AECOM

Preliminary Ground Movement Assessment

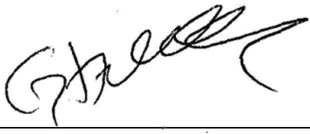
Middlesex Hospital Annexe

University College London Hospitals Charity (UCLHC)

Project Reference: Middlesex Hospital Annexe
Project Number: 60516144
Document Reference: 60516144/GEO/GMA/001

21 April 2017

Quality information

Prepared by	Checked by	Approved by
		
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Revision History

Revision	Revision date	Details	Authorized	Name	Position
01	21/04/2017	First Issue	GKK	Gary Kellett	Associate Director

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Introduction

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1. Introduction

1.1 Reason for the Report

AECOM has been commissioned by the University College London Hospitals Charity (UCLHC) to provide civil and structural engineering advice in relation to the proposed redevelopment of the Middlesex Hospital Annexe in London. As part of this appointment, historical site investigation data has been reviewed to obtain information on the geotechnical ground and groundwater conditions to assist with the preliminary design of foundations. This Ground Movement Assessment report has been prepared for the anticipated sequence of basement construction for the proposed development.

1.2 Report Objectives

The main objectives of the report are listed below:

- Describe the setting of the site
- Summarise the underlying geology and hydrogeology
- Reference the conceptual site model of the ground conditions at the site
- Report the geotechnical parameters for the preliminary analysis of the proposed basement development
- Describe engineering details of the basement development, including anticipated methods of excavation and construction
- Summarise details of the geotechnical analysis carried out to estimate ground movement associated with the proposed development
- Consider the impact of the proposed basement development on the surrounding buildings

1.3 Sources of Information

The following source of information has been referred to in the preparation of this report:

- AECOM (2016) *Phase 1 Geotechnical and Geo-environmental Desk Study Report*. Middlesex Hospital Annexe, Issue 2 8th December 2016, 60516144/DS/002.
- AECOM (2017) *Geotechnical and Geo-environmental Interpretative Report.* Middlesex Hospital Annexe, 8th April 2017, 60516144/GIR/001.
- AECOM (2017) *Site Investigation Data Report.* Middlesex Hospital Annexe, 8th April 2017, 60516144/SIR/01.

1.4 Limitations

This report considers adjacent buildings to the Middlesex Hospital Annexe. A full detailed condition survey has not been undertaken of these buildings surrounding the site, which may have the potential of being impacted by the proposals. It is recommended that a specialist is appointed to carry out such a survey and that following this it is recommended that a review of the information in this report relating to ground movements and stability of neighbouring structures is carried out. A programme of monitoring of the surrounding buildings should then be carried out during the construction works. Preliminary monitoring details are proposed in this report and these will require further assessment once investigation data and the condition survey work has been carried out.

The preliminary designs and assessments presented herein have been prepared using the information available at the time of the preparation of the report and on the basis of the stated assumptions. It must be noted that these preliminary calculations and findings will vary and require updating as the design progresses in the next stage and when a Contractor is selected for the works. The Contractor's final proposals for excavation and construction will need to be incorporated in any update to this report. The responsibility for the detailed design of the basement retaining wall will remain the responsibility of the specialist contractors. The ground movement predictions are based on the anticipated construction methods at the time of this report. No external development has been considered in this assessment. Any demolition, excavation or construction in the vicinity of the site at the time of the construction will need to be considered as to whether this impacts the assessment.

The predictions made are also highly dependent on the quality of workmanship employed. Therefore actual movements could be different to the predicted movements.

The information, views and conclusions drawn concerning the site are based, in part, on information supplied to AECOM by other parties. AECOM has proceeded in good faith on the assumption that this information is accurate. AECOM accepts no liability for any inaccurate conclusions, assumptions or actions taken resulting from any inaccurate information supplied to AECOM from others.

Site Description and Ground Conditions

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2. Site Description and Ground Conditions

2.1 Location

The site is located within the London Borough of Camden. It is approximately centred on National Grid Reference (NGR) 529262, 181811. A site location plan is provided as Figure 1.

2.2 Site Setting

The site is located on Cleveland Street, approximately 250m west of the Goodge Street London Underground Station.

The site boundary encloses an area of approximately 0.32ha. The site consists of North House located in the northwest corner of the site; South House located in the southwest corner of the site; and the Grade II listed Middlesex Hospital Annexe (the former Union Workhouse) located in the centre of the site with two wing buildings at the rear.

Relevant features immediately surrounding the site are summarised in Table 2.1.

Table 2.1: Features Surrounding the Site

Direction	Summary
North	The Sainsbury Wellcome Centre with Howland Street and the BT Tower beyond.
South	Middlesex House and the former Tottenham Mews Resources Centre.
East	Astor College with Charlotte Street beyond.
West	Cleveland Street with commercial units beyond.

2.3 Site Walkover Survey

An external inspection of the site was completed by an AECOM Engineer on 4th August 2016. The visit was carried out to inspect the site as well as identify potential sources of ground contamination.

- Part of the Union Workhouse building and its associated wings and South House were occupied by 'guardians' and could be accessed using a secure entrance on Cleveland Street.
- North House was in use as a site office by Graham Construction for their site located opposite Middlesex House. A separate secure entrance for this part of the site was located on Cleveland Street.
- A pub and a derelict building and residences were located across the street to the west of the site.
- The Union Workhouse building consisted of four storeys and a single level basement. Its associated wing buildings consisted of three storeys. North House consisted of two to three storeys and a single level basement. South House consisted of three storeys.
- An enclosed courtyard was located between the wings of the Union Workhouse building. Overgrowth was evident around the courtyard.
- Skips containing household waste were present on site. An area containing general waste was observed to the south of the Union Workhouse building.
- A small tank was observed above a storage building in the southwest corner of the site. No bunding was present around the tank.
- The basement of the Union Workhouse building was unoccupied. Parts of the basement were damp with evidence of water on the floor but no seepages from perimeter walls. The basement areas were derelict, mainly containing equipment associated with former uses of the building, with a boiler room and pump room at the locations suggested on the historical plans.

2.4 Geology

2.4.1 Geological Information from Published Information and Maps

The published 1:50,000 scale geological map of the area produced by the British Geological Survey (Sheet 256, "North London", 2006) indicates the site is underlain by the following geological succession:

Table 2.2: Geological Succession from Published Mapping

Age	Geological Stratum
Quaternary	Lynch Hill Gravel
Eocene	London Clay Formation
Palaeocene	Lambeth Group
	Thanet Formation

The existing topography and history of development of the site suggests that, in addition to these natural strata, Made Ground may be present on the site.

2.4.2 Geological Information from BGS Records

All the available data from relevant BGS records concerning the vicinity of the site have been considered. They are discussed in the relevant Phase 1 (AECOM, 2016) and Phase 2 (AECOM, 2017) reports.

2.5 Hydrogeology

2.5.1 Aquifer Classification

The EA's Groundwater Protection Policy adopts aquifer designations that are consistent with the Water Framework Directive. According to this system:

- The Lynch Hill Gravel is classified as a Secondary A Aquifer. These are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
- The London Clay Formation is classified as a Non Productive Stratum. These are rock layers or drift deposits with low permeability that has negligible significance for water supply or river base flow.

The site is underlain by the water-bearing Chalk-Basal Sands aquifer of the London Basin. There is hydraulic continuity between the Chalk and Thanet Formation and some continuity with the basal Lambeth Group units depending on the clay and sand content.

2.5.2 Vulnerability of Groundwater Resources

The EA's Groundwater Vulnerability Map of the area shows that the soils overlying the Secondary A Aquifer have a High Leaching Potential (U). The mapping indicates the site does not lie within a Source Protection Zone.

2.5.3 Site Characteristics

The anticipated depth to the water table in the Lynch Hill Gravel (Secondary A Aquifer), i.e. the thickness of the unsaturated zone, is anticipated to be in the order of a few metres. Historical monitoring data is reported in the Geotechnical Interpretative Report, and this gives levels ranging between 21.45 and 21.65m AOD. The regional direction of groundwater flow is expected to be to the south and southeast.

2.5.4 Risk from Rising Groundwater Levels in the Deep Aquifer

The site lies within the critical areas in the London basin defined in CIRIA Special Publication SP 69 (Simpson and others, 1989) in which exceptional structures are potentially at risk from the rising groundwater levels in the deep aquifer.

With reference to the latest Environment Agency data, the estimated level of the potentiometric surface of the lower Basal Sands and Chalk aquifer in January 2016 was between -35 and -36mAOD, and the latest reported rate of rise is between 1 and 2m per year

2.6 Hydrology

2.6.1 Surface Water Courses and Drainage

The nearest surface watercourse/feature to the site appears to be a fountain within Hanover Square located 780m southwest of the site.

The Lost Rivers of London (1992) suggests that the River Tyburn (now covered/culverted) is located approximately 1.1km west of the site.

The River Thames is located approximately 2km southeast of the site flowing in a north-easterly direction.

2.6.2 Flooding

The indicative floodplain map for the area, published by the EA, shows that the site does not lie within an area susceptible to risk of flooding from rivers and sea.

Environmental Simulations International (ESI) groundwater flood data indicate that the site is located within an area with a negligible risk of groundwater flooding. Any groundwater flooding incidence has a chance of less than 1 in 100 (<1%) probability of occurrence.

BGS flood data suggest that the site is located within an area with a potential for groundwater flooding of property situated below ground level.

2.6.3 Planning Policy for Flood Risk

The National Planning Policy Framework (NPPF) for England requires local planning authorities to take account of flood risk and the implications of climate change. It requires that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk, but where development is necessary, making it safe without increasing flood risk elsewhere.

Technical guidance on flood risk accompanies the NPPF and sets out how this policy should be implemented. It stipulates that development proposals in flood risk Zone 2 (medium probability), Zone 3a (high probability) and Zone 3b (the functional floodplain) should be accompanied by a flood risk assessment.

Conceptual Site Ground Model and Design Parameters

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3. Conceptual Site Ground Model and Design Parameters

3.1 Introduction

This section defines the site geology and geotechnical properties of the ground based on findings from the previous ground investigations undertaken by URS, GEA, BGS and others. The exploratory hole records are provided in the Site Investigation Data Report.

The main investigation fieldworks (Phase 2 report Section 2.15) were carried out during the period 17th to 25th September 2014 and 25th February to 30th March 2014 respectively, comprising 5 cable percussive boreholes, 37 diamond cored holes, 4 window sample boreholes and 21 trial pits excavated from ground level.

The previous ground investigations encountered a variable thickness of Made Ground overlying the Lynch Hill Gravel further overlying Weathered London Clay. The base of the London Clay Formation was London Clay overlying Lambeth Group.

3.2 Ground Model

Based on the review of published geological and hydrogeological information and a selection of historical borehole records and findings from the previous ground investigations, a conceptual site ground model for the purposes of the ground movement assessment is presented in Table 3.1.

Table 3.1: Ground Model

Geology		
Stratum	**Typical Description**	**Top of Stratum mbgl (mAOD)**
Made Ground	Highly variable in nature. Reference should be made to the fieldwork records for detailed descriptions of the materials encountered.	G.L. (26.7)
Lynch Hill Gravel	The Lynch Hill Gravel typically comprises sand and gravel, locally with lenses of silt, clay or peat.	3.8 (22.0)
Weathered London Clay	See below.	7.7 (16.6)
London Clay	The London Clay Formation is typically a firm to stiff to very stiff to hard, fissured grey to blue-grey over-consolidated clay, which, at outcrop, becomes firm, brown weathered clay typically within the upper 5m of the stratum. The Formation often becomes sandy to very sandy towards its base with associated high content of glauconite mineral and occasionally bands of laterally extensive imbricated cobbles and boulders of claystone (argillaceous limestone concretions).	7.8 (13.4)
Lambeth Group	The Lambeth Group comprises strata from the Upnor, Woolwich and Reading Formations. The group comprises laguno-marine sediments that have been deposited in an embayment of a deep marine water basin with brackish water lagoons, barrier beaches and alluvial plains. It is described as mottled clay with sand and pebble beds.	28.2 (1.7)
Groundwater		
Designation	**Description**	**Groundwater Level m bgl (m AOD)**
Secondary A Aquifer	Lynch Hill Gravel	4.08 (21.5)
Non Productive Stratum	Weathered London Clay / London Clay	–

3.3 Preliminary Design Parameters

3.3.1 Introduction

Preliminary design parameters for each stratum have been derived from in-situ testing and laboratory testing results as part of the ground investigation undertaken by URS and GEA.

The design philosophy adopted for the retaining wall analysis is in accordance with CIRIA 760 – Guidance on embedded retaining wall design. The document sets out two design approaches in terms of ultimate limit state and serviceability limit state analyses. The pile length of the secant bored pile wall will largely be determined by the vertical load carrying capacity of the piles, so this report considers the findings of the SLS analysis.

3.3.2 Summary of Design Parameters for WALLAP Analyses

The program WALLAP is used to predict the wall movements, bending moments and shear forces of the proposed secant bored pile wall. The SLS unfactored design parameters are presented

Table 3.2 for all three cases A1, A2 and B (Figure 3).

Table 3.2: Summary of SLS Design Ground Parameters

Parameters		**Strata**			
		Made Ground	**Lynch Hill Gravel**	**Weathered London Clay**	**London Clay**
Case A(1)					
Angle of shearing resistance	ϕ'	22	30	21	23
Drained cohesion	c' (kN/m²)	0	0	0	0
Undrained shear strength	s_u (kN/m²)	20	–	50	50 to 67.5
Bulk unit weight	γ_b (kN/m^3)	18	19.5	19.6	19.6
Young's modulus – undrained	E_u (kN/m²)	10,000	–	10,000	20,000 to 27,000
Poisson's ratio – undrained	ν_u	0.5	–	0.5	0.5
Kr ratio (ν/1- ν)	K_r	1	–	1	1
Young's modulus – drained	E' (kN/m²)	2,860	14,400	5,200	6,300 to 8,925
Poisson's ratio – drained	ν'	0.25	0.25	0.2	0.2
Kr' ratio (ν /1- ν)	K_r'	0.33	0.33	0.25	0.25
Case B(2)					
Angle of shearing resistance	ϕ'	22	30	21	23
Drained cohesion	c' (kN/m²)	0	0	0	0
Undrained shear strength	s_u (kN/m²)	20	–	50	50
Bulk unit weight	γ_b (kN/m^3)	18	19.5	19.6	19.6
Young's modulus – undrained	E_u (MN/m²)	10,000	–	10,000	20,000
Poisson's ratio – undrained	ν_u	0.5	–	0.5	0.5

Parameters		**Strata**			
		Made Ground	**Lynch Hill Gravel**	**Weathered London Clay**	**London Clay**
Kr ratio (v/1- v)	K_r	1	–	1	1
Young's modulus – drained	E' (MN/m²)	2,860	14,400	5,200	6,300
Poisson's ratio – drained	v'	0.25	0.25	0.2	0.2
Kr' ratio (v /1- v)	K_r'	0.33	0.33	0.25	0.25

Notes 1:
1. The active and passive earth pressure coefficients are calculated by WALLAP.

Notes 2:
(1) In Case A the secant pile wall is assessed along the northwest – southeast direction;
(3) In Case B the secant pile wall is evaluated along the southwest – northeast direction.

Development Details and Analyses

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4. Development Details and Analyses

4.1 Details of Proposed Development

4.1.1 Development Proposal

The proposed development comprises new build with a single level basement to the rear of the existing Work House building. The new basement is constructed in a propped excavation supported by perimeter secant pile wall.

The proposed basement level is at 22.80m AOD, some 2 to 3m lower than the existing basement to the Work House building, which is generally around 25m AOD in the central section.

The proposed basement structure involves a basement floor slab (Level B1) and a ground floor slab (Level 00), both of which act to prop the perimeter basement wall in the permanent case.

In the temporary construction case the basement excavation may be supported by the perimeter secant piled wall, with temporary propping and berms and a sequential construction sequence. The proposed construction sequence considered for this ground movement assessment is provided in the next section.

For the movement assessment associated with the basement construction two cross sections have been considered as representative of perimeter conditions to assess the potential for effects on adjacent buildings;; and these are respectively University College (Sainsbury Wellcome Centre) to the north west and Astor College to the north east.

4.1.2 Perimeter Buildings

It is noted that the buildings surrounding the new basement are set back more than 3m from the perimeter of the basement structure; and most have basement structures that are close to or lower than the proposed basement construction. The exception to this is the building in Tottenham Mews, which is located at the north east corner of the new basement (a stiff point in the new structure). The layout for perimeter buildings is indicated on the sketch in Appendix A, alongside the topographical survey for external levels.

4.1.3 Proposed Construction Sequence

This report has been prepared in advance of detailed design and contractor involvement. For this report a ‘bottom up’ construction sequence has been assessed (i.e. install wall, limited initial excavation, brace and excavate, then construct permanent works from the bottom of the excavation upwards). This assessment approach has been used so that conservative assumptions are made at this stage.

Similarly conservative assumptions have been made for the assessment of perimeter buildings in that the sections have considered ground movements at ground level, and no account has been take of the likely reduction in ground movement with depth to account for the level of the adjacent basement structures.

A summary of the proposed construction sequence for the basement structure is presented as follows:

- Install perimeter secant piles and construct capping beam
- Construct working platform and install permanent piles for new building
- Excavate to strut level within excavation (i.e. upper metre of excavation)
- Install corner props and horizontal props to capping beam
- Excavate to pile caps in central area leaving perimeter berm
- Construct pile caps and install raking props within excavation (i.e. from pile caps to capping beam)
- Excavate to final depth on passive side removing berm only once propping is in place
- Install structural slab at basement B1 level
- Install structural slab at ground floor 00 level

The previous monitoring indicates groundwater in the Lynch Hill Gravel is below the basement excavation level (this will be checked during further investigation works). Any perched water within the Made Ground will be controlled via the secant piles and, if required selective grouting in the areas of underpinning.

The proposed sequence of construction provided above is considered appropriate for the single level basement in the ground conditions discussed in Section 3.2.

4.2 Basement Wall Vertical Capacity

In one position in the north western corner of the site the secant bored pile wall is to support axial loads from four columns to the proposed eight-storey structure. In this location the male piles will be designed to support the vertical load in accordance with Eurocode 7.

4.3 Analysis of Wall Movement

4.3.1 Method of Analysis

The installation of the wall and the staged construction of the basement have been analysed with the proposed options for temporary support and construction sequencing. Retaining wall analyses have been carried out to provide an initial indication of wall movements, bending moments, shear forces and prop loads. Analyses have been carried out using the commercially available computer program WALLAP.

WALLAP uses the limit equilibrium method of analysis to estimate the minimum required toe depth of the wall. This is followed by a pseudo finite element method of analysis to estimate the bending moments, shear forces and prop forces generated, along with an initial assessment of the wall movements for the calculated or user-specified toe depth of the wall.

4.3.2 Prediction of Vertical Ground Movement

In accordance with CIRIA C760, a vertical ground surface displacements can be derived from the wall deflection profile as predicted by the WALLAP analyses. In general it is assumed the wall deflection profile is reduced by half and then rotated by 90° at the top of the wall towards the retaining side and combined with the application of a ‘stretching’ factor of 1.5 to the length of the wall deflection profile.

4.3.3 Prediction of Horizontal Ground Movement

The relationship between the wall deflection profile and the horizontal ground surface displacement profile is not explicitly described in CIRIA C760. For the purpose of the settlement analysis it has been assumed the horizontal ground surface displacement profile is a 90° rotation of the wall deflection profile without stretching or reduction factors. It is considered conservative as the actual horizontal ground movements are likely to be less than those predicted by this assumption.

4.3.4 Secant Pile Wall Stages of Analysis

For the purposes of the WALLAP analysis the proposed construction sequence has been divided into stages. A design case comprising a single level of temporary props to the perimeter wall capping beam has been analysed and is presented below:

Stage 0 Initial condition: Ground level at its initial stage. A strip load of 20kN/m² of infinite width from the edge of the wall has been applied on the ground surface at the initial level to simulate loading from adjoining surface areas (adjoining structures are set back from the perimeter and for A-A and B-B are piled)

Stage 1 Apply groundwater profile with undrained ground conditions

Stage 2 Apply surcharge on active side

Stage 3 Excavate to strut level on passive side

Stage 4 Excavate to final depth on passive side with berm

Stage 5 Install strut on passive side

Stage 6 Apply long term drained ground conditions: Drained soil properties, allow groundwater level to rise / equalise and allow for 30% wall relaxation

4.3.5 Wall Details

The wall parameters used in the analysis were determined using the guidance in CIRIA C760 and C143 and assume a wall with alternating "hard" and "firm" secant piles of 600mm diameter with an overlapped spacing.

4.3.6 Propping Details

For this assessment the proposed concept for propping is indicated on the temporary works concept drawing in Appendix A. For the purposes of the WALLUP section analyses props have been assessed using a UC 305 x 305 x 118 steel section.

Struts are applied at 25m AOD both horizontally for corner propping and cross propping and vertically for raking props. For this stage prop spacing of 4m has been assumed.

Once the basement has been constructed the permanent works will provide restraint to ground pressures by the structural slabs at B1 and 00 levels and the perimeter basement wall.

Structural Assessment of Ground Movement

05

5. Structural Assessment of Ground Movement

5.1 Introduction

This section provides an engineering interpretation of the impact of the development on the buildings surrounding the site. The buildings considered are:

1. The University College (UCL) Building – Sainsbury Wellcome Centre (Section A – A);
2. The Astor College building (Section B – B)

5.2 Visual Building Inspection Report

A detailed condition survey of the buildings surrounding the site which have the potential of being impacted by the proposed basement development has not been carried out at this stage. It is recommended that a specialist undertakes such a survey and that following this a review of the information in this report relating to ground movements and stability of neighbouring structures is carried out (Section 6.1).

The programme of monitoring of the surrounding buildings outlined in Section 6 of this report should then be developed and carried out during construction works (Section 6.2). At construction stage a Monitoring Specification will be prepared.

5.3 Building Damage Assessment

5.3.1 Classification of Damage

An assessment of the potential damage to neighbouring structures immediately around the proposed basement has been undertaken. The adopted assessment methodology for buildings looks at the likely risk of damage to a structure. The degree of damage is generally categorised into three progressive levels:

- Visual appearance or aesthetics
- Serviceability or function
- Stability

As ground movements beneath the foundations to adjacent structures increases, the damage to a building will move through these three categories. Burland et al. (1977) defined the classification of visible damage. In addition, further work by Boscardin and Cording (1989) introduced the concept of limiting tensile strain. Following this the categories of damage identified by Burland et al. (1977) have been related to ranges of limiting tensile strain. Table 5.1 summarises the categories of damage identified by Burland et al. (1977) and the relevant limiting tensile strains. In the table categories 0, 1 and 2 relate to aesthetic damage, categories 3 and 4 relate to serviceability damage and category 5 relates to stability damage.

Table 5.1: Classification of Visible Damage to Walls

Damage Category[(1)]	Normal Degree of Severity	Description of Typical Damage (Ease of Repair in Bold Type)	Limiting Tensile Strain ε_{lim} (%)
0	Negligible	Hairline cracks less than about 0.1mm wide	0 - 0.05
1	Very slight	**Fine cracks that are easily treated during normal decoration.** Damage generally restricted to internal wall finishes. Close inspection may reveal some cracks in external brickwork or masonry. Typical crack widths up to 1mm.	0.05 - 0.075
2	Slight	**Cracks easily filled. Redecoration probably required. Recurrent cracks can be masked by suitable linings.** Cracks may be visible externally and **some repointing may be required to ensure weather tightness.** Doors and windows	0.075 - 0.15

		may stick slightly. Typical crack widths up to 5mm.	
3	Moderate	**The cracks require some opening up and can be patched by a mason. Repainting of external brickwork and possibly a small amount of brickwork to be replaced.** Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired. Typical crack widths are 5-15mm or several >3mm.	0.15 - 0.3
4	Severe	**Extensive repair work involving breaking out and replacing sections of walls, especially over doors and windows.** Windows and door frames distorted, floor sloping noticeably. Walls leaning of bulging noticeably, some loss of bearing in beams. Service pipes disrupted. Typical crack widths are 15 - 25mm, but also depends on the number of cracks.	> 0.3
5	Very severe	**This requires a major repair job involving partial or complete rebuilding.** Beams lose bearing, walls lean badly and require shoring. Windows broken with distortion. Danger of instability. Typical crack widths are greater than 25mm but depends on the number of cracks.	-

Notes:
(1) In assessing the degree of damage, account must be taken of its location in the building structure.

The categories of damage given above and the limiting tensile strains suggested by the published literature are based solely on masonry structures. Where a different structural type is present the limiting tensile strains and categories of damage are not directly applicable and may be generally considered conservative. However, in the absence of suitable alternative screening criteria, the assessment methodology based on masonry structures may be permissible for non-masonry buildings in conjunction with engineering judgement.

5.3.2 Basis of Building Damage Assessment

The Building Damage Assessment uses the work described in Burland et al (2001) and Gaba et al (2003). In this approach the façade of the building is represented by a simple beam whose foundations are assumed to follow the displacement of the ground in accordance with 'greenfield' site assumptions. The maximum tensile strains are then calculated using pairs of equations that consider combinations of horizontal strain, bending strain and diagonal strain. If necessary the building is sub-divided into separate structural elements.

Although this stage of assessment is relatively detailed it is usually still conservative. **Consequently, the categories of damage derived in this level of assessment are only possible degrees of damage. The actual damage should be less than the predicted level of damage in the majority of cases.** The reason for this is that the stiffness of the building will be such that the foundations will interact with the supporting ground and tend to reduce both the deflection ratio and the horizontal strains.

5.3.3 Calculations

The two structures surrounding the site have been considered in this assessment. Assumptions made in the calculation relating to the structures are listed below in Table 5.2. The cross sections used in the calculations are shown in Figure 3.

Table 5.2: Summary of Building Damage Assessment Sections

Drawing Section	Structure Reference	Distance from Wall to Structure Edge (m)	Structure Width/Length Perpendicular to the Excavation (m)	Estimated Structure Height (m)
A – A	Astor College building	0	70	16.00
B - B	University College London building	0	55	29.00

The calculations undertaken are based on the procedure presented by Burland et al (2001). For each of the walls considered in this assessment the resultant tensile strain has been calculated. The calculations use the following four equations:

$$\frac{\Delta}{L} = \left(1 + \frac{HL^2}{18I}\frac{G}{E}\right)\epsilon_d$$

$$\frac{\Delta}{L} = \left(\frac{L}{12t} + \frac{3I}{2tLH}\frac{E}{G}\right)\epsilon_b$$

$$\epsilon_{bt} = \epsilon_h + \epsilon_b$$

$$\epsilon_{dt} = 0.35\,\epsilon_h + \sqrt{(0.65\,\epsilon_h)^2 + {\epsilon_d}^2}$$

Where:

Δ = deflection from straight line settlement

H = height of the building

L = length of the building (but limited by any point of inflexion)

E = Young's modulus of building

G = shear modulus of building

I = second moment of area (= $H^3/12$ in the sagging zone and $H^3/3$ in the hogging zone)

t = the furthest distance from the neutral axis to edge of 'beam' (= H/2 in the sagging zone and H in the hogging zone)

ε_b = maximum bending strain

ε_d = maximum diagonal strain

ε_h = maximum horizontal strain

ε_{bt} = total bending strain

ε_{dt} = total diagonal strain

5.3.4 Results

The results for a ***high support stiffness retaining wall*** (as defined in CIRIA C760) for the long term case are summarised in Table 5.3 below. The results assume that the buildings act as a 'whole'. If there are discrete elements of the structures then these will act separately and the results presented below are not valid.

Table 5.3: Result of Building Damage Assessment for the End of Construction Case

Structure Reference	End of Construction Case			
	Vertical Movement at near side (mm)	Vertical Movement at far side (mm)	Limiting Tensile Strain ε_{lim} (%)	Damage Category
Astor College building	2.5	10.1	0.03	0 – Negligible
University College London building	8.5	0.5	0.07	1 – Very Slight

5.4 Conclusion

A Ground Movement Assessment has been undertaken for the proposed redevelopment of the Middlesex Hospital Annex. This has included calculations of predicted ground movements and an assessment of the structural impact on the surrounding buildings.

A range of calculations have been undertaken to assess the potential impact on the surrounding structures. Ground movements in this report are based on the deflection profile of the retaining wall predicted by the WALLAP program. The calculations have been carried out using appropriate high support stiffness retaining wall parameters and based on the assumption that a 'bottom-up' construction sequence will be adopted.

It is important to emphasize the discrepancy in relation to ground and groundwater conditions, construction sequence and retaining structure between the empirical case study data in CIRIA C760 and the current project, particularly for the determination of geotechnical design parameters. The predicted ground movements have been used to calculate potential resultant tensile strains in the structures and thereafter the potential damage category in line with the categories proposed by Burland et al (2001).

Two structures have been assessed using this method with the resultant potential damage categories calculated. The results indicate that following detailed design process these will be at worst within Damage Category 1 "Very Slight" range of building strains. The damage category is likely to reduce when basement levels for perimeter buildings are taken into account. Category 1 Damage is noted to be limited to fine cracks that are easily treated during normal decoration.

Recommendations for Further Work

06

6. Recommendations for Further Work

6.1 Structural Survey of Surrounding Buildings and Infrastructure

A detailed condition survey of the buildings surrounding the site which have the potential of being impacted by the proposed basement development has not been carried out at this stage by AECOM. It is recommended that a specialist undertakes such a survey and that following this a review of the information in this report relating to ground movements and stability of neighbouring structures is carried out.

6.2 Ground and Structure Movement Monitoring

6.2.1 Scope of the Monitoring Regime

Monitoring of the predicted ground settlements and movements is proposed to be implemented to ensure compliance between the ground movements associated with the proposed development and those predicted. At this stage the monitoring scheme is anticipated to comprise the following:

1. Pre-construction inspections to establish the existing conditions of the adjacent perimeter buildings:
    i. Astor College
    ii. University College London
    iii. Tottenham Mews
    iv. Day Hospital
    v. Middlesex House
2. Present condition surveys for buildings with a damage classification of 1 or higher
3. Monitoring of existing cracks to adjacent buildings with a damage classification of 1 or higher
4. Monitoring of the settlement and movement of the secant pile wall during construction to provide data on wall movements
5. Post construction inspection of the adjacent buildings
6. Review of the monitoring results against predicted displacement levels

The buildings to be monitored will be confirmed following detailed design, ground movements and further building damage assessment.

Once implemented the results from the monitoring regime will be assessed against trigger and action levels set following detailed design analyses for the monitoring and controlling of ground movements due to the construction works.

The instrumentation work is to be carried out in accordance with the ICE (2007) Specification for Piling and Embedded Retaining Walls (SPERW), 2nd edition.

6.2.2 Monitoring of adjacent buildings

The preliminary assessment indicates Category 0 for Astor College and Category 1 for the UCL building. Similar ground movements and categories will apply for the other perimeter buildings. It is noted that both Astor College and the UCL building have basement structures and the preliminary assessment work has not considered the influence of these basements as it assesses ground movement and influence at ground level. The depth of the basements and foundations should reduce the movements and may change damage categories. Further work will be carried out at the next stage following building inspections and more detailed ground movement assessment. Where buildings are in Category 1 or above, or the inspections and Present Condition Surveys indicate existing cracks, monitoring will be recommended.

On site a Present Condition Surveys shall be carried out for the retained structure prior to the start of demolition of the existing buildings. The survey shall provide a record on all existing internal and external cracks and signs of damage to the retained building, any structural distortions, chemical corrosion, misalignment of structural elements and additional observations in accordance with BRE Digest 343.

Monitoring will be carried out of existing significant cracks identified from the survey before, during and post construction or of cracks or distortion where analyses indicate potential risk areas during construction works. The rear wall to the retained building will be supported and monitored for distortion during the basement construction works.

6.2.3 Monitoring of the secant pile wall deflection

Regarding the secant pile wall, the capping beam will be surveyed (3D) in selected positions using precise levelling to establish initial and subsequent positions. Dependent on the results of the detailed design work individual piles may also be instrumented and monitored using torpedo or non-torpedo inclinometers to provide data on the deflection along the length of the pile.

6.2.4 Monitoring details

A Monitoring Specification will be prepared to specify all the required monitoring details. Each monitoring location will be monitored at predetermined intervals with the designated method and accuracy level as prescribed in the specification. Green, Amber and Red limits shall additionally be determined to classify the level of required action at any occurrence. The system for dealing with amber and red alerts will be specified and appropriate mitigation measures recorded (for example: cessation of excavation; backfilling; additional propping).

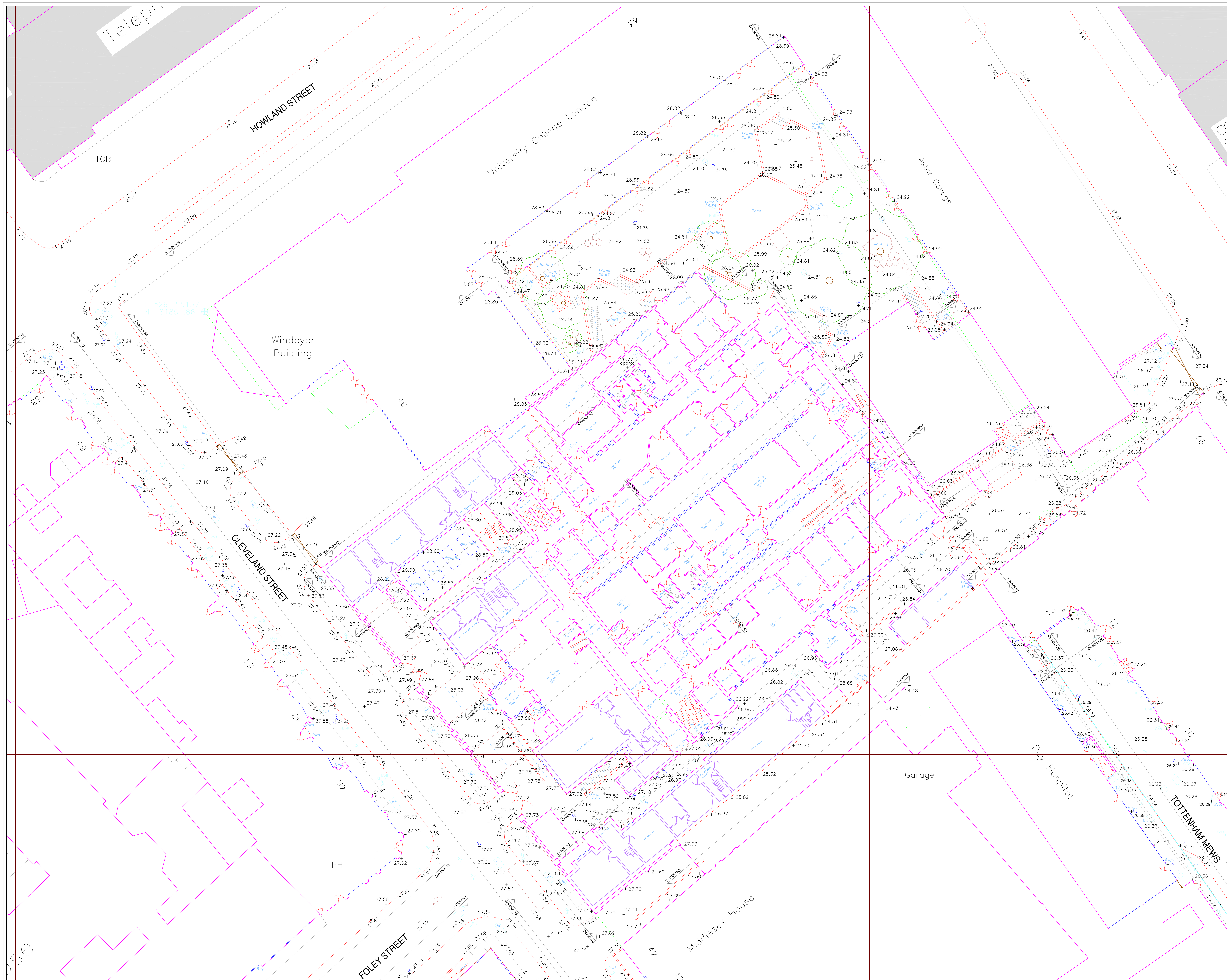
Figures

Figures

Figure 1: Site Location Plan

Figure 2: Adjacent basement Structures

Figure 3: Preliminary Temporary Works Concept Plan - showing Cross-sections used for Ground Movement Assessment



Station Information:

Station	Easting (m)	Northing (m)	Level (m)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

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.

Topographical Legend:

Note:
Although O.S. Coordinates may be shown on this plan the grid is to be treated as arbitrary.
No scale factor has been applied to the survey therefore the any coordinates shown are not true O.S. Coordinates.
Please refer to Survey Station Coordinate Table above to enable correct establishment of the on-site grid used.

OS Buildings | Surveyed Buildings

Rev	Date	Description	Drawn	Q. Ref
A	17.06.10	Minor update	L.W	

greenhatch group
Topographical Surveys
Site Engineering
Measured Building Surveys
3D Laser Scanning

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CLIENT
Inventures

PROJECT
UCLH
Middlesex Hospital,
Cleveland Street.

TITLE
Existing Ground Floor Composite Drawing.

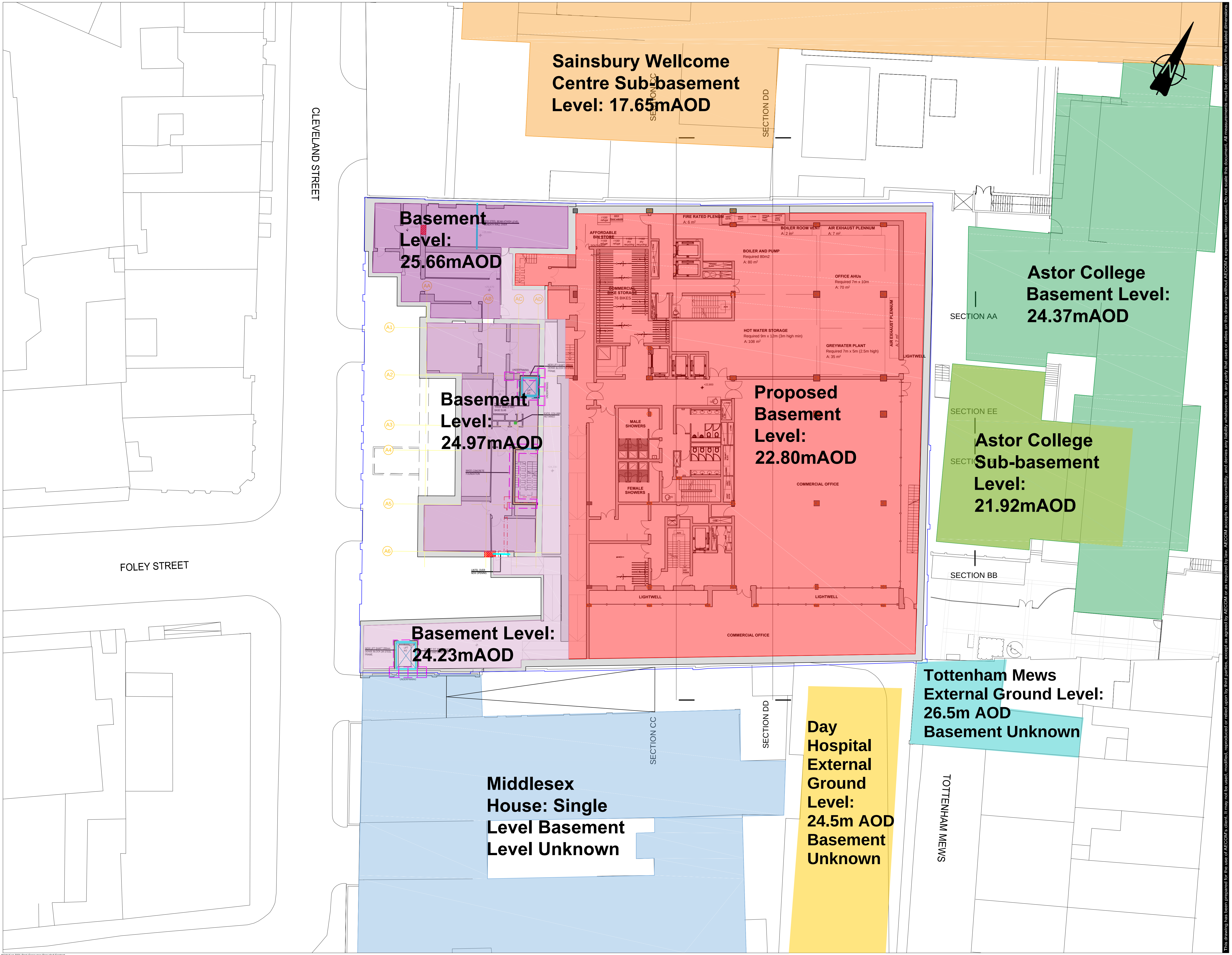
SCALE	DATE	DRAWN	QUALITY REF
1: 200	June 2010	LW	B0350

Level datum	Ordnance Survey GPS
Grid orientation	Ordnance Survey GPS
Job number	13514

Drawing No.	Rev.
13514_11_P	A

Comments
This plan should only be used for its original purpose. GreenHatch Ltd accepts no responsibility for this plan if supplied to any party other than the original client.
All dimensions should be checked on site prior to design and construction.
Drainage information (where applicable) has been visually inspected from the surface and therefore should be treated as approximate only.

Notes:
Care is to be taken when scaling from hardcopies. Greenhatch cannot verify the accuracy of hardcopies.



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PROJECT

Middlesex Hospital Annexe

CLIENT

University College London Hospitals Charity (UCLHC)

ISSUE/REVISION

I/R	DATE	DESCRIPTION
01	20/09/2016	For BIA

SHEET TITLE

Figure 2
Adjacent Basement Structures

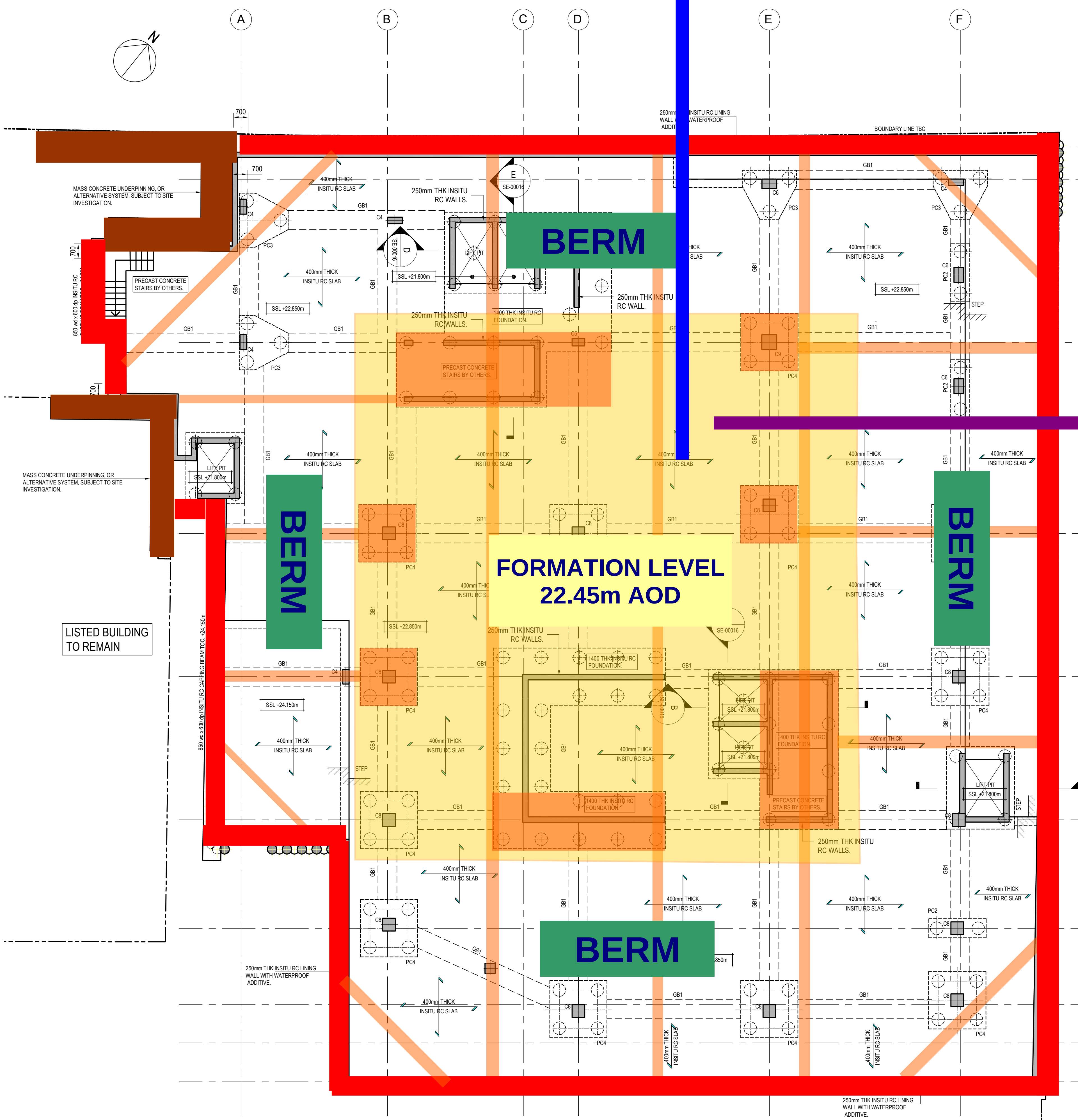
SHEET NUMBER

60516144/BIA/Fig2

SCALE

1:200 @ A1

ISO A1 594mm x 841mm
Project Management Initials: Designer: JC Checked: PAS Approved: PAS
Project Reference Number: 60516144
Last saved by: CHENGJ1(2016-12-15) Last Plotted: 2016-12-15
Filename: P:\UKSTA1-IE\PROJECTS\CGEO\ENQUIRIES\1201-1300\1273 MIDDLESEX HOSPITAL\DOCUMENTS\BASEMENT IMPACT ASSESSMENT\DRAWINGS\PROP - B1.DWG



NOTE: Preliminary assessment includes a 0.5m over-dig below formation level

NOTES:

- GB1 GROUND BEAMS TO BE 900wd x 900dp.
- PC2 PILECAP TO BE 900wd x 2700lg x 1400dp.
- PC3 PILECAP TO BE 2700wd x 2700lg x 1400dp.
- PC4 PILECAP TO BE 2700wd x 2700lg x 1400dp.

COLUMN SCHEDULE

COL REF	COL SIZE
C1	300 wd x 300 lg
C2	300 wd x 400 lg
C3	300 wd x 500 lg
C4	300 wd x 700 lg
C5	350 wd x 600 lg
C6	450 wd x 700 lg
C7	475 wd x 475 lg
C8	600 wd x 600 lg
C9	700 wd x 700 lg
SC1	254x254UC73

PERIMETER SECANT PILED WALL CAPPING BEAM

UNDERPINNING TO THE EXISTING STRUCTURE (where no piles)

PERIMETER SECANT PILED WALL - CASE A SECTION A - A

PERIMETER SECANT PILED WALL - CASE B SECTION B - B

0 1 2 3 4 5 6 7 8 9 10m

SCALE 1:100

AECOM

PROJECT

MIDDLESEX HOSPITAL ANNEX

CLIENT

UNIVERSITY COLLEGE LONDON HOSPITALS CHARITY

CONSULTANT

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GENERAL NOTES

1. THIS DRAWING TO BE READ IN CONJUNCTION WITH ALL RELEVANT DOCUMENTATION.
2. DO NOT SCALE FROM THIS DRAWING, USE ONLY PRINTED DIMENSIONS.
3. ALL DIMENSIONS ARE IN MILLIMETERS. ALL CHAINAGES, LEVELS AND COORDINATES ARE IN METRES UNLESS DEFINED OTHERWISE.
4. THIS DRAWING TO BE READ IN CONJUNCTION WITH THE POTENTIAL HEALTH AND SAFETY FILE FOR ANY IDENTIFIED POTENTIAL RISKS.
5. FOR GENERAL NOTES, REFER TO AECOM DRG No. MHA-ACM-XX-XX-GN-S-00001.
6. This temporary works arrangement is an indicative preliminary layout and not for construction. The Contractor shall develop their temporary works approach and update all assessment as necessary.

ISSUE/REVISION

I/R	DATE	DESCRIPTION
A	5/04/2017	ISSUED FOR PLANNING

KEY PLAN

PROJECT NUMBER

60516144

SHEET TITLE

PRELIMINARY TEMPORARY WORKS CONCEPT

SHEET NUMBER

MHA-ACM-NB-B1-DR-S-GEO-00001

ISO A1 594mm x 841mm

Approved: Checked: Designer: Project Management Initials:

Last saved by: CHRIS.PRYOR(2016-12-16) Last Plotted: 2016-12-16
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