University College London Hospitals NHS
NHS Foundation Trust

Demolition of the existing buildings and redevelopment for a building of 6 storeys in height including ground and 3 storeys basement for use a specialist head and neck facility (Class D1)

Former University College London (UCL) Student Union and Royal Ear Hospital, Huntley Street, Bloomsbury

Basement impact assessment (incorporating ground movement analysis)

February 2015

[this page is intentionally blank]

RPS Group

University College London Hospitals NHS Foundation Trust

Former University College London (UCL) Student Union and Royal Ear Hospital, Huntley Street, Bloomsbury

Basement impact assessment

(incorporating ground movement analysis)

Document No: UK14046-R01_4

OTB Engineering

RPS Group
University College London Hospital
Former University College London (UCL) Student Union and Royal Ear Hospital, Huntley Street.
Basement impact assessment (incorporating ground movement analysis)

Issue and approval control sheet

Client:	RPS Group
Address:	14 Cornhill, London, EC3V 3ND
Project:	University College London Hospital - Former University College London (UCL) Student Union and Royal Ear Hospital, Huntley Street, Bloomsbury
Document Title:	Basement impact assessment (incorporating ground movement analysis)
Document No:	UK14046-R1-4

Issue	Version No.	Date	Format
DRAFT	1	4th February 2014	PDF
DRAFT with minor revisions	2	6th February 2014	PDF
FINAL	3	10th February 2014	PDF
FINAL incorporating comments from JLL	4	17th February 2014	PDF

	Name	Signature and Date
Prepared by:	Naomi Wheeler	N Wheeler
Checked by:	Darren Page	
Approved by:	Darren Page	17/2/15.

OTB Engineering Ltd

46 Loman Street London SE1 0EH Tel +44 (0)207 099 2608 www.otbeng.com

1. INTRODUCTION

1.1 General

University College London Hospital NHS Foundation Trust (UCLH) proposes to redevelop the sites of the former University College London (UCL) Student Union and the former Royal Ear Hospital. The works will involve the demolition of the existing buildings and, and redevelopment for a building of 6 storeys in height and a 3 storey basement for use as a specialist head and neck facility (Class D1).

The site is located within the Bloomsbury Ward of the London Borough of Camden and this report forms part of the planning application for the proposed development.

1.2 Project status

The design is currently at the planning application stage.

As part of the planning application, it is necessary to prepare a basement impact assessment to assess the impacts of the development of the basement on buildings surrounding the site. In addition, further information is required for detailed design and construction, this includes a ground investigation and its analysis.

1.3 Terms of reference

A brief for the site investigation and basement impact assessment report (tender) has been prepared by Clarke Nicholls Marcel for UCLH Trust [2]. The proposed work described is being carried out by RPS Group. OTB Engineering (OTB), under contract to RPS Group, is tasked with performing the following aspects of the brief:

6.2 Geotechnical Assessment

- The short and long term settlements and/or heave movements resulting from the new structure.
- Impact on adjacent structures including Gordon Mansions and the Georgian townhouses opposite on Huntley Street from deflections of retaining walls resulting from the proposed structure.
- Determination of the hydrogeological regime to assess the potential damage caused by hydrostatic build-up next to the basement walls and to assist with regard to the design of appropriate basement waterproofing and drainage.
- Calculation of the heave/shrinkage potential of the London Clay Formation.
- Comment on soil stability during the proposed groundworks and excavation, particularly associated with the presence of any elevated groundwater levels.

6.4 Basement impact Assessment

There are five stages to the assessment of impact:

- Stage 1 - Screening
- Stage 2 - Scoping
- Stage 3 - Site investigation
- **Stage 4 - Impact assessment**
- Stage 5 - Review and decision making

Stages 1 and 2 have been undertaken out by RSK [3]. Stage 3 has been undertaken by RPS Group [9].

Carried out in accordance with CPG4 [11], this assessment covers the Stage 4 Impact Assessment, which comprises:

- Land stability;
- Groundwater flow;
- Surface flow and flooding.

As the geotechnical assessment forms and integral part of the basement impact assessment it has been included in the same (this) report.

1.4 Sources of information

1.4.1 Project specific

[1]	Concept Site Investigations. 2009. Site investigation report for UCLH Phase 3 on EGA. 30th January 2009.
[2]	Clarke Nicholls Marcel – Site investigation and basement impact assessment report – tender scope of works. UCLH Phase 5 28th October 2014
[3]	RSK. 2014. UCLH Phase 5. Basement impact assessment (Screening and Scoping). November 2014.
[4]	RSK. 2014. UCLH Phase 5. Preliminary risk assessment. November 2014.
[5]	Jones Lang LaSalle Ltd. 2014. Planning application key facts document. 28th November 2014
[6]	Subterra Locating Ltd. 2014. Utilities location survey plans.
[7]	Email from RPS Group (P.Skinner) dated 29th January 2015. Groundwater observations.
[8]	Email from RPS Group (P.Skinner) dated 30th January 2015. Exploratory hole surface elevations.
[9]	RPS. 2015. Phase 5 Development. DRAFT. Geotechnical Interpretative Report.
[10]	Clarke Nichols Marcel. 2015. Proposed structure loads for ground movement check. Dated 13th January 2015. Sketch 001. Clarke Nichols Marcel. 2015. Sectors for existing floor loadings. Dated 12th January 2015. Sketch 002. Clarke Nichols Marcel. 2015. Mark up for ground movement check. Dated 13th January 2015. Sketch 003. Clarke Nichols Marcel. 2015. Mark up for ground movement check. Dated 13th January 2015. Sketch 004. Clarke Nichols Marcel. 2015. Existing building weights – Ear Hospital. Calculation sheets 1 to 2. Dated 13th January 2015. Clarke Nichols Marcel. 2015. Existing building weights – Student Union. Calculation sheets 3 to 4. Dated 13th January 2015. Clarke Nichols Marcel. 2015. Construction sequence. Marked up. 9th January 2015.

1.4.2 Others

[11]	LB Camden. 2013. CPG4 Basements and lightwells. Camden Planning Guidance.
[12]	Construction Industry Research and Information Association. 2003. Embedded retaining walls- guidance for economic design. CIRIA Report C580
[13]	London Underground Ltd. 2010. Civil engineering Technical Advice Notes No. G-058.
[14]	Rutledge and Harrison, Digging for monitoring gold: In-tunnel monitoring during the Crossrail Paddington station box excavation.
[15]	Burland, J. B. (2001). Assessment methods used in design. In: J B Burland, J R Standing and F M Jardine (eds) Building response to tunnelling: case studies from construction of the Jubilee Line Extension, London. Volume 1: Projects and methods. CIRIA Special Publication 200, CIRIA and Thomas Telford, London, pp 23–43.
[16]	Voss, F. 2003. Evaluating damage potential in buildings affected by excavations. MS Thesis, Northwestern University, Evanston, IL. Cited in Finno, R.J., Voss, F.T., Rossow, E and J.T. Tanner Blackburn. XXXX. Evaluating damage potential in buildings affected by excavation. Paper accepted for publication in the Journal of Geotechnical and Environmental Journal. American Society of Civil Engineers.
[17]	Environment Agency. 2014. Management of the London Basin Chalk Aquifer. Status Report.
[18]	Construction Industry Research and Information Association. 1993. A study of the impact of urbanisation of the Thames Gravel aquifer. CIRIA Report 129.
[19]	Clayton, C.R.I., Edwards, A. and Webb, M.J. (1991) Displacements within the London clay during construction. In, Deformation of Soils and Displacements of Structures. Proceedings of the Tenth European Conference on Soil Mechanics and Foundation Engineering, Florence, May 27-30. London, GB, Taylor & Francis, 791-796.
[20]	Construction Industry Research and Information Association. 2004. Engineering in the Lambeth Group. CIRIA Report C583

1.5 Limitations

The work has been undertaken according to the agreed brief. It did not include assessing the impacts of construction due to ground movements upon utilities and other structures other than the principal buildings in the vicinity of the proposed development. The assessment assumes a good standard of design and construction, focussed on limiting ground movements. Impacts due to other construction activities do not fall within the remit of this assessment.

The report has been based on the information provided by others; this information has not been checked or verified by OTB. OTB cannot accept responsibility for inaccuracies in the data supplied by another party.

Other than a site visit, no surveys or investigations have been undertaken to confirm the location, presence or condition of features described. Some assumptions have been made (in particular on the structural form of adjacent structure, their founding level and the presence of basements) and these need to be confirmed by others for the purposes of design.

Whilst advice has been sought and provided, OTB is not the designer of the proposed scheme and accepts no liability as such.

2. SITE DESCRIPTION

2.1 Site location

The site of the proposed development is shown in red on Figure 1.

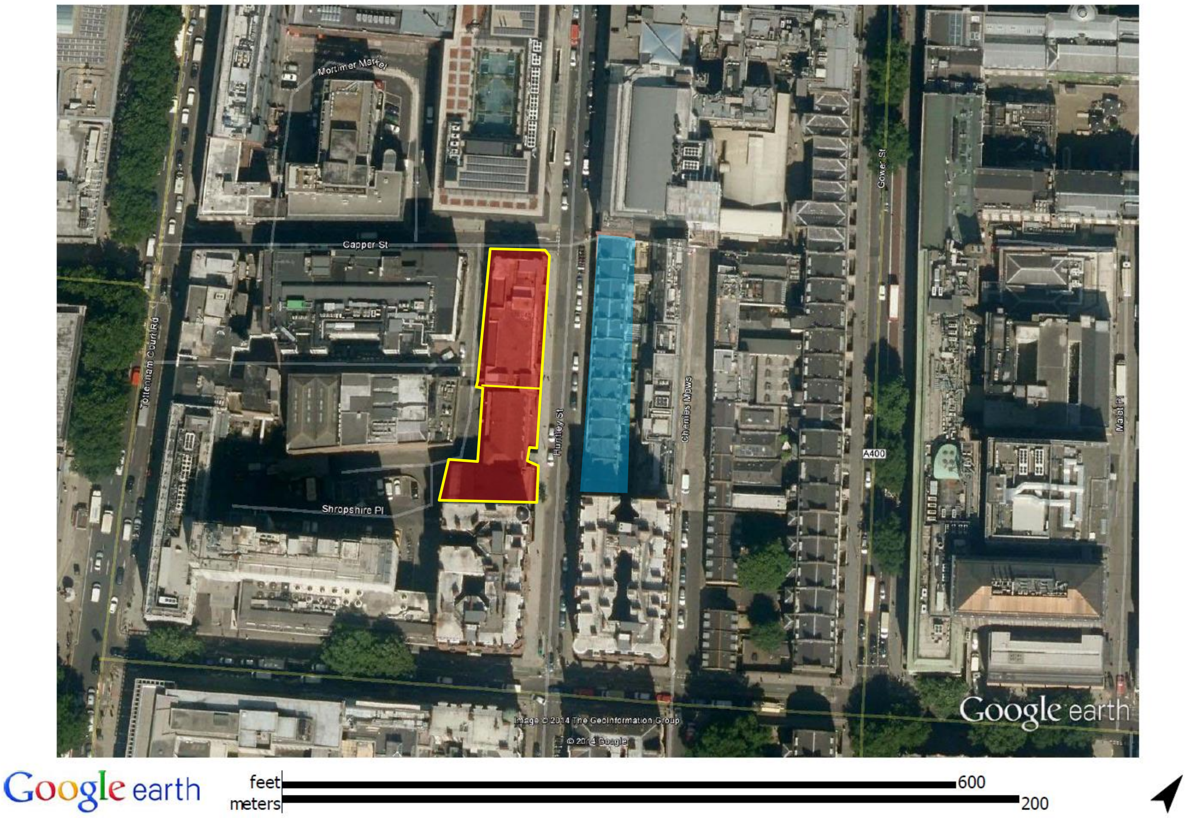

Figure 1 Location plan of proposed development

2.2 Topography

At street level, the ground around the site is approximately level and at 27.3m OD.

Ground levels have been raised up artificially through the development of buildings in the past (mainly due to basement construction) and consequently the natural ground level has been lost.

Around the proposed development ground levels, and the level at which natural ground is found, varies due to the presence of basements and car parks.

2.3 Ground conditions

2.3.1 Desk study

The geological map indicates the site to be underlain by Made Ground, River Terrace Deposits, London Clay, the Lambeth Group, Thanet Sand Formation and the Chalk.

2.3.2 Ground investigation

A ground investigation has been carried out by RPS Group which includes two cable percussion boreholes down to a depth of 41.5m below ground level and six window sampled holes. The results from this investigation are reported in [9].

2.3.3 Conceptual ground model

For the purposes of assessing the impact from basement construction and assessing ground movements a conceptual ground model has been developed (Table 1).

Table 1 Conceptual ground model

Strata	Elevation of top of strata (m OD)	Thickness (m)
Made Ground	27.3	3.5
Lynch Hill Gravel (River Terrace Deposits)	23.8	2.3
London Clay Formation	21.5	14.6
Lambeth Group	6.9	18.4
Thanet Sand Formation	-11.50	5.5m
Chalk	-17	Indeterminate

It is assumed that the stratum boundaries are continuous and horizontal beyond the boundaries of the site.

Faulting has been encountered on other sites in the vicinity and the stratum boundary elevations encountered may be different. This faulting is unlikely to influence the outcomes of this report.

2.3.4 Groundwater

Groundwater observations were made during borehole and window sampled hole construction during the ground investigation and piezometers installed. These are reported in [9].

Groundwater was encountered at elevations between 23m OD and 20.4m OD within the River Terrace Deposits.

2.4 Existing land use and buildings

2.4.1 General

The site is within the London Borough of Camden (Central London) and existing buildings comprise a mixture of ages, forms and styles which vary in use residential, commercial, mixed and institutional (hospital and allied industries) bound by roads and footpaths.

A number of buildings on Huntley Street opposite the proposed development are Grade II Listed (shown in blue in Figure 1).

Utilities are carried within the roads and footpaths.

3. PROPOSED SITE DEVELOPMENT

3.1 Proposed building

The proposed building is a six storey building with a three level basement (Figure 2).

The building is to be supported on a raft foundation founded at 9.8 m OD and a perimeter secant bored pile wall, which retains the basement. There are four levels of permanent props associated with each sub-basement floor.

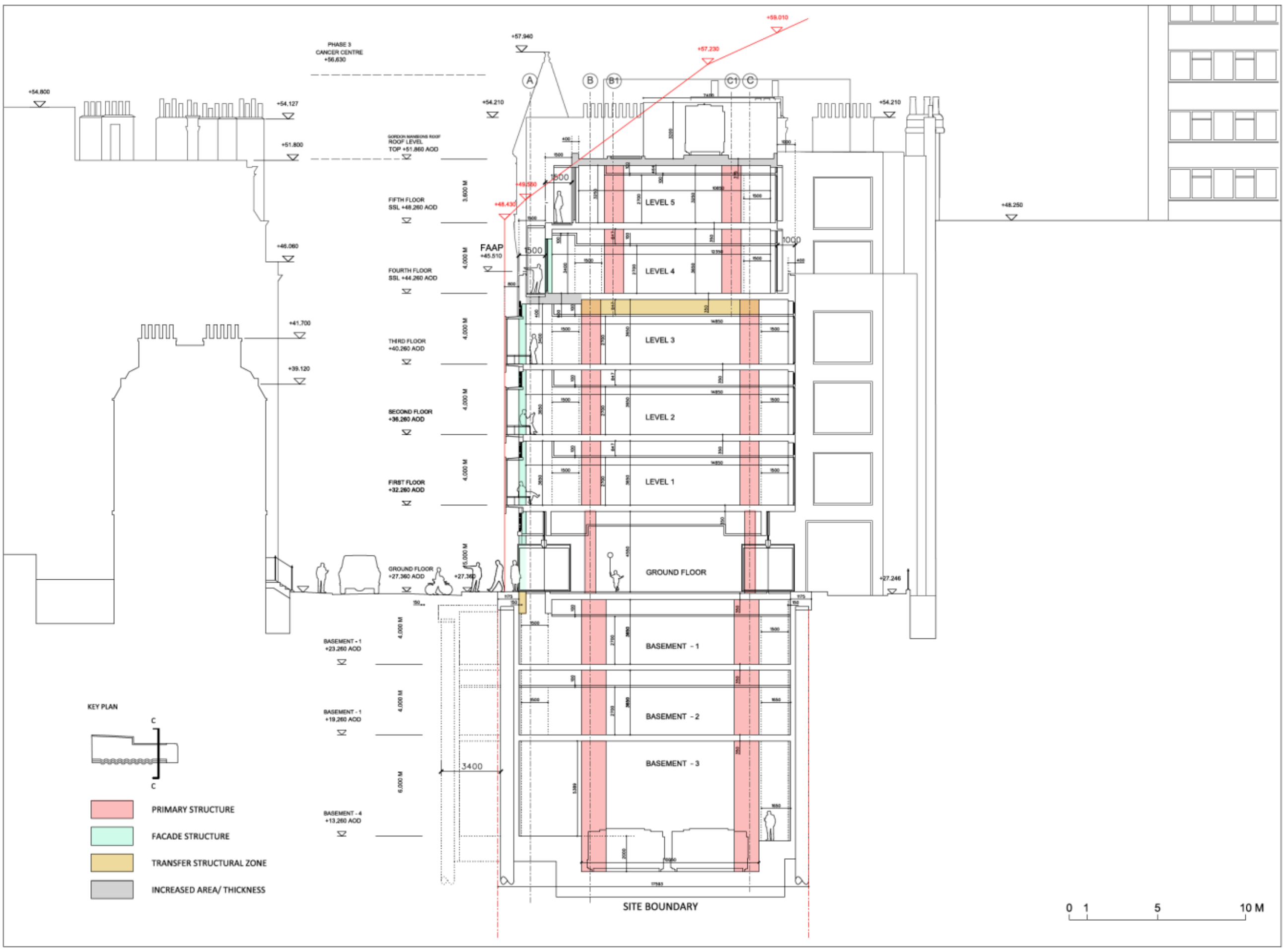

Figure 2 Section through proposed development

3.2 Proposed construction sequence

The proposed construction sequence is given in Table 2 [10]. This sequence has been used in assessing the ground movements arising from basement construction and the new development.

Table 2 Proposed generic construction sequence

Stage 1	**Demolition**	1. The demolition of the two existing buildings will be carried out in a conventional top down manner to existing basement level. 2. The basement will then be partially infilled around the site boundary to allow pilling ring to pile internally from natural ground floor level.
Stage 2	**Basement construction:**	3. Secant Wall Piles around boundary. Pile cap. 4. Secant Pile wall temporally propped at ground floor level. 5. Basement excavated down to basement -1 level. 6. Secant pile wall temporally propped at basement level -. 7. Basement excavated down to basement -2 level. 8. Secant pile wall temporally propped at basement level -2. 9. Basement excavated down to basement -3 level. 10. 1500mm thick basement raft slab cast at basement -3 level. 11. Cast pile facing wall and internal columns up to basement -2. 12. Construct Basement -2 level floor slab, remove props below. 13. Continue above two steps up to ground floor.
Stage 3	**Superstructure construction:**	14. Construct above ground RC superstructure in conventional construction sequencing.

4. GEOTECHNICAL ASSESSMENT

4.1 Short and long term settlement/heave assessment

4.1.1 Methodology

Vertical ground movements, (either heave or settlement), due to unloading as a result of demolition and excavation (short term) and loading due to structural loads have been assessed using the proprietary geotechnical software PDISP provided by OASYS. The three construction stages have been modelled (Section 3.2). Each stage considers the changes in load that have occurred in the previous stage.

A 'greenfield' analysis has been performed and the loads from and the condition of adjacent structures are not considered. The PDisp analysis assumes that the loaded area are fully flexible.

4.1.2 Inputs

Clarke Nichols Marcel. 2015. Proposed structure loads for ground movement check. Dated 13th January 2015. Sketch 001.

Clarke Nichols Marcel. 2015. Sectors for existing floor loadings. Dated 12th January 2015. Sketch 002.

Clarke Nichols Marcel. 2015. Mark up for ground movement check. Dated 13th January 2015. Sketch 003.

Clarke Nichols Marcel. 2015. Mark up for ground movement check. Dated 13th January 2015. Sketch 004.

Clarke Nichols Marcel. 2015. Existing building weights – Ear Hospital. Calculation sheets 1 to 2. Dated 13th January 2015.

Clarke Nichols Marcel. 2015. Existing building weights – Student Union. Calculation sheets 3 to 4. Dated 13th January 2015.

Conceptual ground model (Section 2.3.3).

4.1.3 Geotechnical parameters

Geotechnical parameters have been derived from our knowledge of the properties and behaviour of the materials indicated to be present at the site (Table 3).

Table 3 Geotechnical parameters for ground displacement analysis

Stratum	Unit Weight	Drained Poisson's Ratio	Drained Young's Modulus
Unit	**kN/m^3**	**-**	**MPa**
Made Ground	18	0.2	8
Lynch Hill Gravel (River terrace deposits)	18	0.25	36
London Clay Formation	20	0.25	42 + 4.2z
Lambeth Group	20	0.25	103
Thanet Sand Formation			
Note 1: z is depth below top of London Clay.			

4.1.4 Results

The results from the analysis are plotted on the following figures, which show contours of vertical displacement at ground level (27.3m OD).

Figure	Case A	Stage 1	Demolition (short term)
Figure	Case B	Stage 1 + Stage 2	Demolition + excavation (short term)
Figure	Case C	Stage 1 + Stage 2 + Stage 3	Long term (a period of time after construction)
Figure	Case D	Stage 1 + Stage 3	Short term (after construction) Superstructure without heave from basement excavation. This has been analysed as the heave from excavation may occur after completion of the basement and superstructure.

A further set of analyses were run at basement/foundation level at 25m OD and at 20m OD to derive displacements for the assessment of building damage.

Displacement is very sensitive to the stiffness of the ground. Those at small strains are appropriate for this analysis and this has been reflected in the values adopted (beyond the remit of the ground investigation for this development to measure these). The Lambeth Group lies within 3 to 4m of the base of the excavation. Though not taken into account this material has a very high stiffness [20] and this will significantly affect the response of the excavation and foundation. Actual movements are anticipated to be less than those predicted.

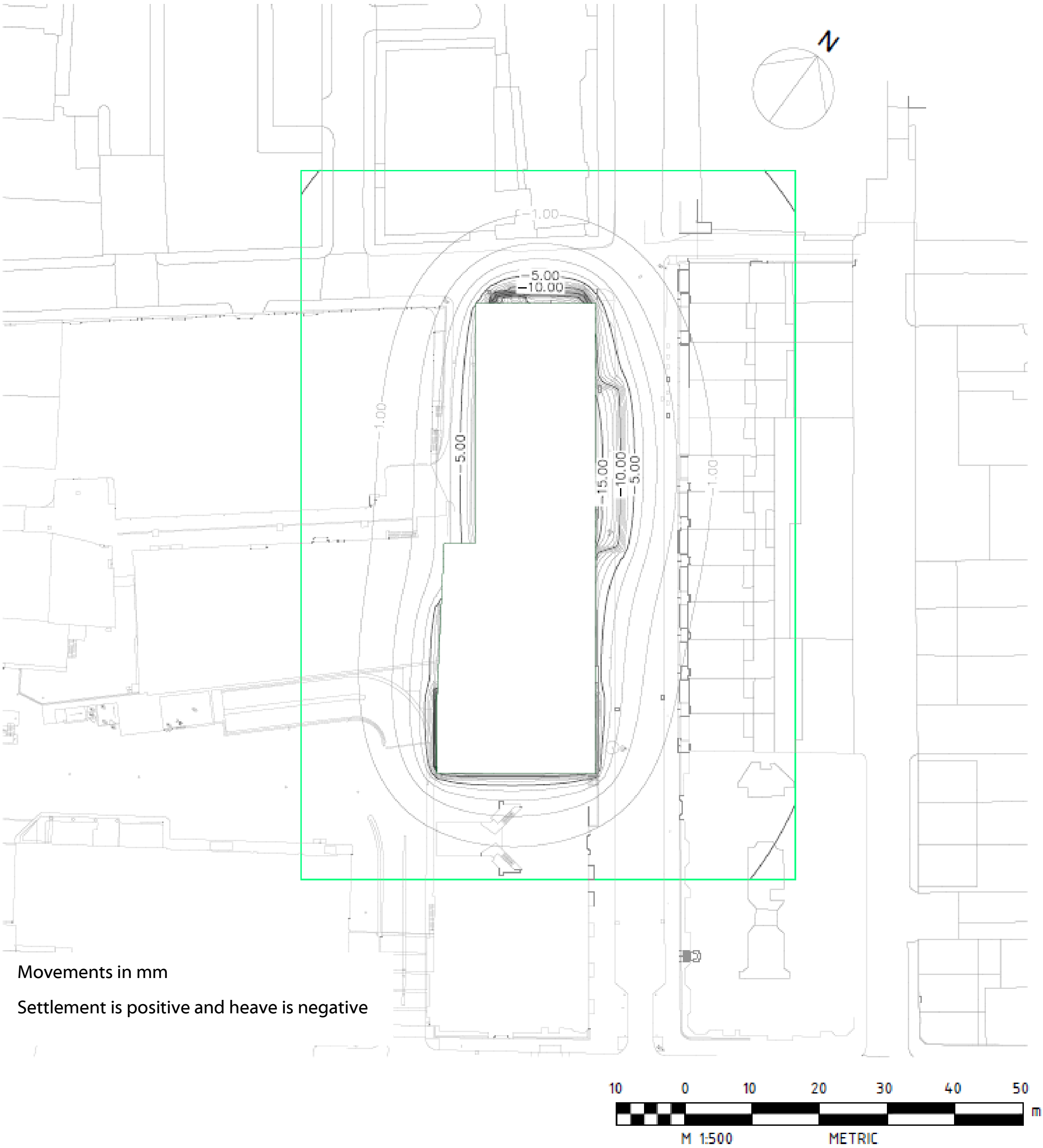

Figure 3 Ground level contours - Case A

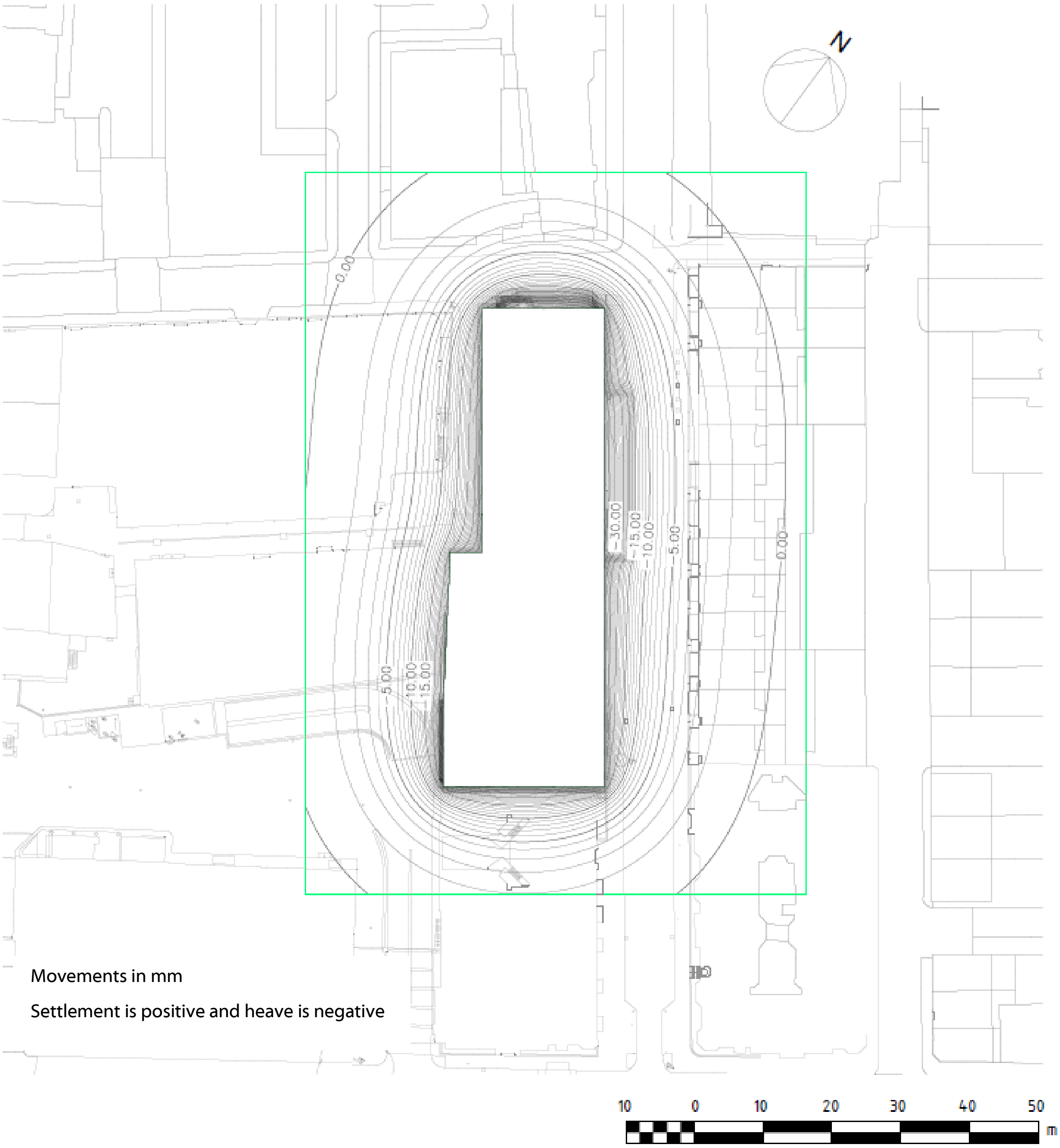

Figure 4 Ground level contours - Case B

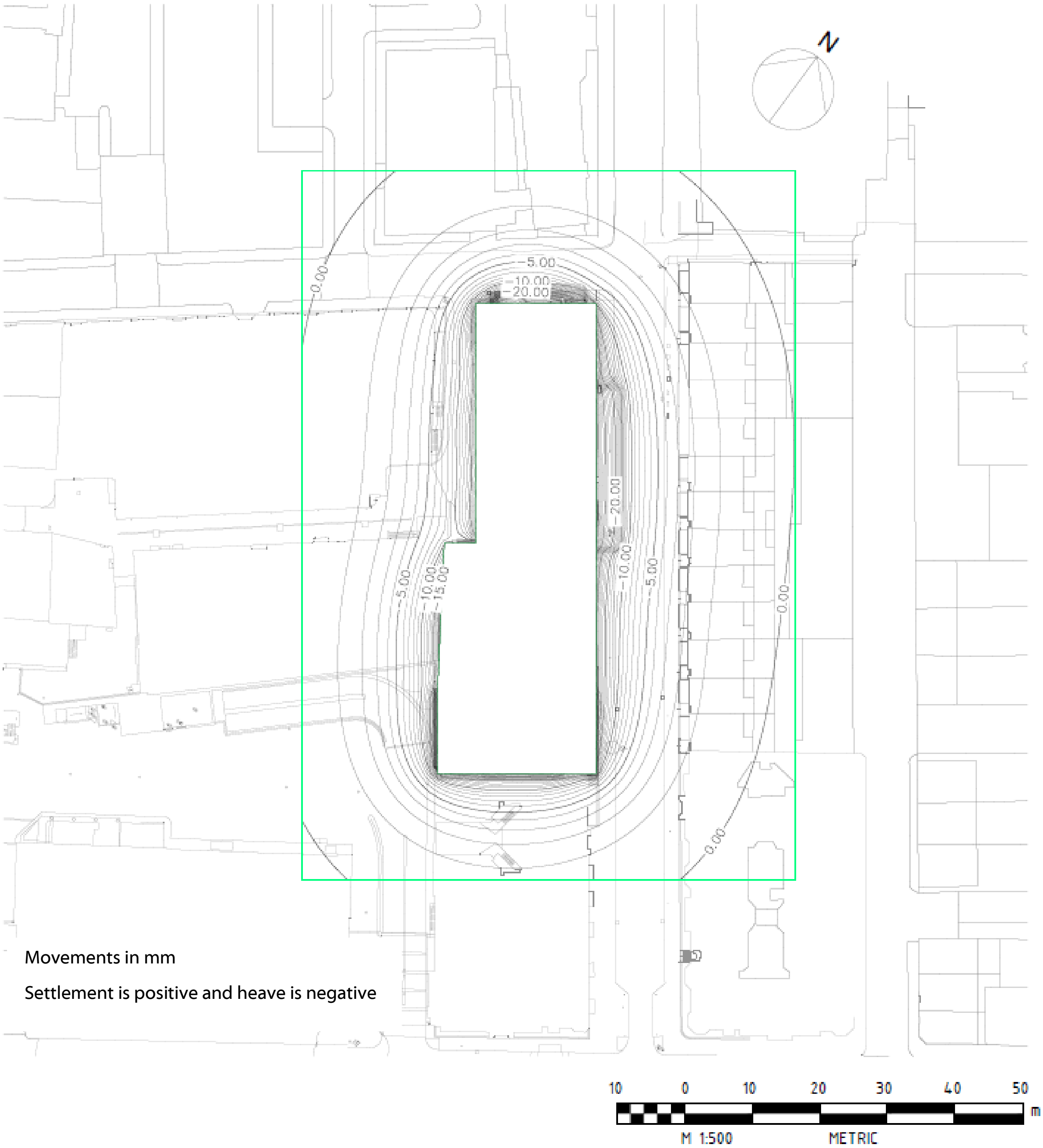

Figure 5 Ground level contours - Case C

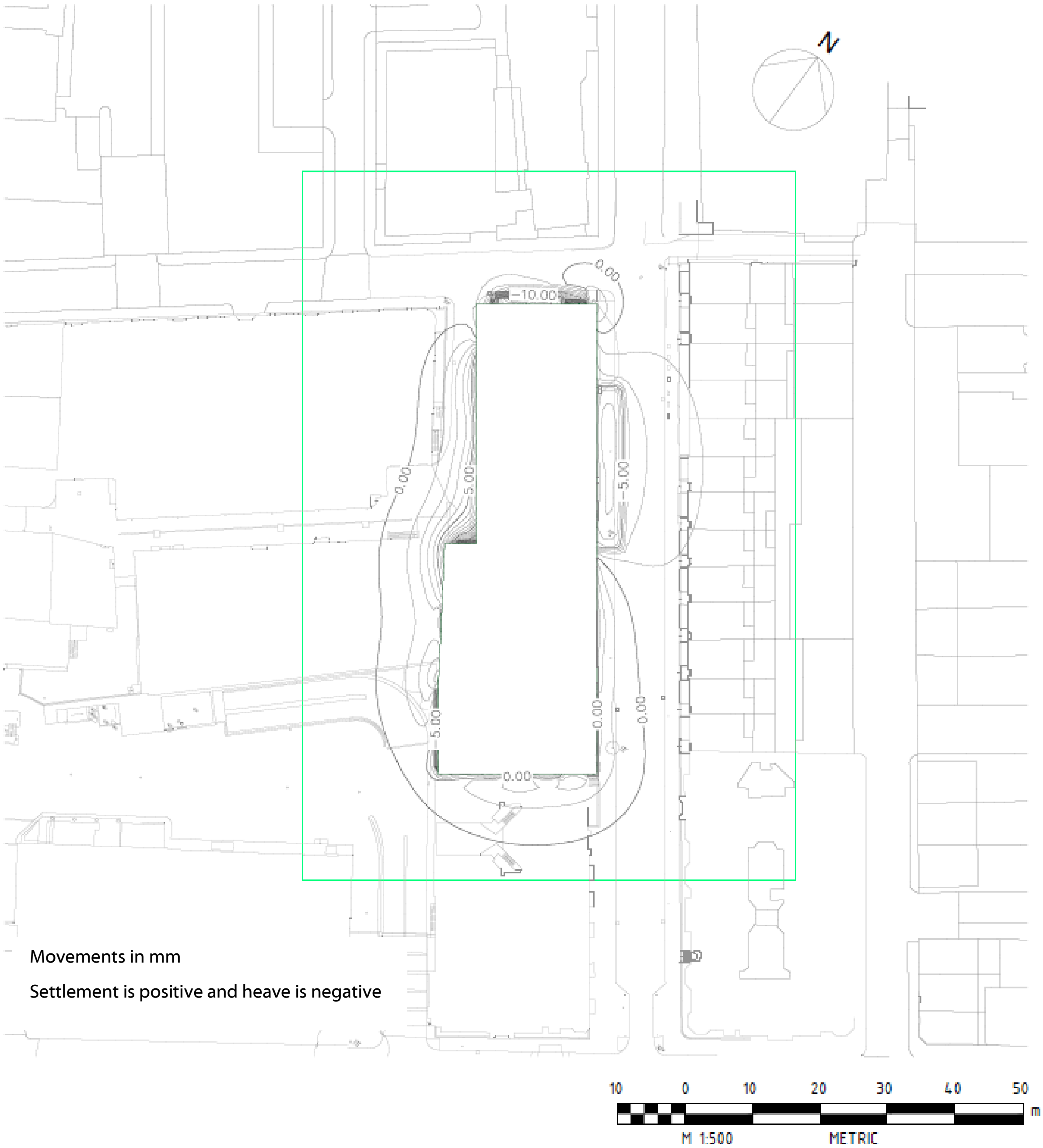

Figure 6 Ground level contours - Case D

4.1.5 Verification

It is particularly difficult to monitor heave due to excavation as the excavation is continually changing as it progresses and, whilst it is possible to install boreholes, this is rarely done. Excavations performed above tunnels, instrumented to measure displacements, offer the opportunity to examine the behaviour of the ground due to excavation. Paddington Station on Crossrail, which required the excavation of some 24m of material overlying tunnels which were uncovered by the excavation; these tunnels heaved between 40mm and 50mm, with the heave diminishing at the edge of the excavation (heave was not measured outside the excavation) [14]. The development of Grand Buildings at Trafalgar Square required the excavation of a foundation to within 5m of the underlying LU railway tunnels, controls were provided to limit heave due to the demolition of the overlying structure and the 7m deep excavation [19]. Heave measured in the underlying tunnel was less than 5mm, again this was found to diminish to the excavation boundary.

Consequently, the calculated heave outside the plan area of the development is overpredicted by the PDISP analysis, but is sufficiently robust for the purposes of this assessment.

4.2 Settlement due to retaining wall deflection

4.2.1 Methodology

Ground movements arise from stress relief and material losses due to pile construction but mainly from deflection of the wall as the excavation proceeds. Ground movements can be limited by prompt pile completion, by the design of the wall, propping arrangement and the excavation sequence. Given the proximity to adjacent structures, a wall with a high stiffness and a good standard of execution is anticipated, and this is reasonable. The prediction is green field and doesn't include the effects of surcharge loads on the back of the wall or locally stiffer areas.

There have been numerous deep basements constructed in London and there are sufficient records of the performance of these projects to reliably predict ground movements as a result of wall deflection (e.g. New Palace Yard car park, the YMCA etc). One of the most recent and most widely acknowledged methods is due to CIRIA Report C580 [12], which provides design charts for an infinitely long wall. London Underground's Technical Advice Note [13] also provides a suitable basis for prediction and this has been used. The most recent adaptation of this approach is the modelling of corner effects [13].

4.2.2 Results

Figure 7 provides a contour plot of predicted settlement at ground level around the basement due to retaining wall deflection as a result of basement excavation.

Settlements diminish with distance from the wall, though there is some uncertainty as to whether the maximum settlement occurs closest to the wall or a short distance behind it. There is evidence to suggest that the wall itself limits settlement immediately adjacent to the wall. The restraining and ameliorating effect of this has been ignored in this assessment.

The zone of influence of the basement excavation is not anticipated to extend more than 60m from the site.

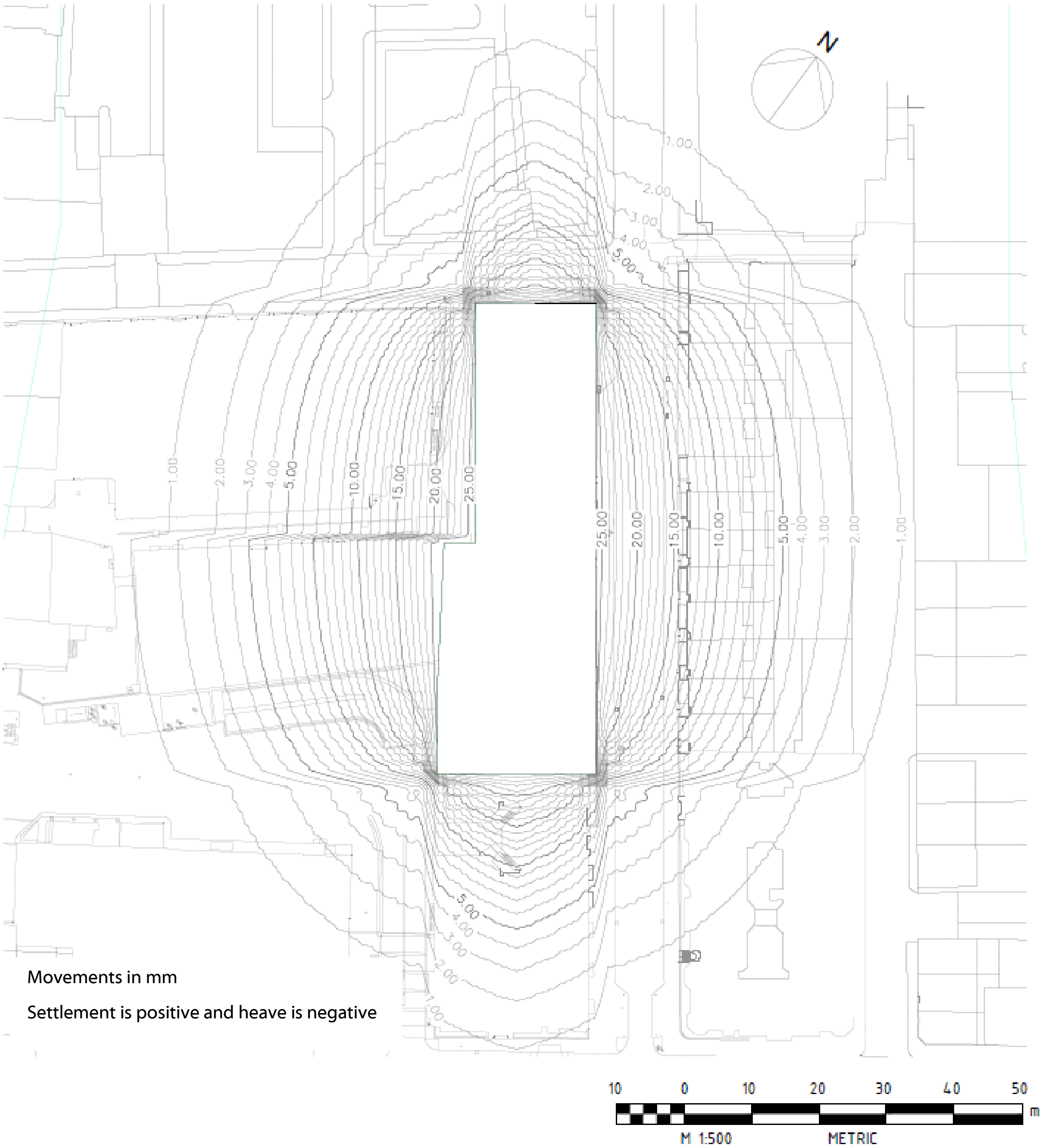

Figure 6 Ground level contours - Case E (Retaining wall deflection)

4.3 Assessment of the risk of damage to adjacent buildings

4.3.1 Methodology

Contours of ground displacement derived from 4.1 and 4.2 were combined as follows:

Case B	Stage 1 + Stage 2	Short term. Demolition + excavation (short term) + settlement due to retaining wall deflection
Case C	Stage 1 + Stage 2 + Stage 3	Long term (a period of time after construction) + settlement due to retaining wall deflection
Case D	Stage 1 + Stage 3	Short term (after construction) Superstructure without heave from basement excavation. This has been analysed as the heave from excavation may occur after completion of the basement and superstructure + settlement due to retaining wall deflection.
Case E	-	Immediate. Settlement due to retaining wall deflection.

After identifying the extent of zone of influence of the works and which structures are assessed to be potentially affected by ground movement, displacement profiles for each of the cases above were interrogated to determine the worst case deflections at foundation level for buildings lying closest to the site.

The performance of the adjacent buildings was assessed at the level of their foundations assuming the buildings are fully flexible and follow the displacement profile (ignoring the ameliorating effect of building stiffness). The buildings are modelled as a deep beam and the maximum tensile strain generated in the beam is calculated. The method is described in [15], modified by [16] assuming they approximate a rectangular beam. Assumptions are made about the properties of the beam according to the type of building. The profiles of predicted displacement lying beneath adjacent buildings are examined and for each case the total displacements and the limiting tensile strain calculated for each building is compared against the damage classification chart in CPG4 [11].

4.3.2 Results

The displacements at foundation level were checked against the preliminary assessment criteria established by Rankin [12] of maximum slope <1/500 and settlement (displacement) less than 10mm.

The results from the analysis are presented in Appendix A.

No structure assessed falls above Category 2 of the damage classification chart in CPG4 [11].

4.4 Hydrogeological regime

4.4.1 Methodology

The hydrogeological regime was assessed from groundwater observations made in boreholes and installations around the site [9]. These were compared against the measured regional groundwater regime for London [18] and measurements from other sites close by within Central London.

The risk of groundwater flooding was assessed from knowledge of the behaviour of the various aquifers.

4.4.2 Results

Groundwater levels in the Lower Aquifer below central London are depressed due to abstraction over a very long period of time. Whilst most of this abstraction has ceased and groundwater levels have risen, the levels are monitored and controlled through strategic abstraction. Groundwater levels in the Lower Aquifer at the site are at about -30 m OD and are usually assumed to be hydrostatic below this level. This level is considerably below the base of the proposed development.

Groundwater levels in the Upper Aquifer are probably hydrostatic from 23mOD, though this can vary.

Groundwater levels in the aquitard comprising the London Clay Formation and upper part of the Lambeth Group vary due to the reduced levels in the Lower Aquifer and to sand layers in the Lambeth Group or at the interface of the London Clay and Lambeth Group. Consequently, in Central London they are intermediate between the Upper Aquifer and Lower Aquifer.

The risk of groundwater flooding is very low. Due to the very transient nature of surface flooding, it is highly unlikely that surface flooding would significantly impact groundwater levels in the Upper Aquifer.

For the design of the basement walls, and to assist with regard to the design of appropriate basement waterproofing and drainage, it can be assumed that the groundwater level in the Upper Aquifer is at 23m OD and pore pressures through the Upper Aquifer and London Clay/Lambeth Group aquitard are hydrostatic from this level.

4.5 Heave/shrinkage potential of the London Clay

4.5.1 Methodology

As the London Clay Formation comprises predominantly clay with variable silt and fine sand content it is susceptible to an increase in volume (that results in heave) with an increase in moisture content, and to a decrease in volume (shrinkage) due to a reduction in moisture content.

4.5.2 Results

As the London Clay lies some 5.8m below ground level and some 1.5m below the level of the piezometric surface of the Upper Aquifer the clay remains in a saturated equilibrium state. Whilst pore pressures will change as a result of the site development and other developments its moisture content will remain constant. In the long term pore pressure will equilibrate to existing levels as the basement is anticipated to have a high degree of water resistance.

4.6 Slope instability during groundworks and excavation

A short-term slope instability assessment has been undertaken for the various materials to be encountered within the excavation (Table 4).

Table 4 Slope instability during groundworks and excavation

Stratum	Anticipated behaviour	Characteristics promoting instability	Mitigation	Impact
Made Ground	1:1 slopes stable in very short term (drained condition) Slopes will collapse (flow) under hydraulic head.	• Low cohesion • Groundwater • Exposure • Loading due to design of excavation and plant	Minimise use and height of very short term drained slopes.	Volume of material within excavation very small.
River Terrace Deposits	2:1 slope stable in very short term (drained condition). Slopes will collapse (flow) under hydraulic head.	• No cohesion • Groundwater • Exposure • Loading due to design of excavation and plant	Minimise use and height of very short term drained slopes	Volume of material within excavation very small.
London Clay	Vertical and overhanging excavations can be formed. Near vertical excavations can remain stable for a considerable period of time (undrained).	• Discontinuities • Groundwater • Exposure • Stress relief • Loading due to design of excavation and plant	Temporary slopes within excavation require design to determine appropriate safe height/geometry. Protect slopes to reduce exposure.	

5. BASEMENT IMPACT ASSESSMENT

5.1 General

LB Camden will not permit a development should it:

a) cause harm to the built and natural environment and local amenity;
b) result in flooding; or
c) lead to ground instability.

A basement impact assessment is therefore required to to *"assess whether any predicted damage to neighbouring properties and the water environment is acceptable or can be satisfactorily ameliorated by the developer".*

A staged approach is adopted detailed in CPG4 [11]. This document provides Stage 4. The final stage, Stage 5, is made by LB Camden based on the preceding stages.

For ease of reference the draft 2014 desk study report, covering Stages 1 and 2 of the assessment can be found in Appendix B.

Stage 3, the ground investigation and its subsequent interpretation have been carried out by RPS [9].

It is noted that the developer has undertaken similar developments, both in terms of size and nature, in the very near vicinity in recent years.

5.2 Land stability

The topography of the site is level and horizontal beyond its boundaries and therefore naturally occurring slope instability due to the presence of slopes does not occur.

The proposed development will require the site to be encapsulated by a structural perimeter secant bored pile wall, the design of which will consider all external loadings due to adjacent structures. The design of this wall is by others and will be according to the relevant codes to prevent instability.

Demolition, excavation for the basement and loading due to the new development will generate movements in the ground around the immediate perimeter of the site. These have been assessed in this report along with the potential impact they may have on surrounding structures and the likely level of damage assessed. The results of this analysis are given in Section 4. The analysis shows that with an appropriately good level of design and construction there should be little impact on adjacent buildings.

Existing basement structures forming part of the existing site extend beyond the plan of the site and lay outside the secant bored pile wall and beneath the footpath and road. These will be backfilled with concrete prior to construction of the bored pile wall.

Monitoring will be required to measure ground movements around the excavation and the behaviour of adjacent structures and utilities. The prediction of ground movements made in this report provides a basis for the design of this monitoring system. A monitoring plan based on a traffic light system (red, amber and green) needs to be devised to control and assure the works.

5.3 Groundwater flow

The basement will be encapsulated within a secant bored pile wall around its full perimeter. As the piles interlock and extend into the London Clay aquitard, this will exclude groundwater flow from the works in the short term. In the long term the basement structure will incorporate a waterproofing layer and internal reinforced concrete walls which further enhance the water resistance of the basement. There will be no change in groundwater levels as a result of the proposed development.

Whilst not readily measured, there is anticipated to be some groundwater flow in the Upper Aquifer. This flow probably mimics surface flow towards the nearest watercourse or former watercourses (most are now the major sewers), though it will be highly influenced by leakage from existing water mains and sewers, as well as the presence of nearby basement structures extending down into the London Clay. However, given the flat lying and level nature of the topography it is unlikely that these flows are significant. It should be noted that the River Terrance Deposits at this site do not form part of the current floodplain of the River Thames and therefore the River Thames does not form a source of groundwater recharge.

Studies of the Upper Aquifer carried out by Scott Wilson Kirkpatrick (now AECOM) for CIRIA and reported in [18] indicate that changes in the level of the Upper Aquifer are very small and there is little evidence for systematic long term change in groundwater levels. It also indicated mains leakage to be a major source of groundwater.

5.4 Surface flow and flooding

The level and horizontal topography of the site and its relative distance from the nearest surface depression (Farringdon Road along the line of the former Fleet River) and open fluvial watercourse (River Thames) indicates that there is a very low risk from surface flooding from fluvial sources.

The greatest risk of flooding at the site comes from water mains. An assessment of the potential for flooding due to this source during construction or in the long term is beyond the remit of a basement impact assessment.

APPENDIX A - Results of risk of damage assessment due to construction induced ground movements.

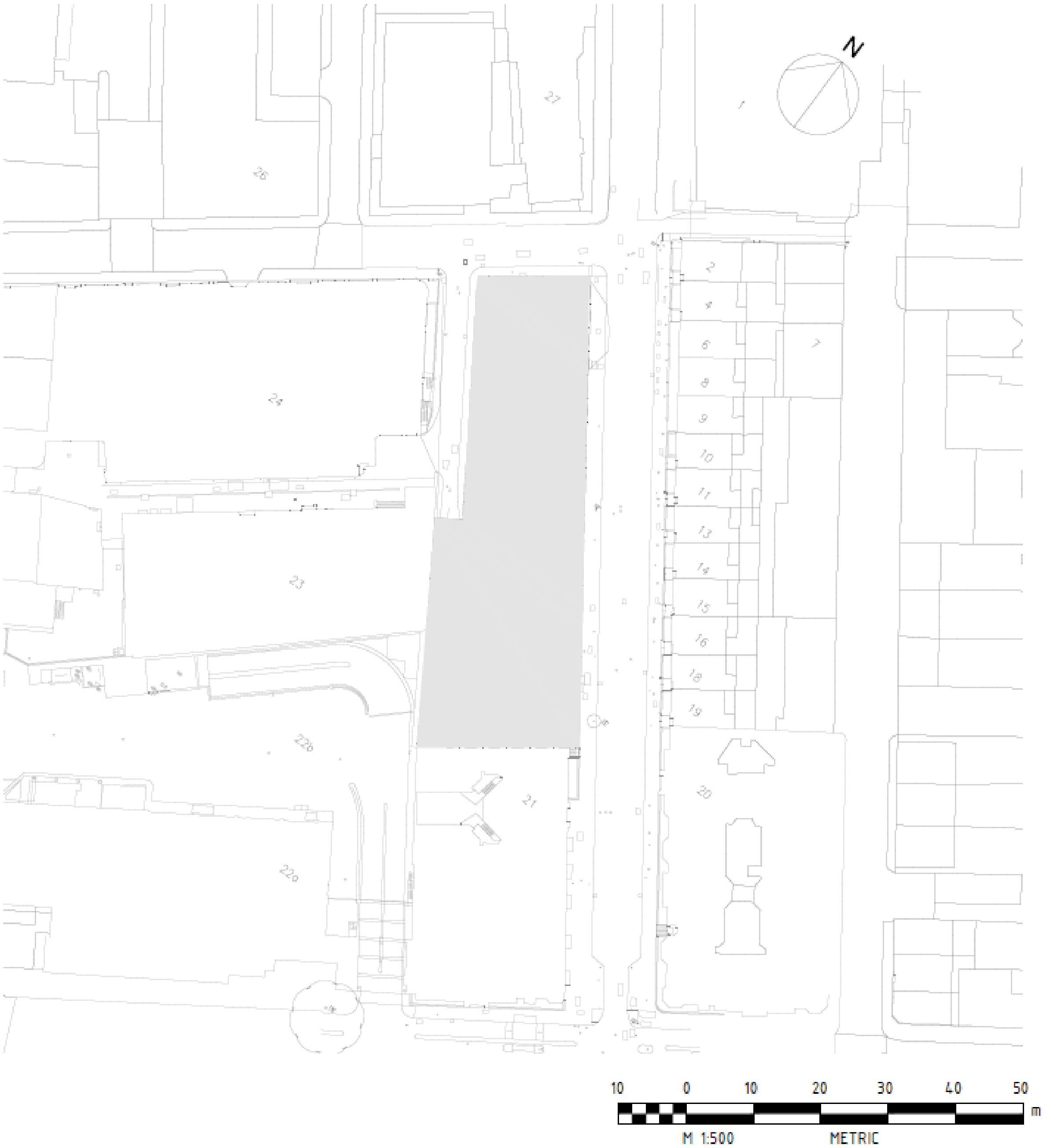

Figure 6 Buildings reference notation

ID	Build Name / No.	Street	Usage	Type	Height from Foundation (m)	Listed Building	Basement present	Level for assessment	Damage Category	Stage	Comment	Maximum Settlement / heave (mm)
1	Paul O'Gorman building – 72	Huntley Street	UCL cancer institute (Non-Residential Institution)	Steel frame 6 story +1 storey basement			Single storey	NA	Negligible		Just inside 1mm contour at level 25mOd therefore not included in analysis	1
2	70	Huntley street	Office space	Brick 3 storey plus mansard + single storey basement	16.7	Grade II	1 floor and possibly a underground link the Paul O'Gorman building	NA	Negligible		Just inside 1mm contour at level 25mOd therefore not included in analysis	5
4	68	Huntley street	Residential flats	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	7
6	66	Huntley street	Pauls cancer centre	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	8
7	UCL institute of hepatology 69-75	Chenies Mews	Institute of hepatology Non-Residential Institution	Streel framed brick clade 4 story + 1 storey basement	16.7		Single storey	25mOD	Negligible	-	Not Analysed as settlement less than 2mm and gradient slight	2
8	64	Huntley street	Pauls cancer centre	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	9
9	62	Huntley street	Pauls cancer centre	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	10
10	60	Huntley street	Residential flats	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	10
11	58	Huntley street	Residential flats	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	10
12	UCL Hatter Cardovascular institute 67 UCL Haemostatic research search unit /Gene therapy 51	Chenies Mews	Cardovascular institute, Non-Residential Institution	Streel framed brick clade 4 story + 1 storey basement	16.7		Single storey including possible tunnel	25mOD	Negligible	-	Not Analysed as settlement less than 2mm and gradient slight	2
13	56	Huntley street	Residential flats	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	10
14	54	Huntley street		Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey (assumed)	25mOD	Negligible	Case E	Worst case section of the building analysed	10
15	52	Huntley street		Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey (assumed)	25mOD	Negligible	Case E	Worst case section of the building analysed	10
16	50	Huntley street	Residential flats	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	9
18	48	Huntley street	Residential flats	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	8
19	46	Huntley street	Residential flats	Brick 3 storey plus mansard + single story basement	16.7	Grade II	Single storey	25mOD	Negligible	Case E	Worst case section of the building analysed	6
21	Gordon mansions	Torrington Place	Residential flats	Brick 7.5 storey with 1.5 storey basement	31.87		1 1/2 storey	20mOD	Very Slight	Case D	This damage is very dependent on the control of pile installation and deflection at the edge of the building	18
20	Gordon mansions	Torrington Place	Residential flats	Brick 7.5 storey with 1.5 storey basement	31.87		1 1/2 storey	20mOD	None	-	Not analysed as not settlement less than 2mm	0
22 b	1-19 (UCL) Car park	Torrington place	Non-Residential Institution	Single floor basement parking structure			Parking garage with a floor level of 20.346mOD	20mOD	Negligible	Case E	Building outside 1mm settlement contour at 20mOd depth Car Park analysed	20
22 a	1-19 (UCL) Buildding	Torrington place	Non-Residential Institution	Reinforced concrete frame 10 Storey +2 floor basement	46.75		Single storey		Negligible			

23	Queens yard	Queens Yard	Gym/ Offices/ Art gallery	Concrete framed brick 5 storey with single storey basement assumed	23.25		Single storey (assumed)	25mOD	Moderate	Case B	Recorded a moderate at Case B this reduces to Slight when 85% of the heave is used.	24
24	Shropshire house -11-20	Capper Street	Office use	Concrete framed brick 6 storeys and a single storey basement	22.89		Single Storey	25mOD	Negligible	Case E		20
26	Mortimer Market Centre /Hospital for tropical diseases	Capper street		RC Frame building brick clad 4 storey	20		Single storey (assumed)	-	Negligible	-	Building lies on the 1mm contour line and therefore has not been analysed	1
27	University Collage Macmillan cancer centre/ Elizabeth Garrett Anderson Building	Huntley Street	Residential Institution	Steel frame mixed cladding 6 storeys	42.35		3 storey (assumed)	16.35 (mOD)	Negligible	-Case E		11