ELLIOTT WOOD LLP

KINGSWAY HOUSE, 103 KINGSWAY, LONDON WC2B 6QX

ASSESSMENT OF IMPACT OF REDEVELOPMENT ON PICCADILLY LINE TUNNELS

REVISION 1

November 2018

GEOTECHNICAL CONSULTING GROUP
52A Cromwell Road Tel: +44 (0) 20 7581 8348
London SW7 5BE Fax: +44 (0) 20 7584 0157
United Kingdom Email: admin@gcg.co.uk
Geotechnical Consulting Group LLP is a partnership registered in England No OC356005 the registered address of which is as above.

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DISCLAIMER

REVISION HISTORY

Revision	Date	Description
Rev. 0	07/11/2018	First issue
Rev. 1	07/11/2018	Revised to reflect comments from Elliot Wood

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1 INTRODUCTION

It is proposed to redevelop a site located to the west of Kingsway as shown in Figures 1 and 2. The site is located at National Grid reference TQ 258 728.

It is currently occupied by Kingsway House, a seven-storey structure with a single level basement. The redevelopment will involve demolition of the existing internal structure, and construction of a new eight-storey structure.

The London Underground Limited's (LUL) Piccadilly Line eastbound (EB) and westbound (WB) tunnels run below the site at about 27m and 33m below the existing basement respectively.

Elliott Wood LLP have instructed the Geotechnical Consulting Group LLP (GCG) to undertake an assessment of the likely ground movements due to the redevelopment. This is in order to determine the potential impact of the resulting ground movements on the underlying tunnels.

This report presents the results of the assessment of the impact of the redevelopment on the underlying tunnels from the perspective of ground movements.

All information used in the assessment was provided to GCG by Elliott Wood, unless noted otherwise. It is outside the scope of this report to consider the adequacy of works as proposed or to consider their impact on any other assets.

2 EXISTING SITE AND PROPOSED REDEVELOPMENT

The site is bounded by Kingsway in the east, Parker Street in the north, Great Queen Street in the south and neighbouring properties in the west (see Figure 2).

A site specific topographic survey (included in Appendix A) indicates that the ground level along the streets around the site is about +22mOD.

It is currently occupied by Kingsway House, a seven-storey building with a single level basement. The survey of the existing building indicates the existing basement floor level at +18.65mOD.

The Kingsway House structure is understood to transfer the existing loads from the building to the underlying ground through a network of load bearing masonry facades, party wall and central core with interior steel columns on shallow concrete footings (Reference [1]).

The redevelopment will involve demolition of the existing internal structure retaining the masonry facades and party wall, and construction of a new eight-storey structure (Reference [1]).

The new structure will have new frame and core on a 0.8m thick raft. The raft extends over two levels (namely, the upper and lower levels) and the footprints of the rafts are as shown on drawing 213461-EW-00-L01-S-0900-T1 (see Appendix A). The formation level of upper and lower rafts are +17.85mOD and +17.05mOD respectively. This means that the upper level raft requires 0.8m of excavation and the lower level raft requires 1.6m of excavation below the existing basement floor level. The existing party wall and the external façade at the northwest corner of the site will be underpinned to facilitate the excavation for lower level raft. The existing foundations of the façade / party walls will be cut locally to construct new columns by extending the new raft.

Appendix A contains key drawings / sketches showing the existing and proposed structures, and the underlying LUL tunnels.

3 LONDON UNDERGROUND LIMITED PICCADILLY LINE TUNNELS

The site is located at about 100m to the south of the Holborn London Underground Station and about 450m to the northeast of the Covent Garden London Underground Station. The Piccadilly line westbound and eastbound tunnels run underneath the site.

The Survey Associates Limited have undertaken a line and level survey of the Piccadilly line tunnels underneath the site (see Drawing SAL 1540-01 01 Rev. 0 in Appendix A). Tunnel lining details have not been supplied. However, based on the information available, the tunnels are thought to have been constructed using bolted cast iron segments. At the location of site, the tunnels are understood to have an internal diameter of 12″ 7′ (3.83m). The soffit levels of the EB and WB tunnels are -8.5mOD and -14.5mOD respectively. These correspond to 25.6m and 31.6m below the formation level of the lower raft. The invert levels of the EB and WB tunnels are estimated to be -12.3mOD and -18.3mOD respectively.

4 GROUND CONDITIONS

The geology of the area shown on the British Geological Survey Geology of Britain viewer suggests that the site is underlain by the River Terrace Deposits, London Clay and Lambeth Group in the same order of succession (Figure 3).

A ground investigation (GI) was undertaken for the site and reported in Reference [2]. This comprised one cable percussion borehole (15m deep), two window sample holes (4-5m deep), three dynamic probes (3.2-4.0m deep) and twelve manually excavated trial pits (0.7-1.4m deep) within the footprint of the existing basement. The locations of these exploratory holes are as shown in Figure 4.

The ground investigation revealed Made Ground (0.3 to 1.0m thick) followed by River Terrace Deposits (1.5 to 2.2m thick) and then the London Clay. None of the exploratory holes proved the base of the London Clay. The borehole and the window sample holes terminated within the London Clay whereas the trial pits terminated within the River Terrace Deposits.

The Made Ground comprised unreinforced basement floor slab (0.15m to 0.20m thick) followed by silty sand and gravel with brick, concrete and occasional timber fragments. The River Terrace Deposits was described as medium dense slightly silty fine to coarse sand and fine to coarse angular to rounded gravel. The London Clay was described as firm fissured silty clay (up to 0.5m thick) at the top followed by stiff fissured silty clay and becoming very stiff at depth.

Based on the GI data described above combined with the published BGS geological maps and the BGS boreholes in the vicinity of the site, the following idealised stratigraphy has been assumed for this site:

Made Ground	+18.65 to +18.25mOD (0.4m thick)
River Terrace Deposits	+18.25 to +16.05mOD (2.2m thick)
London Clay	+16.05 to -8.95mOD (25m thick)
Lambeth Group	-8.95 to -23.95mOD (15m thick)

Based on the above stratigraphy, the proposed raft will be founded within the River Terrace Deposits. The Piccadilly Line tunnels run within the London Clay. The westbound tunnel is located at 24.6m below the top surface of London Clay whereas the eastbound tunnel is located at 30.6m below.

Table 1 presents a summary of soil parameters adopted for the elastic analysis for the short- and long-term conditions. The corresponding undrained and/or drained young's modulus profiles are illustrated in Figure 5. These are based on GCG experience.

5 GROUND MOVEMENTS

5.1 General

It is envisaged that the development will involve the following works, which would cause vertical stress changes and ground movements at the location of the underlying tunnels:

- Demolition of the internal structure of existing building
- Excavation for raft slabs
- Construction of new structure

The demolition and excavation will cause unloading whereas the construction of new structures will cause reloading of the ground below. For the purpose of determining the likely vertical stress changes and ground movements, the demolition and excavation are considered as a single stage.

The following construction stages therefore have been considered for the elastic analyses:

- Stage 1: Demolition of internal structure and excavation for raft slabs
- Stage 2: Construction of new structure
- Stage 3: Long-term

The accumulated vertical stress changes and ground movements at the end of each of the above stages are discussed in the subsequent sections.

The ground movement analyses were undertaken by Boussinesq's method using a computer program Oasys Pdisp. The method assumes a linear elastic behaviour of the soil and a flexible structure. The ground movement calculations therefore represent 'greenfield' ground conditions (i.e. unaffected by the stiffness of the structures) and are considered to be conservative. The analyses were carried out based on the short-term or long-term stiffness parameters presented in Table 1 below, as appropriate.

Table 1. Soil stratigraphy and stiffness parameters adopted for elastic analysis

Strata	*Level at top of stratum (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	+18.65	Drained parameters used			10,000	10,000	0.2
River Terrace Deposits	+18.25	Drained parameters used			30,000	30,000	0.2
London Clay	+16.05	7,000	337,000	0.5	5,600	269,600	0.2
Lambeth Group	-8.95	Drained parameters used			310,000	420,000	0.2

Note: Rigid boundary is taken as -23.95mOD (i.e. base of the Lambeth Group)

Figure 6 shows the footprints of the existing structure, the proposed structure and the EB and WB Piccadilly Line tunnels that were considered for elastic analysis.

5.2 Stage 1: Demolition of internal structure and excavation for rafts

Elliott Wood have provided the loads on the foundations of the existing structure (see Appendix A). These result in an average pressure of 150kPa on the site footprint.

The upper level raft requires about 0.8m of excavation whereas the lower level raft requires about 1.6m of excavation. These excavations are estimated to cause an unloading of 14.4kPa and 28.8kPa respectively with their footprints.

Assuming no significant delays in construction the excavation is modelled using short-term parameters.

5.3 Stage 2: Construction of new structure

As discussed in Section 2, the new structure will be founded on 0.8m thick raft. Loads from the new structure were supplied by Elliott Wood (see Appendix A). The average pressure across the footprint of the raft is estimated to be approximately 200kPa. This stage has also been modelled using short-term parameters.

5.4 Stage 3: Long-term

The ground within the footprint of the development and its vicinity will continue to move in the long-term as a result of the net change of load on the ground. This stage has been modelled using long-term soil parameters.

5.5 Results

Figures 7 and 8 show the predicted vertical stress changes at the end of Stages 1 and 2 for the westbound and eastbound tunnels respectively. There are no further stress changes in the long-term (Stage 3). These figures indicate that the westbound tunnel is predicted to experience a stress reduction up to 24kPa at the end of Stage 1 (demolition and excavation) and a stress increase up to 5kPa at the end of Stage 2 (construction of new structure). Similarly, the eastbound tunnel is predicted to experience a stress reduction up to 21kPa and a stress increase up to 2kPa.

Figures 9 and 10 show the predicted vertical ground movements at the end of each of the Stages 1 to 3 for the westbound and eastbound tunnels. These figures show that the westbound and eastbound tunnels are predicted to experience less than 1mm heave and settlement as a result of the proposed redevelopment.

6 IMPACT ON THE LUL PICCADILLY LINE TUNNELS

The proposed works are well above the LUL's exclusion zone for the underlying Piccadilly Line (westbound and eastbound) tunnels.

The westbound tunnel is predicted to undergo a maximum stress reduction of 24kPa and a stress increase of 5kPa at its soffit level (see Figure 7), and maximum vertical displacements of less than 1mm (see Figures 9 and 10). The predicted stress reduction equates to 4.6% of the existing overburden and the stress increase equates to 0.9%. Similarly, the eastbound tunnel is predicted to undergo a maximum stress reduction of 21kPa and a stress increase of 2kPa (see Figure 8), and maximum vertical displacements of less than 1mm (see Figure 10).

Comparison of the predicted vertical movements along the soffit and invert of the tunnels, at various stages of construction, indicate that the tunnels are predicted to undergo a maximum diametrical distortion of less than 0.5mm. This equates to 0.01% of the internal diameter of tunnels. This level of diametrical strain is unlikely to cause any significant alteration in the stresses in the tunnel linings.

The vertical movement profiles presented in Figure 9 show that the minimum radius of curvature of the westbound tunnel is around 365km. This is predicted to occur at the end of unloading due to demolition and excavation (Stage 1). Similarly, the minimum radius of curvature of the eastbound tunnel is 760km (see Figure 10).

The predicted vertical movements and stress changes are not of concern for the structural integrity of the tunnels.

7 CONCLUSIONS

This report presents an assessment of the impact of the proposed redevelopment of Kingsway House (approximate National Grid reference TQ 258 728) on the underlying LUL's Piccadilly Line tunnels. It describes the analyses undertaken, outlines the underlying assumptions and presents the results of the analyses and the assessment.

The proposed works include the demolition of internal structure of the existing building, the excavation (up to 1.6m below the existing basement) for a new raft and the construction of new structure. The proposed works will result in some movement and stress changes at the location of LUL's Piccadilly Line tunnels located at 25.6m and 31.6m below the formation level of the lower raft.

The predicted displacements and stress changes are not expected to have significant impact on the structural integrity of the tunnels, provided these do not have significant pre-existing structural defects.

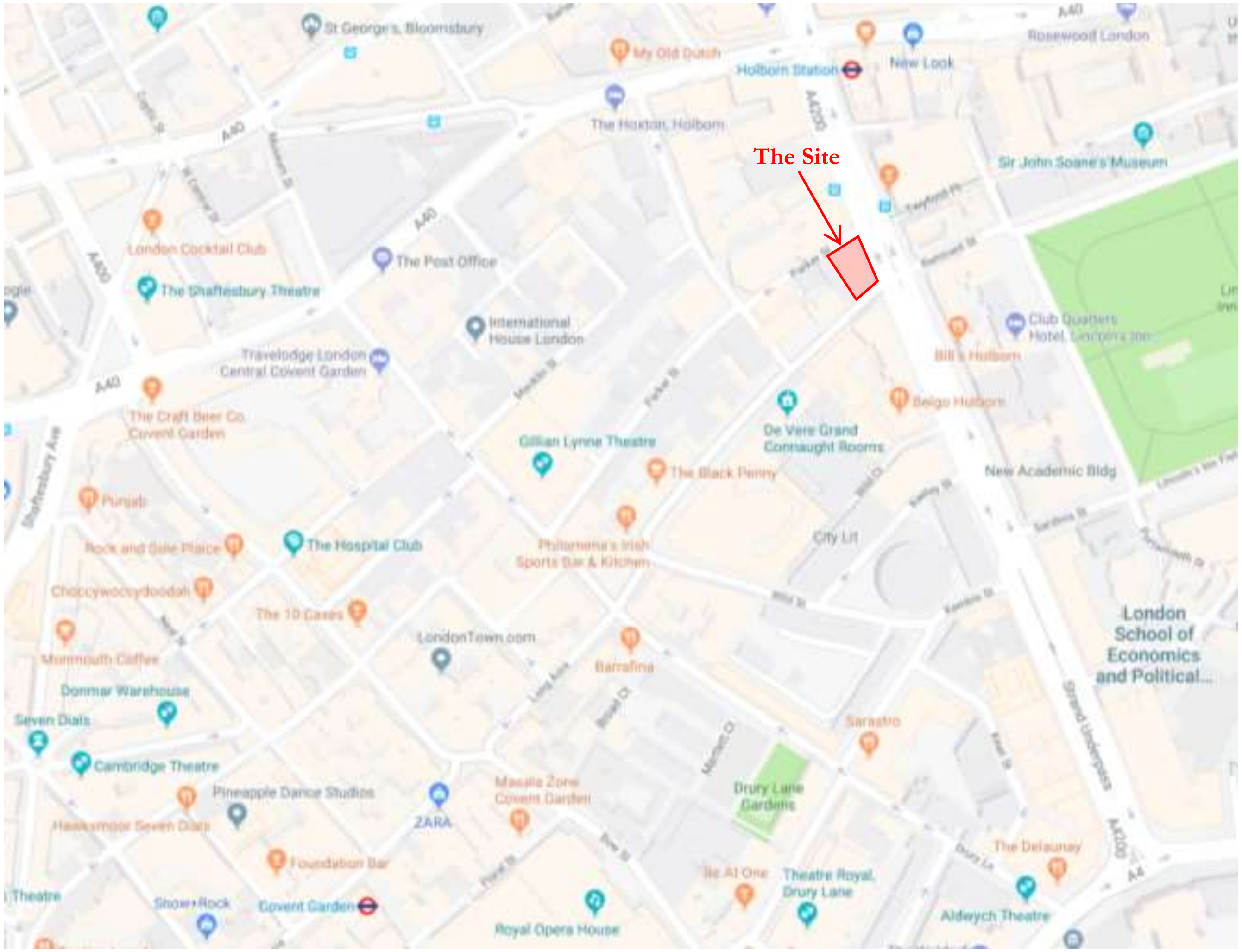
This assessment has been based on the information provided by Elliot Wood LLP. If any of the details changes (e.g. excavation depth, proposed foundation system, loading configuration, and details of the LUL tunnels) then this assessment will need to be reviewed to confirm its validity.

8 REFERENCES

[1] Elliott Wood (2015). Preliminary structural engineering design report for proposed redevelopment of Kingsway House, London WC2B 6QX. Document number 213461-REP-001 Rev. 01, dated 16th March 2015.

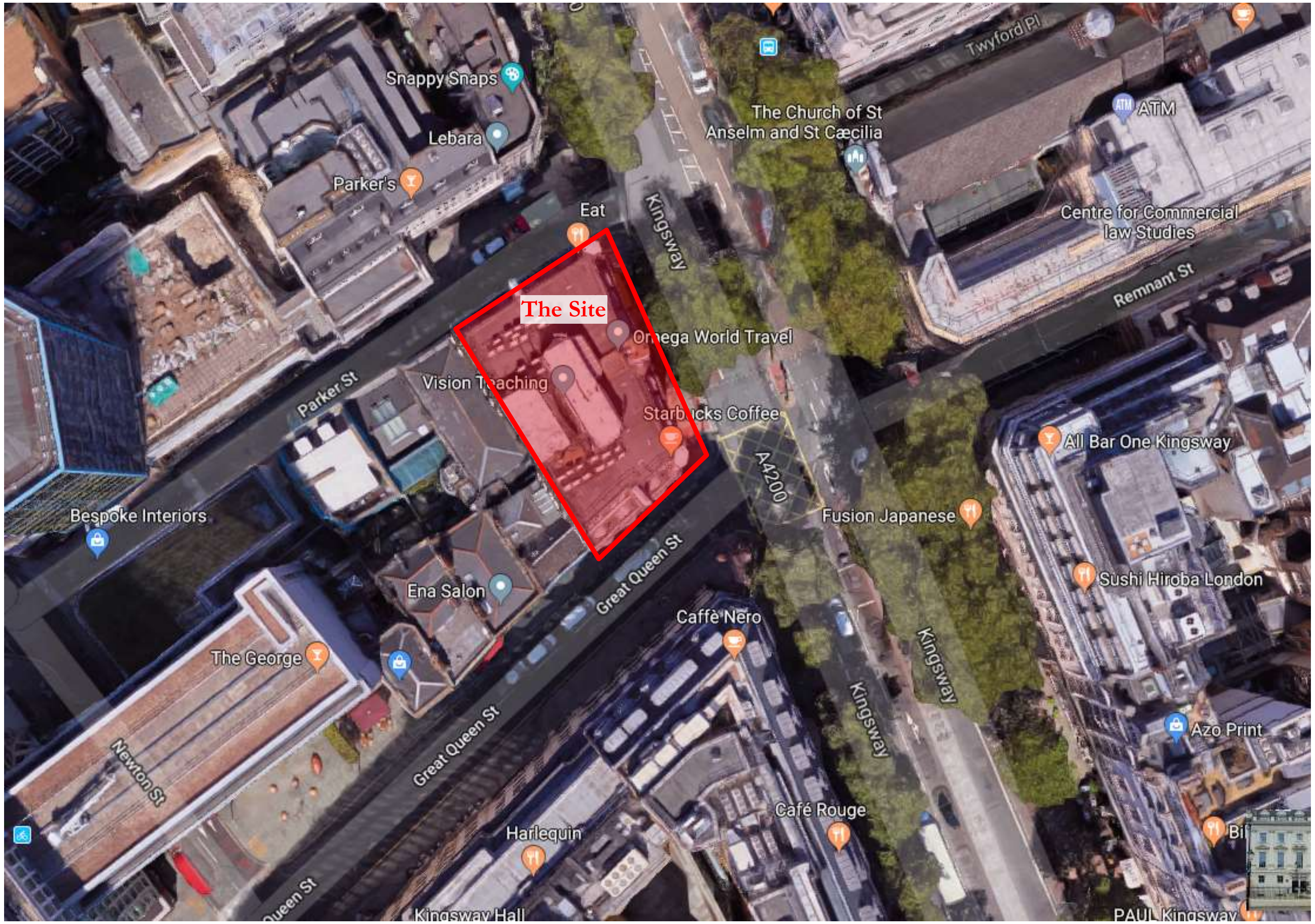
[2] Geotechnical & Environmental Associates (2017). Ground investigation report for Kingsway House, 103 Kingsway, London WC2B 6QX. June 2017. Reference J17049.

FIGURES

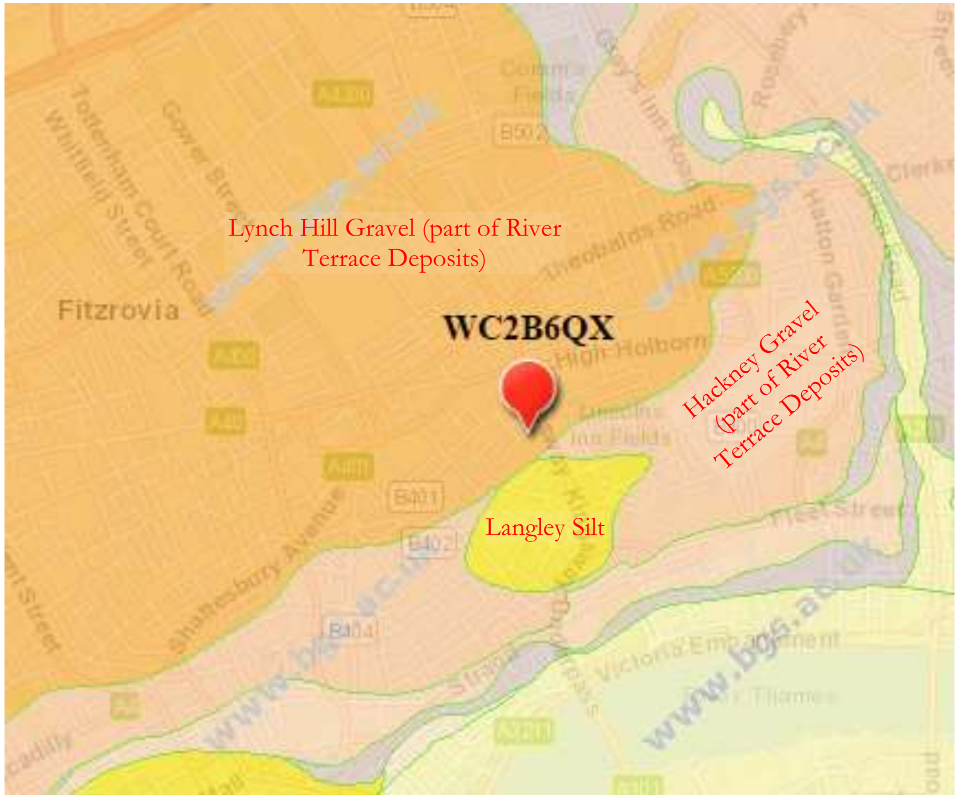


GCG	**Elliott Wood LLP** Kingsway House, 103 Kingsway, London WC2B 6QX	**Figure 1**
	Location of site – Street view (© Google)	

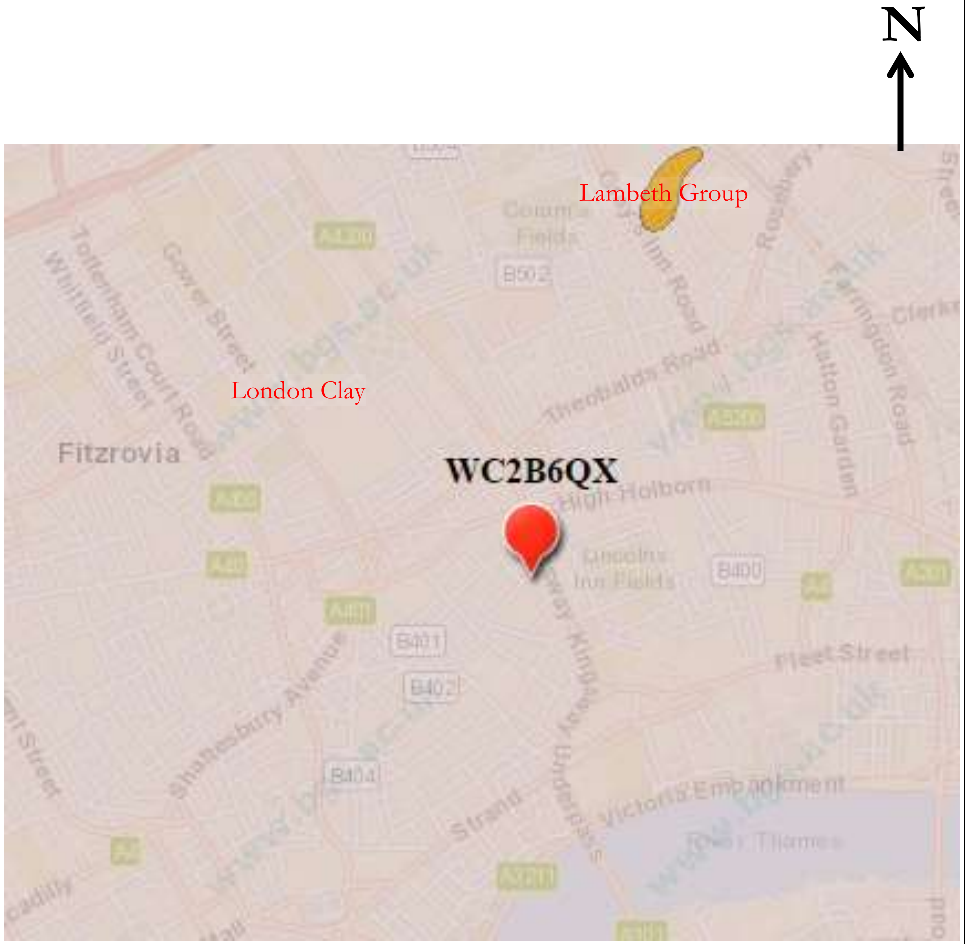
N



	Elliott Wood LLP Kingsway House, 103 Kingsway, London WC2B 6QX	**Figure 2**
	Location of site – satellite view (© Google)	

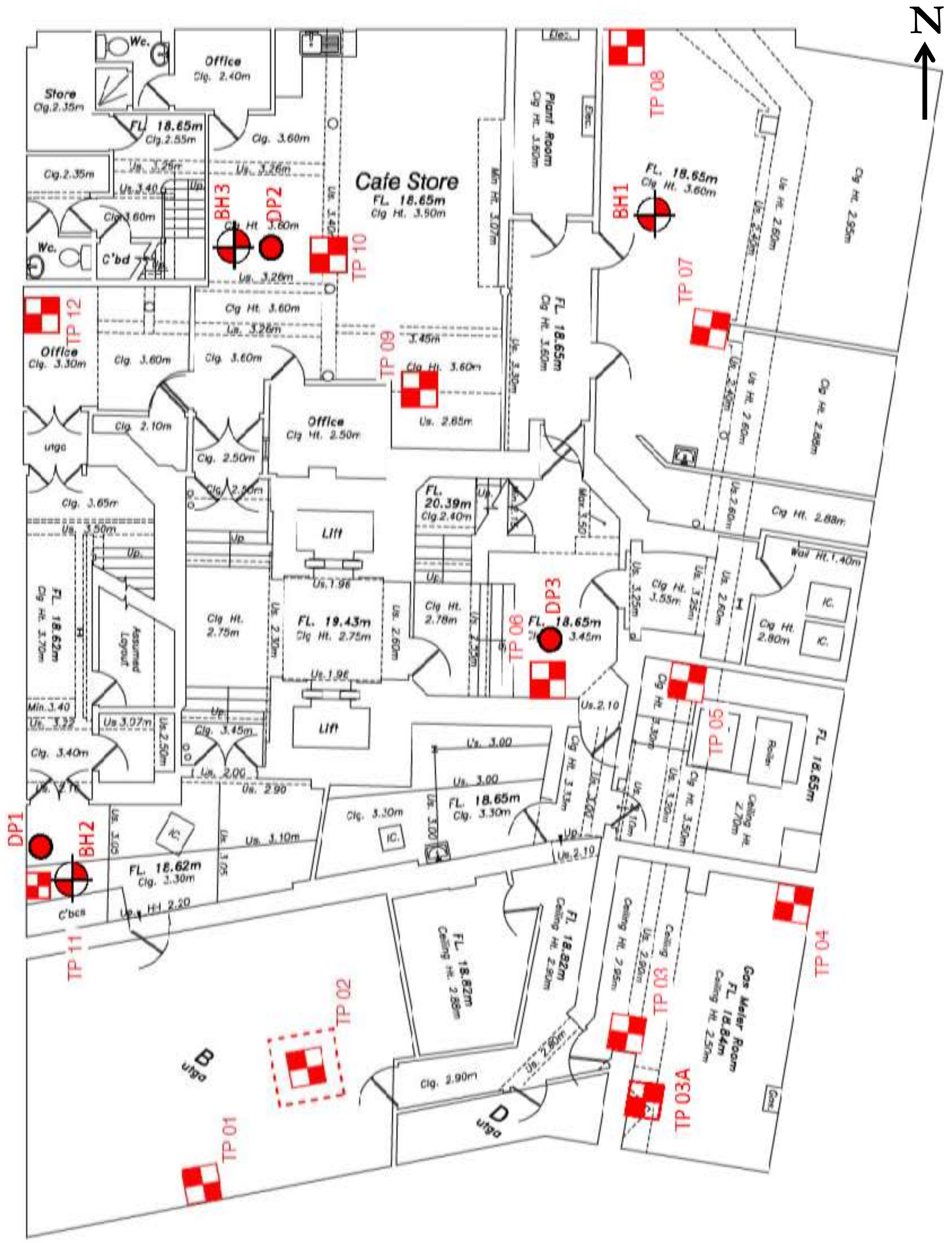


Superficial Geology



Solid Geology

Elliott Wood LLP Kingsway House, 103 Kingsway, London WC2B 6QX		**Figure 3**
Geology of the area shown on BGS maps (http://mapapps.bgs.ac.uk/geologyofbritain/home.html)		



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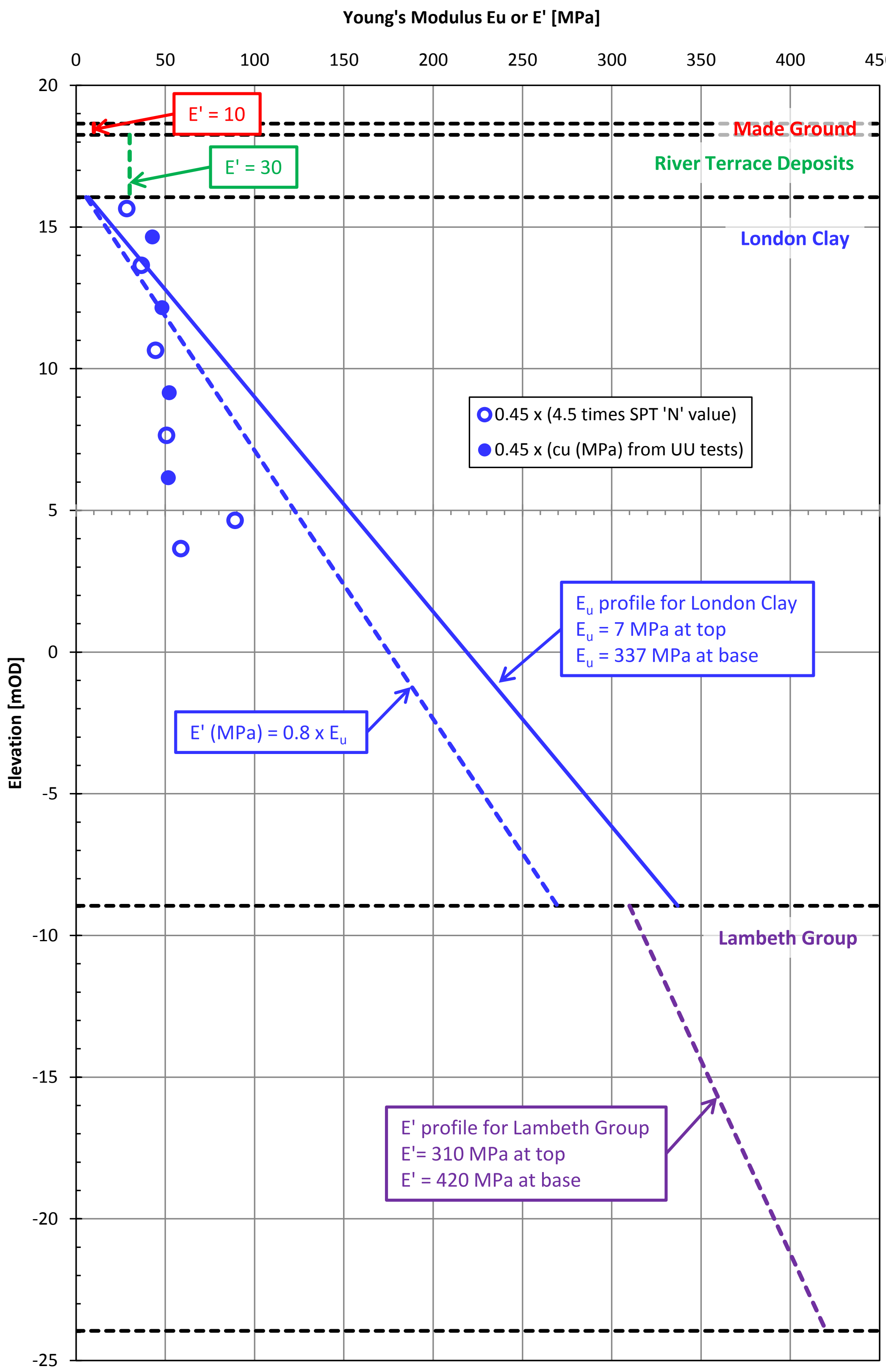
Borehole location plan (extracted from Reference [2])

Figure 4



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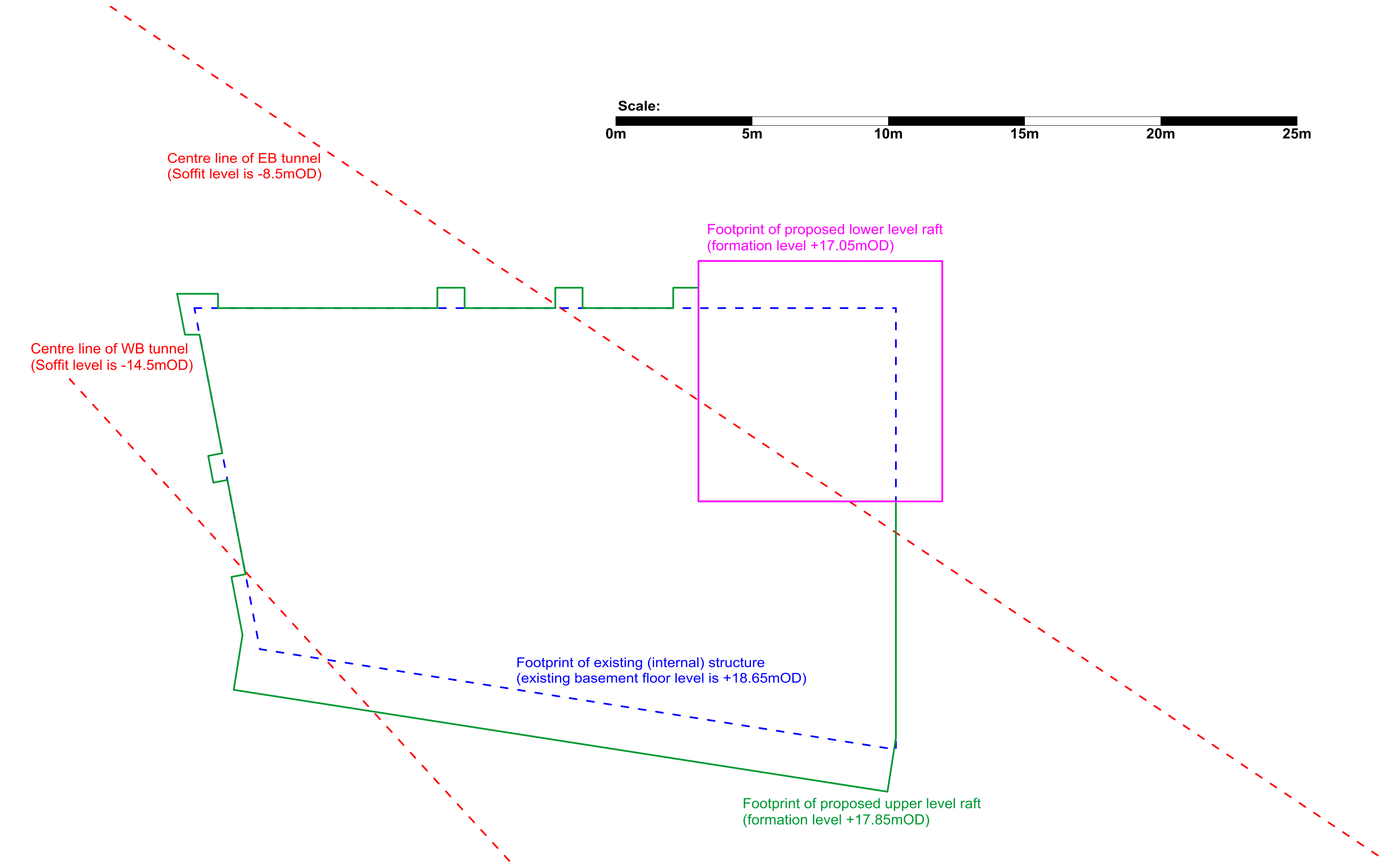
Young's Modulus profile adopted for elastic analysis

Figure 5



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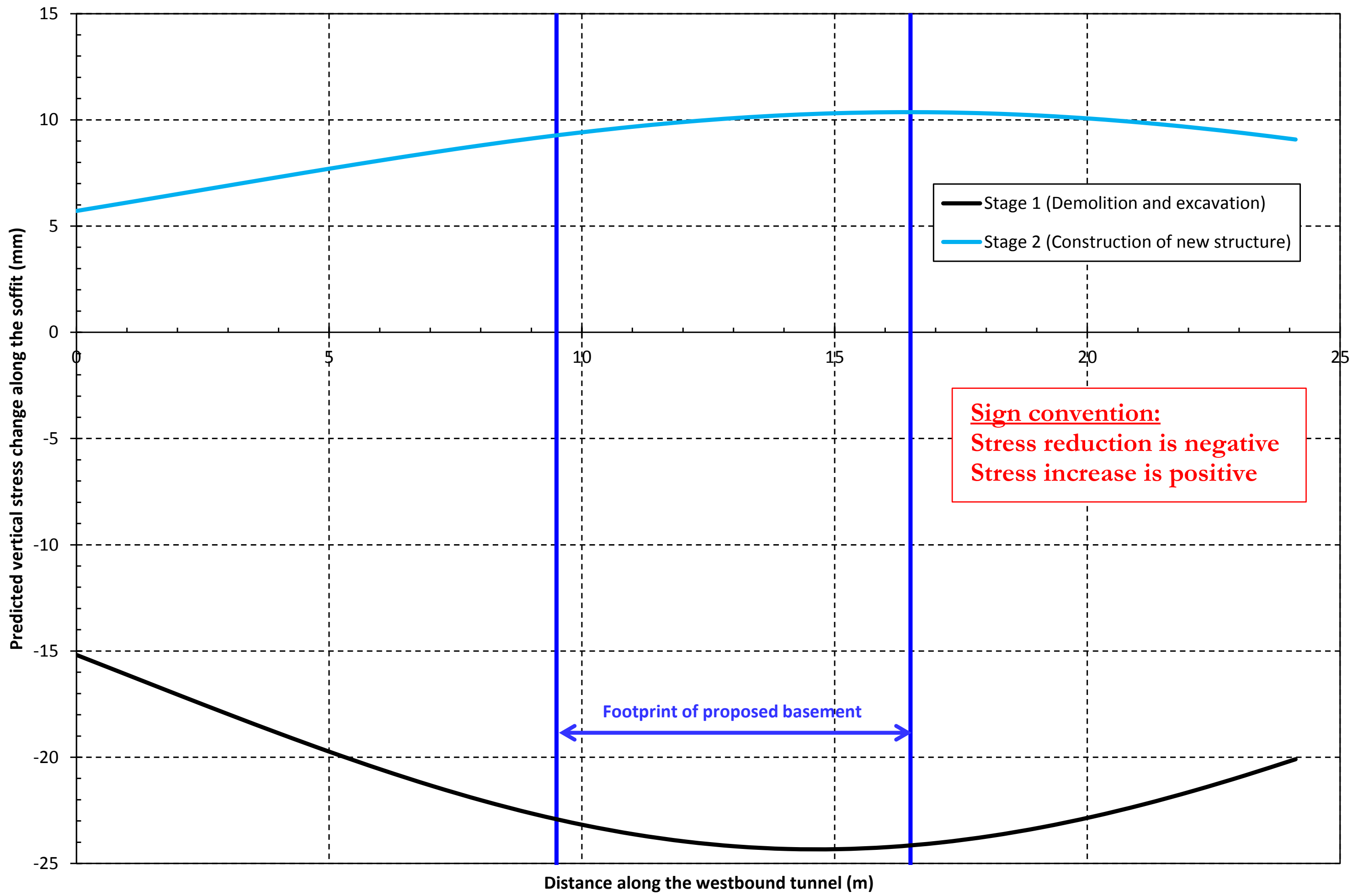
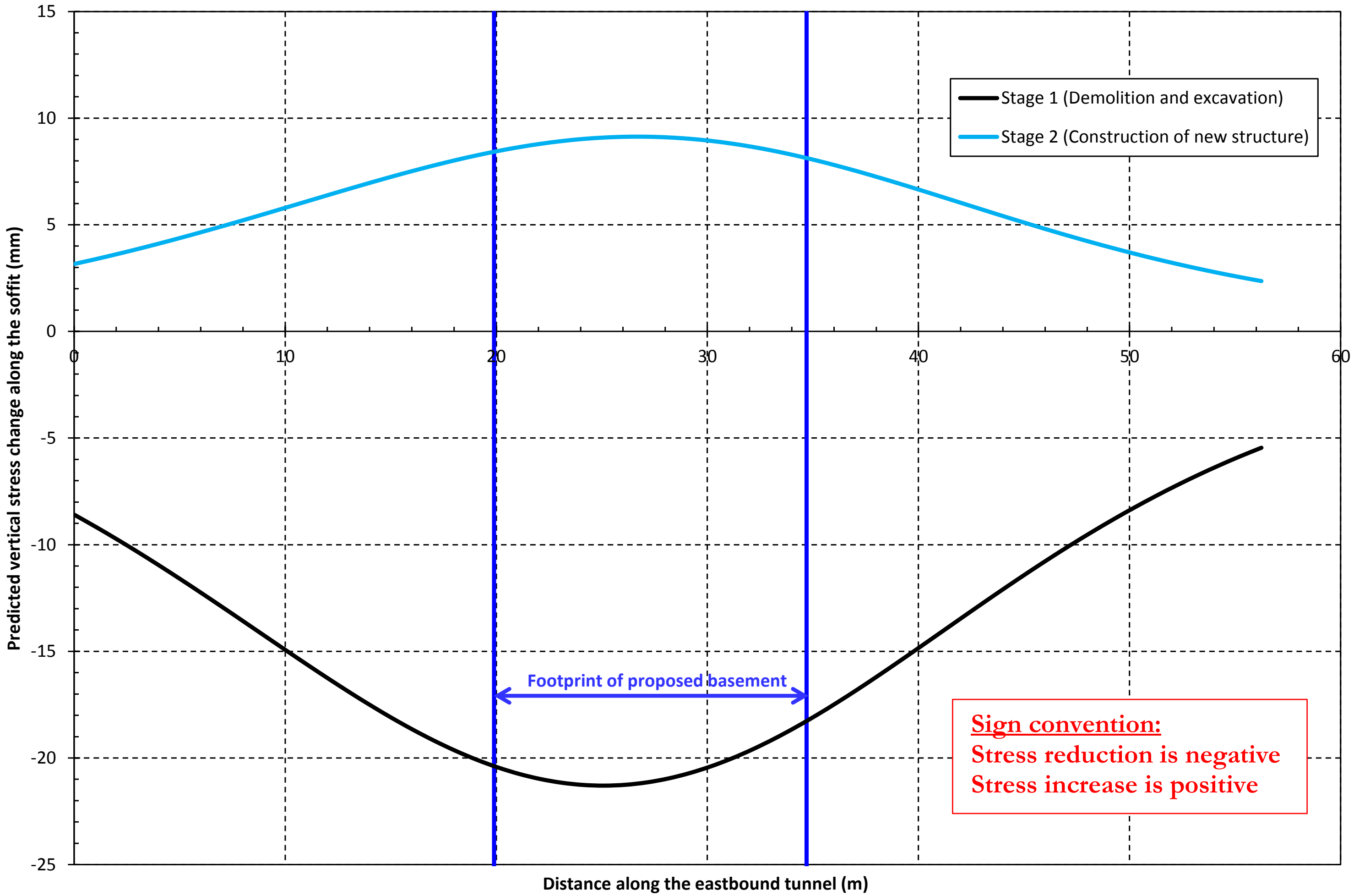
Idealised footprints of existing and proposed structures in relation to the centre lines of eastbound and westbound Piccadilly Line tunnels, modelled in elastic analysis

Figure 6



GCG	**Elliott Wood LLP** Kingsway House, 103 Kingsway, London WC2B 6QX	**Figure 7**
	Predicted cumulative vertical stress changes along the soffit of <u>westbound tunnel</u> at the end of Stages 1 and 2; No further stress changes expected in the long-term (i.e. after Stage 2).	



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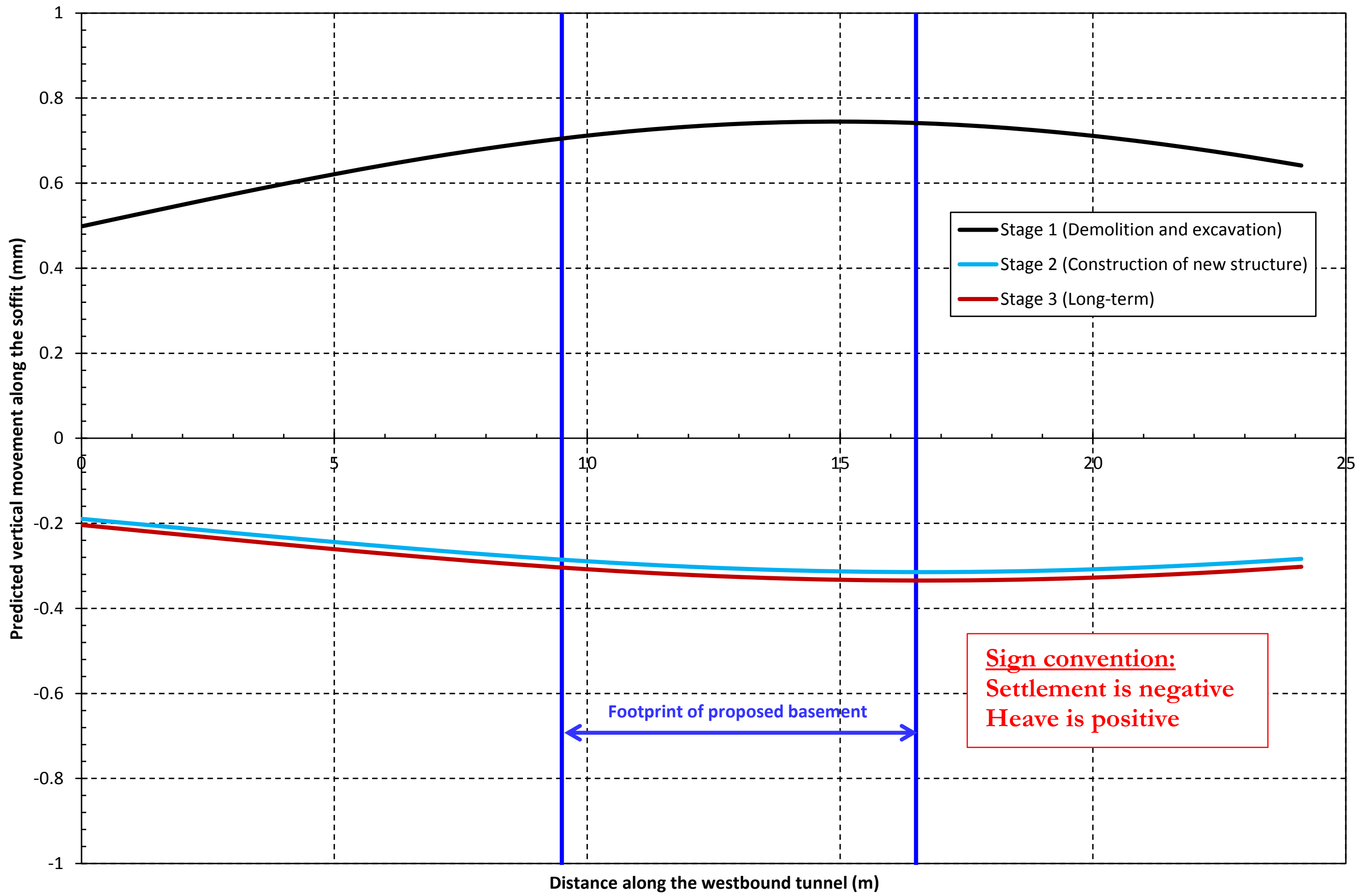
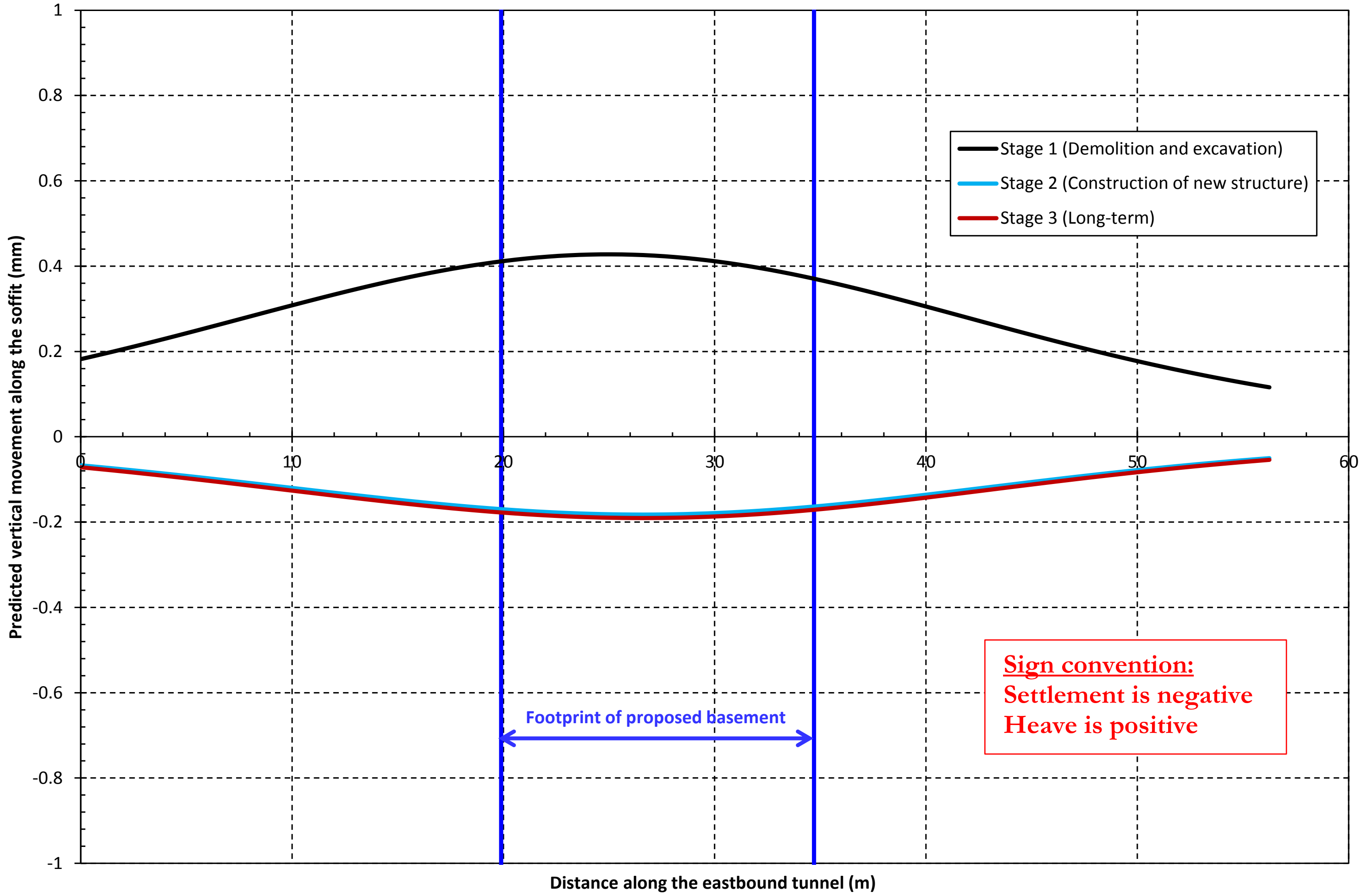
Predicted cumulative vertical stress changes along the soffit of eastbound tunnel at the end of Stage 1 and 2; No further stress changes expected in the long-term (i.e. after Stage 2).

Figure 8



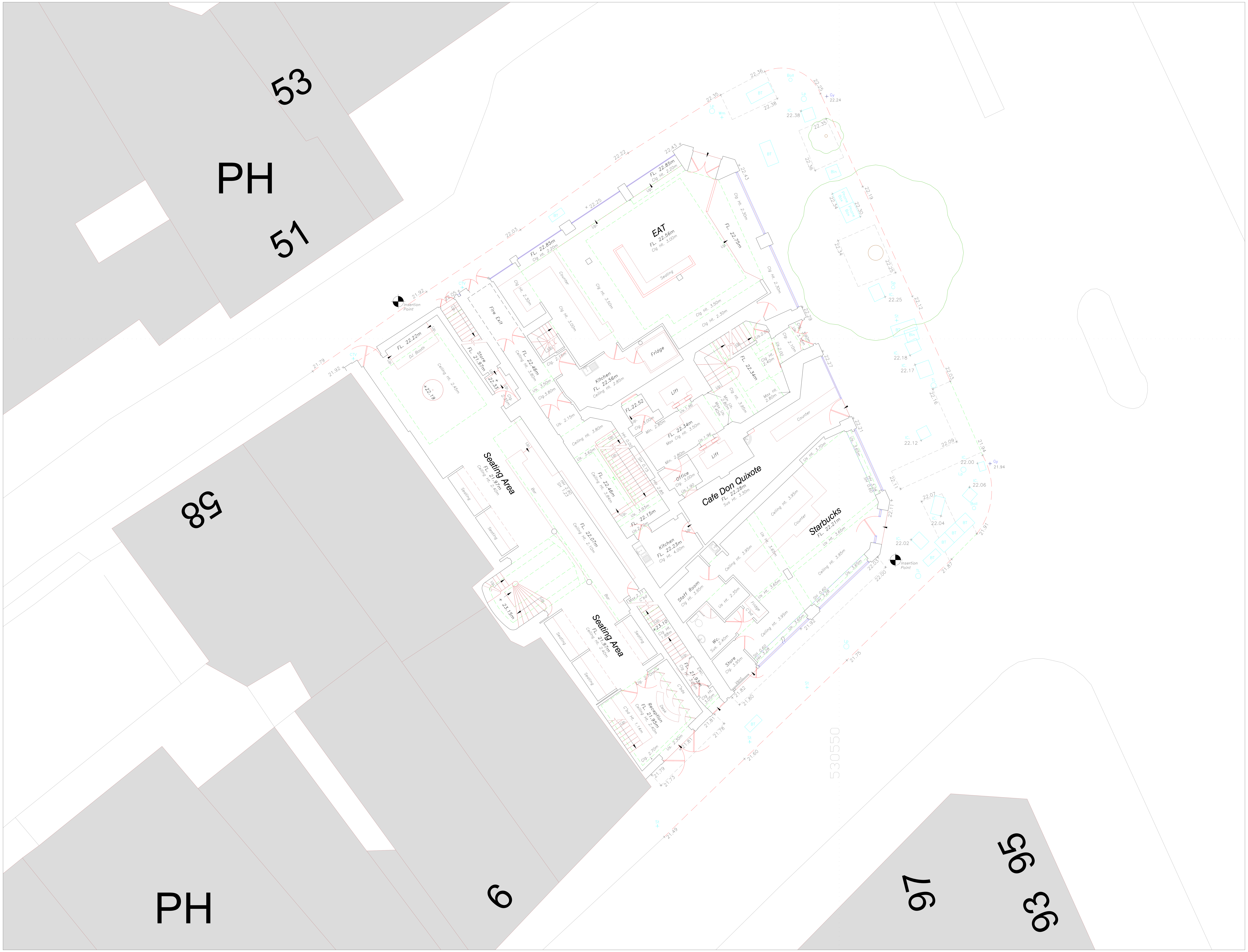
	Elliott Wood LLP Kingsway House, 103 Kingsway, London WC2B 6QX	**Figure 9**
	Predicted cumulative vertical ground movements along the soffit of westbound tunnel at the end of Stages 1 to 3	

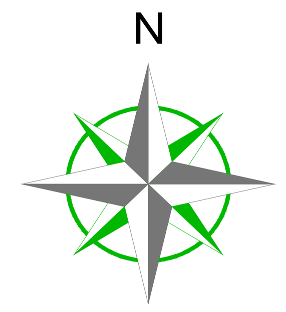


	Elliott Wood LLP Kingsway House, 103 Kingsway, London WC2B 6QX	**Figure 10**
	Predicted cumulative vertical ground movements along the soffit of eastbound tunnel at the end of Stages 1 to 3	

Appendix A: Key drawings of the existing and proposed structures, and LUL tunnels

Site Plan





OS Note:

Some services may have been omitted due to parked vehicles. The Ordnance Survey tile is to be used as a guide only.

OS Buildings | *Surveyed Buildings*

This survey has been orientated to the Ordnance Survey (O.S) National Grid (OSGB36) via Global Navigational Satellite Systems (GNSS) and the O.S. Active Network (OS Net).

A true OSGB36 coordinate has been established near to the site centre via a transformation using the OSTN02 & OSGM02 transformation models.
The survey has been correlated to this point and a further one or more OSGB36 points established to create a true O.S. bearing for angle orientation.

No scale factor has been applied to the survey therefore the coordinates shown are arbitrary & not true O.S. Coordinates which have a scale factor applied.

Please refer to Survey Station Table to enable establishment of the on-site grid.

Building Survey Legend:

SHt 1.00 HHt 2.12	Sill Height from FFL. Head Height from FFL.
SL 51.03m HL 52.82m	Sill Level from defined datum. Head Level from defined datum.
Susp CHt: 2.00 Struct CHt: 3.00	Suspended Ceiling Height from FFL. Structural Ceiling Height from FFL.
Susp Ceil: 30.00m Struct Ceil: 31.00m	Suspended Ceiling Level from datum. Structural Ceiling Level from datum.
IFL: 100.00m +100.00m	Internal Floor Level (General). Internal Floor Level (Specific).
Insertion Point	Insertion Point for overlay drawings of other floors or details.

Legend:

Rev	Date	Description	Drawn	Q. Ref

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Rowan House
Duffield Road
Little Eaton
Derby
DE21 5DR
Tel (01332) 830044 Fax (01332) 830055
admin@greenhatch-group.co.uk
www.greenhatch-group.co.uk

St Albans	Newcastle	Poland
Unit B, The Courtyard Alban Park St Albans Hertfordshire AL4 0LA t. (01727) 854481	24 Riverside Studios Amethyst Road Newcastle Bus. Park Newcastle-U-Tyne NE4 7YL t. (01912) 736391	ul. Panewnicka 91 40-761 Katowice Poland t. 0048 32 202 2292 www.greenhatch.pl

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PROJECT
Kingsway House London

TITLE
Existing Site Plan

SCALE	DATE
A1@ 1: 100	05.08.14
DRAWN	QUALITY REF
PG	

Level datum	GPS
Grid orientation	GPS
Job number	20370
Drawing No.	Rev.
20370_01_P	0

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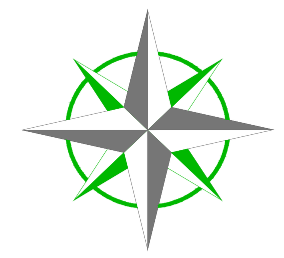

Basement

Ground Floor

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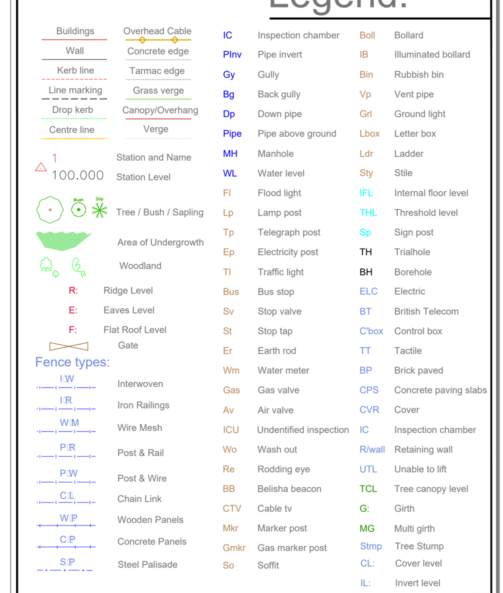

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Kingsway House London

TITLE
Existing Basement & Ground Floor

SCALE	DATE
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PG	

Level datum	GPS
Grid orientation	GPS
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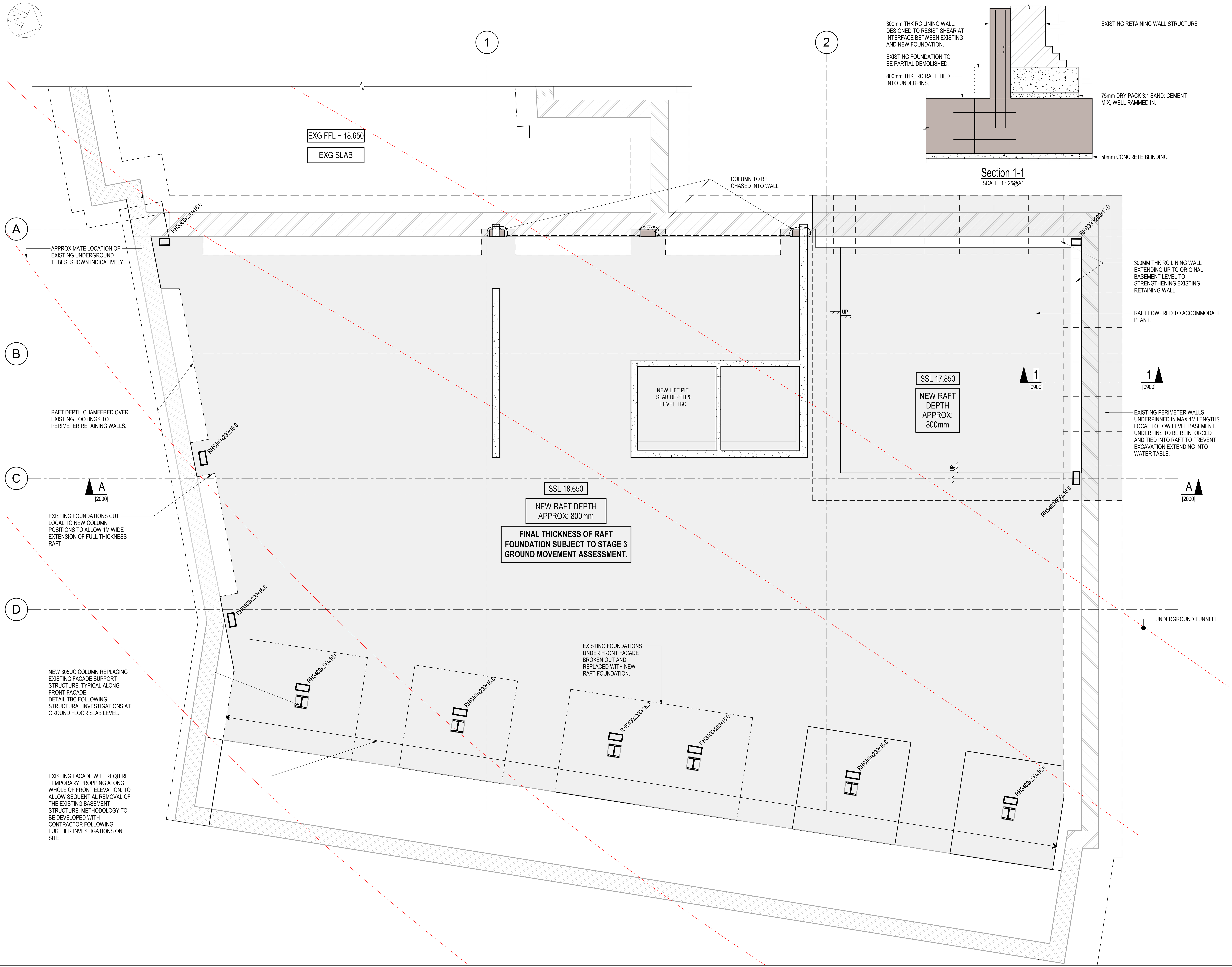

This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.

Do not scale from this drawing.

LEGEND

- EXISTING STRUCTURE
- NEW LOAD BEARING BLOCKWORK
- NEW LOAD BEARING BRICKWORK
- NEW REINFORCED CONCRETE
- NEW MASS CONCRETE
- PADSTONES
- LOAD BEARING STUDWORK
- NON LOAD BEARING WALLS
- LOAD BEARING STRUCTURE BELOW
- EXISTING STRUCTURE TO BE REMOVED
- NEW STEEL BEAMS
- EXISTING BEAMS
- NEW LINTELS OVER OPENINGS
- MOMENT CONNECTION
- 150 MD — 150DP METAL DECK RC SLAB

NOTE:
- ALL STEEL GRADE S355
- ALL CONCRETE GRADE C28/35
- WHERE POSSIBLE ALL STEELS HAVE BEEN DESIGNED AS COMPOSITE WITH METAL DECK SLAB. ALLOW FOR SHEAR STUDS WELDED TO BEAM IN EVERY TROUGH OF DECK.
- ALL STEEL WEIGHTS SUBJECT TO CHANGE SUBJECT TO DETAILED DYNAMIC ANALYSIS OF FLOOR PLATES.
- ALL COLUMNS & PERIMETER BEAMS TO BE TEID INTO MASONRY FACADE @ 450MM HORIZONTAL & VERTICAL C/C WITH HILTI HY-70 RESIN ANCHORS. REQUIREMENT FOR VERTICAL MOVEMENT JOINT TO BE CONFIRMED FOLLOWING COMPLETION OF GROUND MOVEMENT ASSESSMENT IN NEXT STAGE.
- CU=COLUMN UNDER
- ALL BRACING TO BE 150X75X10 UEA **CROSS** BRACING

rev	date	by	chk	description
T1	09.08.17	PL	JGa	Issued for Tender

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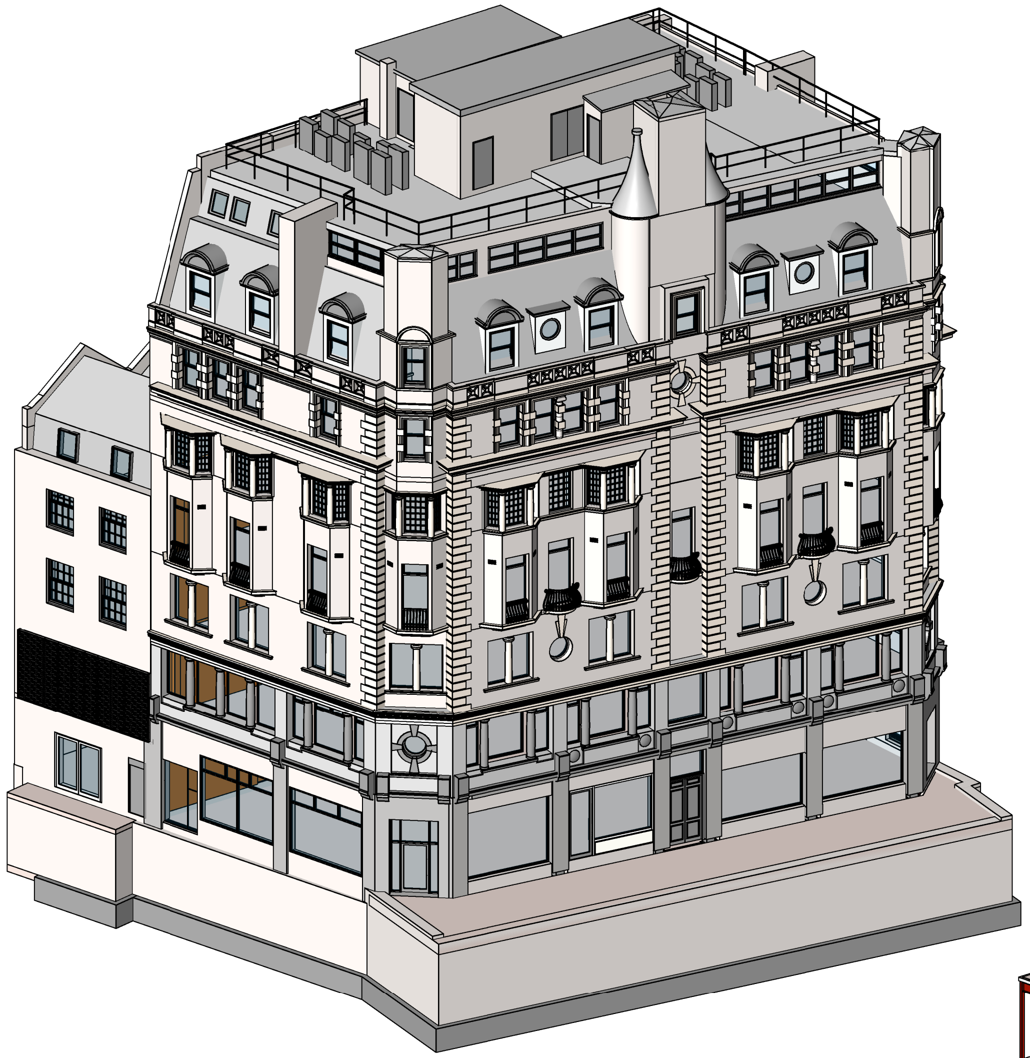
project
Kingsway House
103 Kingsway
London
WC2B

drawing title
Proposed Lower Ground Floor Plan

scale (s)	date	drawn
1:50@A1, 1:100@A3	January 2015	CRa

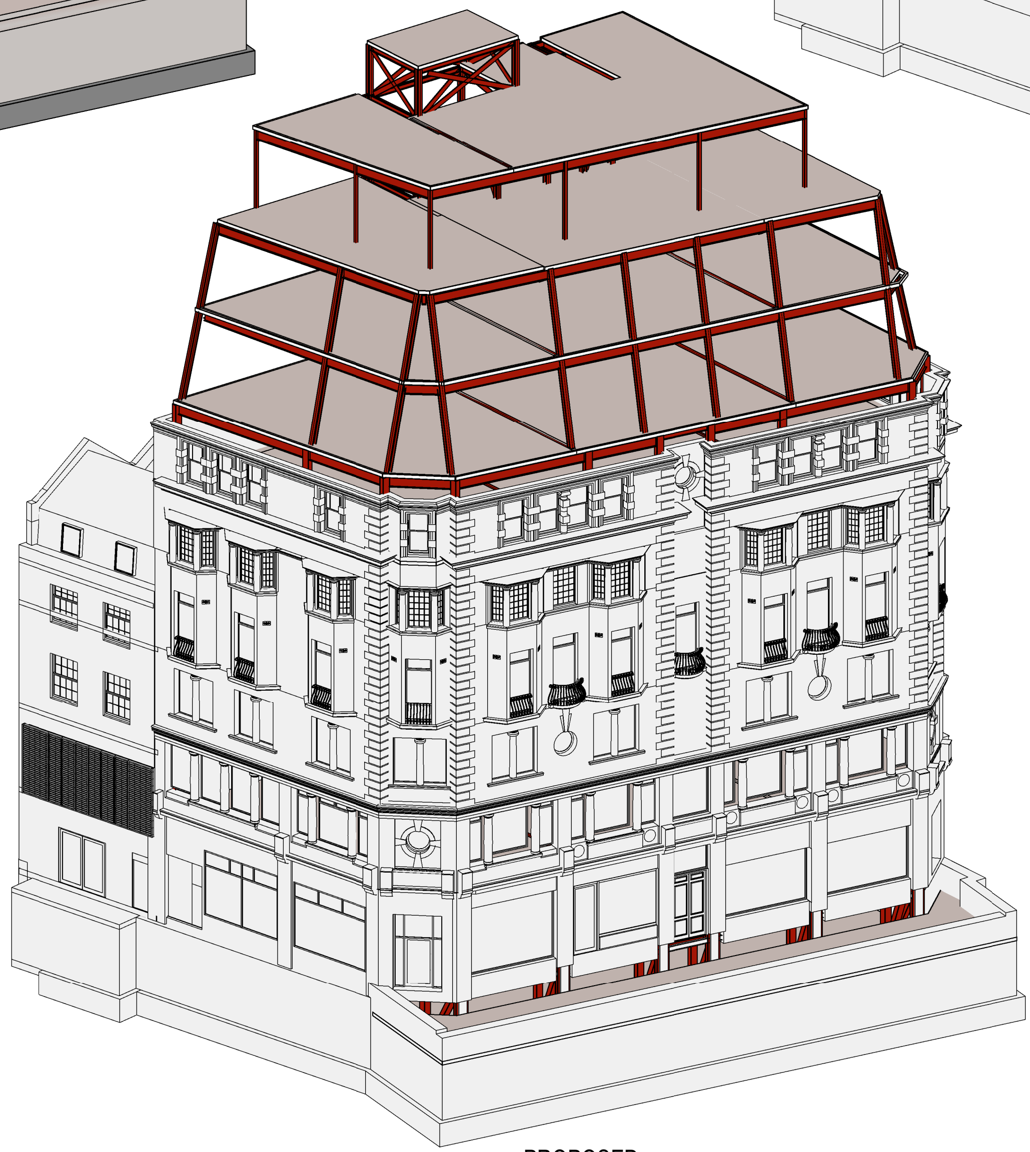
project no.	drawing status
213461	Preliminary

originator	zone	level	role	drg no.	revision
EW	00	L01	S	0900	T1



EXISTING

EXISTING & DEMOLISHED



PROPOSED

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

Do not scale from this drawing.

ISOMETRIC VIEW:

- EXISTING STRUCTURE
- EXISTING STRUCTURE TO BE REMOVED
- NEW REINFORCED CONCRETE
- NEW MASS CONCRETE
- NEW STRUCTURAL STEELWORK
- NEW LOAD BEARING BLOCKWORK
- NEW LOAD BEARING BRICKWORK
- NEW TIMBER
- NEW GLAZING

NOT FOR CONSTRUCTION

rev	date	by	chk	description
P2	16.03.15	CRa	JGa	Issued for Information & Comment
P1	23.02.15	CRa	JGa	Issued for Information & Comment

elliottwood

Elliott Wood Partnership LLP, 241 The Broadway, London SW19 1SD
Consulting Structural and Civil Engineers. www.elliottwood.co.uk
tel: 020 8544 0033. fax: 020 8544 0066. info@elliottwood.co.uk

project

Kingsway House
103 Kingsway
London
WC2B

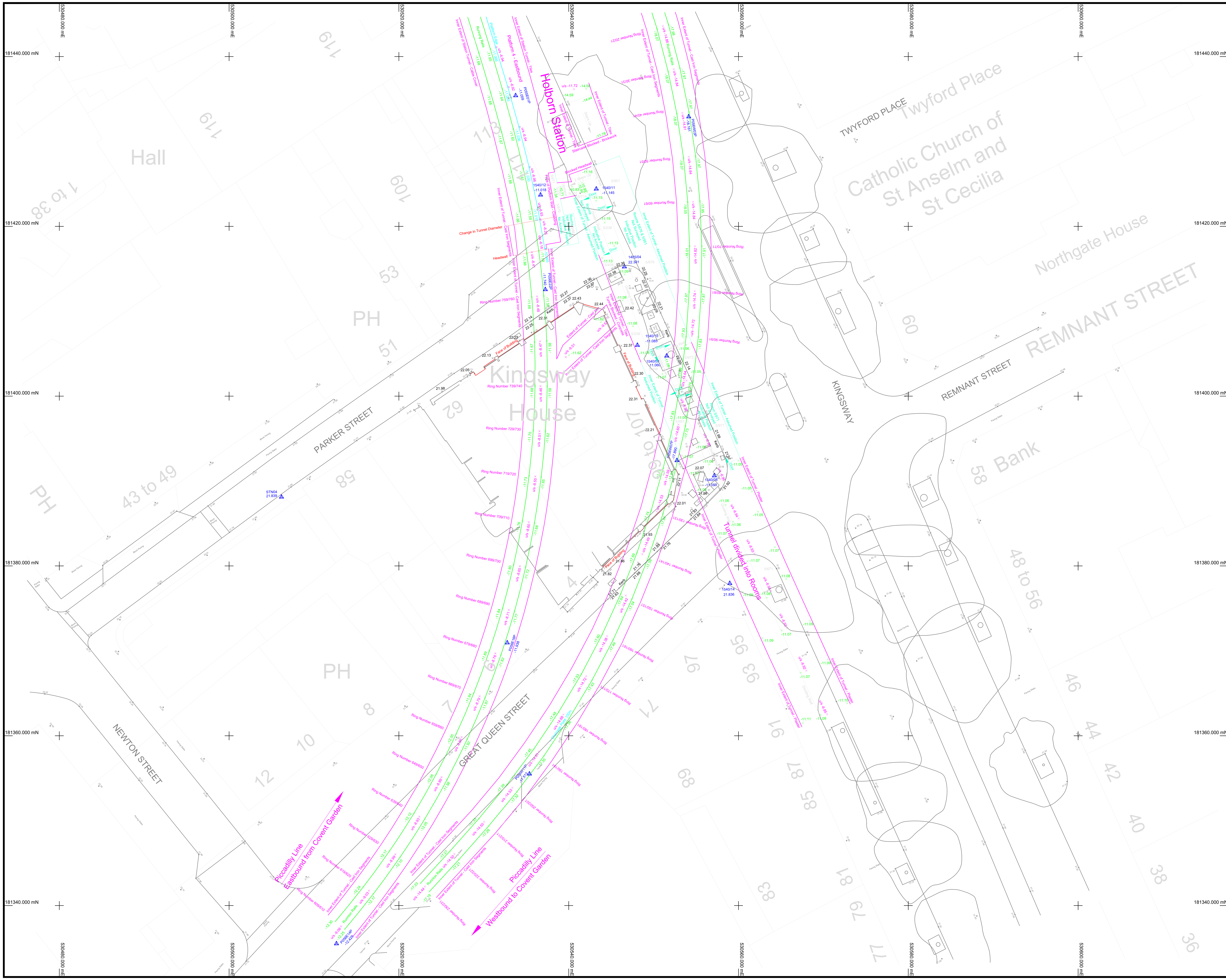
drawing title

3D Views

scale (s)	date	drawn
NTS	February 2015	CRa

project no.	drawing status
213461	Preliminary

originator	zone	level	role	drg no.	revision
EW	00	XX	S	0010	P2



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LAND AND ENGINEERING SURVEYORS

ISO 9001 REGISTERED FIRM
Certificate Number: GB 1461

Unit F , Eden House , The Office Village ,
River Way , Uckfield , East Sussex , TN22 1SL .
Telephone +44 (0) 845 450 4210 - Facsimile +44 (0) 845 450 4220
E-mail: sal.office@survey-associates.co.uk
Visit us @ www.survey-associates.co.uk

Site Grid North

1. This drawing is to Site Grid and Datum.

2. This is a digital survey and is only accurate at the scale which is specified. Please exercise extreme care if used at a larger scale. 3. This survey shows sub-surface parts of Holborn Station and Piccadilly Line Eastbound and Westbound tunnels in correlation with surface topographic survey.

4. Note that the survey of Holborn Station sub-surface areas terminated at places where the tunnels are blocked or approximately 30m from the development.

5. Note that no survey works has been undertaken below Platform Level. Please be aware of the presence of the sub-platform infrastructure.

6. The survey has been limited to the accessible areas and rooms within the Platform level. Note that there are a number of areas where access was not possible due to Safety and Operational Access Restrictions. Note that the assumed Indicative Extents of some areas has been indicated on this drawing. These positions MUST be checked and cannot be assumed to be dimensionally correct.
Please see Drawing Layer Ref: "OS Map from Client".

7. In all cases survey readings have been taken to the internals faces / finishes. Allowances must be made when determining the external position of the Running and Station Tunnels.

8. Soffit levels which have been prefixed u/s and depicted as shown as 'purple' text represent the inner levels on the cast iron rings or other finishes.

9. Topographic Data in layer "OS Map from Client" and "Topo from Client" has been supplied by client and has not been checked or verified by Survey Associates Ltd. This is for diagrammatic purposes only and should not be used for any other purpose. Source drawing ref: 20370_01-13_PES.dwg

10. Critical clearance dimensions, levels and invert levels should be checked prior to design and construction.

11. The difference in level between LUL datum and site datum is based on common topographic detail and equals: LUL Datum - 100.00m = Site Datum

12. Sal Job Reference is 1540-01.

Key & Abbreviations

u/s Inner Crown of Tunnel - Soffit Levels

Control Stations (Site Grid)

Name	Easting [m]	Northing [m]	Level [m]
STN04	530506.168	181388.123	21.839
1485/04	530546.561	181415.240	22.381
1540/14	530558.975	181377.949	21.836

Revisions

No.	Date	Description
0	10/03/2017	Original Survey

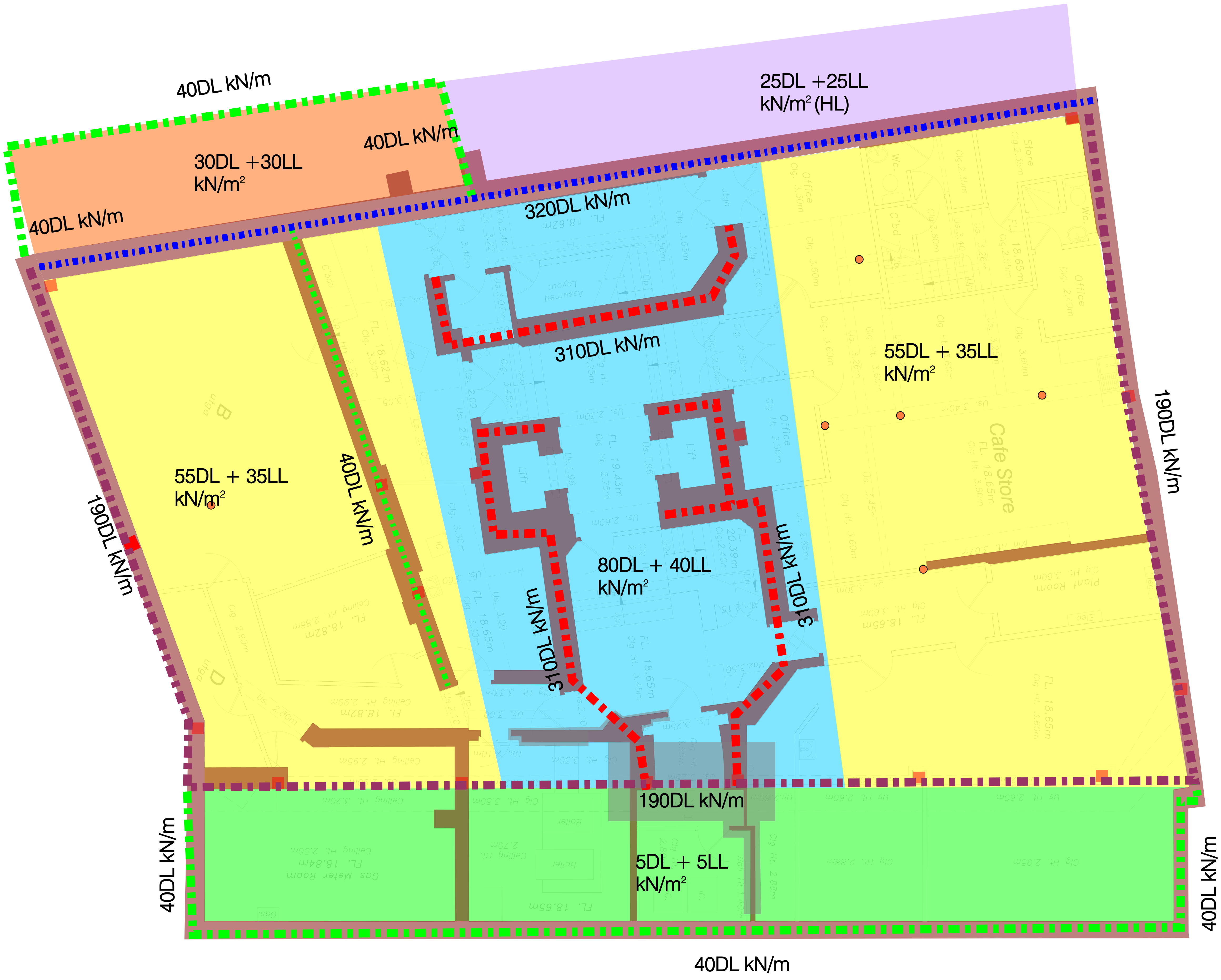
Client : Elliott Wood Partnership Ltd
241 The Broadway
London
SW19 1SD

Project : 1 Kingsway House
Holborn, London

Scale : 1 : 200	Sheet Size : A1
Date of Survey : 10/03/2017	
Project No : 1540-01	Drawn By : JK
Sheet : 1 of 1	Checked By : TC

Title : Correlation Survey

Sheet : SAL 1540-01 01 Rev0



TOTAL WEIGHT OF EXISTING BUILDING (INSIDE SITE BOUNDARY) = <u>61800 DL + 14600LL</u>

rev	date	by	chk	description
P1	08/06/18	LG	JG	Preliminary

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Elliott Wood Partnership Ltd
Wimbledon • Central London • Nottingham
Consulting Structural and Civil Engineers
tel: (020) 7499 5888. www.elliottwood.co.uk

sketch title
EXISTING BASEMENT LOADS

SKETCH

scale (s)	date	drawn
1:100.	JUN 18	LG

project
KINGSWAY HOUSE

Project no.
213461

Sketch no.	revision
SK/XXX	P1

TOTAL WEIGHT OF DEMOLISHED BUILDING (INSIDE SITE BOUNDARY) = <u>22900DL + 700LL</u>

rev	date	by	chk	description
P1	08/06/18	LG	JG	Preliminary

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sketch title
EXISTING BASEMENT LOADS
AFTER INTERNAL DEMOLISHED

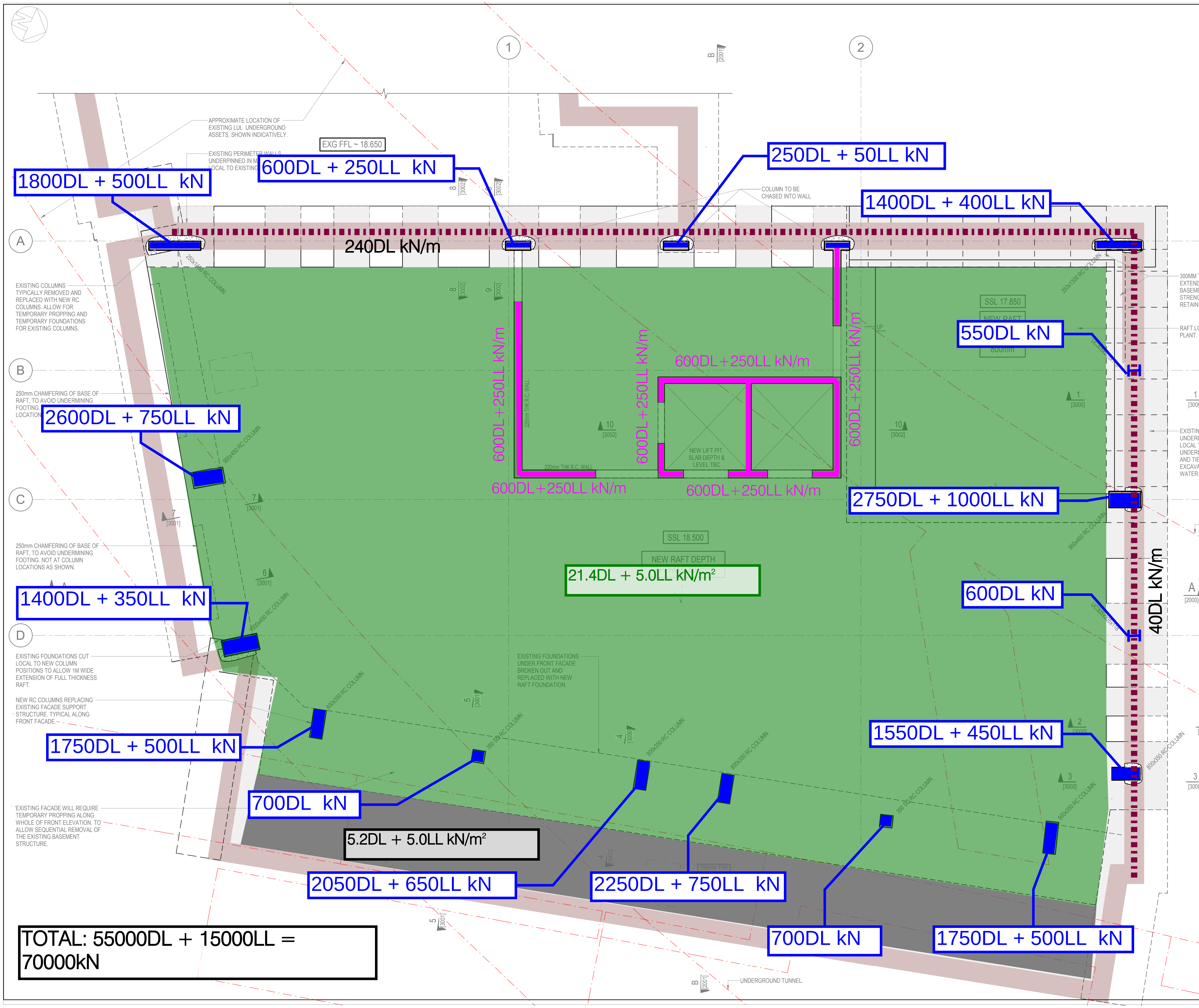
SKETCH

scale (s)	date	drawn
1:100.	JUN 18	LG

project
KINGSWAY HOUSE

Project no.
213461

Sketch no.	revision
SK/XXX	P1



rev	date	by	chk	description
P1	08/06/18	LG	JG	Preliminary

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sketch title
PROPOSED BASEMENT LOADS

SKETCH

scale (s)	date	drawn
1:100.	JUN 18	LG

project
KINGSWAY HOUSE

Project no.
213461

Sketch no.
SK/XXX

revision
P1