TRIGRAM PARTNERSHIP

5 KEMPLAY ROAD, LONDON NW3 1TA

GROUND MOVEMENT IMPACT ASSESSMENT

REVISION 0

NOVEMBER 2014

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1 Introduction

It is proposed to demolish the existing 2-storey semi-detached building and replace it with a larger 3-storey building and a new one level basement underneath its footprint at 5 Kemplay Road, NW3 1TA. Geotechnical Consulting Group LLP (GCG) has received an instruction from Trigram Partnership on behalf of Mr & Mrs Fournier, to undertake an assessment of the likely ground movements resulting from the proposed redevelopment works and to determine its potential impact on the adjacent properties, (in particular, 3 and 7 Kemplay Road).

This report has been prepared by GCG and includes a review of the available information about the site and the proposed construction works relevant to this assessment. It also presents the development of ground movements predicted at different construction stages and their impact on the adjacent properties.

It should be noted that all the information relating to the proposed scheme and the adjacent properties have been supplied by Trigram Partnership. It is outside the scope of this report to consider the adequacy of works as proposed or to consider the impact of the scheme on any other assets.

2 Existing site and proposed redevelopment

The site lies within the London Borough of Camden (LBC) and is located to the south of Kemplay Road and to the northwest of Pilgrim's Lane (Figures 1 and 2). Hampstead Underground Station is about 350m to the northwest of the property and Hampstead Heath Rail Station about 350m to the southeast. The Northern Line Underground Tunnels are about 150m to the southwest of the property.

The site is of a rectangular shape with approximate plan dimensions of 27m x 10.5m, with its shortest side orientated in approximately east-west direction, and it fronts onto Kemplay Road roughly to the north. Currently, a two-storey semi-detached terraced house partially extended in the south and in the east, occupies the site, and is accessed through a paved driveway from Kemplay Road. The ground floor plan of the existing property is shown in Figure 3. At the back of the property, a paved patio, an awning with glass roof, a garden with shrubs around its eastern and southern boundary walls, and a garden shed in the southeast with a paved walkway from the back are present.

Four trial pits dug as part of the site specific ground investigation (MRH, 2013a) revealed that the building is founded on concrete strip footings at approximately 0.9m bgl except its eastern side extension flank wall which is founded at about 0.65m bgl. Site specific survey information suggests that the ground floor level of the existing building is about +85m OD. Therefore, the foundation depths 0.9m bgl and 0.65m bgl correspond to elevations +84.1m OD and +84.35m OD.

The site is bounded by private properties in the east and west: 3 Kemplay Road, an older three-storey semi-detached house to the east, and 7 Kemplay Road, a two-storey semi-detached terraced house (adjoining 5 Kemplay Road) immediately to the west (see Figures 2 and 4). It is understood that 3 Kemplay Road has a cellar within its rear half extending to a depth of approximately 1.5m below its ground floor level. It is believed that ground floor level of 3 Kemplay Road is 0.5m lower than that of 5 Kemplay Road. Therefore, the base of the cellar corresponds to an elevation of approximately +83m OD.

The desk study report & historical maps produced by MRH Geotechnical (MRH, 2013b) suggests that the Kemplay Road and other surrounding roads were laid out by 1878 and the current building has been present since 1965.

It is proposed to redevelop the site by demolishing the existing two-storey building and replacing it with a larger three-storey building and a new one level basement underneath the existing building's footprint. Figure 5 shows the plans of the proposed redevelopment at basement and ground floor levels together with the extents of the proposed basement. No. 3's existing basement / cellar is also shown on the figure, highlighted by red dotted lines. Figure 6 shows section view of the proposed redevelopment. The proposed basement is rectangular in shape with approximate plan dimensions of 14m x 10m approximately covering about 50% of the length and 95% of the width of the site. The longer axis of the proposed basement is orientated perpendicular to Kemplay Road, approximately in north-south direction. The depth of excavation for the basement is anticipated to be about 3.55m below the ground floor level of the existing building (which corresponds to +81.45m OD) except for the localised sump in the northwest which will be slightly deeper.

It is understood that the basement will be constructed using a bottom-up construction methodology. It is anticipated that a sheet pile wall, with interlocking steel sheet piles driven into the ground using a vibration-free hydraulic ram, will be installed around the proposed basement prior to the excavation. The excavation will be supported by a two-level temporary propping, as shown in Figure 6, in the short term (i.e. during excavation) and by the cast in-situ water-proofed Reinforced Concrete (R.C) retaining walls around the inside of sheet pile walls, with the ground floor slab and the basement slab providing lateral support, in the permanent condition. Therefore, it is anticipated that the sheet pile wall may not be required to extend significantly deeper than the excavation depth.

The Patio at the back of the basement will be supported by new mass concrete foundation and reinforced concrete (RC) retaining walls (see Figures 5).

3 Ground conditions

Site specific ground investigation suggests that the ground within the site is relatively level with an elevation of about +85m OD except the entrance to the driveway at the front, which is slightly sloping down towards the pavement on Kemplay Road.

The desk study report by MRH Geotechnical suggests a drop in pavement level by about 0.5m from west to east across the whole width of the site, and rising ground at the driveway entrance with respect to the pavement, along Kemplay Road. The topography of the surrounding area, the pavements on Kemplay Road (to the north of the site running west to east) and Willoughby Road (to the east of the site running north to south), suggests that the pavement level falls to the east and to the south. It also suggests that the ground in No. 3's garden area is about 0.5m lower than that of No. 5 with its eastern boundary wall retaining 0.5m of the material.

The geology of the area is shown on the 1920 British Geological Survey 1:10560 sheet NI S.E. (Figure 7) and on the 1982 Geological Survey 1:10560 sheet TQ28NE. The site is underlain by Claygate Beds overlying the London Clay formation. Approximately 100m away to the southwest of the site, Bagshot Sands are shown to overlie the Claygate Beds. A BGS borehole shown on Figure 7, about 90m away from the site, indicates that the geology consists of about 2m of Made Ground, overlying nearly 108m of London Clay (including Claygate Beds). Lambeth Group, Thanet Sand and Chalk underlie the London Clay in the same order. The most recent, 1993, BGS 1:50000 North London, England and Wales, sheet 256 also shows that the site is underlain by Claygate Beds and then by the London Clay. Two boreholes have been obtained from the BGS records. The boreholes (TQ28NE6 and TQ28NE304) are about 100m away to the northwest and west of the site respectively (Figure 8), both boreholes extended to about 180m depth. They consistently show the presence of about 2m of Made Ground, over about 108m of London Clay (to around -15m OD), 15m of Lambeth Group (to around -30m OD), 10m of Thanet Sand (to around -40m OD) and the Chalk, in the same order of succession.

A site-specific ground investigation was carried out by MRH Geotechnical between 17th and 27th September 2013. This comprised one borehole at the front in the driveway (BH1) and two boreholes in the rear garden (BH2 to BH3), each to a depth of about 10m bgl. Four trial pits, TP1 to TP4, were also excavated in order to reveal the type and depth of existing foundation. The locations of all the above are shown in Figure 9. Groundwater monitoring standpipes were installed in all the three boreholes, BH1 to BH3, one in each to a depth of 10m bgl.

These boreholes revealed a thin layer of Made Ground of between 0.25m to 1.2m thick underlain by Claygate Beds. The latter was proved to be about 4.1m to 5.7m thick, extending down to about 6.9m bgl, where the top of the London Clay was encountered. All the three boreholes were terminated at 10m bgl within the London Clay stratum and did not prove the top of the underlying Lambeth Group.

Based on the site specific ground investigation data combined with the published BGS geological maps and nearby BGS boreholes, an assumed stratigraphy has been developed for the site, as follows:

Made Ground	0.25m to 1.2m thick	(to +83.8m OD)
Claygate Beds	4.1 to 5.7m thick	(to +77.8m OD)
London Clay	93m thick	(to -15m OD)
Lambeth Group	15m thick	(to -30m OD)
Thanet Sand	10m thick	(to -40m OD)

The Made Ground was described as soft to firm or compacted dark grey / black / dark brown sandy clay / clayey sand with occasional or traces of brick fragments. In TP1 to TP4, brick rubble, concrete, roots and clay or silt fill were found. The Claygate Beds mainly comprised of thin layers of firm orange / brown / bluish grey silty and/or sandy clay over the upper 3m, becoming stiff grey silty clay in the last 1m. The London Clay was described as very stiff fissured dark grey clay from below the Claygate Beds to the base of boreholes at 10m bgl.

Water seepages were encountered in two (i.e. BH2 & BH3) of the three boreholes during drilling, at 3.1m bgl and 3.4m bgl, which correspond to +81.48m OD and +81.30m OD. The other borehole, drilled in the front driveway (i.e. BH1), remained dry throughout the drilling. Standpipe installations in all these boreholes have been completed between the 17th and 18th of Sept. 2013. The subsequent post-field works monitoring data up to August 2014 indicated the groundwater levels fluctuated between +82.2m OD and +83.7m OD.

4 Ground movements

4.1 General

There is a potential for ground movements due to the proposed development works including the demolition of the existing building, installation of sheet piles, bulk excavation for the new basement, and construction of the new structure. It is envisaged that the works will take place in the same sequence. Therefore, for the purpose of determining the likely ground movements, the following construction stages were considered.

- Stage 1: Demolition of existing building
- Stage 2: Installation of sheet piles
- Stage 3: Bulk excavation for the new basement
- Stage 4: Construction of new structure

The ground movements due to each of the above construction stages and the corresponding impact on the adjacent properties are discussed in the following subsections.

Ground movement contours are presented for a depth of 1m below ground level which is representative of the foundation level for 7 Kemplay Road. While the basement and foundation level of 3 Kemplay Road is deeper, it is expected that the ground movements will be smaller than those predicted at 1m below ground level.

4.2 Stage 1: Demolition of existing building

The demolition of existing building causes an unloading of about 17 to 22kPa over its footprint as shown in Figure 10. As a result of this unloading, the underlying ground will undergo a reduction in vertical stress and will therefore heave.

A ground movement analysis due to the changes in vertical loading was undertaken using a computer program Oasys Pdisp. This program assumes a linear elastic behaviour of the soil and a flexible structure. The calculations therefore represent 'greenfield' ground conditions (i.e. unaffected by the stiffness of the structures) and are considered to be conservative.

The analysis was carried out based on the short-term (undrained) stiffness values presented in Table 1. These were derived on the following basis:

- For the Made Ground, the Young's modulus was taken as 10MPa, and was assumed constant with depth.

- For the Claygate Beds and London Clay Formation, the undrained Young's modulus (E_u) is assumed to vary with depth and is normally taken as $450c_u$. There is some uncertainty as to how the undrained shear strength (c_u) data presented in the ground investigation reports were derived. Consequently, undrained Young's modulus (E_u) (in MPa) was taken as 10+5.2z for the Claygate Beds and London Clay Formation (where z is the depth in m below the surface of the Claygate Beds), based on Burland and Kalra (1986). As shown in Figure 11, this provides a conservative estimate for undrained strength. Drained Young's modulus (E') was taken as 0.8 E_u for both the Claygate Beds and London Clay Formation.

Table 1: Soil stratigraphy and stiffness parameters adopted in Pdisp model

Strata	*Level at top (mOD)*	*Short-term (undrained)*			*Long-term (drained)*		
		E_u (top), kPa	*E_u (base), kPa*	*Poisson's ratio*	*E' (top), kPa*	*E' (base), kPa*	*Poisson's ratio*
Made Ground	+85.0	10000	10000	0.2	10000	10000	0.2
Claygate Beds	+83.8	10000	41200	0.5	8000	32960	0.2
London Clay Formation	+77.8	41200	523760	0.5	32960	419008	0.2

Note: Rigid boundary taken as -15.0mOD (approximate top of the Lambeth Group Formation)

Figure 12 shows the contours of predicted vertical ground movement (heave shown as negative values) due to demolition of the existing building in the short-term. The contours indicate that up to 4mm of heave is predicted outside the footprint of the proposed redevelopment.

4.3 Stage 2: Installation of sheet piles

Ground movements due to the installation of sheet piles depend upon the size of the sheet piles, the method used for installation, and the quality of workmanship. Generally, the movements are likely to be in the form of heave in cohesive soils since sheet piles are displacement piles. Assuming that installation techniques that minimise movements are employed, vertical ground movements might be extended to a horizontal distance up to a pile length on either side of the pile, with the total volume of ground heave being equal to the volume of the sheet pile installed. For the purpose of estimating the likely ground movements, the sheet pile wall is conservatively assumed to be 8.2m long (i.e. at least 1m embedment into the London Clay) with a cross-sectional area of $113.3\text{cm}^2/\text{m}$ run for a "U602" type sheet pile wall. This assumption gives a maximum potential heave of about 11.3mm next to the pile wall to 0mm of heave at 8.2m distance away from the pile wall. The horizontal ground movements due to installation of sheet piles are generally considered to be small.

Careful control of works will be required, since poorly controlled sheet pile installation can generate excessive ground movements.

Sheet pile installation may also induce noise and ground vibrations. Detailed assessments of the noise and vibrations due to sheet pile installation are outside the scope of this report. Appropriate noise and vibration control measures may be required.

4.4 Stage 3: Bulk excavation for the new basement

Bulk excavation for the new basement causes the ground outside the footprint of excavation to move towards the excavation due to loss of support, and the ground within the footprint of excavation heaves due to the changes in vertical loading caused by the removal of soil.

The magnitude and extent of ground movements resulting from the excavation in front of the piled wall are typically estimated based on the guidance given in the CIRIA publication *C580 Embedded retaining wall – guidance for economic design*. This guidance is based on the behaviour of embedded walls at numerous sites in London. These are predominantly walls embedded in the London Clay, though typically with some near surface deposits consisting of Made Ground, and hence the conditions at this site (i.e. 5

Kemplay Road) are compatible with the dataset on which the CIRIA guidance is based on.

Excavation for a basement in front of a sheet pile wall will induce vertical and horizontal movements of the ground behind the wall. The depth of excavation for the proposed basement has been taken as 3.55m. The excavation is assumed to be supported by a series of temporary props at two levels as shown indicatively in Figure 6 (providing high support stiffness, as defined in CIRIA C580) during the construction and by the basement raft and ground floor slab in the permanent condition.

CIRIA guide indicates that for a rectangular excavation with high support stiffness such as assumed here, the ground movements are a maximum of 0.15% of the excavation depth horizontally and 0.1% vertically. The resulting maximum ground movements due to excavation are about 5mm horizontally and 3 to 4mm vertically. These movements do assume a relatively high stiffness propping system being applied, but do not allow for the stiffening effects of corners. Also, the CIRIA guide indicates that maximum vertical movements do not occur immediately adjacent to the wall, but at a distance approximately half the excavation depth (i.e. 1.78m) away from the wall. The vertical movement immediately adjacent to the wall is 0.05% of the excavation depth, which is about 2mm. Vertical movements due to excavation become negligible beyond 3.5 times the excavation depth (i.e. 12.4m) from the wall whereas the horizontal movements become negligible beyond 4 times the excavation depth (i.e. 14.2m).

4.5 Stage 4: Construction of new structure

As discussed in Section 2, the new structure will be founded on a raft foundation. The loads imposed by the new structure were supplied by Trigram Partnership (Figure 13). The figure indicates that the new structure imposes a loading of about 36kPa which is relatively small compared to the loads removed by the demolition and excavation as in Stages 1 and 3. Also, it is understood that the new structure does not impose any additional loads onto the sheet pile walls.

The ground movement analyses due to the net vertical loading between the demolition of the existing structure, excavation and construction of new structure were undertaken using Pdisp (as discussed in Section 4.2) based on the short-term and long-term stiffness values presented in Table 1. It should be noted that Pdisp tends to over-predict the magnitude of ground movements outside the footprint of the new basement structure as it does not consider the influence of the sheet pile wall around the basement. Therefore the predicted ground movements outside the footprint are likely to be conservative. Also, it should be noted that the ground movements discussed in Section 4.4, based on CIRIA C580, generally include the effects of excavation and construction of new structure in the short-term.

Figure 14 shows the contours of vertical ground movements that are predicted to occur between the short-term and long-term conditions (i.e. after the construction of new structure) due to the net vertical loading imposed by the proposed redevelopment. The contours indicate that the adjacent properties, 3 and 7 Kemplay Road, are predicted to be subjected to up to 2 to 3mm of heave in the long-term.

5 Ground movement impact on the adjacent buildings

The predicted vertical and horizontal ground movements presented in Section 4 suggests that the adjacent properties located at 3 and 7 Kemplay Road will be affected by the proposed works. A summary of predicted ground movements at the end of Stages 1 to 4 are presented in Table 2 below.

Table 2: Summary of predicted ground movements at the end of Stages 1 to 4

Construction Stage	*3 Kemplay Road*		*7 Kemplay Road*	
	Accumulated maximum vertical movement (mm)	*Accumulated maximum horizontal movement (mm)*	*Accumulated maximum vertical movement (mm)*	*Accumulated maximum horizontal movement (mm)*
Stage 1: Demolition of existing building	-1	Negligible	-3	Negligible
Stage 2: Installation of sheet piles	-12	Negligible	-14	Negligible
Stage 3: Bulk excavation for the new basement	-7	4	-9	4
Stage 4: Construction of new structure	-9	4	-12	4

Note: -ve vertical movement indicates heave; and +ve horizontal movement indicates ground moving towards the basement.

Based on the predicted ground movements summarised above, the properties 3 and 7 Kemplay Road are unlikely to suffer any damage greater than CIRIA C580 Damage Category 1 (Very Slight). The potential degrees of damage corresponding to different Damage Categories are described in Table A1 of Appendix A.

6 Conclusions

This report presents the assessment of the effects of the proposed redevelopment at 5 Kemplay Road on the adjacent buildings. It describes analyses undertaken, outlines the underlying assumptions and presents the results of the analyses.

Demolition of the existing building, installation of sheet piles, excavation of the basement up to a maximum depth of 3.55m below the existing ground level and construction of the new structure have been considered in the assessment. It is concluded that the existing buildings at 3 and 7 Kemplay Road are likely to be affected by the proposed works.

The predicted maximum degree of damage to 3 and 7 Kemplay Road, assuming the structures are currently in good condition, at various construction stages is unlikely to be more severe than Damage Category 1 (Very Slight).

In general, ground movements can be minimised by careful supervision of the works, ensuring that a high quality of workmanship is maintained.

Groundwater control measures will be required to minimise the groundwater inflow during the excavation and construction of the basement.

Any remedial measures undertaken to repair damage resulting from the ground movements, such as redecorating, should be delayed until the redevelopment work at 5 Kemplay Road is completed, to allow time for most of these ground movements to develop.

Sheet piles are assumed to be pushed into the ground by “silent and vibrationless” system. In any case, assessment of the impact of noise and vibration during sheet pile wall installation has not been considered in this report and should be carried out separately, if needed.

This assessment has been based on the information provided by Trigram Partnership and some assumptions where necessary. In particular, high support stiffness is assumed during the excavation and construction of basement. If any of the details changes (e.g. retaining system, method of installing the piles, construction sequence, temporary propping), this assessment will need to be reviewed and confirmed.

7 References

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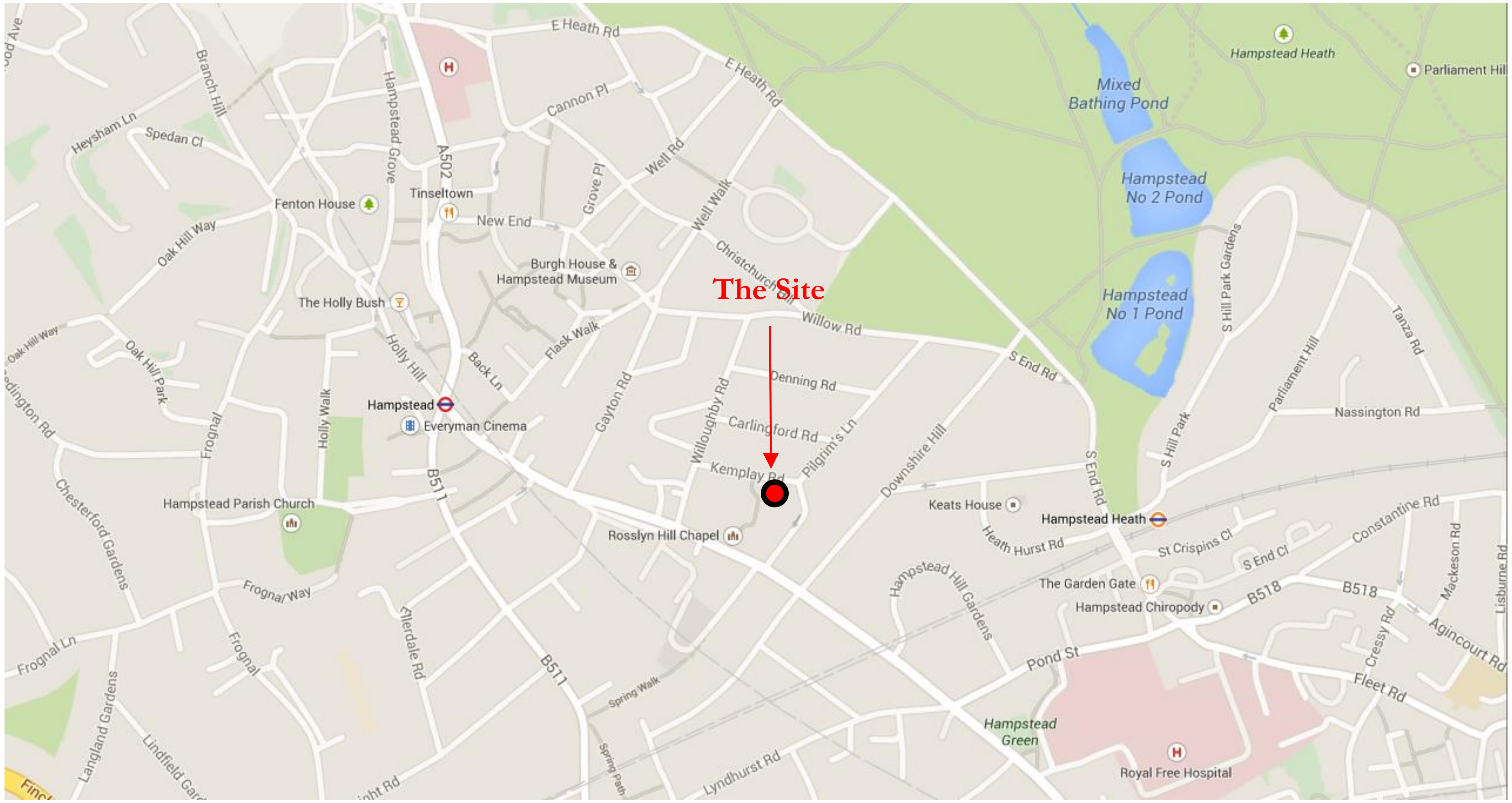
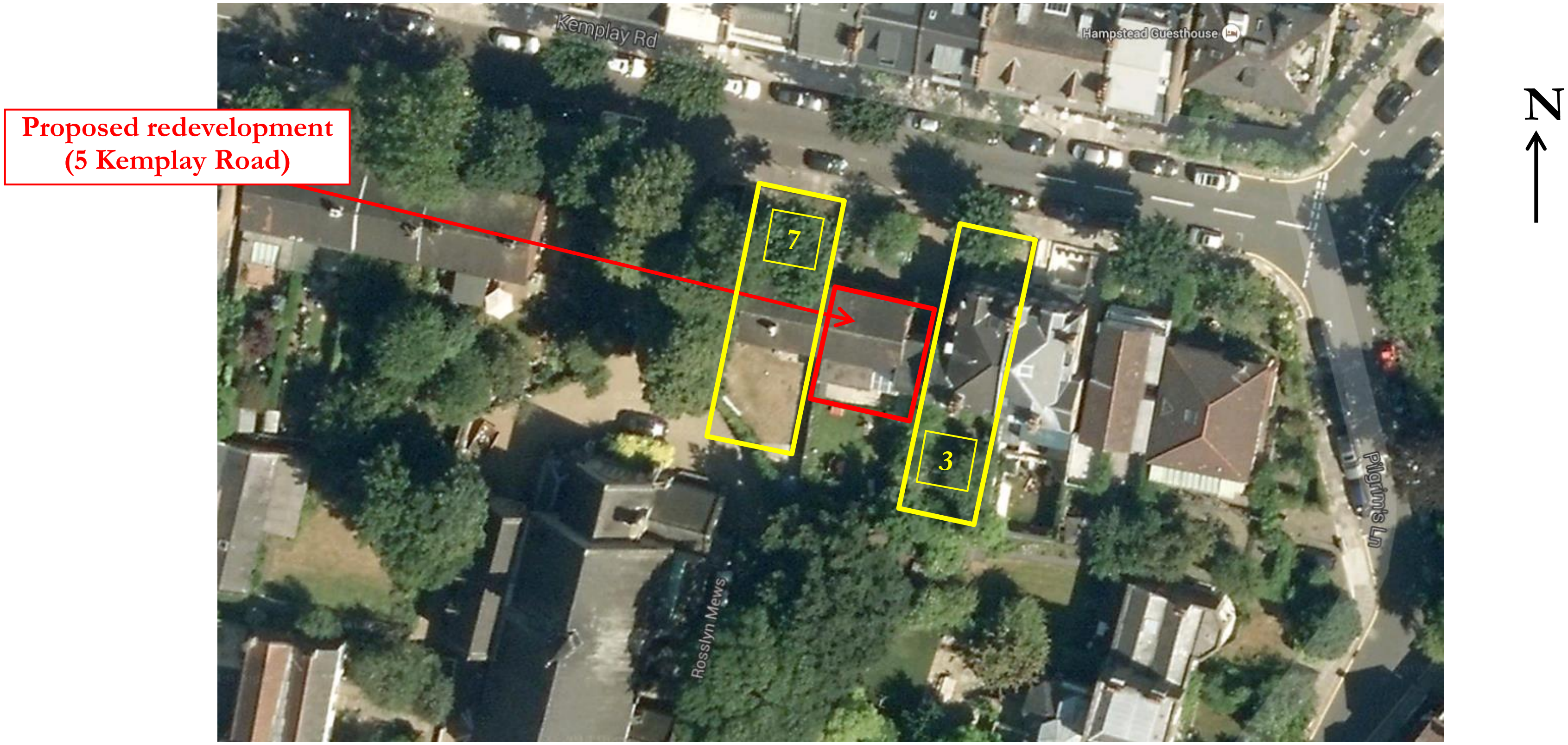
MRH Geotechnical. 2013b. *Desk study and Stage I Risk Assessment report for 5 Kemplay Road, London NW3 1TA.*(Report No. 131410/DS)

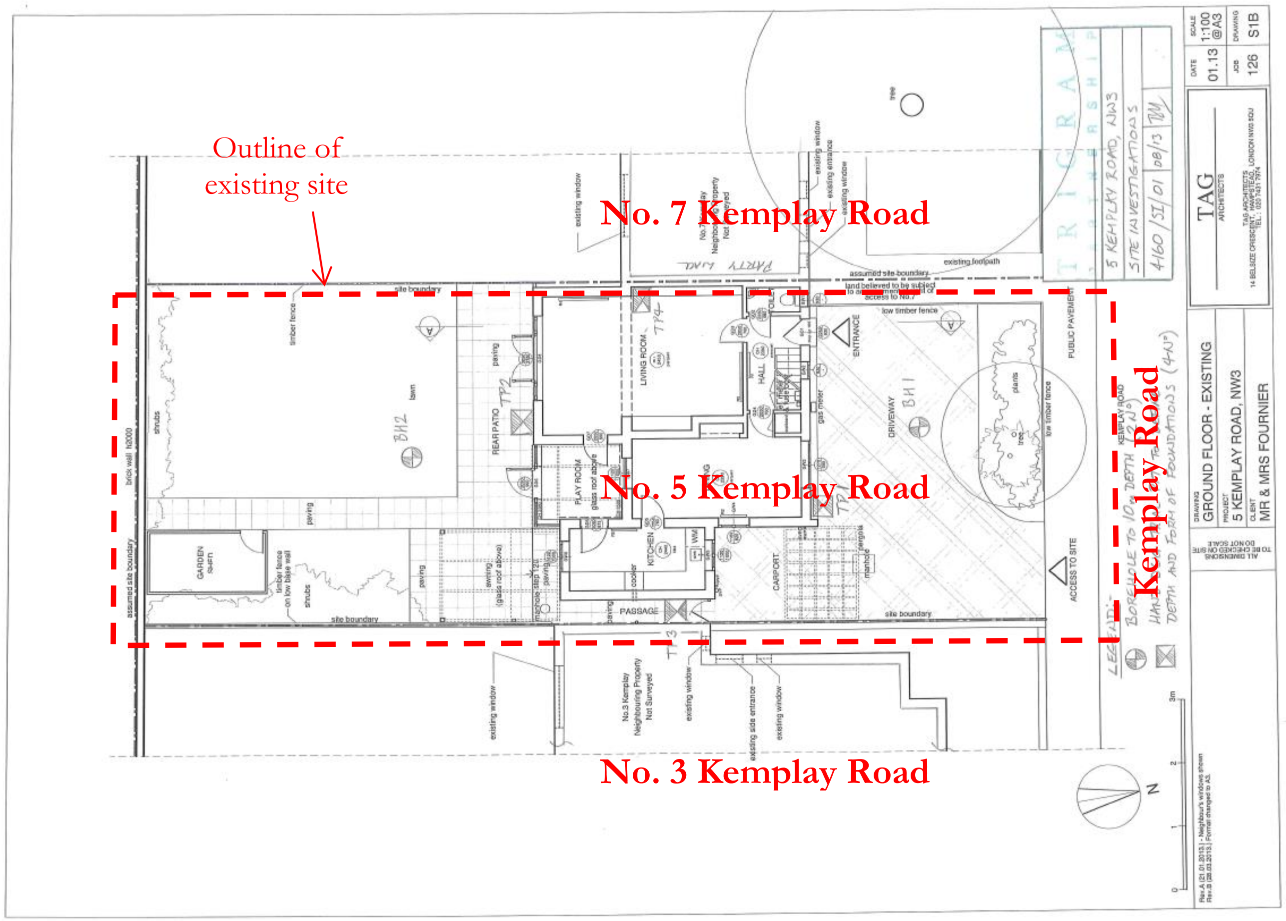
FIGURES



	Trigram Partnership 5 Kemplay Road, London NW3 1TA	**Figure 1**
	Title Location of site – road map (Google Maps)	



	Trigram Partnership 5 Kemplay Road, London NW3 1TA	**Figure 2**
	Proposed redevelopment and adjacent buildings (Google Maps)	



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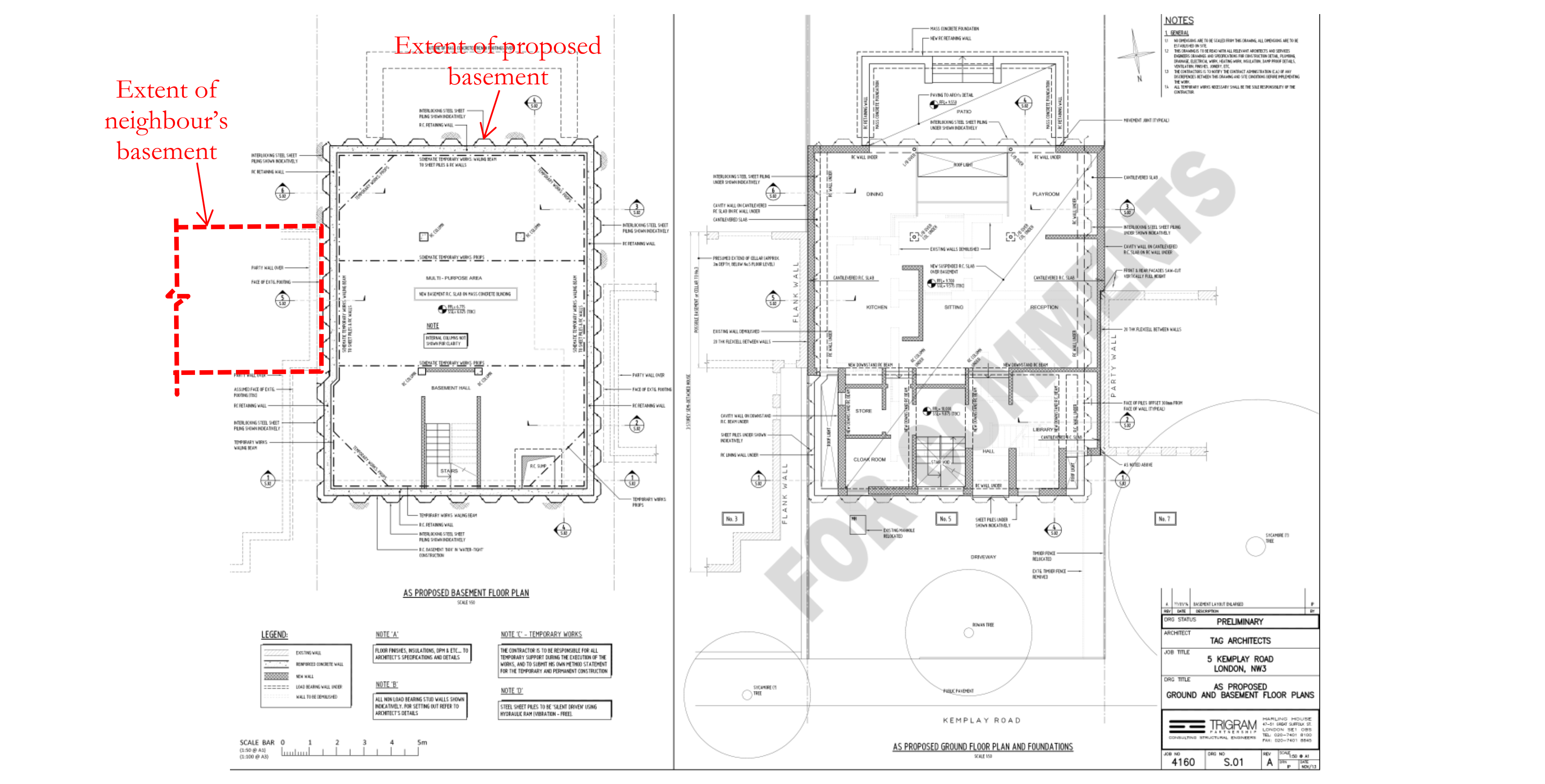
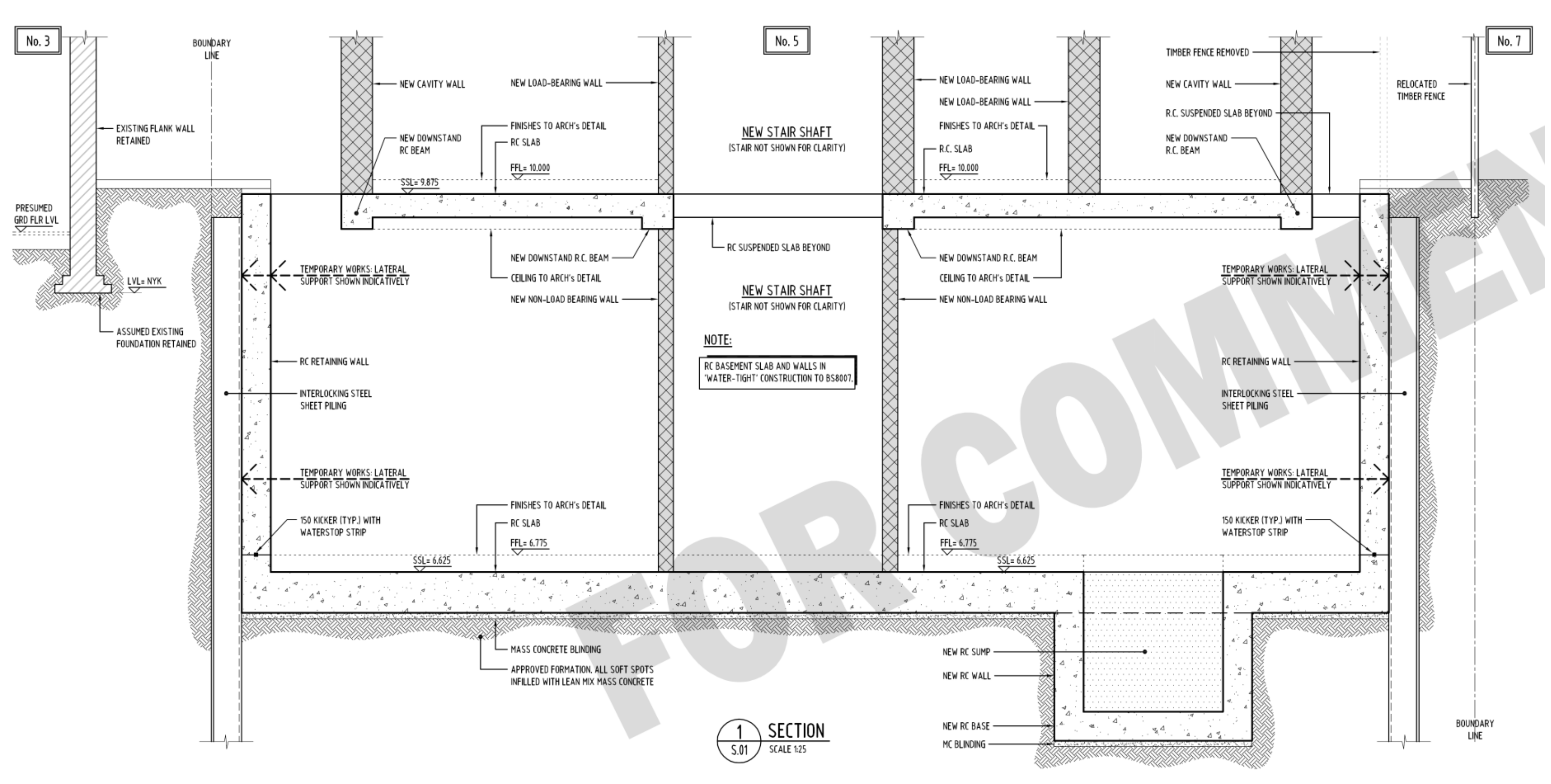
Existing layout of the property (Trigram Partnership, Sept. 2013)

Figure 3

GCG	**Trigram Partnership** 5 Kemplay Road, London NW3 1TA	**Figure 4**
	5 Kemplay Road – street view (Google maps)	



	Trigram Partnership 5 Kemplay Road, London NW3 1TA	**Figure 5**
	Plan of the proposed building at basement and ground floor levels (Trigram Partnership)	



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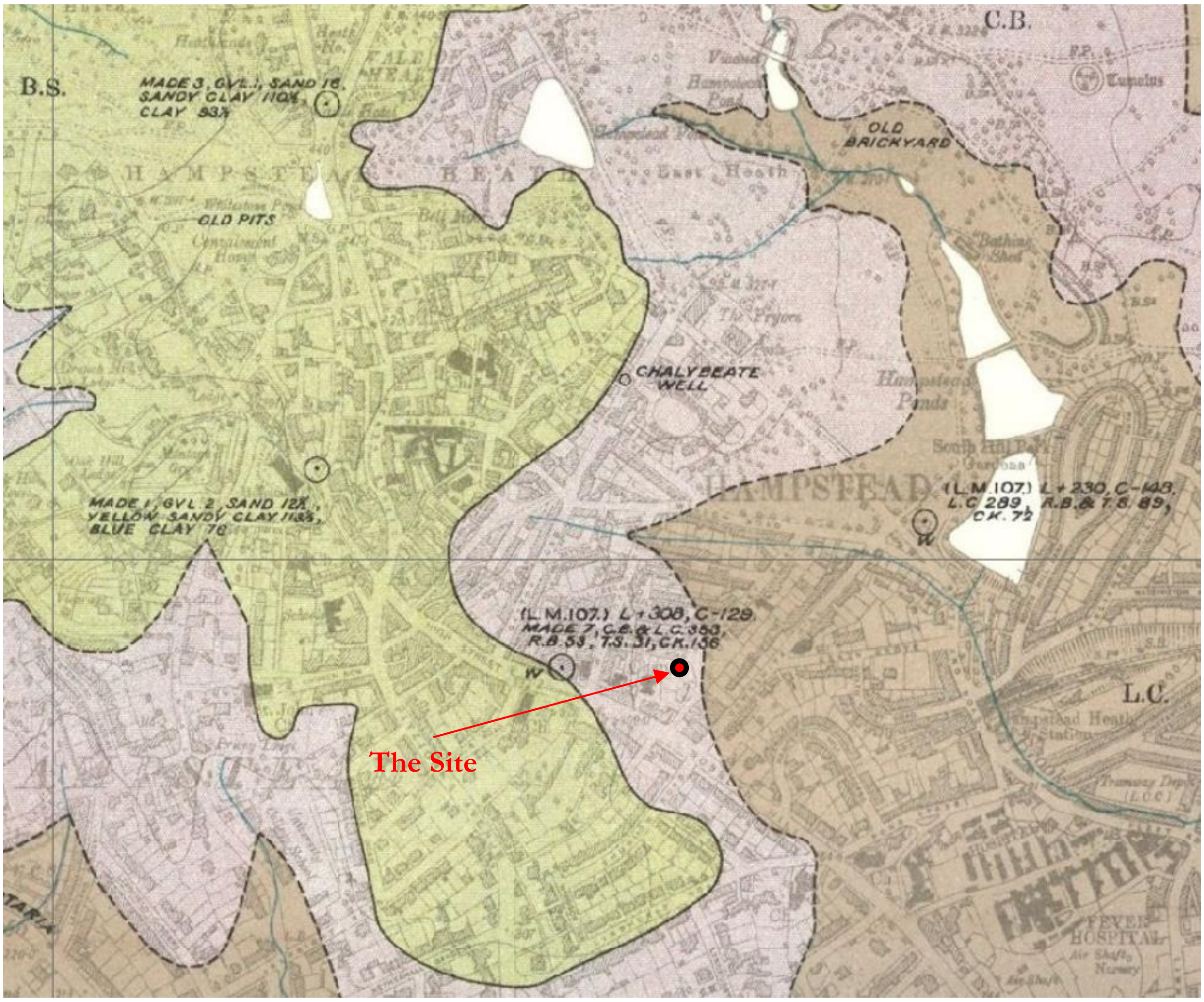
5 Kemplay Road, London NW3 1TA

Typical section of the proposed building (Trigram Partnership)

Figure 6



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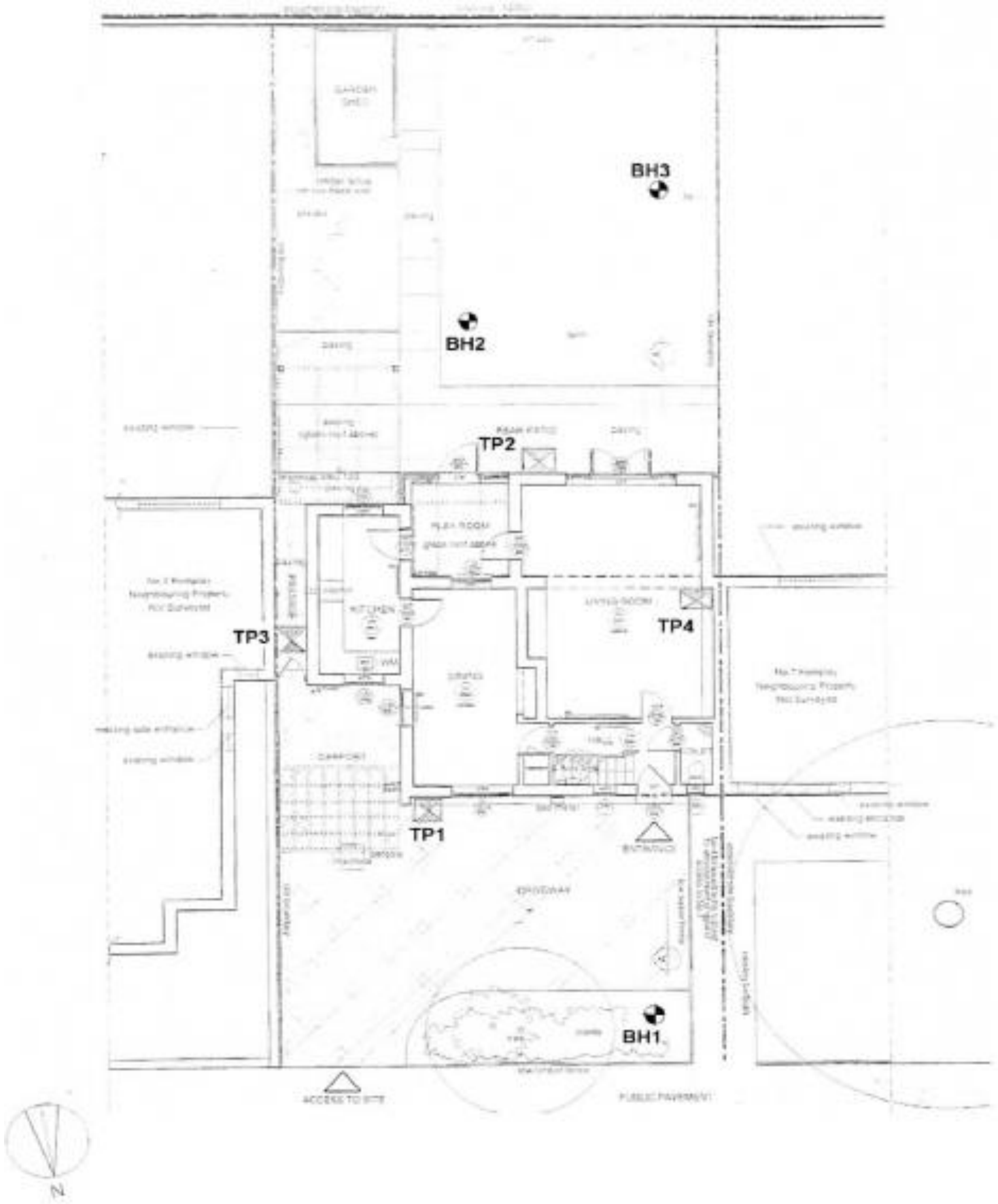
1:10560 BGS Map Sheet NI S.E. (1920)

Figure 7

Trigram Partnership
5 Kemplay Road, London NW3 1TA

Location of BGS Boreholes
(http://mapapps.bgs.ac.uk/boreholescans/boreholescans.html)

Figure 8



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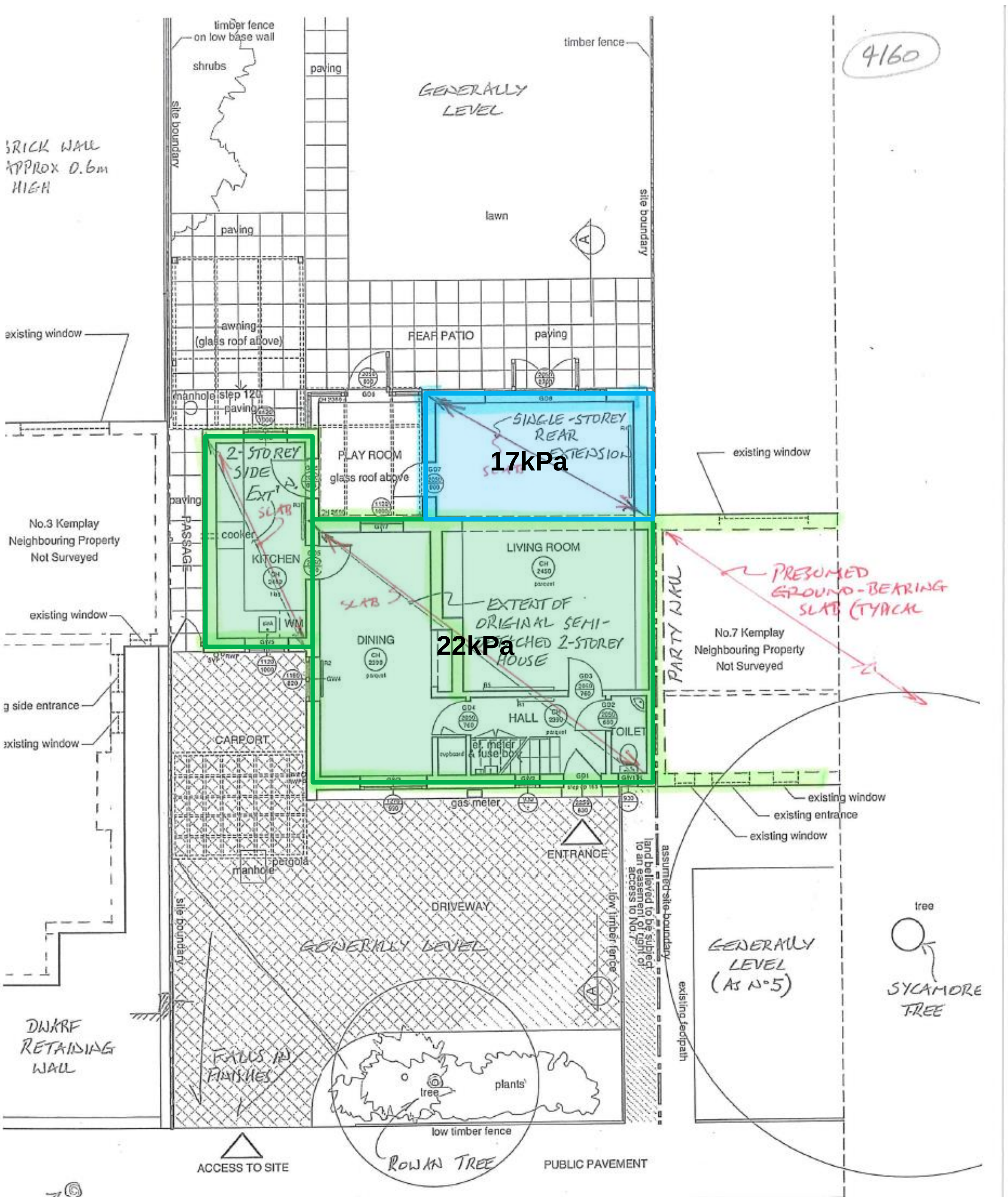
Exploratory borehole locations (MRH Geotechnics, Sep 2013)

Figure 9



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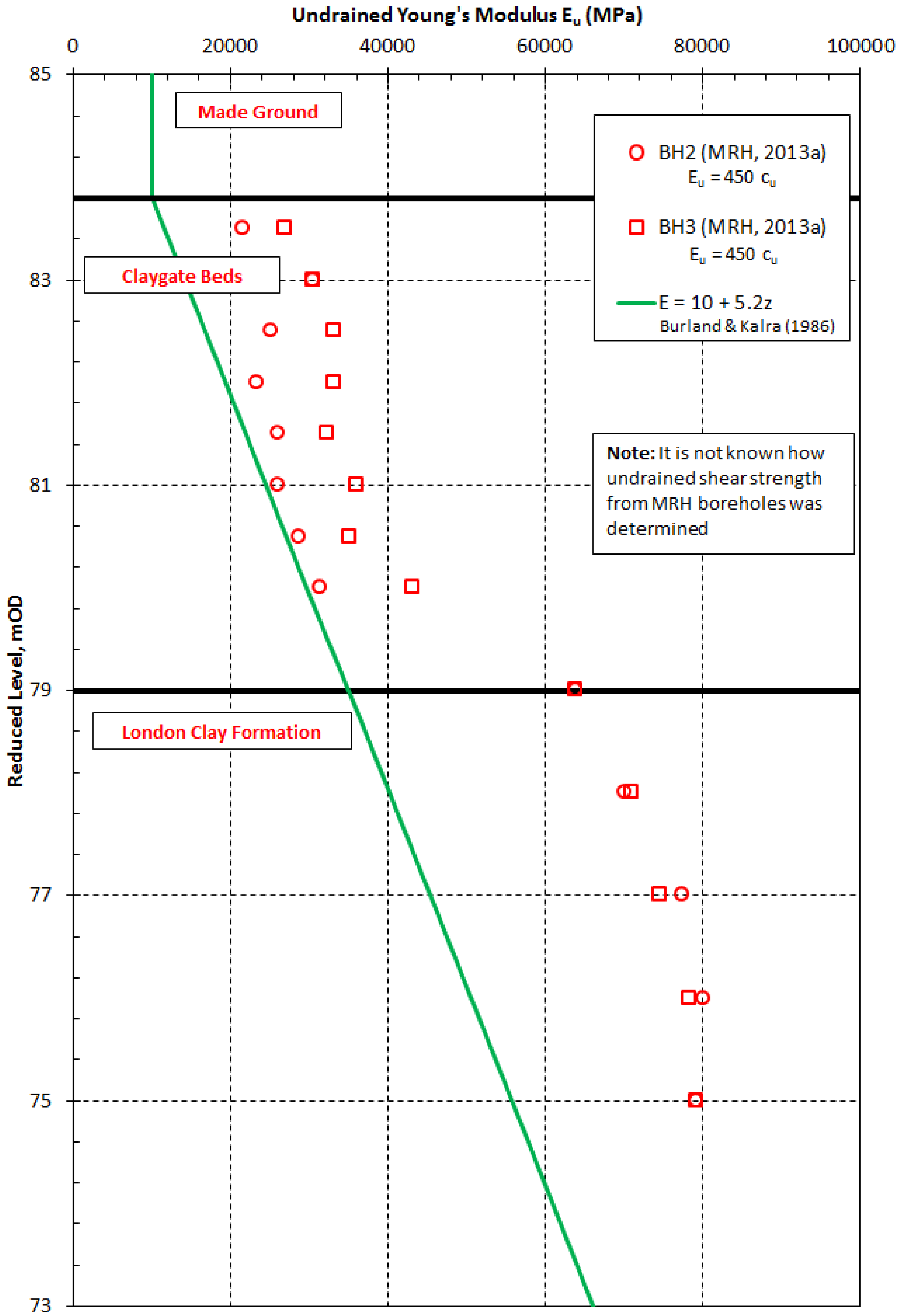
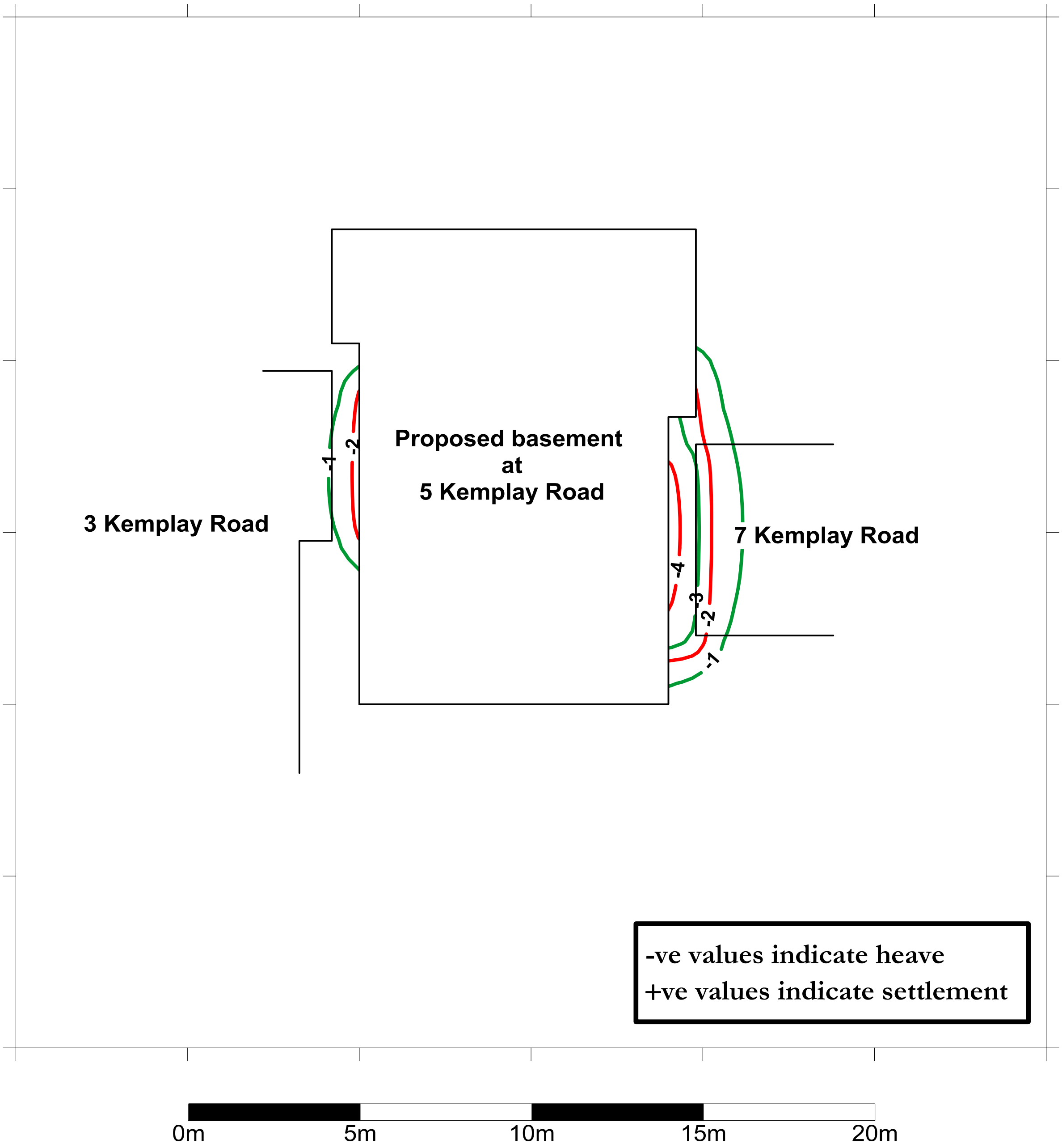
Existing building loads (provided by Trigram Partnership)

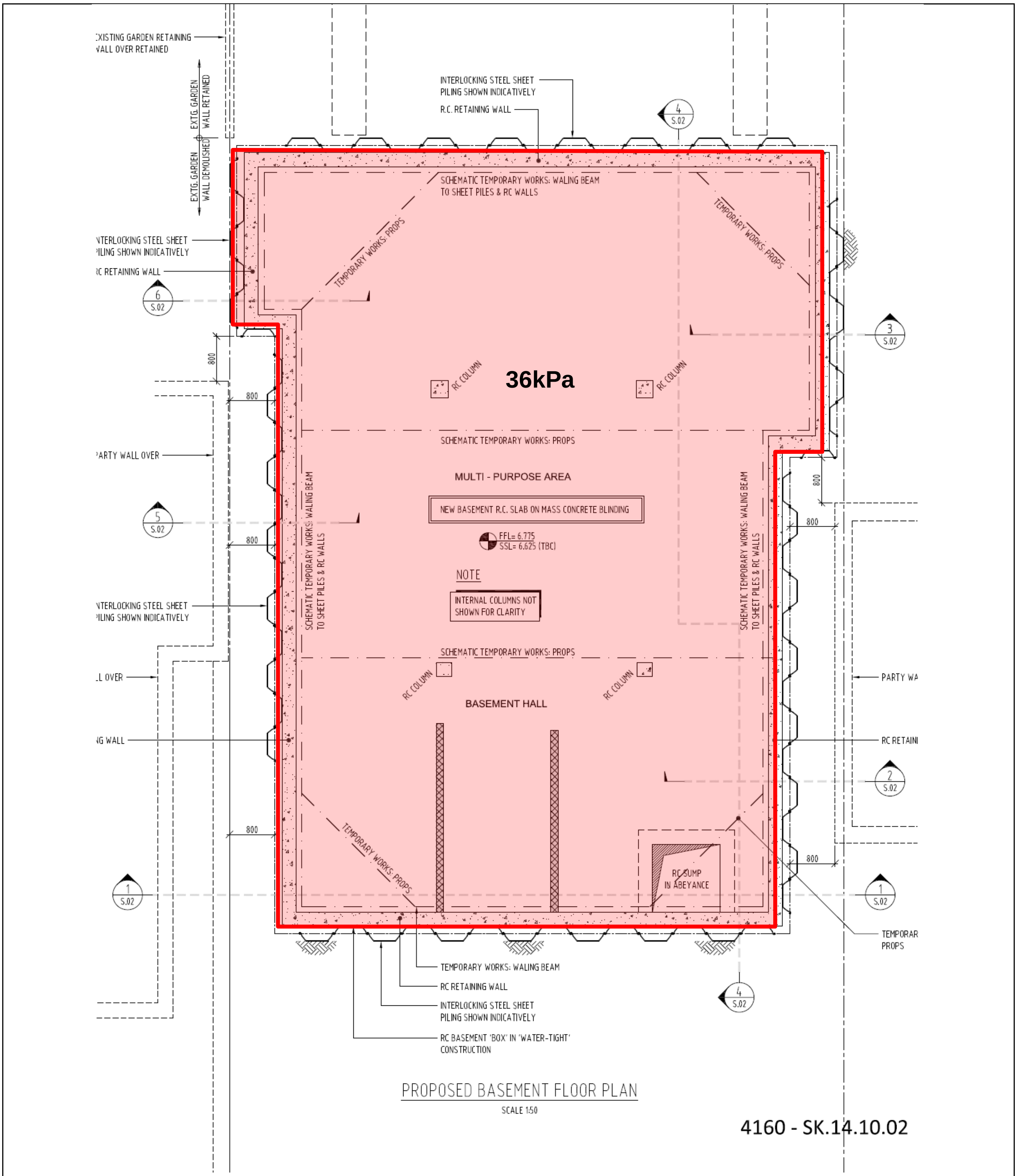
Figure 10



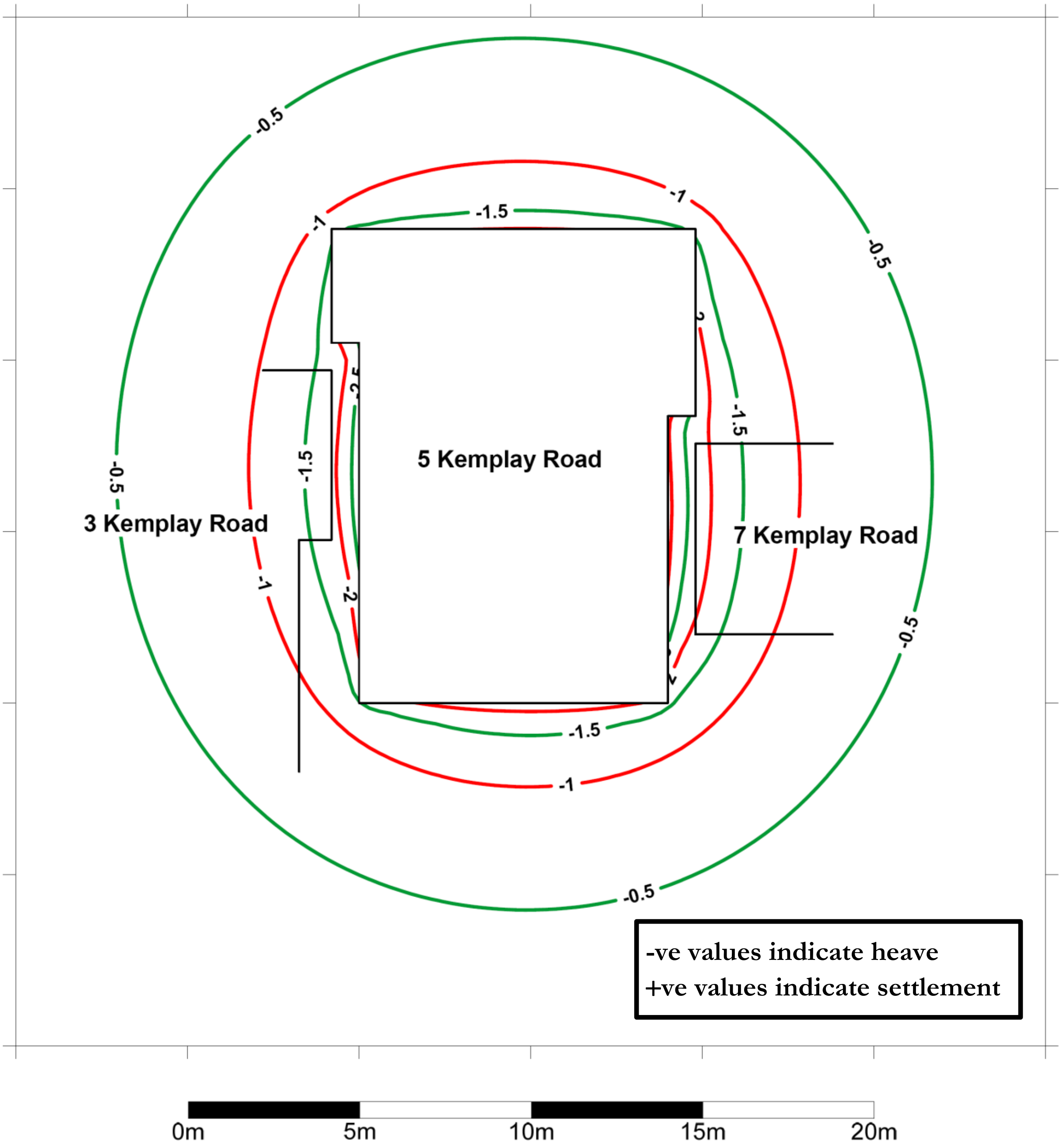
GCG	**Trigram Partnership** 5 Kemplay Road, London NW3 1TA	**Figure 11**
	Undrained Young's modulus profile with reduced level	



GCG	**Trigram Partnership** 5 Kemplay Road, London NW3 1TA	**Figure 12**
	Contours of predicted vertical ground movement due to demolition of existing building at 5 Kemplay Road (Stage 1)	



GCG	**Trigram Partnership** 5 Kemplay Road, London NW3 1TA Proposed structural loads applied by the raft foundation (provided by Trigram)	**Figure 13**



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5 Kemplay Road, London NW3 1TA

Contours of predicted vertical movements between the short-term and the long-term (i.e. after the end of construction) due to the net vertical loading imposed by the new structure.

Figure 14

APPENDIX A

Damage category classifications from CIRIA C580

Table A1 – Damage category classifications (CIRIA C580)

Category of damage		**Description of typical damage** (ease of repair is underlined)	**Approximate crack width (mm)**	**Limiting tensile strain %**
0	Negligible	Hairline cracks of less than about 0.1mm are classes as negligible.	<0.1	0.0-0.05
1	Very Slight	Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection.	<1	0.05-0.075
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly.	<5	0.075-0.15
3	Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired.	5-15 or a number of cracks >3	0.15-0.3
4	Severe	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Windows and frames distorted, floors sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15-25 but also depends on number of cracks	>0.3
5	Very Severe	This requires a major repair involving partial or complete rebuilding. Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	Usually >25 but depends on number of cracks	