MR A ANDREWS

17 WADHAM GARDENS, NW3 3DN

GROUND MOVEMENT IMPACT ASSESSMENT

REVISION 1

September 2015

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REVISION HISTORY

Revision	Date	Prepared by	Reviewed by	Description
Rev. 0	September 2015	Dr A. Gasparre Dott. Ing. PhD DIC Ceng MICE	M. Crilly BSc MSc DIC	Issued for comments
Rev 1	October 2015	Dr A. Gasparre Dott. Ing. PhD DIC Ceng MICE	M. Crilly BSc MSc DIC	Minor changes

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1 Introduction

It is proposed to redevelop a site at 17 Wadham Gardens, London, NW3 3DN. The site is currently occupied by a two-storey detached house with partly grassed and paved front and rear gardens.

The development involves the construction of a basement under the footprint of the existing building and partly under the rear and front paved areas of the property. A Network Rail (NR) tunnel runs underneath the rear garden of the site.

Geotechnical Consulting Group LLP (GCG) has received an instruction from Mr A Andrews, to assess the impact of the ground movements associated with the basement construction on the adjacent structures. It is outside the scope of this report to consider the impact of the proposal on any other underground services or on the NR tunnel.

The expected movements in the area around the site have been estimated using an empirical approach that is based on field measurements of movements from a number of basement constructions across London (CIRIA C580).

Information on the proposal has been supplied by Pringuer-James Consulting Engineers (PJCE), who are the structural engineers for this project, Gpad London Ltd, architects for the project, and Axiom Structures Ltd, temporary works designers.

2 Existing site and proposed redevelopment

The site is located at approximate National Grid Reference TQ 272 840. It lies to the north side of Wadham Gardens, and is bounded by 15 Wadham Gardens to the west and 19 Wadham Gardens to the east and rear gardens of private properties facing King Henry's Road to the north (Figure 1). Ground level appears to be generally flat around the site, at about +50.2mOD.

Currently, the site is occupied by a two-storey detached house (plus additional roof level accommodation) with partly grassed and paved front and rear gardens. Record documents suggest that the house was constructed between 1890 and 1911, when Wadham Gardens was developed.

The house is approximately 22m x 12m in plan. There is a basement under its north-western part (roughly 10m long by 4.5m wide) which extends to about +48.4mOD. The existing building is understood to be founded on strip foundations at about 1.5m below the corresponding base slab levels.

It is proposed to construct a basement under the footprint of the existing building and partially under the front and rear garden areas. Figure 2 shows the footprints of the existing building and proposed basement.

The formation level of the new basement will be between +46.1mOD and +46.7mOD across most of the area except in the north and north-western part of the site, where it will be deepened to +43.9mOD to locate plant rooms. Figures 3 and 4 show the plans of the proposed development at plant and basement levels whereas Figures 5 and 6 show the development in section view.

Considering the depth of the basement slabs, the required excavations will be approximately 4.5m across most of the basement area and 6.3m in the plant room areas. Under the existing basement an excavation of 4.5m will be required. The proposed excavation depths across the site are marked in Figure 4.

The basement will be formed by a combination of contiguous piled wall and underpinning of existing walls (Figure 4). The front basement walls will be formed by contiguous piles whereas all the other walls will be formed by 2-stage RC underpinning in a hit and miss sequence in small sections of 1 to 1.5m wide. A third stage underpinned will also be adopted in the plant and swimming pool area, where the excavation is deeper. At the second (and third) stage of underpinning, sacrificial trench sheets may be installed between enabling sections to retain the soil during construction.

The new building will be founded on a combination of strip (i.e. underpinned walls around the basement boundary), pads and raft foundations as shown on basement and plant level plans.

3 The neighbouring buildings

As show in Figure 2 the properties that are most likely to be affected by the proposed basement construction are No. 15 and No. 19 Wadham Gardens, which bound the site to the east and to the west.

3.1 No. 15 Wadham Gardens

This is a three storey masonry house with mansard roof and a single storey extension at the rear. The house has an L shape with the edges being approximately 22m and 17m. The longest edge stretches north-south along the boundary with No. 17 Wadham Gardens and the narrower width of the house is about 9m.

There is a basement at the rear of the western side of the main house. This is approximately 6m x 17m in plan and 3.8m deep. It is a late addition to the original 1890s house and it was completed in 1998. Record documents show that the basement was constructed using underpinning techniques to create a concrete wall along the perimeter. Temporary pile walls were used to support the existing house during construction.

Figure 7 shows the façade of the house and a plan with the extent of the existing basement. The main house and the rear basement are set about 3m away from the main house on No. 17 Wadham Gardens.

Detailed information on the foundation level of the main house are not available, but, considering that the house was built at the same time as No. 17 Wadham Gardens, for the purposes of the analyses herein it will be assumed that the foundation level of the masonry walls are 0.5m below ground level. It is also assumed that the house is in good conditions.

3.2 No. 19 Wadham Gardens

This is a three storey masonry house with mansard roof similar to the other houses on Wadham Gardens (Figure 8). The house has an L-shape with edges of 20m and 18m length. The longest edge is orientated north-south along the boundary with No. 17 Wadham Gardens and the narrower width of the house is about 9m. Record information suggests that the house has a rear extension to its north-eastern side that was completed in the early 1990s.

Details of the existing structure are unknown. For the purposes of this assessment it will be assumed that the house is in good conditions and its foundations are about 0.5m below ground level in Wadham Gardens.

4 Ground conditions

The geology of the area shown on the British Geological Survey (BGS) maps suggests that the site is underlain by the London Clay Formation (Figure 9). The Lambeth Group, Thanet Sand Formation and Chalk Group underlie the London Clay Formation in the same order of succession.

A site-specific ground investigation was carried out by Soil Consultants in February 2015 (Reference [1]). This comprised two exploratory boreholes using cable percussive techniques (BH1 and BH2, extending to 15m and 7m deep respectively).

Borehole logs recorded the ground level as +50.2mOD. The boreholes revealed Made Ground/Langley Silt (to about +49.1 to +49.5mOD) followed by London Clay Formation. Flint gravel was recorded in the upper part of the clay immediately below the Made Ground. This is probably due to natural re-work of the upper part of the London Clay Formation. The boreholes terminated within the London Clay Formation and did not prove the top of the underlying Lambeth Group.

Based on the site specific ground investigation data combined with the published BGS geological maps, GCG archive records and BGS boreholes in the vicinity of the site, the following idealised stratigraphy has been assumed for this site:

Made Ground	+50.2 to +49.3mOD
Weathered London Clay Formation	+49.3 to +44.2mOD
London Clay Formation	+44.2 to -30mOD

Groundwater strike was recorded during the investigation at the junction between the Made Ground and the clay.

Based on the above stratigraphy, the basement will be founded within the London Clay Formation. The piled wall extends through the Made Ground and into the London Clay Formation.

5 Ground movement analyses

5.1 Background

The works for the basement construction would induce ground movements inside and outside the area of the new basement. Inside the basement area ground movements will be due to the net change of vertical load on the ground and the basement structure should be designed accounting for these movements.

Around the basement area ground movements during and after the works would be due mainly to:

- the underpinning of the existing foundations,
- piling along the front edge of the new basement
- the excavation of the main basement, which would induce a reduction of vertical and lateral stresses in the ground along the excavation boundaries.

The magnitude and distribution of the ground movements inside and outside the excavated area are a function of changes of load in the ground and workmanship. The way that the existing buildings around the site respond to the movements is dependent on their current conditions and the precautions that are taken to reduce the risk of building movements.

The estimated ground movements and their impacts on adjacent houses are discussed below.

5.2 Movements due to underpinning

The perimeter walls of the existing house and the rear edge of the proposed basement will be underpinned to enable the basement excavation works.

The underpinning will involve a transfer of vertical loads from the current to deeper foundation levels. Considering that only small net load changes would occur, most of the ground movements due to underpinning are likely to be settlements due to construction effects.

The depth of the underpinning would be approximately 4.5m around most of the perimeter and approximately 6.5m along the rear section of the swimming pool, where the excavation is deeper.

Experience suggests that for these underpinning depths, if the work is carried out with good workmanship and in the dry, the ground movements can be controlled so that these do not exceed 10mm. The settlements would be localised under the underpinned walls and any damage caused by these movements will affect the underpinned walls and should be capable of being repaired afterwards.

It should be noted that perched groundwater was found at the junction of the Made Ground with the London Clay. This is unlikely to be of concern but it should be accounted for during construction and, if necessary, measures should be taken to ensure that the works can be carried out in the dry.

5.3 Movements due to installation of piled wall

Bored pile walls are to be installed along the front edge of the basement. The length would be dictated by the surcharge loads applied behind the wall and by the vertical loads on the walls. The final pile design has not yet been completed, but, considering the depth of the excavation and assuming that the walls will be propped during construction, for the purposes of the analyses herein the piled walls around the perimeter of the basement will conservatively be assumed to be around 7m long.

The installation of bored piles is known to cause ground movements as a consequence of a loss of horizontal support during drilling. Record data on basement construction in London (CIRIA C580) are shown in Figure 10 and can be used to estimate the expected movements.

Records of data on horizontal movements are limited and very scattered and in practice horizontal movements can be ignored. Record data on settlements show a large scatter over a distance of about 0.2 times the wall length behind the wall. Behind that all but a very few measurements show that the settlements are less than 0.02% of the wall length. The movements are highly dependent on the piling method and the care taken. Based on the record data and recent monitoring information (Ball et al., 2014), for the purposes of estimating overall settlements the curve marked on the figure can be used.

For basement walls of 7m the expected settlements are less than 1.5mm at the back of the wall and less than 1mm at 5m from the wall.

5.4 Movements due to excavation

The excavation would cause upward ground movements in the excavated area and under the underpinned perimeter walls as a result of the vertical change (reduction) of loads on the excavated surface. Behind the retaining walls the ground would tend to settle and move towards the excavation as the retaining walls bend towards the excavation due to the reduction of lateral support to them.

Figure 11 shows empirical data based on the movements of ground behind retaining walls as a result of excavations in typical London ground conditions. The movements depend on the propping sequence and on the depth of the excavation and although there is a considerable scatter, the data lies within an envelope, which can be used to predict the likely upper limit of movement at any particular distance from the excavation. Although the database refers to embedded retaining walls, there is a lack of reliable data on ground movements behind underpinnings so the CIRIA C580 data is typically used also for underpinning.

The main basement will be excavated in front of bored walls and the underpinned walls, which would be propped prior to the start of any significant excavation. Record data referring to stiff support of the walls could therefore be used to estimate the expected movements.

The ground behind the walls would tend to sag and therefore the maximum settlements would occur at a distance behind the retaining walls. The values estimated from the record data occur behind the walls, at the corners ground movements would be restricted to about half of the predicted values.

These would add to any predicted movements due to wall installation or underpinning construction.

Contour plots of the predicted ground movements due to the combined effect of excavation and bored pile installation around the basement area have been constructed and are shown in Figures 12 and 13. It should be noted that these are the ground movements calculated at the level of the ground around the excavation (i.e. +50.2mOD)

In the long term upwards movements would be expected as a result of the net changes of vertical load on the ground. These could affect the underpinned walls but are not likely to affect adjacent structures because the stiffness of the basement box would tend to confine the movements within the boundaries of the excavated area.

6 DISCUSSION OF THE GROUND MOVEMENT ANALYSES

The ground movements caused by the basement construction could extend to a distance up to 25m from the rear of the new retaining walls. The impact of these movements on the surrounding structures can be estimated as suggested in CIRIA C580 by looking at the combined effects of the horizontal strains and the deflection ratio, which is the ratio between the maximum distortion of a structure and its length.

These effects are discussed below:

6.1 No. 15 Wadham Gardens

Figures 12 and 13 show that the across the main house on this property the ground would tend to settle between 3-4mm, which could induce the house to tilt towards the new basement. The rear of the house would tend to settle slightly more as the ground behind the plant room areas settles more due to the deeper excavation depth. This could cause some minor distortions across the eastern wall of the house. Horizontally the house would tend to move up to 7-8mm along the eastern wall and between 1.5 mm and 4.5mm along the eastern walls of the house at the front and at the rear respectively. These movements could cause horizontal strains that could be estimated to be approximately 0.045% across the rear part of the house and approximately 0.035% across the front part. It should be noted that the estimated movements and distortions do not account for the stiffness of the house, which would tend to restrict the predicted movements. The strains and the distortions across the house are therefore likely to be lower than predicted.

At the rear of the main house the effective ground movements would be lower than predicted because the rear basement is founded at about 4m below the level at which the movements are calculated. It is unlikely that the maximum movements under the area of the basement exceed 2mm. Behind the line of the basement the movements are likely to be negligible.

The potential deflections that could arise from the tilt of the house, would be in the order of 0.02%. These, together with the maximum predicted horizontal strains, could induce damage to the house that can be classified at border between Category 0 (negligible) and 1 (very slight) in the Damage Category Chart shown in Figure 14.

6.2 No. 19 Wadham Gardens

Figures 12 and 13 show that the across the main house on this property the ground would tend to sag settling up to 3.5mm under the western part of the house. Slightly higher settlements could also occur under the rear corner of the house, which is behind the area of the plant room, where the excavation is deeper. The maximum distortion ratio across the house is calculated to be less than 0.03%. Horizontally the house would tend to move up to 7-8mm along the western wall and between 2-3mm along eastern walls of the house at the rear and at the front respectively. These movements could cause horizontal strains that could be estimated to be approximately 0.045% across the rear part of the house and approximately 0.035% across the front part.

These classify the potential damage on this house between Category 0 (negligible) and Category 1 (very slight).

7 Monitoring

It would be prudent to monitor movements during construction. Monitoring targets could be installed on the walls of adjacent properties and retained structures. These could be supplemented by precise levelling points that tend to show less scatter that the monitoring targets. Base readings should be taken before work commences.

The movements occurring during underpinning are unlikely to affect the surrounding structure. It is recommended that these movements are monitored so that they do not exceed 10mm.

Having completed the underpinning, the following trigger levels on the horizontal and vertical movements are suggested:

Trigger Level	Movements [mm]
green	<6
amber	7-9
red	>10

These are overall trigger levels applied to movements of the retaining walls.

8 Conclusions

The movements associated with the proposed basement construction at 15 Wadham Gardens have been estimated using empirical methods.

Providing that good workmanship and a robust construction sequence are used and that full support from high level is provided to the retaining walls during excavations, the basement construction is unlikely to cause settlements and horizontal strains that would induce other than limited damage to the surrounding structures.

With reference to CIRIA (C580), the damage to adjacent properties should not exceed that of Damage Category 1 (very slight).

Given their magnitude, the predicted movements are considered acceptable and it is unlikely that mitigation measures can be adopted to further reduce them. Any crack occurring on the neighbouring houses will be repaired afterwards.

Monitoring of movement during construction is recommended.

9 References

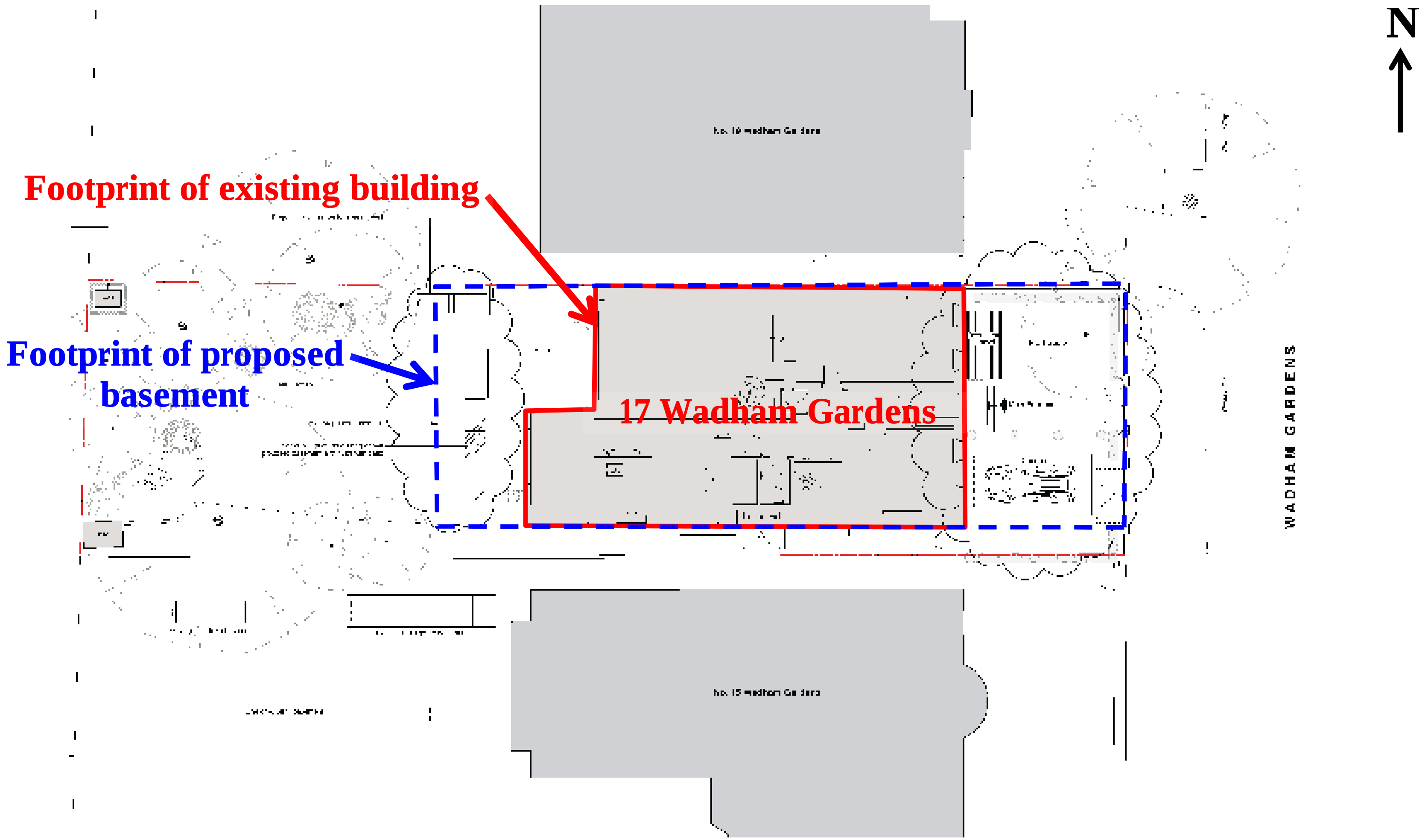
[1] **Soil Consultants. 2015.** *Report on a site investigation for proposed redevelopment at 17 Wadham Gardens, London NW3 3DN (dated 10th February 2015; Report reference 0722/KOG/JRCB).*

[2] **Burland, J. B, and Kalra, J. C. 1986.** Queen Elizabeth II Conference Centre: Geotechnical aspects. *ICE Proceedings*, Vol. 80. No. 6. Thomas Telford.

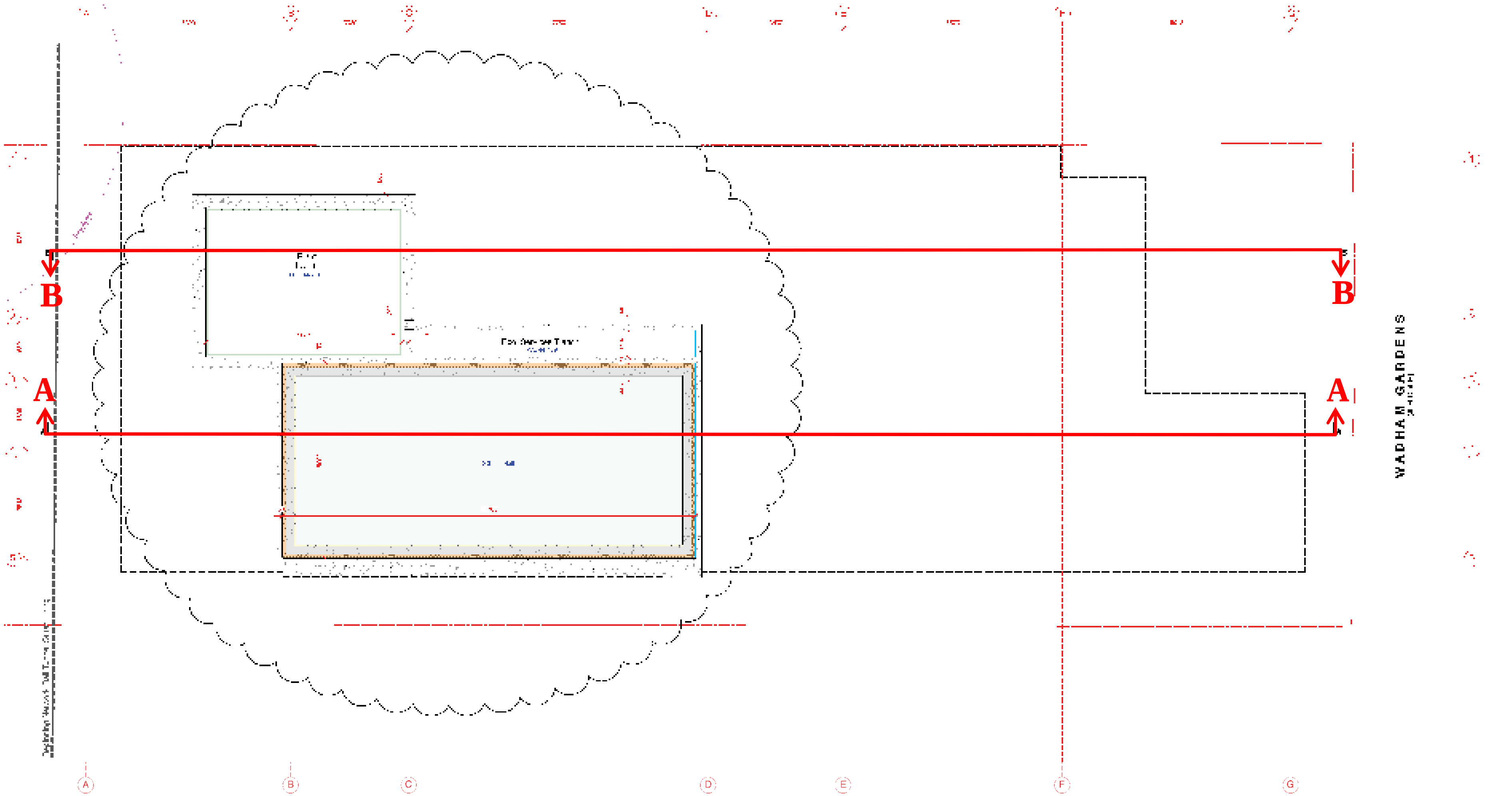
[3] **Ball, R, Langdon, N & Creighton, M. 2014.** Prediction of party wall movements using Ciria report C580. *Ground Engineering*, Sept 2014, 25-29.

FIGURES

Mr A Andrews 17 Wadham Gardens, NW3 3DN	**Figure 1**
Location of site – Aerial view (Google earth)	



Mr A Andrews 17 Wadham Gardens, NW3 3DN	**Figure 2**
Footprints of the existing building and proposed basement at 17 Wadham Gardens.	



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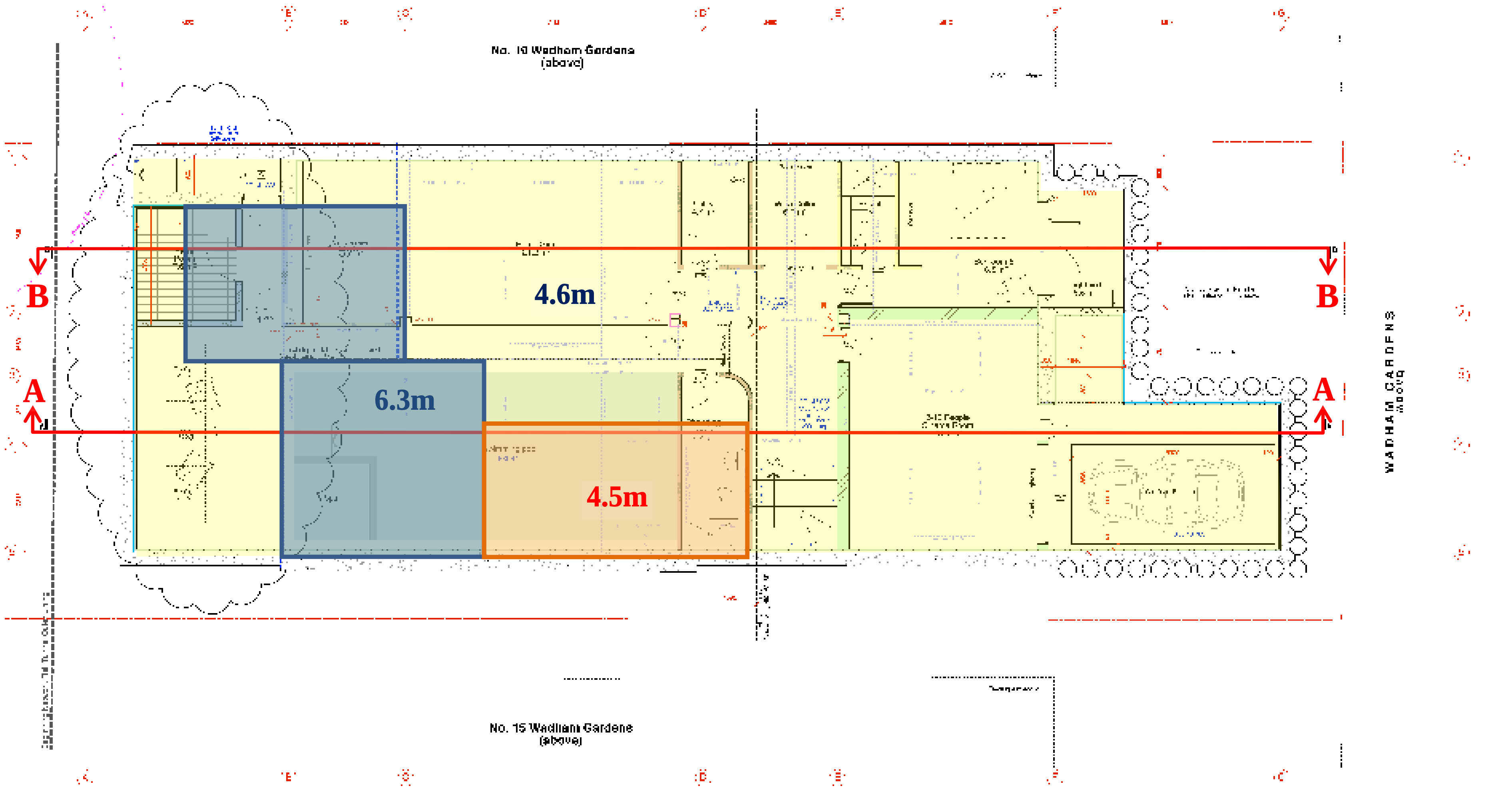
Proposed plant level plan.

Figure 3



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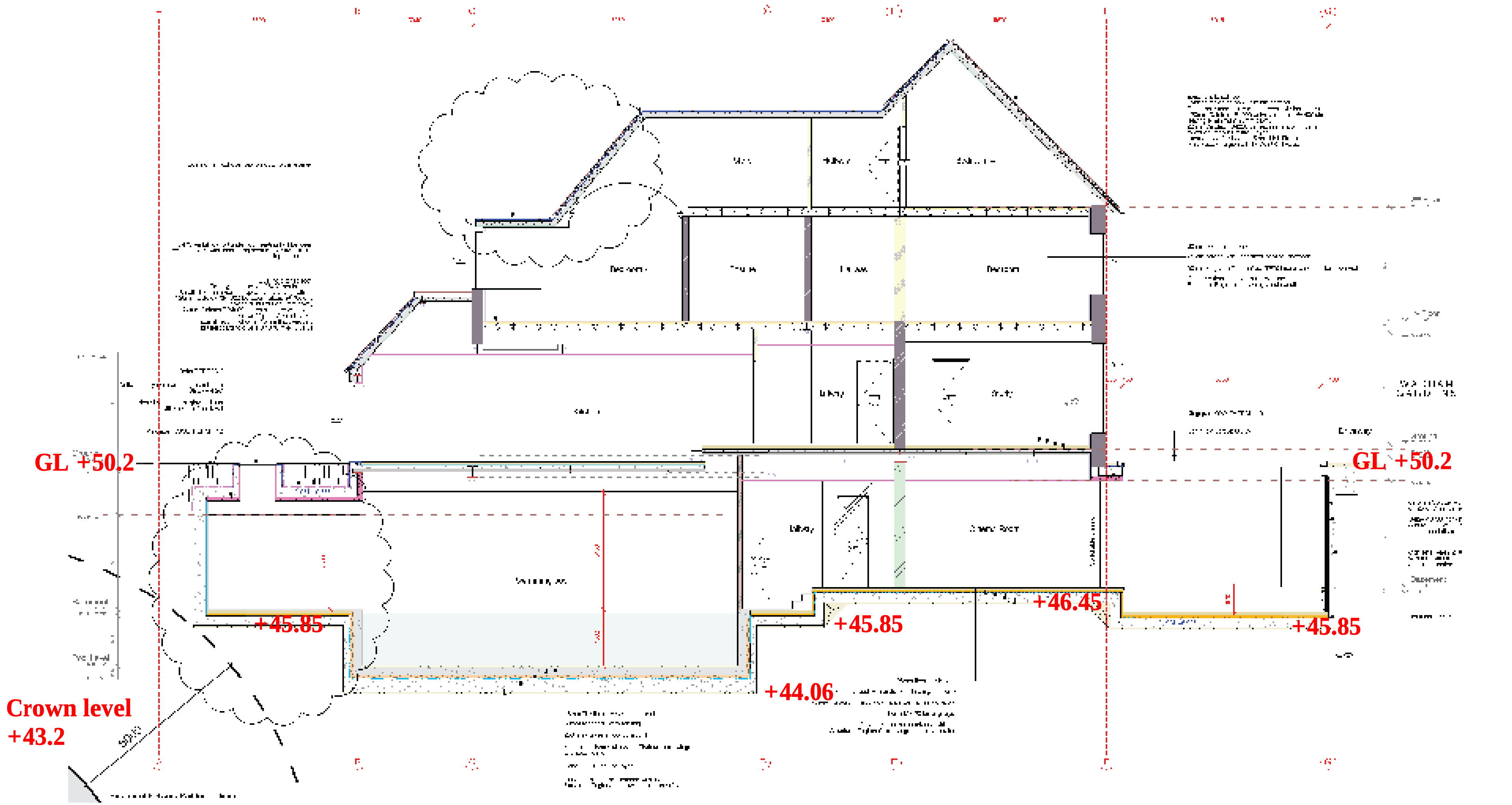
Proposed basement plan.

Figure 4



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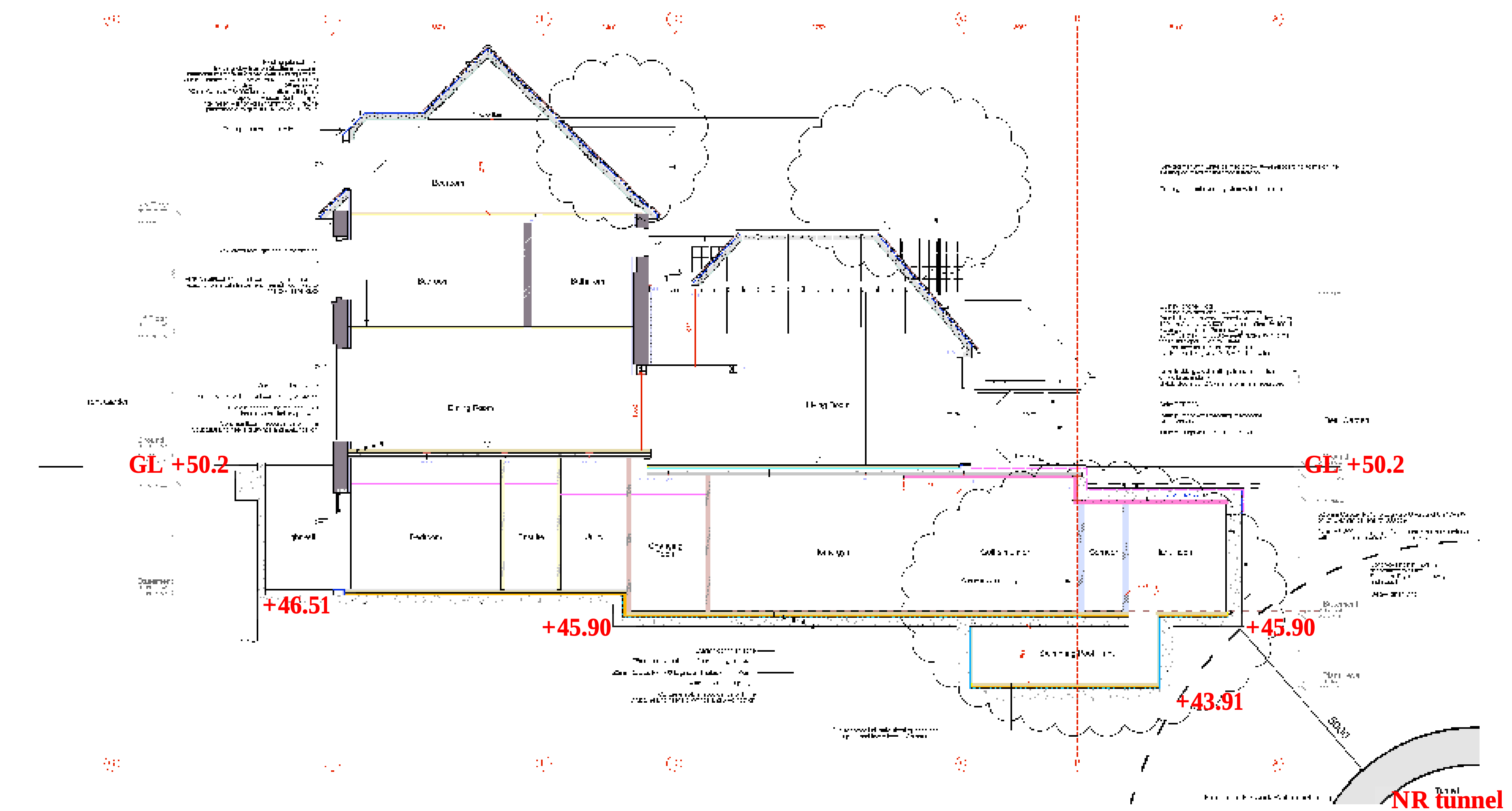
Section A-A (see Figures 3 and 4 for the location of section).

Figure 5



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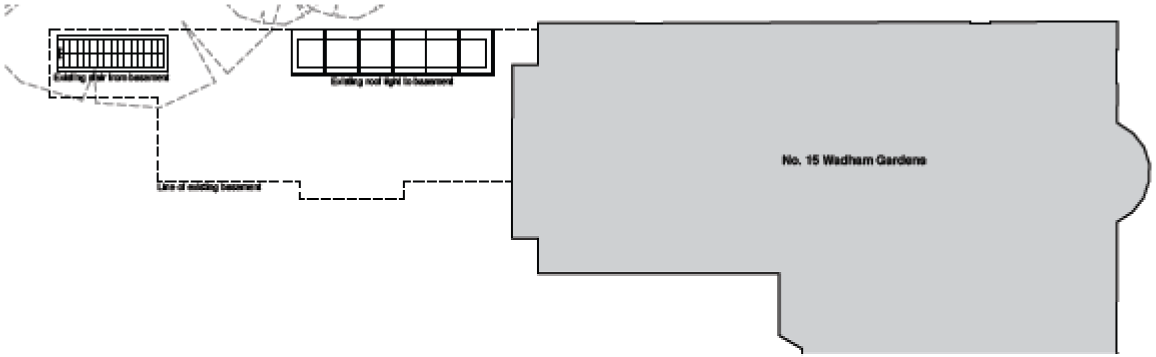
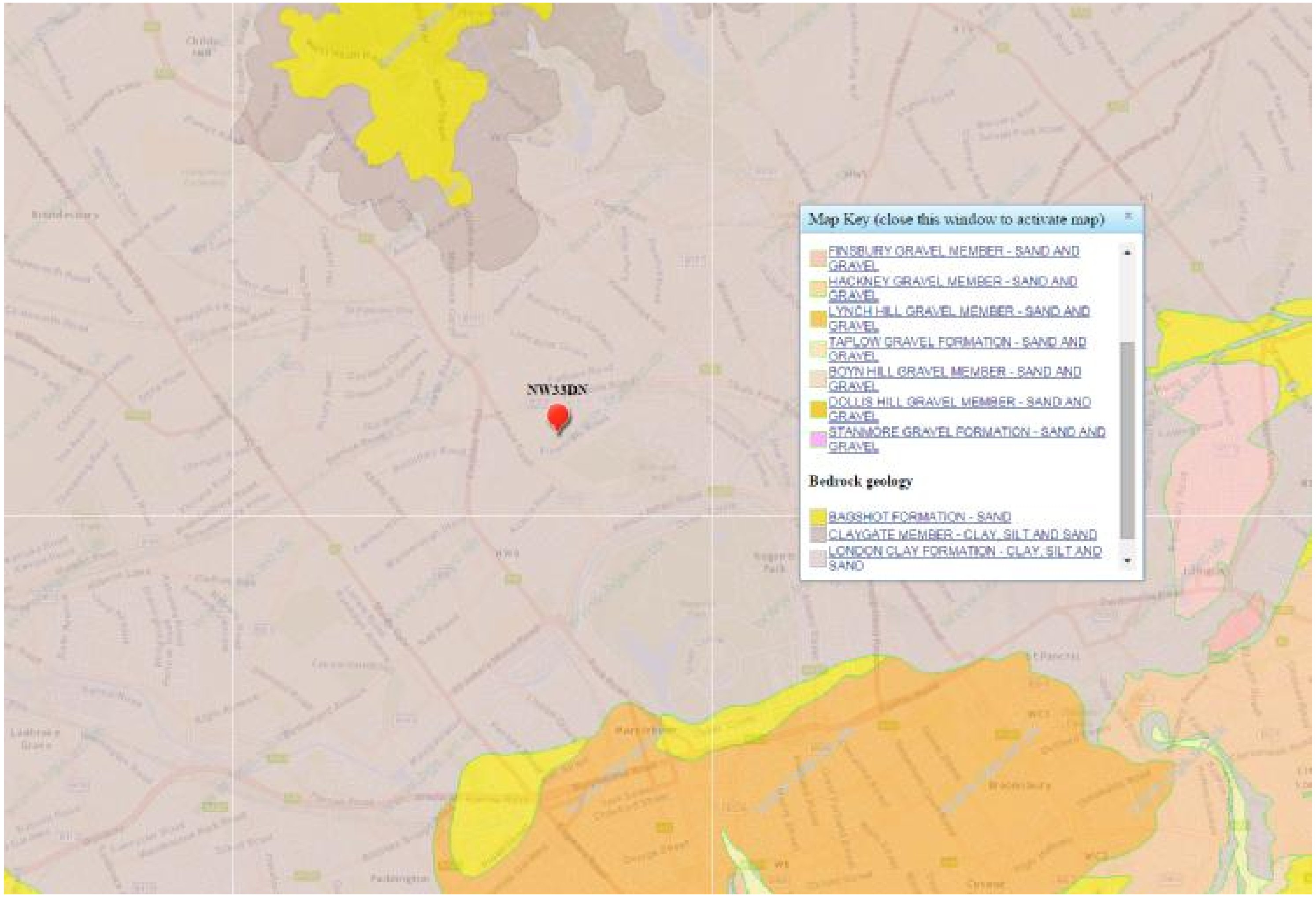
Section B-B (see Figures 3 and 4 for the location of section).

Figure 6

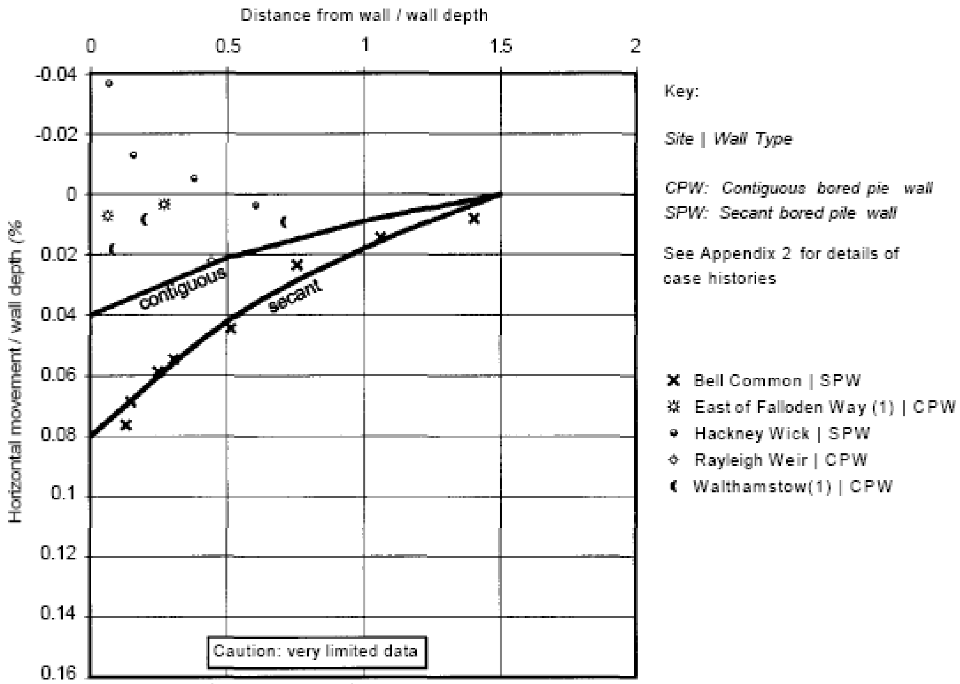


GCG	**Mr A Andrews** 17 Wadham Gardens, NW3 3DN	**Figure 7**
	No 15 Wadham Gardens	

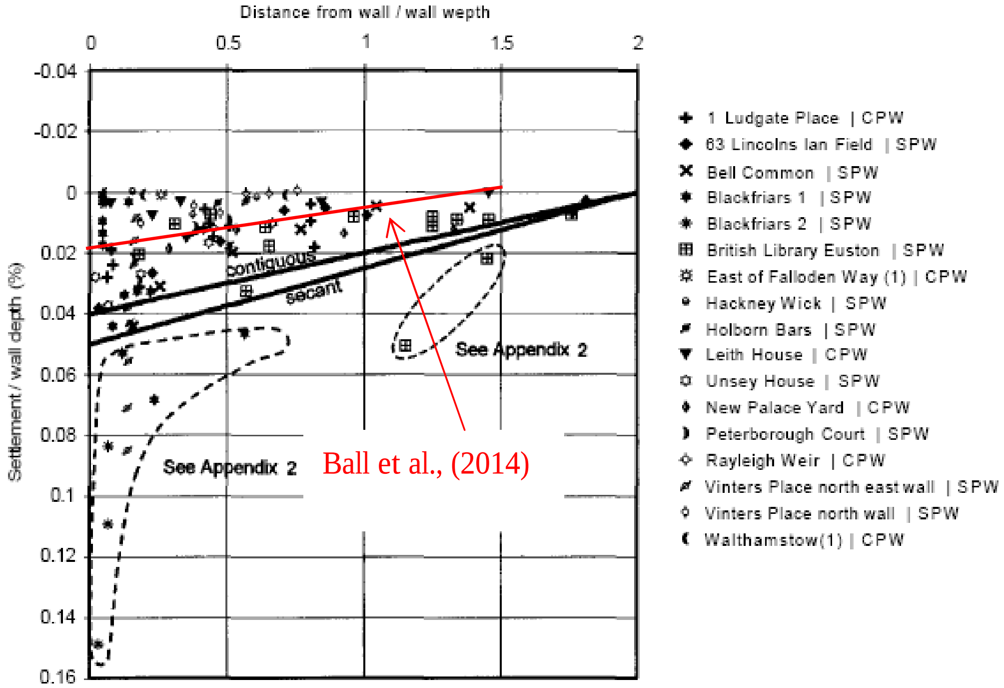
	Mr A Andrews 17 Wadham Gardens, NW3 3DN	**Figure 8**
	No 19 Wadham Gardens	



Mr A Andrews 17 Wadham Gardens, NW3 3DN		**Figure 9**
Geology of the area shown on BGS maps (http://mapapps.bgs.ac.uk/geologyofbritain/home.html)		



(a) Horizontal movements



(b) Vertical movements

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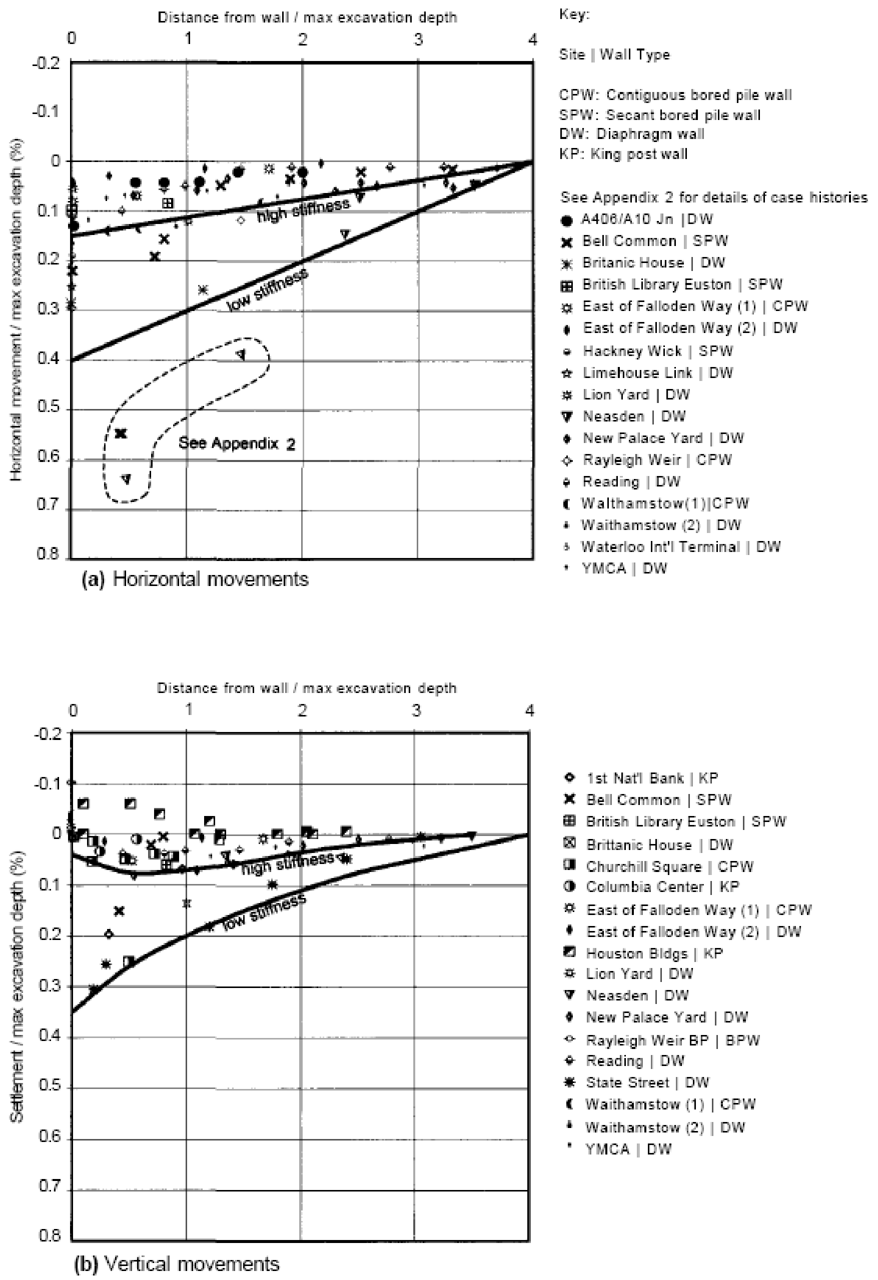
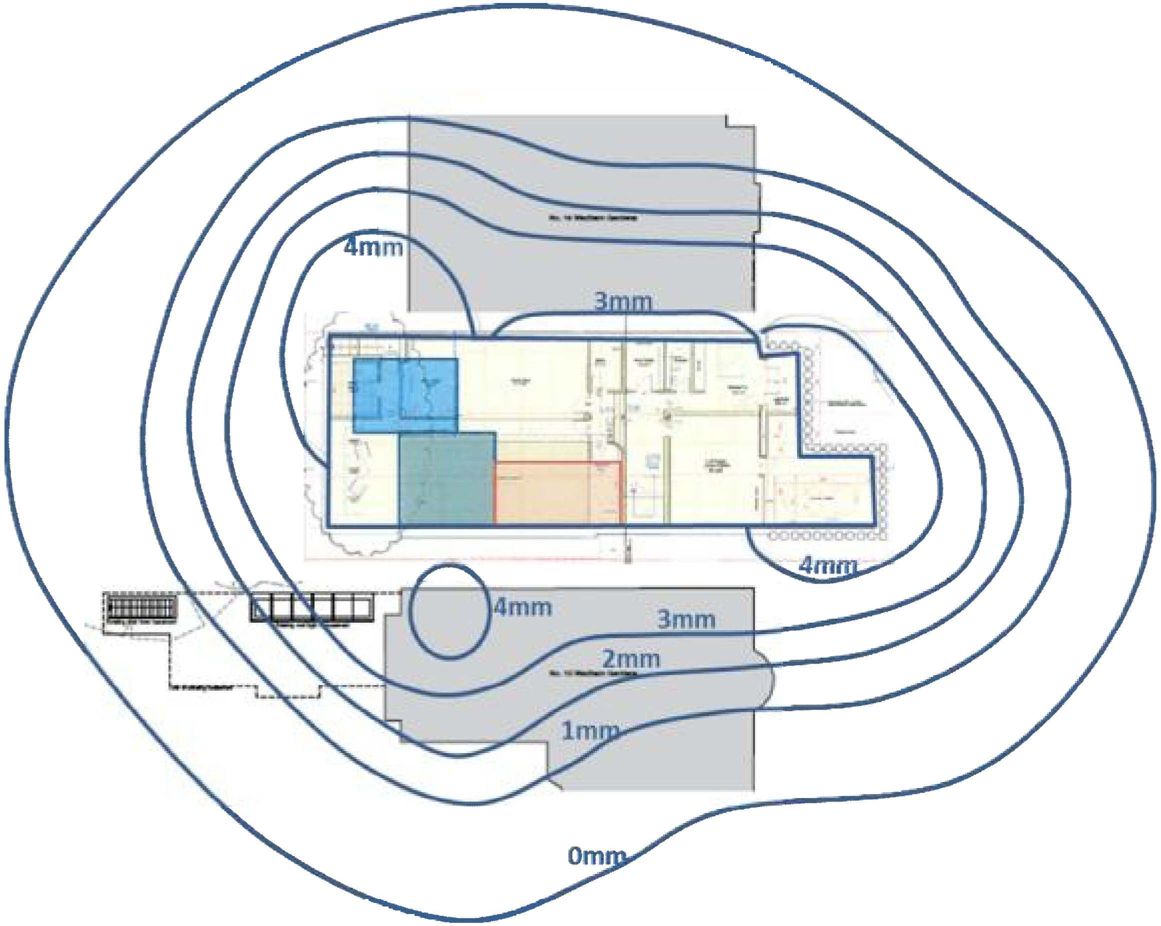
Field measurements of ground movements due to bored pile wall installation in stiff clay (CIRIA C580)

Figure 10



Mr A Andrews 17 Wadham Gardens, NW3 3DN		**Figure 11**
Field measurements of ground movements due to excavation in front of wall in stiff clay (CIRIA C580)		



GCG	**Mr A Andrews** 17 Wadham Gardens, NW3 3DN	**Figure 12**
	Ground movements induced around the site **Total vertical movements behind retaining walls**	

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Ground movements induced around the site
Total horizontal movements behind retaining walls

Figure 13

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

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Damage Category Table, Ciria C580

Figure 14