) on completion.

9.8 Standpipes were installed to the base of BH1 at 5.1m bgl, and to a depth of 6.0m bgl in BH2, with water level readings taken on 26th October and 4th November 2015. During this short period of monitoring, the water levels in both boreholes rose, from 3.60 to 3.27m bgl in BH1, and from 2.26 to 1.45m bgl in BH2. The most recent levels may not have equilibrated fully with water pressures in the clay, so may not have been representative of the groundwater levels/pressures in the surrounding ground.

9.9 Laboratory Testing:
Laboratory tests were carried out by Chelmer Geotechnical Laboratories (CGL) and others on samples recovered from the boreholes. The testing comprised classification tests, including moisture content and plasticity, one particle size distribution analysis (grading), and chemical testing to assess the potential for acid or sulphate attack on buried concrete. The results were presented in CSI's Factual Report (Appendix C).

9.10 Plasticity tests were performed on a total of six samples of the London Clay, recovered from BH1 at 2.5m and 3.5m bgl, and from BH2 at 3.5, 4.5, 5.5 and 6.5m bgl. All six of these samples were found to be of Very High Plasticity as classified by BS5930 (1999, 2010), and High volume change potential, as defined by the NHBC (NHBC Standards, 2016, Chapter 4.2, Building near Trees).

9.11 The moisture contents of the same six samples recovered from BH1 & BH2 were found to vary between 29% and 35%; all of them were at least 6% above the Plastic Limit, which indicates that the samples were not desiccated. In BH2 these moisture contents progressively decreased with depth (see plotted profile in CGL's report).

9.12 The single particle size distribution analysis (grading) test was carried out on a sample of the gravel horizon recovered from BH1 at a depth of 2.0m bgl (paragraph 9.4). The analysis classified the sample as very clayey/silty, very sandy, fine to medium GRAVEL.

9.13 The chemical tests were undertaken to assess the potential for acid or sulphate attack on buried concrete, and were carried out by QTS Environmental Ltd on a total of six samples, in accordance with BRE Special Digest 1 (2005). The samples were recovered from BH1 at 1.0, 2.0 and 3.5m bgl, and from BH2 at 2.0, 4.5, and 8.0m bgl, so included Made Ground, River Terrace Deposits and London Clay (both weathered and un-weathered. The following ranges of results were recorded.

pH value:	7.6 – 8.0
Water-soluble sulphate:	283 – 2630 mg/l
Total Sulphur:	0.04 – 0.63 mg/kg
Water-soluble magnesium:	9.2 – 130 mg/l

Calculations following BRE Digest SD1 gave ‘derived’ values:

Total Potential Sulphate:	0.12 – 1.89%
Oxidisable sulphides:	0.01 – 0.72%.

These results indicated that the samples fell within the following Design Sulphate Classes, as defined by BRE Special Digest 1 (2005):

DS-1 to DS-3: Samples from the Made Ground
DS-2: Sample from the River Terrace Gravels
DS-2 to DS-4: Samples from the London Clay.

Non-technical Summary – Stage 3:

9.14 The site-specific ground investigation at No.76 Fleet Road recorded CLAYS of the London Clay Formation, as mapped by the British Geological Survey (BGS), as well as a small thickness of suspected River Terrace Deposits beneath the front of the property. Made Ground was also found overlying the natural strata across the site, with both thickness and depth increasing towards the rear of the site where the former course of the river Fleet was located.

9.15 No groundwater entries were recorded in either of the boreholes during drilling; however, during the short monitoring period, groundwater levels of up to 3.27m bgl in BH1, and 1.45m bgl in BH2 were recorded. These levels may not have equilibrated fully with water pressures in the clay, so may not have been representative of the groundwater levels/pressures in the surrounding ground.

10.0 STAGE 4 – BASEMENT IMPACT ASSESSMENT

10.1 Conceptual Ground Model

10.1.1 The desk study evidence, together with the ground investigation findings, suggest a conceptual ground model for the site characterised by:

- Made Ground: Made Ground was discovered within all of the exploratory holes, to a maximum depth of 2.9m below ground level (bgl), with increasing thickness to the rear of the site). As usual, it varied in its composition, with descriptions of the Made Ground ranging from "slightly sandy silty **clay**" to "silty sandy fine to coarse **gravel**". Brick, clinker and concrete fragments were found throughout most of the Made Ground, however other materials, as well as other soil types and greater thicknesses/depths are also likely to be present on site, owing to the inherent variability of Made Ground. The deepest parts of the Made Ground may have been disturbed in-situ soils.
  The ground level within the rear garden is thought to have been artificially raised sometime after the area was first developed, and the western branch of the River Fleet was filled in or culverted. As a result, the depth of Made Ground may be greater towards the northern end of the site, which is consistent with the findings of the two site-specific boreholes.
  Perched groundwater should be expected in any Made Ground during at least the winter and spring seasons.
- River Terrace Deposits/Made Ground: Directly beneath the Made Ground, BH1 recorded 0.6m of very sandy GRAVEL. It should be noted that the Made Ground in BH2 (at the rear) extended beneath the base/level of this GRAVEL, therefore it is possible that the gravel once extended across the entire site, but has been excavated or removed, and replaced with Made Ground in some locations.
  As shown on the historic OS maps (see Appendix G and paragraph 4.1), the western branch of the River Fleet used to flow through the rear garden, close to the northern site boundary. Whether that stream had sufficient energy to transport gravel is unclear. It remains a possibility that this gravel actually forms part of the Made Ground, and was artificially placed on site, however it is considered much more likely that these gravels are part of the Thames River Terrace Deposits which can be found across London.
- Head (?): It is possible that the upper part of the stiff CLAY in BH2 which contained "occasional fine gravel" (below 2.9m) is a Head deposit. Head deposits were described in one of the nearby BGS boreholes (see paragraph 4.6 and Table 1), and the location of No.76 in the floor of the valley is also compatible with the potential presence of Head deposits, so it remains possible that the upper part of the stiff CLAY in BH1 is also a Head deposit.
- Weathered in-situ London Clay: Stiff, to very stiff, brown/grey, slightly sandy silty CLAYS were found directly beneath the Made Ground and River Terrace Deposits/Made Ground in both of the site-specific boreholes (see paragraph 9.4) although, as noted above, it is possible that the upper part of these clays is a transported Head deposit. The in-situ clays are likely to be fissured and will undergo heave movements in response to unloading by the basement excavation. They typically contain selenite (a form of gypsum) which is aggressive to buried concrete, and often contain claystone nodules/horizons. The "stiff" and "very stiff" consistency descriptions were probably based in part on the vane test results, which are known to over-estimate the shear strength of fissured clays.
- London Clay Formation (un-weathered): Un-weathered, very stiff, grey, slightly sandy silty CLAY of the London Clay Formation was encountered from the base of the Weathered London Clay, to the

maximum depth drilled (see paragraph 9.4). Based on the logs of other boreholes in the area, the base of the Weathered London Clay can be found at depths ranging from 4.25m to 9.15m bgl.

- Hydrogeology
  - Groundwater pressures are expected to be essentially hydrostatic within the depth of current interest in the London Clay. Groundwater flow through these clays is likely to be minimal, in practice being limited to seepage through any of the silt/sand partings which are sufficiently interconnected. Below 5.2m in BH2, "partings of brown and orange silt and fine sand" were recorded, however no individual silt/sand layers of sufficient size to warrant separate identification were found in the London Clay in either of the site-specific boreholes.
  - The horizon of gravel recorded beneath the Made Ground in BH1 was not found to be water bearing, however it may at times contain perched groundwater and much higher permeabilities should be expected within these gravels, compared with the underlying London Clay.
  - The hydrogeology may be complicated further by the backfill in service trenches and granular pipe bedding (where present) forming preferential groundwater flow pathways within the strata they pass through.

10.1.2 The hydrogeological regime outlined above will be affected by long-term climatic variations as well as seasonal fluctuations, all of which must be taken into account when selecting a design water level for the permanent works. No multi-seasonal monitoring data are available, so a conservative approach will be needed, in accordance with current geotechnical design standards which require use of 'worst credible' groundwater levels/pressures. See paragraph 10.2.6 for the recommended provisional design groundwater levels.

10.1.3 No railway tunnels are known to pass below or close to the site. Other infrastructure (including tunnels) for cables or communications might be present within the zone of influence of the proposed basement, so an appropriate services search should be undertaken. If any such infrastructure is identified, then its potential influence on the proposed basement must be assessed. These searches will not identify any private services.

10.2 Subterranean (Groundwater) Flow – Permanent Works

10.2.1 Most of the Made Ground comprised variably sandy, silty clays which are relatively low permeability materials, so are likely to permit little or no flow of any perched groundwater (unless the clays are voided). Perched groundwater would be expected at times where the upper part of the Made Ground was primarily silt or sand (BH1 and TP1, at the front part of the site) though flow is still expected to be minimal, and where the lower part of the Made Ground was primarily gravel (as in BH1) then any groundwater would be perched on the underlying natural clays.

10.2.2 No groundwater entries were recorded in the ground investigation's trial pits and boreholes (during digging/drilling), although the lack of a groundwater entry into a small diameter borehole in clayey strata does not necessarily mean that groundwater was absent; rather the low permeability of the clays merely means that the flow rate was too slow for groundwater entries to occur before the instrumentation (standpipes) were installed in the boreholes, or the boreholes were backfilled, and any water in silt/sand partings was sealed in by smearing of clays during the drilling process. However, if groundwater had been present in the gravel then it would have been recorded, so the gravel may be acting as an under-drain to the overlying Made Ground.

Existing Basements:

10.2.3 The only known existing basements in the vicinity of No.76 are those beneath No's 84/86, upslope of No.76 in the same terrace, though separated by three houses. A drawing with a 1996 planning application shows that this basement underlies the full footprint of No.84 and probably of both properties. These basements are not close enough to cause any cumulative effect, though might already partially obstruct any groundwater flow down the base of the valley.

Other Proposed Basements:

10.2.4 No planning consents were identified by our searches for other new basements beneath any properties which are sufficiently close to No.76 to create a cumulative impact on groundwater seepage/flows.

Proposed Basement at No.76:

10.2.5 Details of the proposed basement are provided in Section 3. The proposed founding depth (formation level) for the whole of the proposed basement is expected to be in the natural clays below the Made Ground. The basement will therefore obstruct any flows of perched groundwater but it is not expected to create any significant impact owing to the lack of evidence for perched groundwater, the mainly clayey nature of the Made Ground, and the minimal gradients. The service trenches beneath the carriageway and footway are likely to provide flow paths with higher permeabilities than most of the surrounding natural ground, with the exception of the gravel (which was dry). Thus the proposed basement is considered acceptable in relation to groundwater flow.

10.2.6 In the unlikely event that the basement excavations encounter a local deposit of more permeable soils containing mobile groundwater which has remained undetected within the London Clay (or the suspected Head deposits), of sufficient thickness and extent to permit significant flow, then it is possible that an engineered groundwater bypass might be required. This bypass would have to be detailed once the geometry of the permeable soil unit is known. Water-bearing claystone horizons in the London Clay can also permit significant seepage/flow and might require similar treatment if encountered.

10.2.7 The highest groundwater level reading from the standpipes during the limited monitoring period was 1.45m bgl in the rear garden. While the backfill to service trenches under Fleet Road may be acting as land drains, it is also possible that the 3.27m bgl maximum level in BH1 had not equilibrated with the surrounding groundwater, and so was not representative.

10.2.8 Current geotechnical design standards require use of a 'worst credible' approach to selection of groundwater pressures. On sites such as this where high plasticity clays are present close to surface, the groundwater table (or phreatic surface) may rise into the overlying Made Ground, at least in the wettest winters, unless mitigation measures such as land drainage can be installed. No acceptable disposal location exists for such water (because there is no accessible watercourse nearby, and Thames Water will not allow long-term disposal of groundwater to the mains drainage system). As a result, use of a provisional design groundwater level at the level of the rear garden is recommended for the whole basement, subject to further groundwater monitoring this winter.

10.2.9 The basement structure must be designed to resist the buoyant uplift pressures which would be generated by groundwater at the design level. The variable depth of the design water level means that the uplift pressures will also vary across the basement from 14kPa beneath the front lightwell, to 24kPa below the front basement and to 34kPa beneath the whole of the lower, rear part of the basement (both un-factored).

10.2.10 The proposed basement will need to be fully waterproofed in order to provide adequate long-term control of moisture ingress from the groundwater. Detailed recommendations for the waterproofing system are beyond the scope of this report although it is noted that, as a minimum, it would be prudent for the system to be designed in compliance with the requirements of BS8102:2009. If a cavity drainage system is used, then a sump and pumped collection system must be included.

10.2.11 The National House Building Council published new guidance on waterproofing of basements in November 2014 (NHBC Standards, Chapter 5.4). Compliance would be compulsory if an NHBC warranty is required, otherwise it may provide a useful guide to best practice.

10.2.12 In view of the "slightly pungent" state of the Made Ground in BH2, and elevated carbon dioxide readings, consideration should be given to making the basement airtight as well as watertight.

10.3 Subterranean (Groundwater) Flow – Temporary Works

10.3.1 Local groundwater entries/seepages may occur into the excavations for the basement though, on current evidence, they are likely to be minor and should be manageable by sump pumping provided that they are not being fed by defective drains or water supply pipes. It would be prudent to ensure the external isolation stopcock is both accessible and operational before the start of the works. An appropriate discharge location must be identified for the groundwater removed by sump pumping.

10.3.2 All groundwater control measures should be supervised by an appropriately competent person. A careful watch should be maintained to check that fine soils are not removed with the groundwater; if any such erosion/removal of fines is noticed, then pumping should cease and the advice of a suitably experienced and competent ground engineer should be sought.

10.3.3 The unloaded clays at/beneath formation level will readily absorb any available water which would lead to softening and loss of strength. It will therefore be important to ensure that the clays at formation level (onto which the underpins and the basement slab will bear) are protected from all sources of water, with suitable channelling to sumps for any groundwater seeping into the excavations. The formation clays should be inspected and then blinded with concrete immediately after completion of final excavation to grade. Any unacceptably soft/weak areas must be excavated and replaced with concrete.

10.4 Slope and Ground Stability

Slope Stability

10.4.1 With overall slope angles of approximately 0.75-2.4° around and upslope of this property, the proposed basement excavation raises no concerns in relation to the overall stability of the slope, subject to normal precautions in supporting the ground around the basement.

Basement Retaining Wall Construction

10.4.2 Fridum's drawing No.FR-STRU-1001 shows the proposed layout of underpinning bases required for the basement. The calculated levels/depths of the underpins for the front and rear parts of this basement and the front lightwell are explained in paragraphs 3.2 and 3.3.

10.4.3 The perimeter walls of the lightwells will be constructed as reinforced concrete (RC) retaining walls in panels not exceeding 1.0m in width (1.2m for the front lightwell) as shown on Fridum's plan, on the same 'hit and miss' basis as the underpinning.

10.4.4 Underpinning methods involve excavation of the ground in short lengths in order to enable the stresses in the ground to 'arch' onto the ground or completed underpinning on both sides of the excavation, together with the ability of stiff homogenous clays to stand un-supported for a limited period of time. Loads from the structure above will similarly arch across the excavation, provided that the structure is in good condition.

10.4.5 Some ground movement is inevitable when basements are constructed. When underpinning methods are used, the magnitude of the movements in the ground being supported by the new basement walls is dependent primarily on:

- the geology,
- the adequacy of temporary support to both the underpinning excavations and the partially complete underpins prior to installation of full permanent support;
- the quality of workmanship when constructing the permanent structure.

A high quality of workmanship and the use of high stiffness temporary support systems, installed in a timely manner in accordance with best practice methods, are therefore crucial to the satisfactory control of ground movements alongside basement excavations (see also 10.4.7 below). Any cracks in load-bearing walls which have weakened their structural integrity should be fully repaired in accordance with recommendations from the appointed structural engineer before any underpinning is carried out.

10.4.6 The minimum temporary support requirements recommended for the excavations for the proposed underpins and RC retaining walls at No.76, subject to inspection and review as described in 10.4.8 below, are:

- Full face support must be installed as the excavations progress for all excavations through the Made Ground and the gravels.
- Closely spaced support where any firm clay is present at the top of the London Clay/Head deposits.
- More widely spaced temporary support may be adequate in the stiff or very stiff clays of the London Clay Formation, depending on the degree of fissuring, except at corner excavations where closely spaced support should be provided.
- Temporary support will be required to all the new underpins and RC retaining wall panels, and must be maintained until the full permanent support has been completed, including allowing time for the concrete to gain adequate strength.

10.4.7 Under UK standard practice, the contractor is responsible for designing and implementing the temporary works, so it is considered essential that the contractor employed for these works should have completed similar schemes successfully. For this reason, careful pre-selection of the contractors who will be invited to tender for these works is recommended. Full details of the temporary works should be provided in the contractor's method statements.

10.4.8 In accordance with normal health and safety good practice, the requirements for temporary support of any excavation must be assessed by a competent person at the start of every shift, and at each significant change in the geometry of the excavations as the work progresses.

10.4.9 The construction sequence is covered in Fridum's Construction Method Statement.

Geotechnical Design

10.4.10 Design of the basement retaining walls must include all normal design scenarios (sliding, over-turning and bearing failure) and must take into consideration:

- Earth pressures from the surrounding ground (see also paragraph 10.4.11 below);
- Dead and live loads from the structures above, including loads from the adjoining buildings which are carried on the party walls;
- Surcharge loads from the load-bearing walls in the neighbouring properties which are within the zone of influence for active earth pressures acting on the basement walls;
- Vehicle loads on the adjacent footway and normal surcharge allowances elsewhere;
- Swelling displacements/pressures from the underlying clays;
- A provisional design groundwater level at ground level in the rear garden (see paragraph 10.2.8);
- Precautions to protect the concrete from sulphate attack.

10.4.11 The following geotechnical parameters should be used when calculating earth pressures:

Made Ground (clays):	Unit weight, γ_b:	18.0 kN/m^3
	Effective cohesion, c':	0 kPa
	Angle of internal friction, φ':	25°
River Terrace Deposits: (gravels)	Unit weight, γ_b:	19.0 kN/m^3
	Effective cohesion, c':	0 kPa
	Angle of internal friction, φ':	30°
London Clay Fm/Head:	Unit weight, γ_b:	20.0 kN/m^3
	Effective cohesion, c':	0 kPa
	Angle of internal friction, φ':	22°

Coefficient of earth pressure at rest, k_0: 1.0, after the likely existing higher stresses have been released by the excavations.

These parameters should be used in conjunction with appropriate partial factors dependent upon the design method selected.

10.4.12 The formation level clays onto which the underpins/RC walls and the basement slab will bear must be protected from water to prevent softening and loss of strength, as described in 10.3.3 above.

10.4.13 The extent of the root protection areas for the Silver Birch tree on the adjacent public footway should be identified; an arboricultural survey will therefore be required. Based on estimated distances and criteria given in NHBC Chapter 4.2, the proposed basement will be deep enough to be founded below the zone of significant influence of roots from this tree when mature.

10.4.14 Normal good practice in foundation construction requires progressive stepping up between foundations of different depths beneath a single structure. Subject to agreement under the Party Wall Act negotiations, transitional underpins should therefore be considered for all adjoining load-bearing walls in No's 74 & 78.

10.5 PDISP Heave/Settlement Assessment

Basement Geometry and Stresses:

10.5.1 Analyses of vertical ground movements (heave or settlement) have been undertaken using PDISP software in order to assess the potential magnitudes of movements which may result from the changes of vertical stresses caused by excavation of the basement. These preliminary analyses have not modelled the horizontal forces on the retaining walls, so have simplified the stress regime significantly.

10.5.2 Figure D1 in Appendix D illustrates the layout of the proposed basement. Figure D2 shows the layout of PDISP zones used to model the underpins and basement slab, based on Fridum's basement plan (Drg No. No.FR-STRU-1001). The maximum overall dimensions of the basement are approximately 5.0m wide by 16.3m long.

10.5.3 Table 2 presents the co-ordinates used to input the main elements of the basement's geometry into PDISP based on the illustration in Figure D2, together with the net changes in vertical pressure for four major stages of the stress history of the basement's construction, as detailed in paragraph 10.5.6 below. The gross bearing pressures which will be applied by the underpins and RC retaining walls were obtained from Fridum's design calculations for these retaining walls.

Table 2: Coordinates and changes in vertical stress for PDISP Zones

ZONE	Centroid		Dimensions		Net change in vertical pressure (kPa)		
#	Xc(m)	Yc(m)	X(m)	Y(m)	Stage 1	Stage 2	Stages 3 and 4
1	10.500	0.600	9.200	1.200	25.50	25.50	25.50
2	15.700	1.900	1.200	3.800	-31.00	-31.00	-31.00
3	10.500	4.400	9.200	1.200	25.50	25.50	25.50
4	3.400	4.400	5.000	1.200	48.10	48.10	48.10
5	0.450	3.100	0.900	3.800	-11.30	-11.30	-11.30
6	1.200	2.500	0.600	2.600	-21.30	-21.30	-21.30
7	3.400	0.600	5.000	1.200	48.10	48.10	48.10
8	6.400	2.500	1.000	2.600	-37.10	-37.10	-37.10
9	11.000	2.500	8.200	2.600	0.00	-65.20	-59.20
10	3.700	2.500	4.400	2.600	0.00	-43.60	-37.60
11	15.700	4.400	1.200	1.200	-10.90	-10.90	-10.90
12	7.050	0.600	2.300	1.200	-82.20	13.80	13.80
13	7.050	4.400	2.300	1.200	-82.20	13.80	13.80

Ground Conditions:

10.5.4 The ground profile was based on the site-specific ground investigation by Chelmer Site Investigations, as presented in Sections 9 and 10.1 above, and the desk study information.

10.5.5 The short-term and long-term geotechnical properties of the soil strata used for the PDISP analyses are presented in Table 3, based on this investigation and data from other projects.

Table 3: Soil parameters for PDISP analyses

Strata	**Level** (m bgl)	**Undrained Shear Strength,** Cu (kPa)	**Short-term, undrained Young's Modulus,** Eu (MPa)	**Long-term, drained Young's Modulus,** E' (MPa)
London Clay	3.0 13.0	80 155	40 77.5	24 46.5

Where:

Undrained shear strength, Cu assumed as Cu = 65 + 7.5z kPa
where z = depth below the top of the stratum (3.0m bgl)
Undrained Young's Modulus, Eu = 500 * Cu
Drained Young's Modulus, E' = 0.6 Eu

PDISP Analyses:

10.5.6 Three dimensional analyses of vertical displacements have been undertaken using PDISP software and the basement geometry, loads/stresses and ground conditions outlined above in order to assess the potential magnitudes of ground movements (heave or settlement) which may result from the vertical stress changes caused by excavation of the basement. PDISP analyses have been carried out as follows:

- Stage 1 – Construction of underpins/retaining walls – Short-term condition
- Stage 2 – Bulk excavation of central area to formation level – Short-term condition
- Stage 3 – Construction of basement slab – Short-term (undrained) condition
- Stage 4 – As Stage 3, except – Long-term (drained) condition

10.5.7 The results of the analyses for the Stages 2, 3 and 4 are presented as contour plots on the appended Figures D3, D4 and D5 respectively.

Heave/Settlement Assessment:

10.5.8 Excavation of the basement will cause immediate elastic heave in response to the stress reduction, followed by long-term plastic swelling as the underlying clays take up groundwater. The rate of plastic swelling in the in-situ clays will be determined largely by the availability of water and as a result, given the low permeability of the clays in the London Clay Formation, can take decades to reach full equilibrium. The basement slab will need to be designed so as to enable it to accommodate the swelling displacements/pressures developed underneath it.

10.5.9 The PDISP analyses indicated that only very small movements are likely to develop beneath the basement slab and walls. The ranges of predicted short-term and long-term movements for each of the main walls are presented in Table 4 below.

Table 4: Summary of predicted displacements

Location	Stage 2 (Figure D3)	Stage 3 (Figure D4)	Stage 4 (Figure D5)
Front lightwell	0 – 0.5mm Heave	< 0.5mm Heave	0 – 1mm Heave
76/74 & 76/78 party walls	0 – 1mm Heave	1mm Heave – 0.5mm Settlement	2mm Heave – 1mm Settlement
Transverse underpins across middle of basement	0.5 – 1.5mm Heave	0.5 – 1.5mm Heave	1 – 3mm Heave
Rear lightwell	0.5 – 1.5mm Heave	0.5 – 1.5mm Heave	1 – 3.5mm Heave
Centre of basement slab – front	0 – 1mm Heave	0 – 1mm Heave	0 – 2mm Heave
Centre of basement slab – rear	1.5 – 2.5mm Heave	1 – 2mm Heave	1 – 4.5mm Heave

10.5.10 All the short-term elastic displacements would have occurred before the basement slab is cast, so only the post-construction incremental heave/settlements are relevant to the slab design. The analyses indicated that the maximum predicted post-construction displacements beneath the slab are likely to be about 3mm (total and differential).

10.6 Damage Category Assessment

10.6.1 When underpinning it is inevitable that the ground will be un-supported or only partially supported for a short period during excavation of each pin, even when support is installed sequentially as the excavation progresses. This means that the behaviour of the ground will depend on the quality of workmanship and suitability of the methods used, so calculations of predicted ground movements can never be rigorous. However, provided that the temporary support follows best practice as outlined in Section 10.4 above, then extensive past experience has shown that the bulk movements of the ground alongside the basement caused by underpinning for a single-storey basement (typical depth 3.5m) should not exceed 5mm in either horizontal or vertical directions.

10.6.2 In order to relate these typical ground movements to possible damage which adjoining properties might suffer, it is necessary to consider the strains and the angular distortion (as a deflection ratio) which they might generate using the method proposed by Burland (2001, in CIRIA Special Publication 200, which developed earlier work by himself and others).

10.6.3 The adjoining properties on each side of No.76 are broadly similar, with parapet front and rear walls. The worst case scenario will occur at the main rear wall of the terrace, where the depth of excavation will be greatest, with the slight increase in wall height being of lesser influence. In addition, the main rear wall will not benefit from adjoining a corner of the basement (where the displacements will reduce owing to the presence of the adjacent unexcavated ground). Transverse walls in the adjacent rear projections are significantly higher than they are wide, so have a relatively low vulnerability of deflections following the procedure established by Burland et al.

10.6.4 A single damage category assessment has been undertaken for this worst case scenario; the assessment considered:

- ground movements arising from the vertical stress changes, as assessed by the PDISP analyses (see Section 10.5), including an allowance for the stiffness of the foundations;
- ground movements alongside the proposed underpins and retaining walls caused by relaxation of the ground in response to the excavations.

Ground movements associated with the construction of retaining walls in clay soils have been shown to extend to a distance up to 4 times the depth of the excavation.

No.78, rear wall of main house (applicable also to No.74):

10.6.5 The relevant geometries, based on information in paragraphs 3.2 and 3.3, are:

Depth of foundations = 0.45m (from TP2)
Depth of excavation = 3.35 – 0.45 = 2.90m.
Width (L), zone of affected soils = 2.9 x 4 = **11.6m**, so will reach the near side of No.82.
Height (H) = 11.3 + 0.45 = **11.75m** (parapet wall + foundation).
Hence L/H = **0.99**.

10.6.7 Thus, for an anticipated 5mm maximum horizontal displacement (reduced pro-rata to the limited depth of excavation), the strain beneath No's 78/80 would be in the order of $\varepsilon_h = 4.3 \times 10^{-4}$ (0.043%).

10.6.8 The maximum settlement predicted by the PDISP analysis beneath the 76/78 party wall, close to the rear wall, in Stage 4 was 1mm (0.5mm for the 76/74 party wall, though expected to be identical in practice). This must be added to the typical settlement caused by relaxation of the ground alongside the basement in response to excavation of the underpins, giving a maximum predicted settlement of the ground of approximately 6mm at the level of No.78's foundations. The settlement profile is expected to be convex, with a worst case (low stiffness) deflection, Δ = 0.07% of the excavation depth (based on Figure 2.11(b) in CIRIA Report C580), occurring at a distance greater than the depth of excavation from the excavation, so beyond the influence of the vertical stress changes modelled by PDISP. Hence, Δ = 2.03mm, which represents a deflection ratio, $\Delta/L = 1.72 \times 10^{-4}$ (0.017%). .

10.6.9 Using the graphs for L/H = 1.0, these deformations represent a damage category of 'very slight' (Burland Category 1, ε_{lim} =0.05-0.075%) as given in CIRIA SP200, Table 3.1, and illustrated in Figure 9 below.

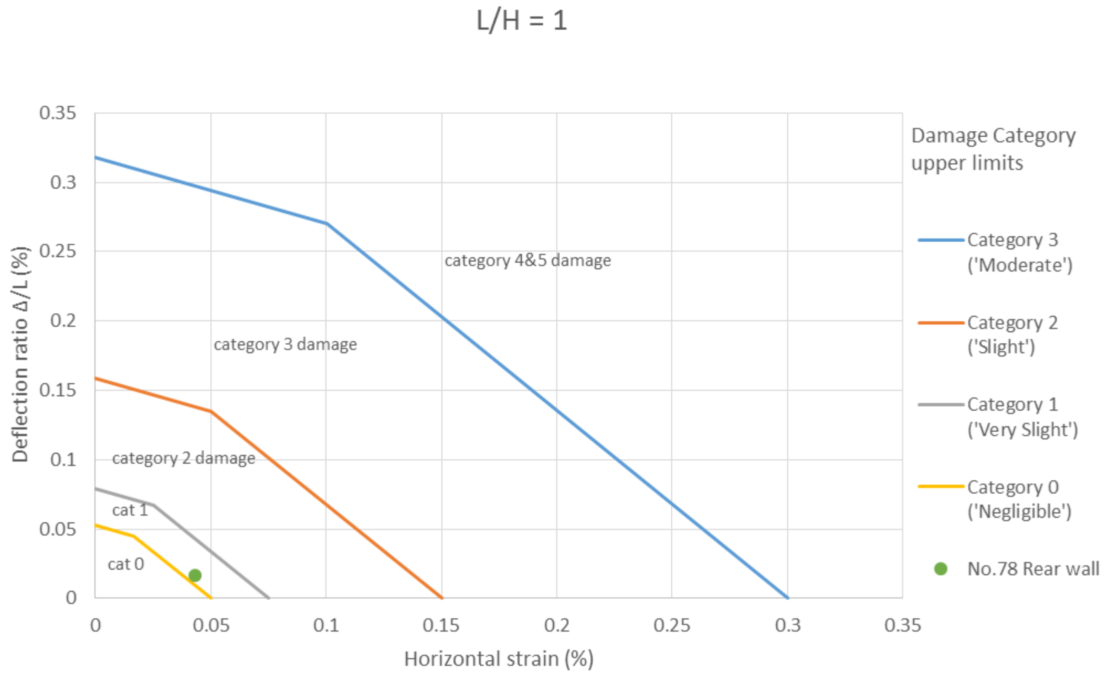

Figure 9: Damage category assessment for No.78's rear wall.

10.6.10 Use of best practice construction methods, as outlined in Section 10.4 above, will be essential in order to ensure that the ground movements are kept in line with the above predictions.

10.7 Monitoring

10.7.1 Condition surveys should be undertaken of the neighbouring properties before the works commence, in order to provide a factual record of any pre-existing damage. Such surveys are usually carried out while negotiating the Party Wall Award and are beneficial to all parties concerned.

10.7.2 Precise movement monitoring should be undertaken weekly throughout the period during which the basement walls and slab are constructed with initial readings taken before excavation of the basement starts. Readings may revert to fortnightly once all the perimeter walls and the basement slab have been completed. This monitoring should be undertaken with a total station instrument and targets attached at a minimum of two levels at the following locations:

- internally, at two equally spaced locations on the 76/74 party wall and at three equally spaced locations on the 76/78 party wall;
- externally, on the front wall, on the centrelines of the party walls with No's 74 & 78;
- externally, on the front walls of No's 74 & 78, on the centrelines of the 72/74 and 78/80 party walls;
- externally, on the main rear wall, at the junction with No.78's rear projection, at three positions and on the line of the 76/74 party wall above the rear projection;
- Subject to adequate sight lines, externally on No.74's main rear wall, at the junction with its rear projection;
- Externally on both rear corners of the rear projections to No's 74 & 78.

- at the client's discretion, since outside the Party Wall Agreement, it would also be sensible to monitor the rear projection to No.76.

10.7.3 The accuracy of this system of monitoring is usually quoted as +/- 2mm. Thus, if recorded movements in either direction reach 5mm, then the frequency of readings should be increased as appropriate to the severity of the movement, and consideration should be given to installing additional targets. If the recorded movements in either direction reach 8mm, then work should stop until new method statements have been prepared and approved by the appointed structural engineer.

10.7.4 If any structural cracks appear in the main loadbearing walls, then those cracks should be monitored using the Demec system (or similar) on the same frequency as the target monitoring.

10.8 Surface Flow and Flooding

10.8.1 The evidence presented in Section 5 has shown that:

- the site lies within the Environment Agency's Flood Zone 1 which means that it is considered to be at negligible risk of fluvial flooding;
- the site is not at risk of flooding from reservoirs, as mapped by the Environment Agency;
- Fleet Road was affected by the surface water flooding event in 2002 but not in 1975, although the extent of the road affected was probably quite small;
- there are no surface water features within 250m of the site;
- the latest flood modelling by the Environment Agency appears to show a 'Low' risk of surface water flooding in No.76's rear garden, and a localised 'Low' to 'High' risk of flooding on Fleet Road in the vicinity of No.76 (see Figure 6);
- The Camden SFRA (2014) shows that Fleet Road is not in a Critical Drainage Area, though predicts a very similar pattern of surface water flood risk as given in the Environment Agency's model.

<u>Change in Paved Surfacing & Surface Water Run-off:</u>

10.8.2 The proposed basement and lightwells will not result in any change in paved surface area because the two sections of flower bed which have to be removed for the rear lightwell will be replaced by a new flower bed immediately alongside the rear lightwell. All the other areas where the proposed basement extends beyond the footprint of the existing building are already fully paved. Thus, there will be no adverse effect on surface water run-off characteristics.

<u>Surface Water (Pluvial) Flooding:</u>

10.8.3 In view of the possible risk of surface water flooding in No.76's rear garden and on the adjacent part of Fleet Road (see Section 5), flood resistance measures will be required to protect the basement from local surface water flooding, including:

1. An upstand around the front lightwell.
2. Either a water-tight front door, or a raised threshold and a demountable flood barrier which can be fitted across the lower part of the front doorway when required.
3. A raised threshold at the access doorway from the rear lightwell into the basement, of sufficient height to protect the basement from the maximum depth of flooding in the lightwell predicted by appropriate calculations. It is likely to be beneficial to link the surface water storage volume in the lightwells with the temporary interception storage recommended in paragraph 10.8.6.
4. Removal of any low airbricks in areas which might flood and replacement with solid bricks.

5. Re-building the 76/74 boundary wall in the rear garden, and maintenance of all the boundary walls in good condition in the long-term.

<u>Sewer Flooding:</u>

10.8.4 The Camden SFRA noted that Thames Water's DG5 Flood Register had no records of flooding from public sewer affecting this post code area ('NW3 2', see 5.10). However, no drainage system can be guaranteed to have adequate capacity for all storm eventualities and all drainage systems only work at full capacity when they are properly maintained, including emptying gullies and regular checks of the sewers themselves for condition and blockages. Maintenance of the adopted sewers is the responsibility of Thames Water, so is outside the Applicant's control and largely outside of the Council's influence. The probability of future sewer flooding affecting No.76 is considered to be very low, provided that the sewer system is well maintained and appropriate flood resistance measures are implemented, as set out below.

10.8.5 Drainage systems are designed to operate under 'surcharge' at times of peak rainfall, which means that the level of effluent in the sewers may rise to ground level. When this happens, the effluent can back-up into un-protected properties with basements or lower ground floors. During major rainfall events it is possible for some sewers to overflow at ground level, though this is rare.

10.8.6 Non-return valves and/or pumped above ground loop systems must therefore be fitted on the drains serving the basement and the lightwells, in order to ensure that water from the mains sewer system cannot enter the basement when the adjacent sewer is operating under surcharge. All drains which discharge via the same outfall as the basement must be protected, including those carrying foul water and roof/surface water. A battery powered reserve pump should be fitted to ensure that the system remains functional during power cuts.

10.8.7 If non-return valves are used without above-ground loops, then no effluent would at times be able to enter the mains sewer system when the flow in that sewer is sufficient to close the valves. The basement could then be vulnerable to flooding via the gullies in the lightwells and/or other low entry points on the drainage system within the basement. Sufficient temporary interception storage would therefore be required, to hold temporarily the predicted maximum volume of water from all relevant sources which discharge via the valve-protected outfall (including surface water from the various roofs, lightwells, any drainage gullies in the rear garden, and foul water), for the duration of the predicted surcharged flows in the sewer. If decking is used in the rear lightwell, then the area beneath the decking could be used for interception storage, deepened as necessary to provide adequate capacity, though it must be protected from backup of foul sewage. This temporary interception storage would require formal design to ensure satisfactory performance.

10.8.8 If a non-return valve is fitted with an above-ground loop, then the loop must rise high enough above ground level to create sufficient pressure head to open the valve when the sewer flow is surcharged to ground level, otherwise the basement would once again be vulnerable to flooding while the surcharged flow continues. If it is not possible to achieve a sufficient rise of the loop above ground level, then temporary interception storage should be provided as recommended above.

10.9 Mitigation

10.9.1 The following mitigation measures have been recommended in Sections 10.2-10.8:

- In the unlikely event that the excavations encounter a local deposit of more permeable soils which has remained undetected, or the gravel in BH1 is found to support significant groundwater flow, then it is possible that an engineered groundwater bypass might be required (10.2.6).
- Any measures recommended by the arboricultural report proposed herein (see 10.4.13).
- Consideration should be given, under Party Wall Act protocols, to installation of transition underpins beneath all load-bearing walls to No's 74 & 78 (10.4.14).
- Creation of a new flower bed alongside the rear lightwell, as already shown on the scheme drawings, in mitigation for the loss of two small areas of the existing flower beds (see 10.8.2).
- Re-building the 76/74 boundary wall in the rear garden, and maintenance of all the boundary walls in good condition in the long-term (see 10.8.3).
- Provision of various other flood prevention measures as listed in paragraph 10.8.3.
- Non-return valves or pumped above ground loop systems should be fitted on the drains serving the basement and lightwells, with associated temporary interception storage (see paragraph 10.8.5, 10.8.6).

11.0 NON-TECHNICAL SUMMARY – STAGE 4

11.1 This summary considers only the primary findings of this assessment; the whole report should be read to obtain a full understanding of the matters considered.

11.2 A services search should be undertaken (10.1.3).

11.3 The proposed basement is considered acceptable in relation to the likely limited or nil flow of groundwater through the essentially clayey Made Ground and the London Clay. There are no basements close enough to create any cumulative effect (10.2.1 to 10.2.5). In the unlikely event that the excavations encounter a local deposit of more permeable soils which has remained undetected, or the gravel in BH1 is found to support significant groundwater flow, then it is possible that an engineered groundwater bypass might be required (10.2.6).

11.4 The highest recorded groundwater level in the standpipes was 1.45m bgl in the rear garden. The deeper water level in BH1's standpipe probably did not reflect the water pressures in the surrounding ground. A provisional design groundwater level equal to ground level in the rear garden is proposed, subject to review following further monitoring this winter, which means that the basement must be able to resist buoyant uplift pressures (un-factored) which vary across the basement up to 14-34kPa (10.2.7 to 10.2.9). The basement will need to be fully waterproofed and consideration should be given to making it airtight owing to the presence of slightly pungent Made Ground (10.2.10 to 10.2.12).

11.5 Water entries into the basement excavations are likely to be manageable by sump pumping (10.3.1). The clays onto which the underpins and the basement slab will bear must be blinded with concrete immediately following excavation and inspection (10.3.3).

11.6 There are no concerns regarding slope stability (10.4.1).

11.7 The basement will be constructed using underpinning techniques and RC retaining walls in panels of limited width. Use of best practice methods and high stiffness temporary support systems, installed in a timely manner, will be crucial to the satisfactory control of ground movements around the basement (10.4.2 to 10.4.8).

11.8 Various other guidance is provided in relation to the geotechnical design and construction of the basement's perimeter walls (10.4.10 to 10.4.12).

11.9 An arboricultural report is required regarding the Silver Birch tree on the public footway (10.4.13). Good practice requires stepping up between footings at different depths, so consideration should be given to installing transition underpins beneath all load-bearing walls to No's 74 & 78 under Party Wall Act protocols (10.4.14).

11.10 The basement slab must be designed to accommodate swelling displacements/pressures generated by heave of the underlying clays. A preliminary heave/settlement assessment has been undertaken using PDISP software which predicted between 1mm of settlement and 3.5mm of heave beneath the underpins, and up to 4.5mm of heave below the basement slabs. However, only the preliminary predicted 3mm of post-construction incremental displacement is relevant to the design of the basement slab (Section 10.5).

11.11 A damage category assessment indicated that, provided best practice construction methods are employed, the worst case predicted deformation (in the rear wall to the adjoining properties on both sides of No.76) is likely to fall within Burland Category 1, termed 'very slight' (Section 10.6).

11.12 Condition surveys of the neighbouring properties should be commissioned and a programme of monitoring the adjoining structures should be established before the works start (Section 10.7).

11.13 The basement will not alter the paved area draining to sewer at present, so should not result in any increase in surface water discharge to sewers (10.8.2).

11.14 The Environment Agency's recent modelling of risk of flooding from surface water appeared to predict a Low flood risk within No.76's rear garden, and a Low to High risk of surface water flooding on the adjacent part of Fleet Road (10.8.1). Recommendations are given for mitigation measures to increase the property's resistance to surface water flooding (10.8.3).

11.15 Thames Water had no records of flooding from public sewers affecting postcode area 'NW3 2', so the probability of future sewer flooding affecting No.76 is considered to be very low, provided that the sewer system is well maintained and appropriate flood resistance measures are implemented (10.8.4).

11.16 Non-return valves or pumped above-ground loop systems should be fitted to the drains serving the basement and gullies in the lightwells. Temporary interception storage may also be required, with sufficient capacity for the predicted maximum volume of discharges (from all sources) via the 'protected' outfall pipe(s), for the duration of the predicted surcharged flows in the sewer; formal design would be required (10.8.6 to 10.8.8).

11.17 Mitigation measures which have been recommended in Sections 10.2-10.8 are summarised in Section 10.9.

References

Arup (November 2010) Camden geological, hydrogeological and hydrological study – Guidance for subterranean development. Issue 01. London.

Barton N (1992) The Lost Rivers of London. Historical Publications Ltd, London.

BS 5930 (1999, 2010) Code of practice for site investigations. Including Amendment No.2. British Standards Institution, London.

BS 8002 (1994) Code of Practice for Earth retaining structures. British Standards Institution.

BS 8102 (2009) Code of practice for protection of below ground structures against water from the ground. British Standards Institution, London.

BS EN 1997-1 (2004) Eurocode 7: Geotechnical Design – Part 1: General rules. British Standards Institution.

Ellison RA et al (2004) Geology of London. Special Memoir for 1:50,000 Geological sheets 256 (North London), 257 (Romford), 270 (South London) and 271 (Dartford) (England and Wales). British Geological Survey, Keyworth.

London Borough of Camden (2003) Floods in Camden, Report of the Floods Security Panel.

NHBC (2016) NHBC Standards, Chapter 4.2, Building Near Trees.

NHBC (2016) NHBC Standards, Chapter 5.4, Waterproofing of basements and other below ground structures.

URS (2009) Camden Infrastructure Study: Utilities and Physical Infrastructure Needs Assessment.

URS (2014) London Borough of Camden SFRA – Strategic Flood Risk Assessment. Final report.

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Project:

76 Fleet Road, London, NW3 2QT

16493

Photo 1: Front elevation (street scene) looking north-east. No.76 Fleet Road is a 3-storey, mid terrace house, situated on the north side of Fleet Road, between No's 78 and 74.

Photo 2: Front elevation (street scene) looking north-west. To the west of No.76, No's 84/86 Fleet Road have basements, with iron-railings around the front lightwells.

Title:	**Photographs - Sheet 1**					Sheet	**A1**
Date:	November 2015	Checked:	AG	Approved:	KRG	Scale :	NTS

Project:

76 Fleet Road, London, NW3 2QT

16493

Photo 3 (above): The footway in front of No.76 falls gently towards the Fleet Road carriageway, away from the property. Note the small amenity area which extends across the full width of the property.

Photo 4 (left): To the rear of the house there is an original two storey rear projection, and a single storey rear extension which is a later addition to the property.

Title:	**Photographs - Sheet 2**					Sheet	**A2**
Date:	November 2015	Checked:	AG	Approved:	KRG	Scale :	NTS

Project:

76 Fleet Road, London, NW3 2QT

16493

Photo 5: The rear garden is surfaced with paving slabs alongside the rear projection, and concrete beyond it, with a perimeter raised flower bed formed from 'railway sleepers' surrounding the rear part of the garden. The brick boundry wall between No's 74 & 76 is in poor condition.

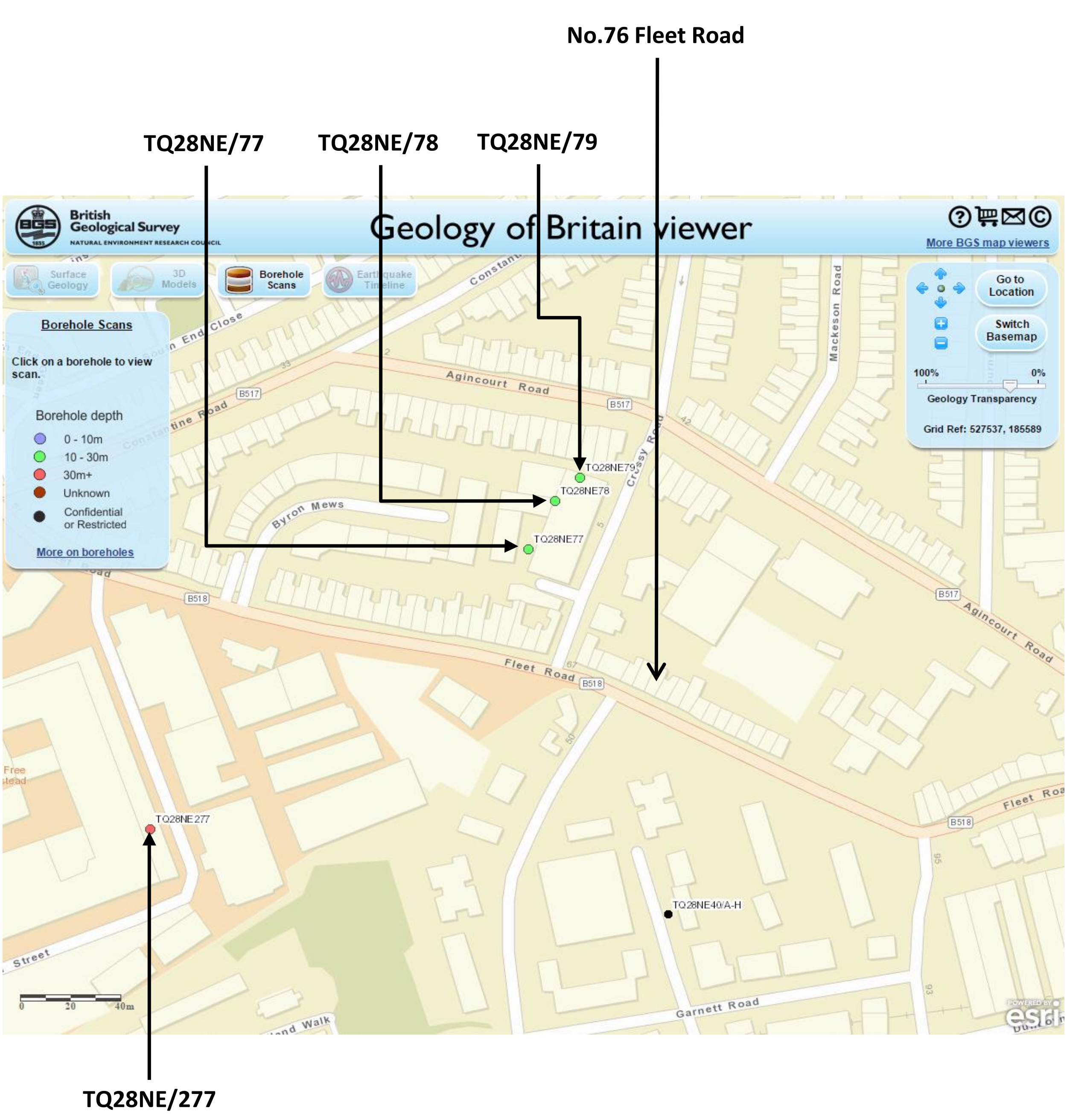
Photo 6: **H**igh brick walls form the northern and western boundaries to the site, between the Camden Ambulance Station and No.78 Fleet Road respectively. Note the iregular nature of the northern boundry, which is believed to follow the former course of the River Fleet.

Title:	**Photographs - Sheet 3**					Sheet	**A3**
Date:	November 2015	Checked:	AG	Approved:	KRG	Scale :	NTS

Project:

76 Fleet Road, London, NW3 2QT

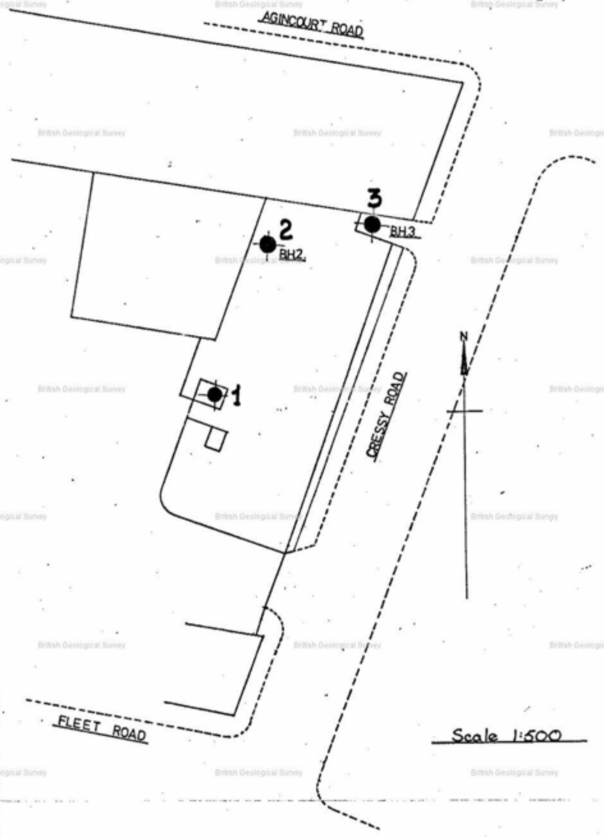
16493



Title:	**Location Plan of Boreholes**					Sheet	**B1**
Date:	January 2016	Checked:	AG	Approved:	KRG	Scale :	NTS

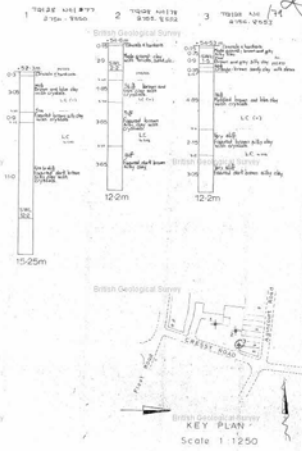
DUPLICATE. TQ/28NE/77-74.

1" : 256. 607



Site plan showing the location of Boreholes

GROUND EXPLORATIONS Ltd.	Drwn. by: WBH Ckd. by: BW	Report No. 5332
69/76 Alpha Street Slough, Bucks.	Date June 1971	Figure No. 1



Size A2 16½" x 23⅜" — 420mm x 594mm

div.	job no.	drg. no.	rev.
G	3287 SW	01	

JOB D.M.F.S. OFFICES & WORKSHOPS CRESSY ROAD CAMDEN

TITLE TRIAL BORINGS 1–3 KEY PLAN & SECTIONS

scale VERTICAL 1:100

date	drawn	checked
21.7.1971		N.C.T.

GLC ILEA

Dept of Architecture and Civic Design

Architect

01-633 5000 Ext. 8381

NOTES

1 Newlyn Datum Levels
2 ⌖ Denotes Trial Boring
3 WS. Denotes Water Strike
4 SWL Denotes Standing Water Level at the time of boring in July 1971

REVISIONS

no.	date

COPY

reference

div.	job no.	drg. no.	rev.
G	3287 SW	01	

Size A2 16½" x 23⅜" — 420mm x 594mm

TQ 28 NE /77-79.

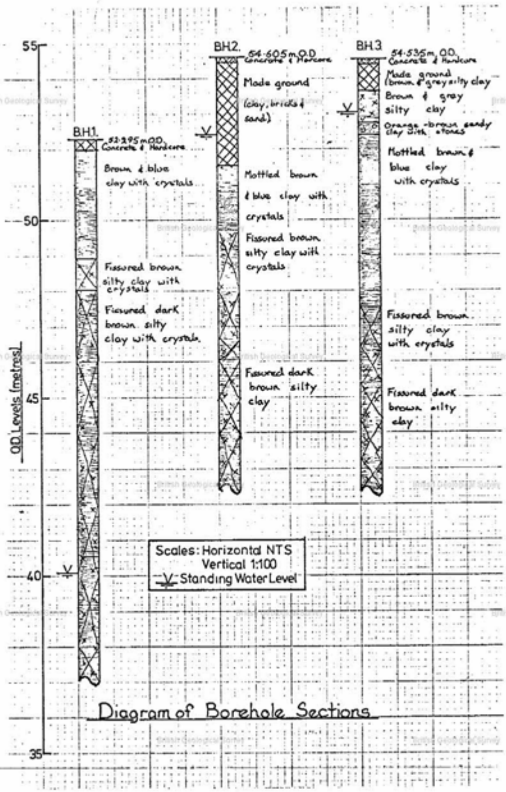


Diagram of Borehole Sections

GROUND EXPLORATIONS Ltd.	Drwn. by: WBH Ckd. by: BW	Report No. 5332
68/76 Alpha Street, Slough, Bucks.	Date July 1971	Figure No. 2

GROUND EXPLORATIONS LTD.

TQ28NE/77

BOREHOLE NO. 1

2754.8550.

Contract Name Cressy Road, Camden

Report No. 5332/DW/MA

Client Greater London Council,
Department of Architecture

Address and Civic Design,
The County Hall,
London, S.E.1.

ORDER NO.: BC.85977

Site Address
Cressy Road,
Camden,
London, N.W.3.

Standing Water Level 12.2 m.

Method of Boring Shell and auger

Water Struck -

Diameter 0.15m.

Ground Level 52.295m. O.D.

Start 7.6.71. Finish 9.6.71.

Remarks

JARS metres				CORES metres		BULK metres	
1530	0.75	1550	15.25	1531	1.05		
1532	2.3	1551	Water	1533	2.6		
1534	3.5			1535	4.1		
1536	4.7			1537	5.65		
1538	6.25			1539	7.15		
1540	7.75			1541	8.7		
1542	9.3			1543	10.2		
1544	10.8			1545	11.75		
1546	12.35			1547	13.25		
1548	13.85			1549	14.8		

Description	Thickness m	Depth m
Concrete and hardcore.	0.3	0.3
Stiff Brown and blue clay with crystals	3.05	3.35
Firm Fissured brown silty clay with crystals	0.9	4.25
Firm to stiff fissured dark brown silty clay with crystals.	11.0	15.25
TOTALS	15.25	15.25

Notes 1. Descriptions are in accordance with B.S. Code of Practice C.P. 2001
Clients are requested to compare with samples submitted.
2. Core samples are nominally 4 ins. diameter and 18 ins. long.
Depths shown are to top of sample.

GROUND EXPLORATIONS LTD.

TQ/28NE/78
2755 8552

BOREHOLE NO. 2

Contract Name: Cressy Road, Camden.
Report No. 5332/BW/MA

Client Address: Greater London Council, Department of Architecture, and Civic Design, The County Hall, London, S.E.1.
ORDER NO.: BC.85977

Site Address: Cressy Road, Camden, London, N.W.3.

Standing Water Level: 2.2 m.
Method of Boring: Shell and auger
Water Struck: -
Diameter: 0.15 m.
Ground Level: 54.605 m. O.D.
Start: 3.6.71.
Finish: 9.6.71.

Remarks

JARS metres		CORES metres		BULK metres	
1513	0.75	1517	3.5	1514	1.5
1515	2.3	1519	5.05		
1516	3.2	1521	6.55		
1518	4.7	1523	8.1		
1520	5.65	1525	9.6		
1522	7.15	1527	11.15		
1524	8.7				
1526	10.2				
1528	12.35				
1529	Water				

Description	Thickness m	Depth m
Concrete and hardcore	0.15	0.15
Made ground : clay with bricks, sand, etc.	2.9	3.05
Stiff brown and blue clay with crystals	1.85	4.9
Stiff Fissured brown silty clay with crystals	3.65	8.55
Stiff Fissured dark brown silty clay	3.65	12.2
TOTALS	12.2	12.2

Notes 1. Descriptions are in accordance with B.S. Code of Practice C.P. 2001
Clients are requested to compare with samples submitted.
2. Core samples are nominally 4 ins. diameter and 18 ins. long.
Depths shown are to top of sample.

PR9308

GROUND EXPLORATIONS LTD.

TQ28NE179
2756.8553

BOREHOLE NO. 3

Contract Name Cressy Road, Camden — Report No. 5332/BW/MA

Client Greater London Council, Department of Architecture
Address and Civic Design, The County Hall, London, S.E.1.
ORDER NO.: BC.85977

Site Address Cressy Road, Camden, London, N.W.3.

Standing Water Level 1.5 m. — Method of Boring Shell and auger

Water Struck - — Diameter 0.15 m.

Ground Level 54.535 m. O.D. — Start 28.5.71. Finish 9.6.71.

Remarks No water encountered while drilling. Bore left open over weekend - now standing at 5'0" from surface.

JARS metres				CORES metres			BULK metres	
8294	0.75	1600 Water		8296	1.05			
8295	1.05			8298	2.0			
8297	2.0			8300	3.5			
8299	2.9			1502	5.05			
1501	4.4			1504	6.55			
1503	5.95			1506	8.1			
1505	7.45			1509	9.6			
1507	9.0			1511	11.15			
1508	9.3							
1510	10.8							
1512	12.2							

Description	Thickness m	Depth m
Concrete and hardcore	0.15	0.15
Made ground : brown and grey silty clay	0.75	0.9
Firm Brown and grey silty clay	0.9	1.8
Stiff Orange-brown sandy clay with stones	0.35	2.15
Stiff Mottled brown and blue clay with crystals	4.85	7.0
Very stiff Fissured brown silty clay with crystals	2.15	9.15
Very stiff Fissured dark brown silty clay	3.05	12.2
TOTALS	12.2	12.2

Notes 1. Descriptions are in accordance with B.S. Code of Practice C.P. 2001
Clients are requested to compare with samples submitted.
2. Core samples are nominally 4 ins. diameter and 18 ins. long.

Site Plan

Notes

Borehole originally drilled for abstraction. Due to extremely low yield converted to OBH.

ROYAL FREE HOSPITAL 256 | TQ 28/198 [redacted]

Owner ROYAL FREE HAMPSTEAD NHT	Licence No.	Nat. Grid Ref. TQ 2739 8538	
Occupier " "	IGS Ref. No.	Status OBH	
Ground Level	m OD	ft. OD	Aquifer UPPER CHALK
Level of Well Top 59.280	m OD	ft. OD	
Rest Water Level 95.65	m bwt	ft. bwt	
(Date 26/7/99)	m OD	ft. OD	

Construction

Depth bwt m	Dia. mm	Linings (below well top) From	To m	Dia. mm	Type
114	300	0	114	200	plain
177	200				

Summary of Geological Section	Thickness m	Depth m
LONDON CLAY	69	69
W&RB	21	90
Thanet Sands	11	101
UPPER CHALK	76	177

Abstraction Rates gph gpd

Type of Pump

Chem./Bact. Anal. YES NO

Well Driller Soil Mechanics

If insufficient space has been allowed, continue in 'Notes' overleaf.

This record has already been entered, but contains some geological information.

*Not found as registered!

EASTERN LS THAMES EA

256 TQ 28 NE

ROYAL FREE HOSPITAL

TQ28/198

Owner ROYAL FREE HAMPSTEAD NHT	Licence No.		
Occupier " "	IGS Ref. No.		
Ground Level	m OD		ft. OD
Level of Well Top	m OD		ft. OD
Rest Water Level 95.65	m bwt		ft. bwt
(Date 26/7/99)	m OD		ft. OD

Nat. Grid Ref. TQ 2739 8538

Status OBH

Aquifer CHALK

Construction

Depth bwt m	Dia. mm	Linings (below well top) From	m To	Dia. mm	Type
114	300	0	114	200	plain
177	200				

Abstraction Rates | Type of Pump

gph | Chem./Bact. Anal. YES NO

gpd | Well Driller [redacted] Soil Mechanics

Summary of Geological Section	Thickness	Depth

If insufficient space has been allowed, continue in 'Notes' overleaf.