THE STUDIO HOUSE
1 HAMPSTEAD HILL GARDENS, LONDON NW3 2PH

GROUND MOVEMENT ASSESSMENT

FOR

CARMI KORINE

September 2018

Our Ref: HLEI64102/GMA/001R

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This report has been prepared in the RPS Group Quality Management System to British Standard EN ISO 9001:2015

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RPS Health, Safety & Environment (London office) is certified to Environmental Management Standard ISO 14001:2015.

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EXECUTIVE SUMMARY

RPS Health, Safety & Environment (RPS) was commissioned by Carmi Korine to undertake a Ground Movement Assessment, relating to the proposed construction of a single level basement beneath the Studio House, 1 Hampstead Hill Gardens, London NW3 2PH. The assessment was required to identify if there would be any potential impact of soil movements caused by the basement construction on neighbouring buildings, existing utilities and the Transport for London (TfL) London Underground and Overground railway tunnels to the south. This report presents an assessment of the anticipated ground movements caused by the proposed basement construction.

The assessment concludes there will be no adverse effects associated with the basement excavation and construction.

1 INTRODUCTION

1.1 Preamble

A Basement Impact Assessment (BIA) was previously undertaken by RPS for the proposed basement works in March 2017 (reference HLEI50381-001R) to satisfy the requirements of the Camden Council's Local Planning Authority (LPA). The BIA included a geotechnical site investigation within the footprint of the proposed basement. The BIA report should be read in conjunction with this report.

RPS Consulting Services Ltd (RPS) was subsequently commissioned by *Cami Korine* to undertake a Ground Movement Assessment for the proposed redevelopment at the Studio House, 1 Hampstead Hill Gardens, London NW4 EPH which comprises the construction of a single storey basement.

The Ground Movement Assessment was required by the LPA to determine the potential impact of the ground movements caused by the construction of the proposed basement and extension on neighbouring structures.

1.2 Objectives

The principal objectives of this assessment were as follows:

- To assess the potential for ground excavations undertaken as part of the development to result in ground movements that could influence neighbouring buildings, existing utilities services and public highways;
- To produce movement calculations for the various phases of the demolition, excavation including potential over dig (10% of the retaining wall height) and construction and
- to assess the potential damage categories that may apply to the impacted buildings in accordance with Burland, J. "The assessment of the risk of damage to buildings due to tunnelling and excavations", Imperial College London, 1995.

1.3 Limitations

The assessment assumes a good standard of design and construction and is not intended to assess the impacts from any nearby activities of other construction related activities or cumulative construction related impacts.

The report has been based on information provided by others in regards to building design and construction. If the plans or design of the building are changed prior to construction, in particular relation to foundation or basement retaining wall design, extent of ground excavation and load then an update will be required to this ground movement assessment report.

This report has not been prepared to meet any specific requirements stipulated by TfL with regards to their assets that comprise the TfL Northern Line running tunnels and the Overground rail running tunnels. Correspondence with London Underground regarding the proximity of their assets is provided in Appendix A.

1.4 Legislation and Guidance

This report has been produced in general accordance with:

- *National Planning Policy Framework (2012);*
- *Camden Planning Guidance, London Borough of Camden, CPG4 Basements and Lightwells*
- *(2013);British Standard requirements for the 'protection of below ground structures against water from the ground - Code of Practice' (ref. BS8102: 2009);*
- *British Standard requirements for the 'Investigation of potentially contaminated sites - Code of practice' (ref. BS10175:2011);*
- British Standard requirements for the *'Code of practice for ground investigations' (ref. BS5930:2015)*;
- CIRIA Report C580, Construction Industry Research and Information Association, Embedded retaining walls – guidance for economic design (2003);
- CIRIA Report 143, Construction Industry Research and Information Association, The Standard Penetration Test (SPT): Methods and use (1995);
- CIRIA Report C760, Guidance on Embedded Retaining Wall Design (2017); and
- Burland, J. "The assessment of the risk of damage to buildings due to tunnelling and excavations", Imperial College London, 1995.

2 THE DEVELOPMENT SITE

2.1 Site Location & Description

The site is located within the London Borough of Camden at National Grid Reference 526950, 185503. A site location plan is presented as Figure 1 as an extract from drawing Nick Leith-Smith Architecture and Design (NLSAD) Drawings 525/A/1.1001-1003.

The proposed development comprises a single-level basement beneath the northern portion of the existing two storey apartment and which will extend beneath the existing conservatory on the northern side and beyond the eastern outer wall of the building to form a light well. Proposed basement, ground and first floor plans for the development are provided as extracts from NLSAD Drawings 525/A/1.1001-1003 as Figures 2 to 4 of this report.

2.2 Ground Conditions

2.2.1 Topography

The ground surface within the site is generally flat at an approximate elevation of 77.25m AOD.

2.2.2 Geology and Hydrogeology

Based on the *RPS Phase 2 Environmental and Geotechnical Site Investigation* (reference HLEI50381-001R), British Geological Survey (BGS) online maps (1:50,000-scale) and the Environment Agency (EA) Groundwater Vulnerability mapping (1:100,000-scale), the stratigraphic sequence is indicated to be Topsoil overlying the London Clay Formation. The geological sequence underlying the site is summarised in **Table 1** below.

Table 1: Encountered Strata

Strata	Depth to Top of Strata m bgl (m AOD)	Aquifer Classification
Topsoil	GL (77.25)	N/A
London Clay Formation	0.40 (76.85)	Unproductive Stratum

A previous intrusive site investigation (SI) was undertaken as part of the BIA which comprised the drilling of one cable percussion borehole (BH1) to a depth of approximately 10.00m below ground level, the installation of a groundwater monitoring well in the borehole and the excavation of a hand dug foundation inspection pit adjacent to the southern party wall within the apartment. The site investigation indicated the following ground conditions.

London Clay Formation

The London Clay Formation was encountered beneath a limited thickness of topsoil at a depth of approximately 0.40m bgl (76.85m AOD). The London Clay Formation was encountered as an orange brown and grey mottled slightly silty clay to a depth of approximately 5.90m bgl (71.35m AOD), at which depth the stratum comprised dark brown-grey very closely fissured clay to the base of the borehole at 10.00m bgl.

Atterberg Limit testing was undertaken on four soil samples collected from the London Clay Formation at depths ranging from approximately 1.50m to 9.00m bgl (68.25m to 75.75m AOD). This testing was undertaken to determine values for Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI). The results for LL were 71% to 78%. The results for PL were 30% to 32%. The results for PI were 41% to 46%. This PI range is indicative of a very high plasticity clay. In accordance with the NHBC Technical Standard, Section 4.3, Building near trees, modified plasticity index values indicate that these samples have a high volume change potential. The natural moisture contents of these samples ranged from 34% to 37%.

Four Standard Penetration Tests (SPT) undertaken within the London Clay Formation at depths ranging from approximately 1.00m bgl to 8.00m bgl (69.25m to 76.25m AOD) gave results ranging from ‘N’ = 11 to ‘N’ = 19 with the ’N’ values increasing with depth.

Approximate undrained shear strengths were calculated from SPT results using the correlation by Stroud:

$$C_u = f_1 \times N$$

Where, a conservative value for $f_1 = 4.5$ is used.

The SPT results generally increased with depth and correspond approximately to undrained shear strength values of $50kN/m^2$ to greater than $86kN/m^2$ which is indicative of a medium, ranging to a high strength cohesive material.

Two quick undrained triaxial compression tests undertaken on samples collected from the London Clay Formation at depths of approximately 6.50m and 9.50m bgl (67.75m and 70.75m AOD) gave results of $77kN/m^2$ and $168kN/m^2$ respectively. These are indicative of a high strength material. The results of triaxial tests were higher than those derived from the SPT’s. The natural moisture contents of both samples were 29%. Bulk density was $1.89Mg/m^3$ and $1.91Mg/m^3$. Dry density was $1.46Mg/m^3$ and $1.48Mg/m^3$.

One multi-stage consolidated Undrained Triaxial test was undertaken on a sample collected from the London Clay Formation at a depth of approximately 2.00m bgl (75.25m AOD), giving a result of $11.2kN/m^2$ for effective cohesion. The natural moisture content of this sample was 29%.

One oedometer consolidation test was undertaken on a sample collected from the London Clay Formation at a depth of approximately 4.00m bgl (73.25m AOD). Between a pressure range of 100kN/m^2 to 200kN/m^2, a coefficient of compression (m_v) value of 0.187m^2/MN was obtained. This is indicative of a medium compressibility material.

Groundwater

Groundwater was not encountered during the SI works (July 2017). Groundwater was encountered at a depth of approximately 1.97m bgl (75.28m AOD) during a subsequent monitoring visit to site on 4th August 2017. It is considered that this is representative of perched water within sandy horizons or claystone bands in the London Clay Formation.

2.3 Existing Land use and Buildings

The development area currently comprises a two storey apartment at the northern end, which is part of a four storey, six-apartment masonry conversion. A garden and a residential garage are located to the northwest of the apartment building.

2.4 Neighbouring structures

Two buildings surround the proposed redevelopment, as per information provided in Figure 1. One is situated at an approximate distance of 1m south of the southern extent of the proposed basement and the second is located at an approximate distance of 3m south west of the southern boundary of the proposed basement.

Two TfL Northern Line rail running tunnels are located to the south west of the proposed redevelopment and their influence zone, which is defined by London Underground, is indicated to be within a 4m distance from the site. Two TfL Overground Line rail running tunnels are situated at an approximate distance of 20m south west of the site.

A draft report on utilities was obtained for the site, which presents the main services present on or around the site. A detailed utilities report is still awaited and is dependent on responses from the relevant providers. However, it is considered unlikely that assets belonging to the remaining providers would adversely affect the conclusions of this assessment. Following review of the final report provided, this report will be updated accordingly, if required. Based on the draft utilities report, the main utilities services are located around the site with the closest one being a low pressure gas pipeline lying beneath the Hampstead Hill Gardens pavement to the east of the site at an approximate distance of 7m from the eastern boundary of the proposed basement excavation. A water main was also recorded running along Hampstead Hill Gardens within the road. The types of pipeline are unknown at the time of writing this report.

3 PROPOSED DEVELOPMENT

3.1 Proposed Building

The proposed development comprises a single-level basement construction beneath the northern portion of the existing two storey apartment, which will extend beneath the existing conservatory on the northern side and beyond the eastern outer wall to form a light well. The extents of the proposed basement excavation are presented in Figure 1.

3.2 Proposed Construction Sequence

The proposed construction sequence is provided by the Basement Construction Method Statement prepared by BCS Consulting, September 2017, and is presented in Table 2. This sequence has been used to assess ground movements arising from the construction of the basement retaining walls, basement excavation and construction beneath the existing building. The existing conservatory is proposed to be demolished and replaced by a new one at the footprint of the previous one, hence no significant stress change has been considered for this element.

Table 2: Preliminary Construction Sequence

Stages	Works	Description
Stage 1	Installation of basement retaining walls	Installation of concrete basement retaining wall by underpinning techniques around the basement periphery. (Short term undrained conditions)
Stage 2	Excavation of basement	Excavation to the proposed basement level at 4m bgl and additional 10% overdig and conservative assumption of one level of strutting at the lower level (Short term undrained conditions)
Stage 3	Substructure construction and superstructure load transition at basement level	Construction of the basement slab and permanent propping of the basement retaining walls by the slab and transfer of superstructure loads at basement level. (Short term undrained conditions)
Stage 4	Consolidation	The long term movement of the ground under the new structure. (Long term drained conditions)

4 ASSESSMENT OF RISK TO NEIGHBOURING BUILDINGS

4.1 General Considerations

An assessment of the vertical and horizontal ground movements due to the proposed site redevelopment and their impact on the adjacent neighbouring buildings, existing utilities, two TfL Northern Line rail running tunnels and two Overground rail running tunnels was undertaken. Ground movements that could pose a risk to adjacent buildings are those related to the basement retaining wall construction, excavation works and basement construction.

4.2 Ground Movement Analysis

The ground movement analysis comprised:

- Assessment of the vertical ground movements due to the proposed redevelopment and associated changes to the vertical stresses caused by the basement retaining wall construction, excavation and construction of the proposed basement was undertaken using the Oasys PDISP software,
- The analysis is based on Boussinesq's theory and the stratum underlying the site is considered as a semi-infinite isotropic, homogeneous elastic material,
- Assessment of the horizontal ground movements acting on the proposed retaining walls as part of the proposed redevelopment at the basement excavation, basement and superstructure construction and consolidation stages undertaken using the Sigma/W software,
- The basement layout has been developed based on information provided by the NLSAD Drawing 525/A/1.1001, an extract of which is presented as Figure 2,
- The basement formation level is proposed to be at 4.0m bgl,
- The loading layout has been modelled as per Figure 5 and comprises the retaining wall construction, the excavation to the basement formation level, the basement slab and superstructure loads transferred through the newly constructed basement slab to the underlying bearing stratum,
- The ground conditions that have been considered for the analysis are presented in Section 2. London Clay is anticipated to underlie the site and the groundwater level is anticipated to be at approximately 2m bgl. Based on the results of the site investigation, the following geotechnical parameters have been derived for undrained and drained analysis:

Table 3: Geotechnical parameters

Stratum	Depth m bgl (m AOD)	Bulk Density (kN/m^3)	Undrained Shear Strength (kN/m^2)	Undrained Young's Modulus (kN/m^2)	Undrained Poisson's ratio	Drained Young's Modulus (kN/m^2)	Drained Poisson's ratio
London Clay Formation	Existing ground level to a maximum proven depth of 10.00 m bgl (67.25 to 77.25)	20	50 at ground level increasing to 85 at 10m bgl	15,000 at ground level to 25,500 at 10m bgl	0.4	12,000 at ground level to 20,400 at 10m bgl	0.2

- Figures 6 to 8 present the vertical displacements produced through the gradual addition of the anticipated loading and unloading due to the proposed redevelopment,
- Figures 9 to 13 present the horizontal displacements acting on the proposed retaining walls at all the development stages,
- Table 4 presents the cumulative results of changes in vertical pressure in each side of the building and impact on nearest sides of neighbouring buildings in the sequence of stress changes developed by the retaining wall construction, excavation and basement construction and transfer of superstructure loads,
- Table 5 presents the tensile strains on adjacent buildings and neighbouring infrastructure,
- Table 6 presents the cumulative results of the horizontal displacements acting on the proposed retaining walls due to the proposed redevelopment in the sequence of stress changes developed by the retaining wall construction, the basement excavation, the basement construction and transfer of superstructure loads and the consolidation stage.

Table 4: Vertical Ground Movement Results (Cumulative)

Location	Stage 1	Stage 2	Stage 3	Stage 4
Western wall	<1mm settlement	0mm to 5mm heave	0 to1mm heave	0 to 1mm heave
Eastern wall	<1mm settlement	2mm to 4mm heave	0 to 1mm heave	0 to 1mm heave
Northern wall	<1mm settlement	2mm to 6mm heave	1 to 2mm heave	1 to 4mm heave
Southern Wall	<1mm settlement	2 to 5mm heave	0 to 1mm heave	0 to 1mm heave
Basement slab	<1mm settlement	5 to 11mm heave	1 to 4mm heave	1 to 6mm heave
Adjacent building 1.5m south of the proposed basement	<1mm settlement	0mm	0mm	0mm
Adjacent building at 3m south west of the proposed basement	<1mm settlement	0mm	0mm	0 to <1mm heave
Northern Line tunnel's influence zone 4m away	0mm	0mm	0mm	0mm
Existing utility services 7m away	0mm	0mm	0mm	0mm
Overground line tunnel's at 20m south west	0mm	0mm	0mm	0mm

The table above presents the anticipated displacements of the various elements of the proposed redevelopment as well as the assessed neighbouring structures. A maximum heave displacement of 11mm is calculated at the excavation stage in the centre of the basement slab but as this displacement would have occurred prior to the slab construction, only post construction displacement are considered relevant to the slab design.

The anticipated strains on adjacent buildings and the existing tunnels were calculated using the anticipated ground movement at the relevant influence distance. The results are presented in Table 5 below:

Table 5: Tensile Strain (%)

Location	Zone of Influence (m)	Stage 1	Stage 2	Stage 3	Stage 4
Adjacent building 1.5m south of the proposed basement	1.5	<0.05	<0.05	<0.05	<0.05
Adjacent building at 3m south west of the proposed basement	3	<0.05	<0.05	<0.05	<0.05
Northern Line tunnel's influence zone 4m away	4	<0.05	<0.05	<0.05	<0.05
Existing utility services 7m away	7	<0.05	<0.05	<0.05	<0.05
Overground Line tunnels 20m south west	20	<0.05	<0.05	<0.05	<0.05

Table 6: Horizontal Ground Movement Results (Cumulative)

Location	Stage 1	Stage 2	Stage 3	Stage 4
Western wall	0mm	-2mm to 2mm	-1.5mm to 1.5mm	-4mm to 4mm
Eastern wall	0mm	-2mm to 2mm	-1.5mm to 1.5mm	-4mm to 4mm
Northern wall	0mm	-2mm to 2mm	-1.5mm to 1.5mm	-4mm to 4mm
Southern Wall	0mm	-2mm to 2mm	-1.5mm to 1.5mm	-4mm to 4mm
Basement slab	0mm	-2mm to 2mm	-1.5mm to 1.5mm	-<1mm
Adjacent building 1.5m south of the proposed basement	0mm	-2mm to 2mm	-<1mm	-2mm to 2mm
Adjacent building at 3m south west of the proposed basement	0mm	-2mm to 2mm	<1mm	-4mm to 4mm
Northern Line tunnel's influence zone 4m away	0mm	-2mm to 2mm	<1mm	-4mm to 4mm
Existing utility services 7m away	0mm	-1mm to 1mm	<1mm	-3.5mm to 3.5mm
Overground line tunnel's at 20m south west	0mm	<1mm	<1mm	<1mm

The anticipated strains on adjacent buildings and the existing tunnels were calculated using the anticipated ground movement at the relevant influence distance. The results are presented in Table 7 below:

Table 7: Tensile Strain (%)

Location	Zone of Influence (m)	Stage 1	Stage 2	Stage 3	Stage 4
Adjacent building 1.5m south of the proposed basement	1.5	<0.05	<0.05	<0.05	<0.05
Adjacent building at 3m south west of the proposed basement	3	<0.05	<0.05	<0.05	<0.05
Northern Line tunnel's influence zone 4m away	5	<0.05	<0.05	<0.05	<0.05
Existing utility services 7m away	7	<0.05	<0.05	<0.05	<0.05
Overground Line tunnels 20m south west	20	<0.05	<0.05	<0.05	<0.05

The above values have been used to assess the damage categories for each case. The damage classification categories, reproduced from Burland, J. "The assessment of the risk of damage to buildings due to tunnelling and excavations" is presented below in Table 8 along with the categorization for the buildings on site presented in Table 9.

Table 8: Building Damage Classification from CPG4 (11) (based on Burland, 1995)*

Category of Damage	Description of Typical Damage	Aprox Cack width (mm)	Limiting Tensile Strain (%)
0 Negligible	Hairline cracks of less than about 0.1mm are classed as negligible	<0.1mm	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 lining. Repointing of external brickworks and possible a small amount of brickwork to be replaced. Doors and windows sticking. Services 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 wall, especially over doors and windows. Windows and frames distorted, floor sloping noticeable. 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 required 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	

* Burland, J.B.(1995), assessment of risk of damage to buildings due to tunnelling and excavation, invited special lecture: 1st International Conference on Earthquake Geotechnical Engineering, IS Tokyo '95.

Table 9: Building Damage Classification Assessment at Hampstead Hill Gardens

Location	Description of Degree of Damage	Damage Category
Adjacent building 1.5m south of the proposed basement	Negligible	0
Adjacent building at 3m south west of the proposed basement	Negligible	0
Northern Line’s influence zone 4m away	Negligible	0
Existing utility services 7m away	Negligible	0
Overground Line’s 20m south west	Negligible	0

5 CONCLUSIONS

5.1 Conclusions

An assessment of the ground movements caused by the proposed site redevelopment which comprises a 4m deep single storey basement construction was undertaken. Anticipated displacements were calculated at different stages of the construction including the basement retaining wall construction, excavation including 10% of the retaining wall height for over dig and conservative assumption of one level of strutting, basement construction and transfer of the existing superstructure loads at basement level including propping of retaining walls and finally consolidation. An assessment of the impact of the ground movements was undertaken on two adjacent buildings, a London Underground's rail tunnel and an Overground rail line as well as on existing utility services. Damage assessment on neighbouring structures was based on Burland, 1996, as described within CIRIA document C760.

The assessment was found that damage caused to neighbouring structures as a result of the basement construction will be negligible (damage category '0' – Burland, 1995).

FIGURES

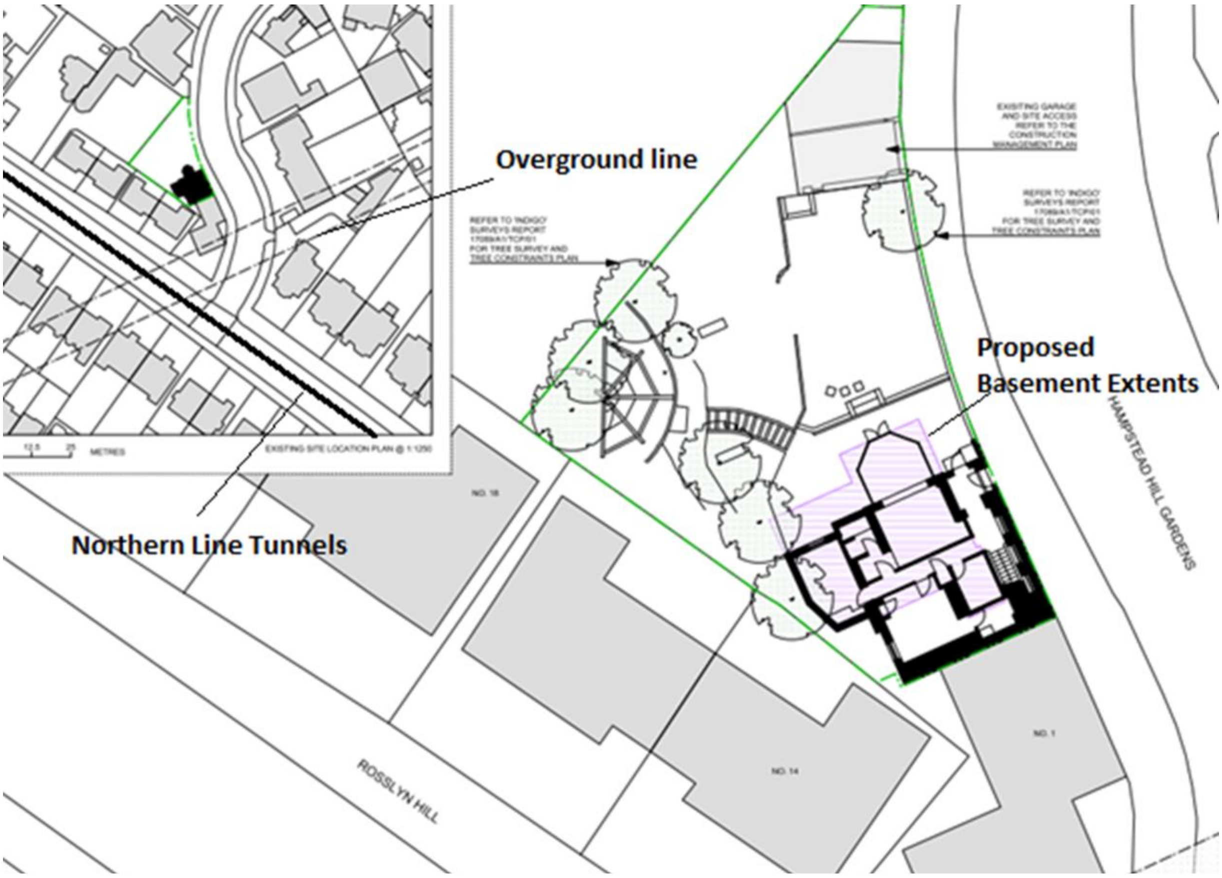

Figure 1: Site Location Plan

Map Date: 2017

Scale: Not to scale

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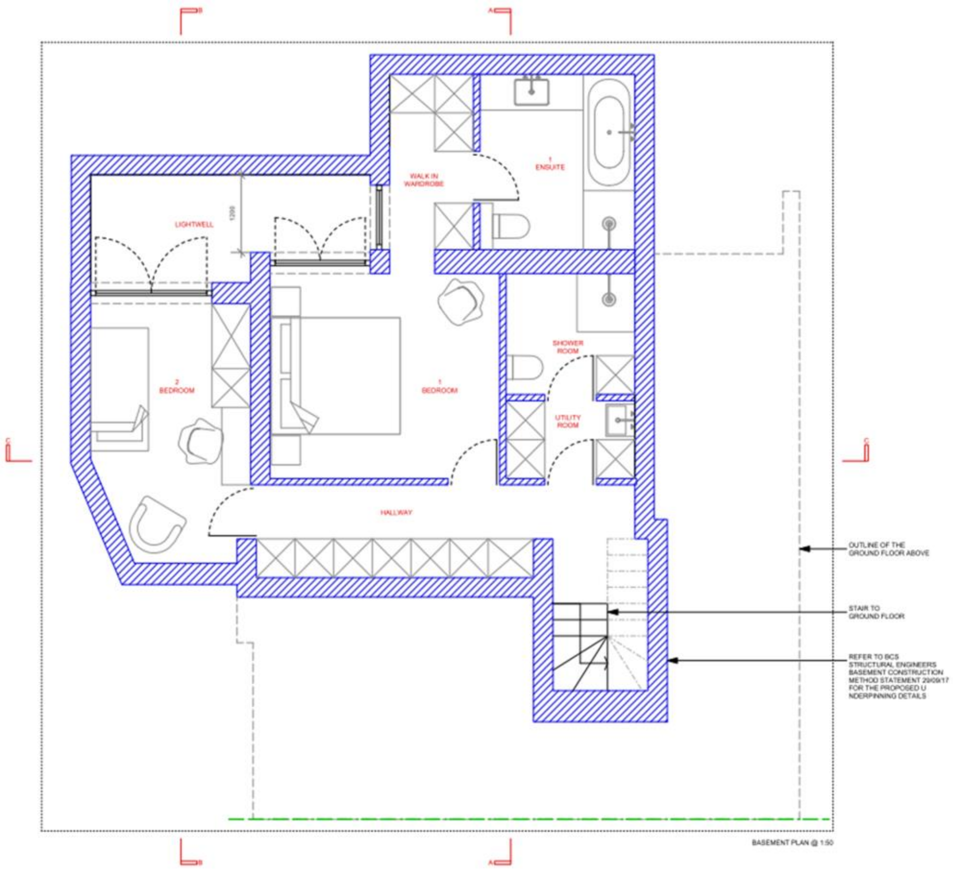

Figure 2: Proposed Basement Plan

Map Date: 2016

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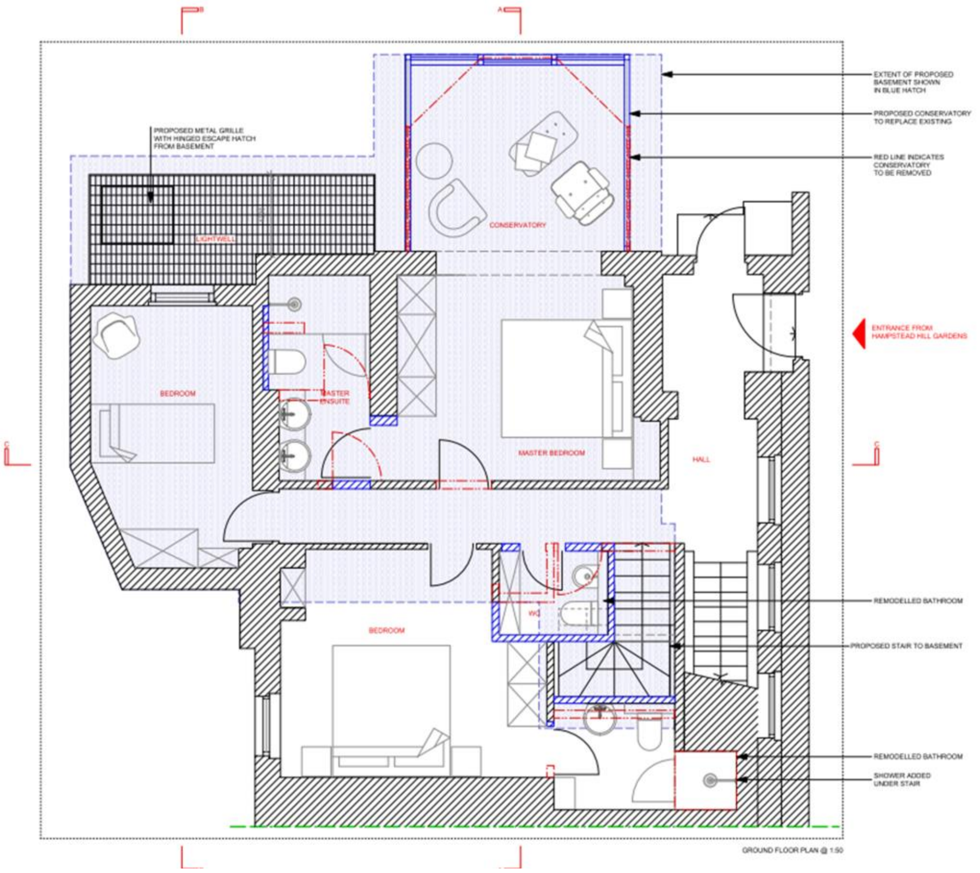

Figure 3: Proposed Ground Level Plan

Map Date: 2016

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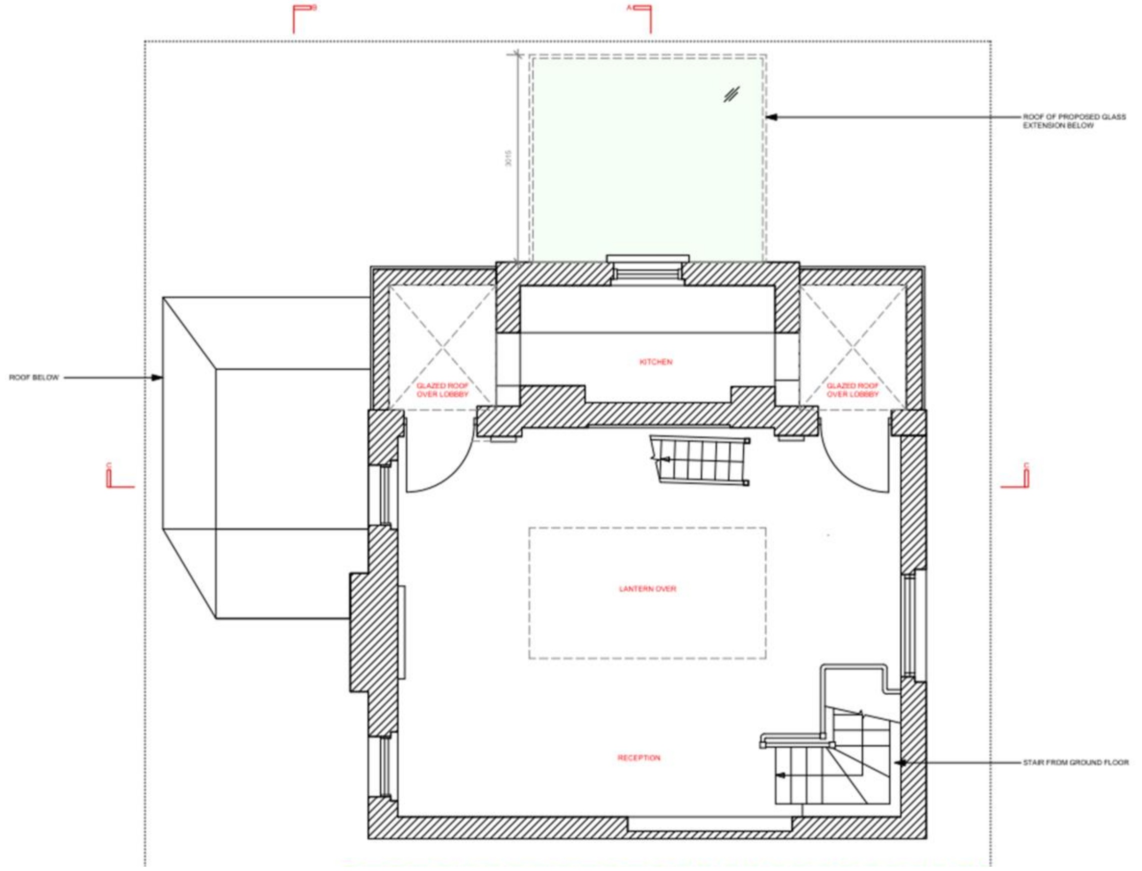

Figure 4: Proposed First Floor Plan

Date: 2017

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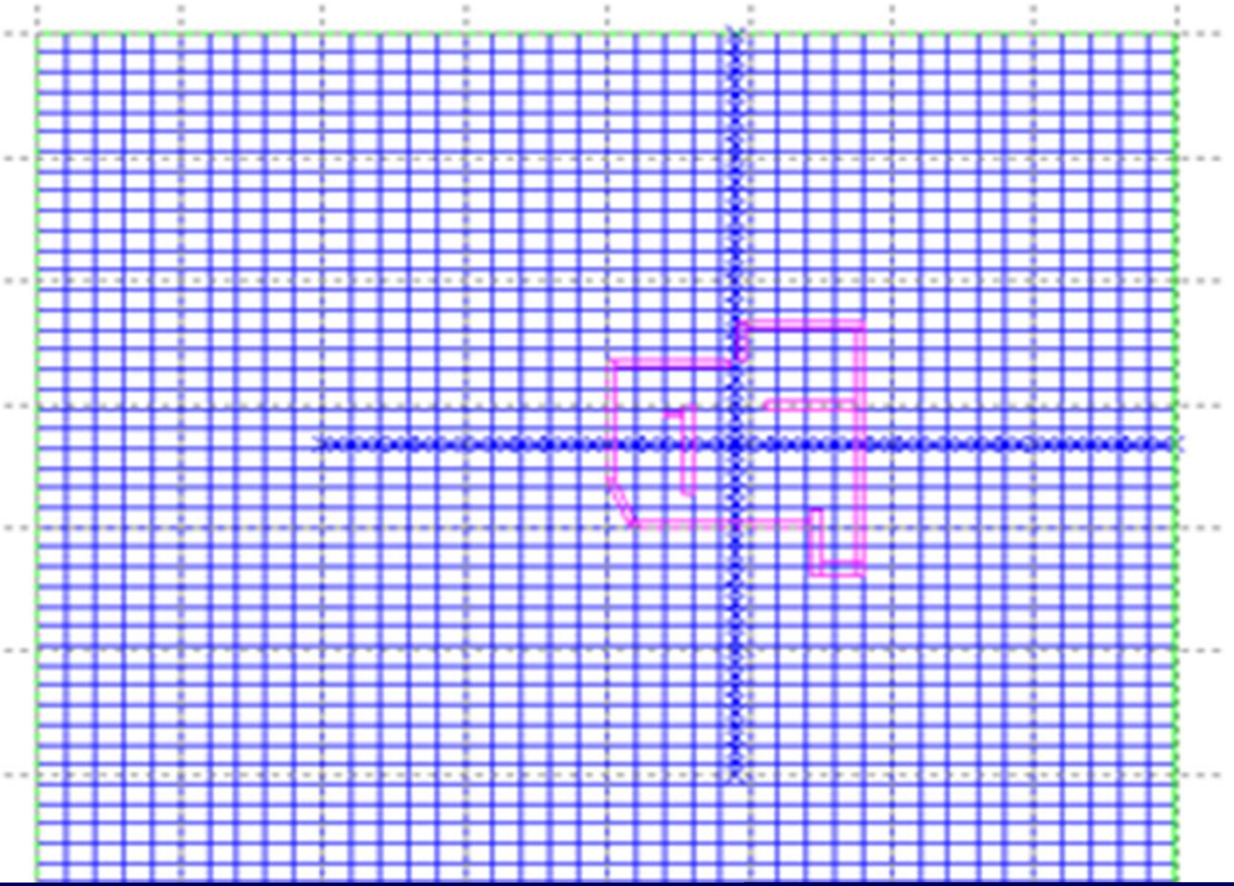

Figure 5: Loading Layout

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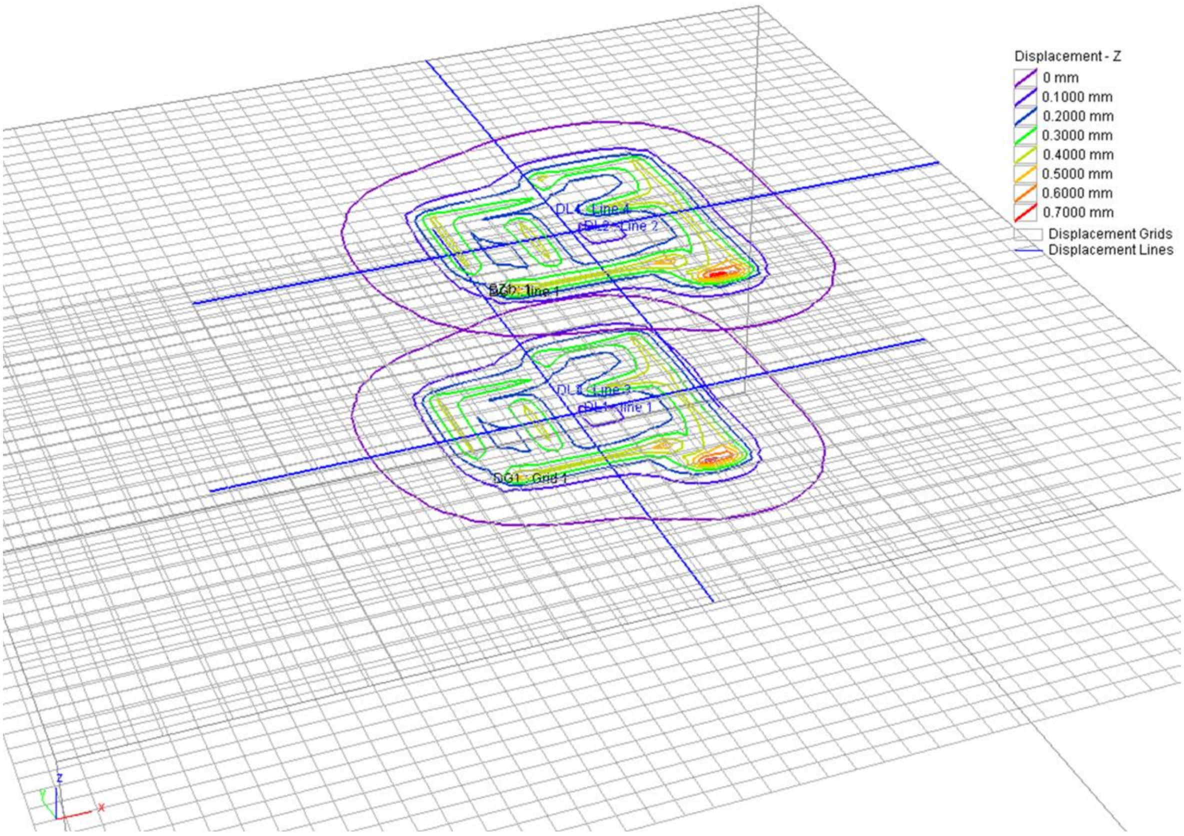

Figure 6:	Stage 1 Retaining Walls Installation – Vertical Displacements	RPS 35 New Bridge Street London EC4V 6BW
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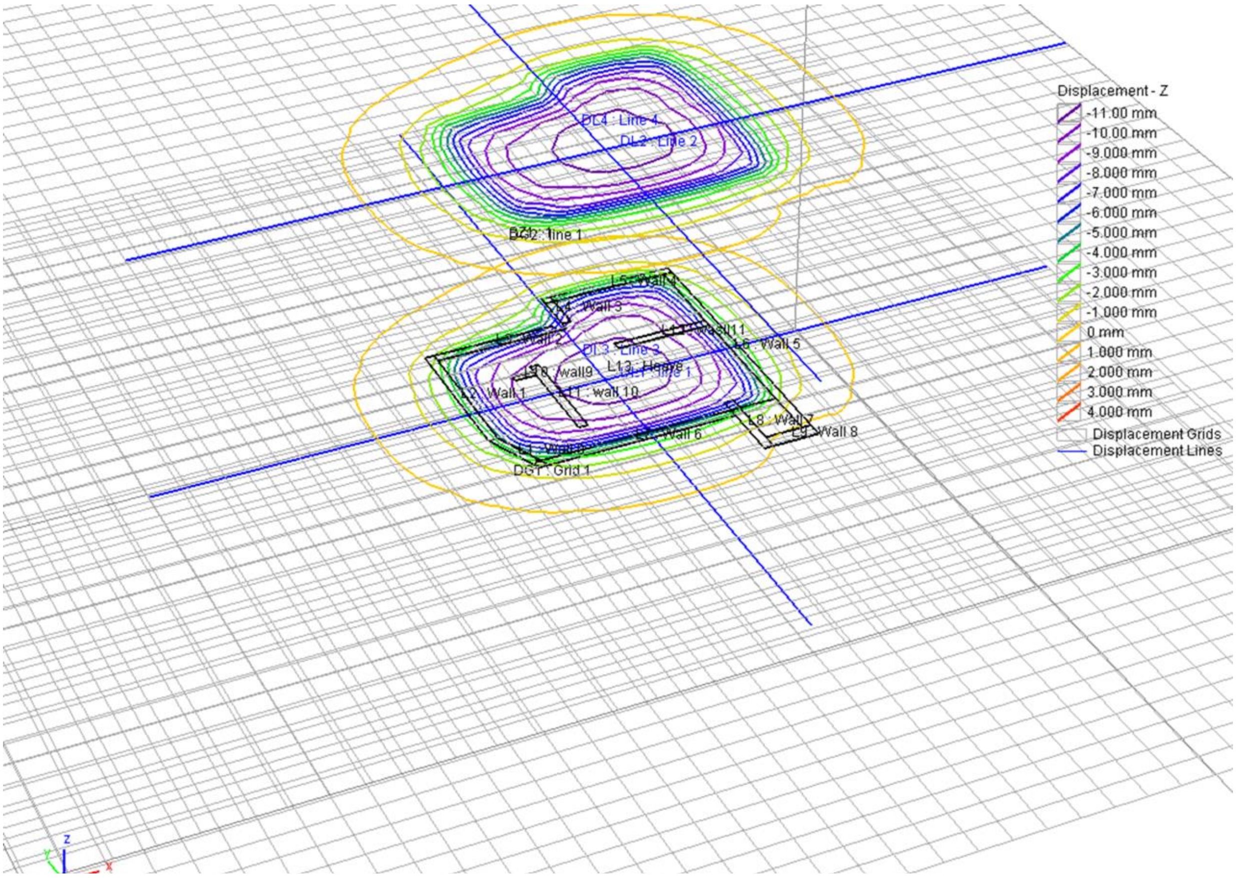

Figure 7	Stage 2 Excavation – Vertical Displacements
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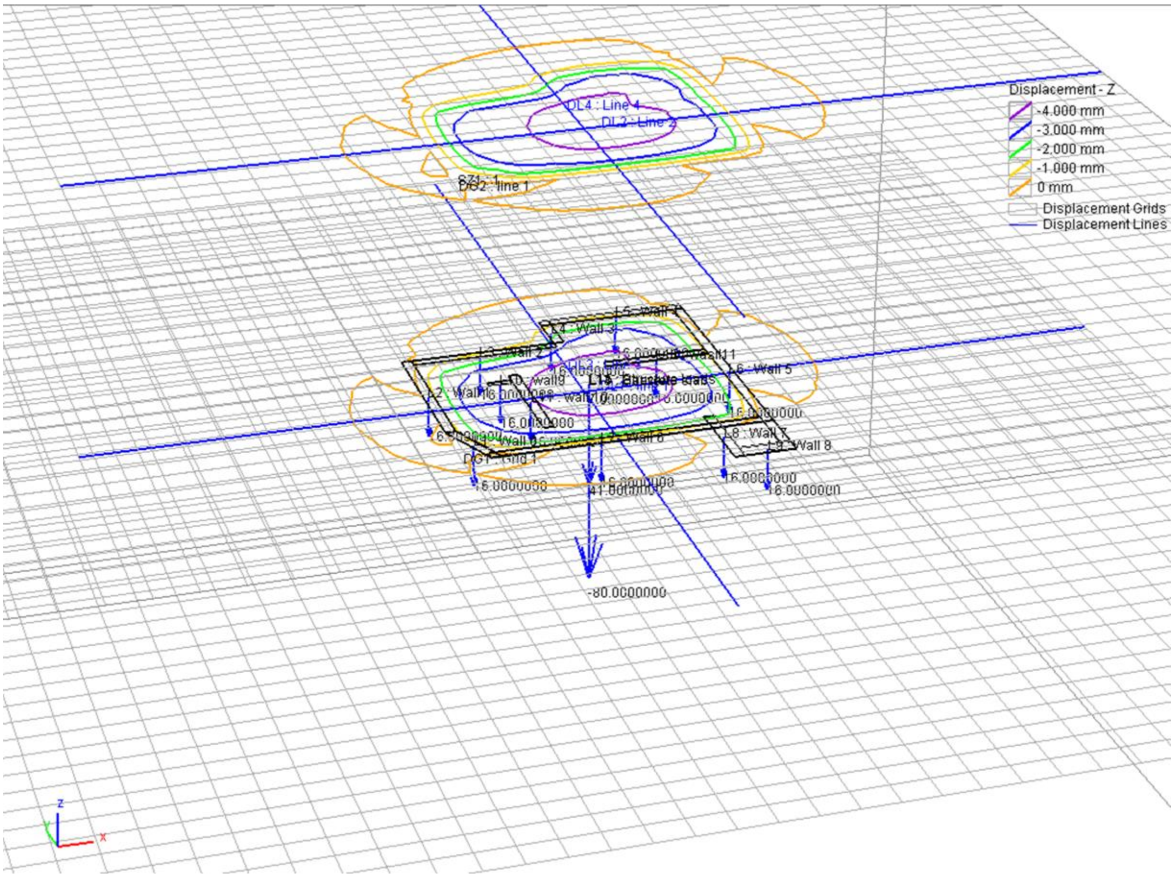

Figure 8:	Stage 3 – Slab construction & Superstructure loads transfer (Short term conditions) – Vertical Displacements	RPS 35 New Bridge Street London EC4V 6BW
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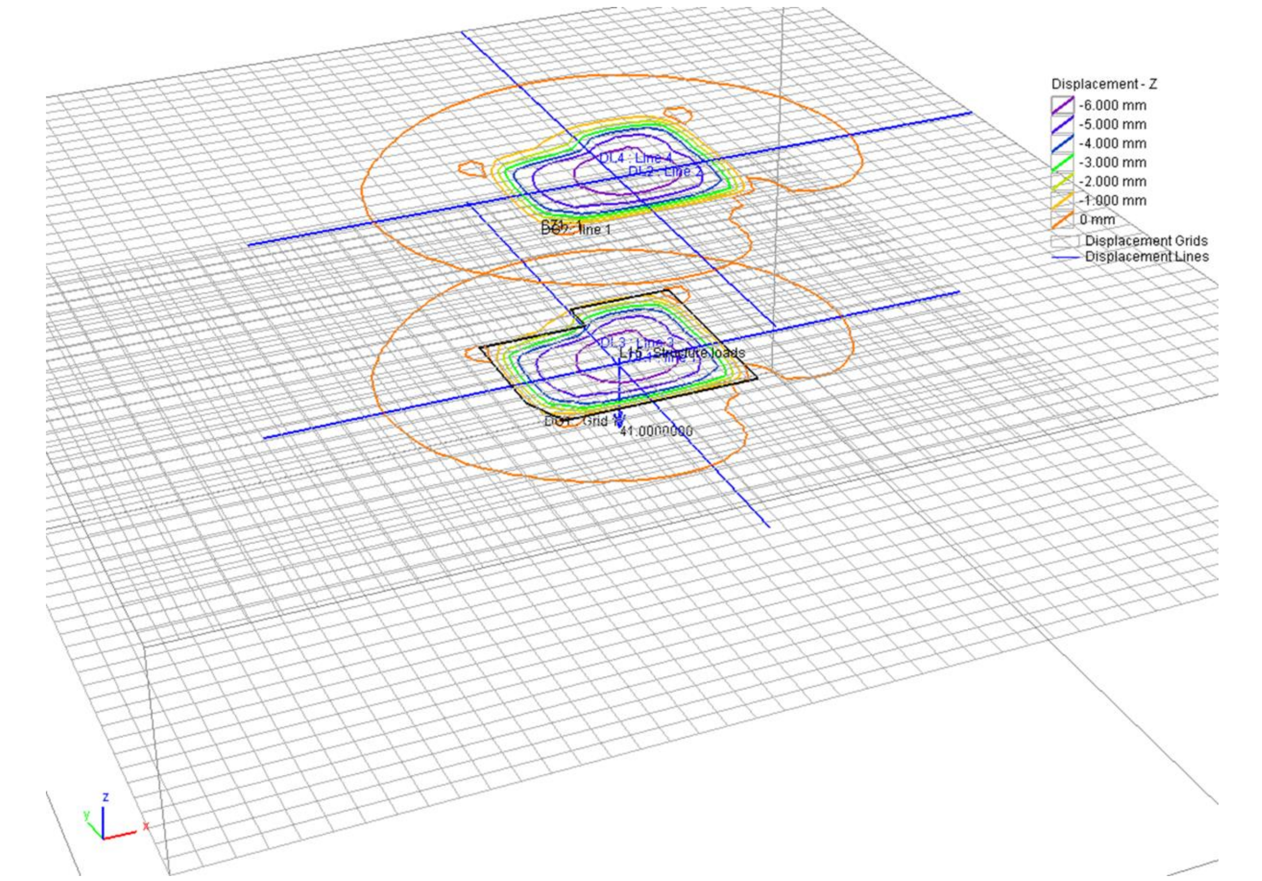

Figure 9: Stage 4 – Slab construction & Superstructure loads transfer (Long term drained conditions) – Vertical Displacements

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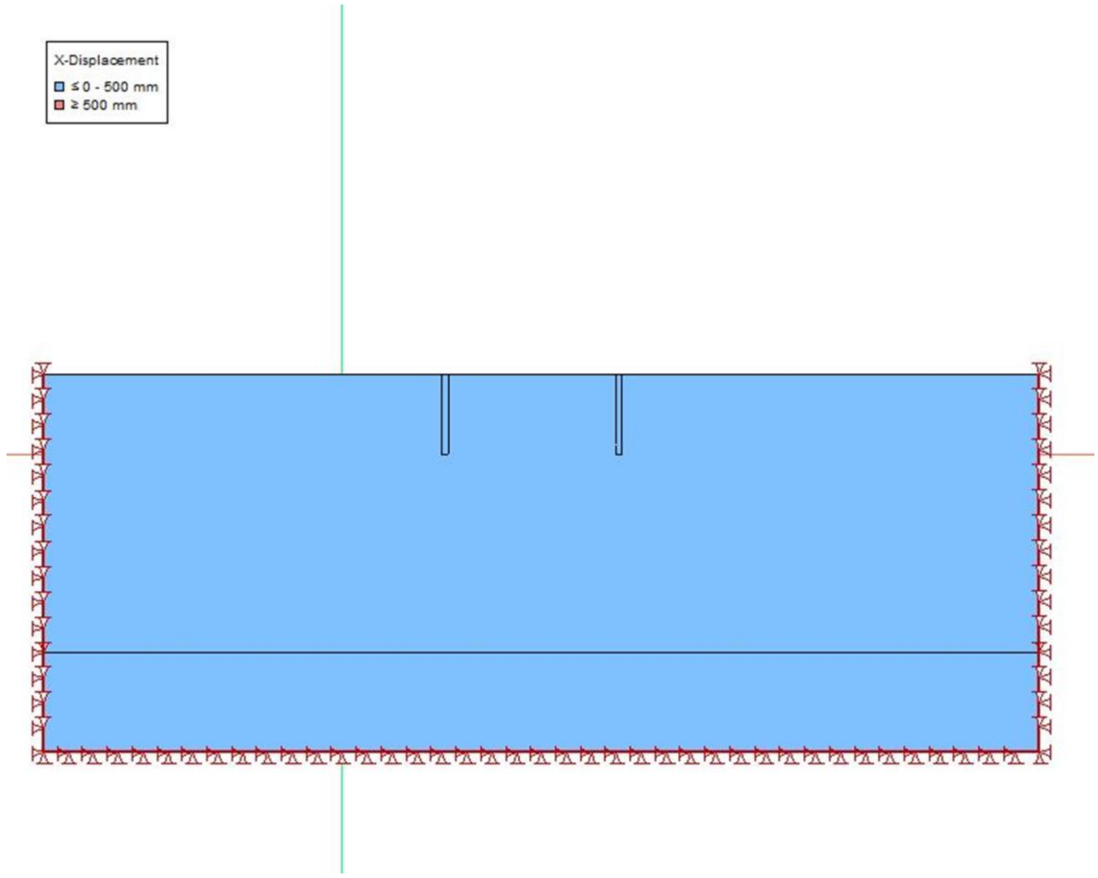

Figure 10: Stage 1 Retaining Walls Installation – Horizontal Displacements on Retaining Wall

Date: 2018

Scale: Not to scale

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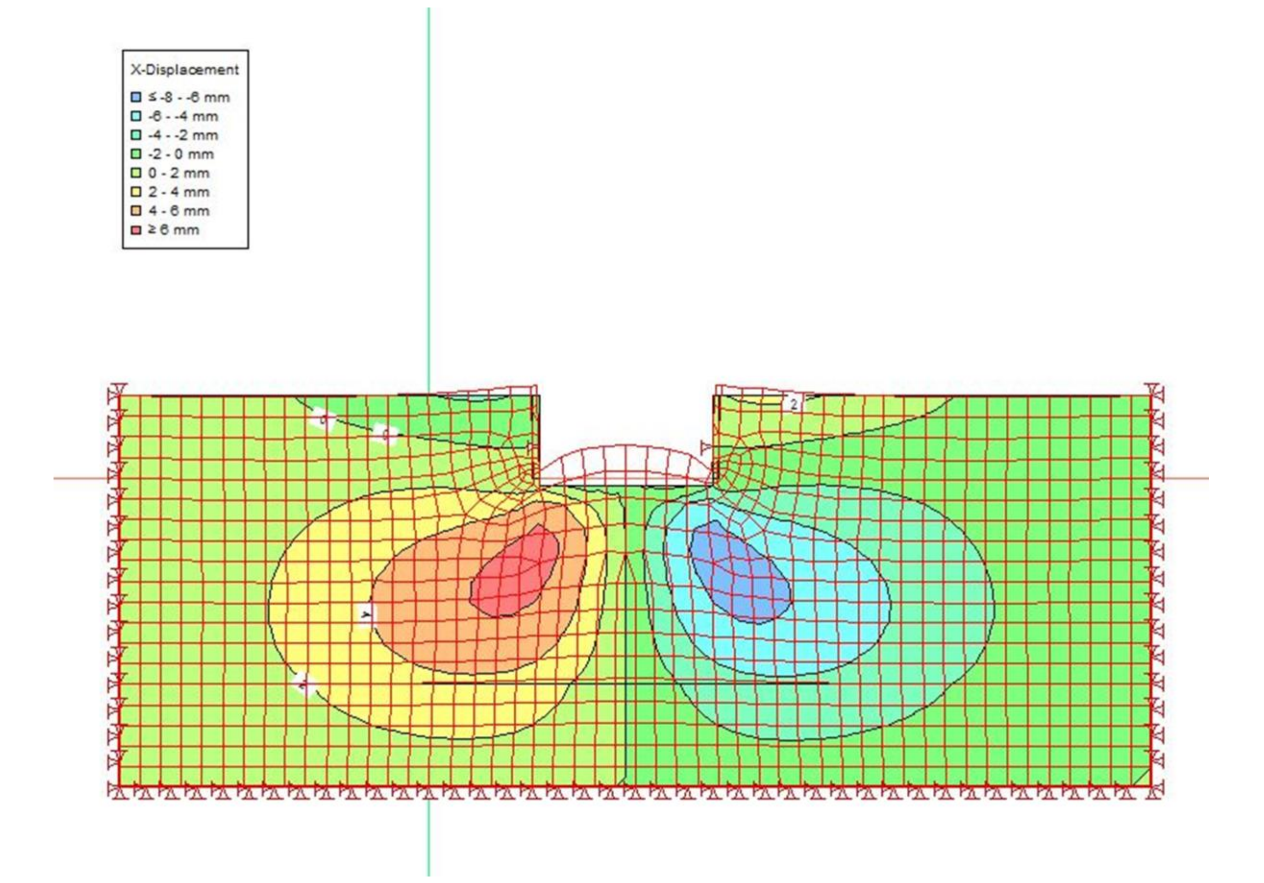

Figure 11:	Stage 2 Excavation – Horizontal Displacements on Retaining Wall
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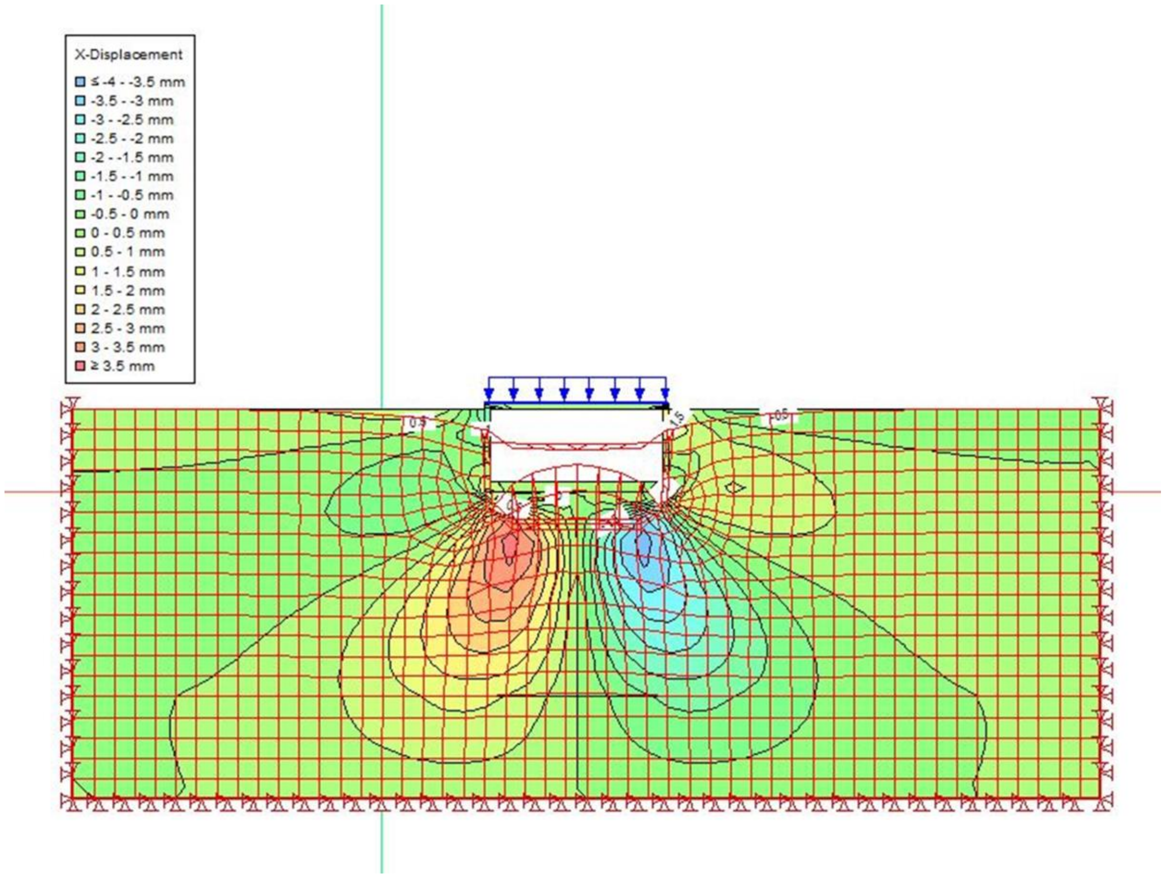

Figure 12: Stage 3 – Slab construction & Superstructure loads transfer (Short term conditions) – Horizontal Displacements on Retaining Wall

Date: 2018

Scale: Not to scale

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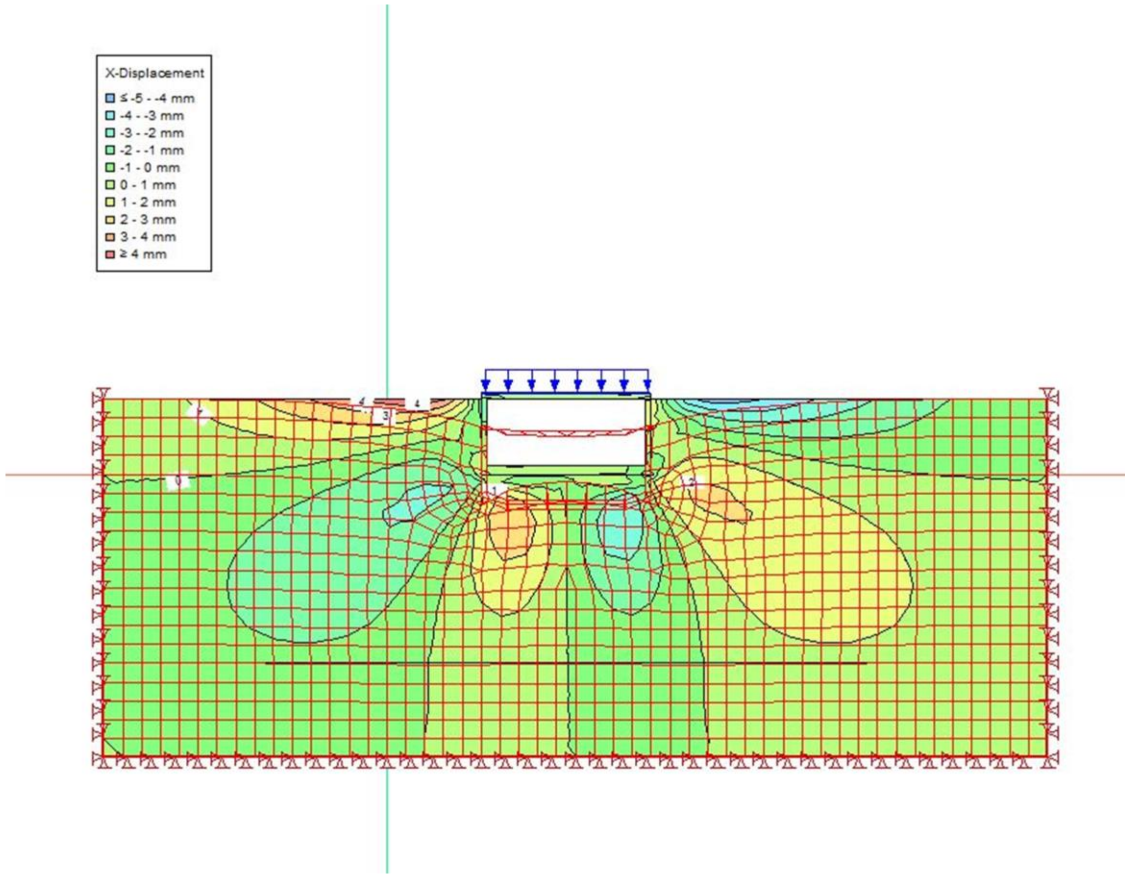

Figure 13: Stage 4 – Slab construction & Superstructure loads transfer (Long term drained conditions) – Horizontal Displacements on Retaining Wall

Date: 2018

Scale: Not to scale

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APPENDIX A

Transport for London
London Underground

London Underground
Infrastructure Protection

3rd Floor
Albany House
55 Broadway
London SW1H 0BD

www.tfl.gov.uk/tube

Your ref:
Our ref: 24211-SI-2-060918

Holli Welsh
Premier Energy
holli.welsh@premierenergy.co.uk

06 September 2018

Dear Holli,

STUDIO HOUSE HAMPSTEAD HILL GARDENS LONDON NW3 2PH

Thank you for your communication of 5th September 2018.

I can confirm that London Underground assets will not be affected by works at the above location.

If I can be of further assistance, please contact me.

Yours sincerely

Shahina Inayathusein
Information Manager
Email: locationenquiries@tube.tfl.gov.uk
Direct line: 020 3054 1365