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29 New End
London NW3 1JD

Basement Impact Assessment Audit

For

London Borough of Camden

Project Number: 12336-80

Rev: F1

October 2016

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Planning Reference	2012/2833/P

Contents

Appendices

1.0 NON-TECHNICAL SUMMARY

1.1. CampbellReith was instructed by London Borough of Camden (LBC) to carry out an audit on the Basement Impact Assessment submitted as part of the Planning Submission documentation for 29 New End (planning reference 2016/2833/P). The basement is considered to fall within Category C as defined by the Terms of Reference.

1.2. The Audit reviewed the Basement Impact Assessment for potential impact on land stability and local ground and surface water conditions arising from basement development in accordance with LBC's policies and technical procedures.

1.3. CampbellReith was obtained the latest revision of submitted documentation from LBC's website and received information directly from the BIA author and reviewed it against an agreed audit check list.

1.4. The BIA and its constituent appendices have been carried out by well-known firms of consultants using individuals who possess suitable qualifications.

1.5. The BIA has confirmed that an existing former nurses home will be demolished and replaced by a seven storey residential building including a basement. The site slopes steeply from rear to front resulting in a 4 metre deep basement at the front and a 10 metre deep, three storey basement at the rear. The proposed basement is approximately 38 metres x 32 metres on plan and is surrounded by listed buildings.

1.6. The BIA identifies that the proposed basement will be founded within the sands and clay bands of the Bagshot Formation and Claygate Member.

1.7. A number of queries were raised on the hydrogeological and hydrology assessments and responses to these were received in a letter from Stephen Buss Environmental Consultancy which is included in Appendix 3. The responses largely address the queries raised, however, it is recommended that continued groundwater monitoring be undertaken to confirm the conclusions remain valid and the mitigation measures proposed are adequate. The results and confirmation of the validity of the assessment should form part of the party wall awards.

1.8. It should be noted a discharge content would be required from the EA to discharge water into the lower aquifer as discussed in Section 4.

1.9. It is accepted that the site is not located within the Hampstead Heath pond chain catchment area, has no anticipated risk of groundwater or fluvial flooding and has no past history of flooding.

1.10. Whilst responses to the queries regarding the GMA have been received, the full input and output data used in the analysis has not been provided as requested. However, the queries raised have been addressed through discussions and email as described in Section 4. It is acknowledged that the assessment has demonstrated ground stability can be maintained and building damage controlled, although the analyses and assessments require to be refined and, where necessary, revised once the final construction sequence and methodology are agreed. The GMA and building damage assessments should be scrutinised as part of the agreement of the party wall awards. Detailed monitoring proposals may also be agreed at this stage.

1.11. It is accepted that the BIA and supporting documents adequately identify the potential impacts arising out of the basement proposals and, subject to the agreement of party wall awards, describe suitable mitigation measures.

2.0 INTRODUCTION

2.1. CampbellReith was instructed by London Borough of Camden (LBC) on 8 July 2016 to carry out a Category C Audit on the Basement Impact Assessment (BIA) submitted to discharge the Condition contained in the Planning Approval at Appeal for 29 New End, Camden Reference 2016/2833/P.

2.2. The Audit was carried out in accordance with the Terms of Reference set by LBC. It reviewed the Basement Impact Assessment for potential impact on land stability and local ground and surface water conditions arising from basement development.

2.3. A BIA is required for all planning applications with basements in Camden in general accordance with policies and technical procedures contained within

- Guidance for Subterranean Development (GSD). Issue 01. November 2010. Ove Arup & Partners.
- Camden Planning Guidance (CPG) 4: Basements and Lightwells.
- Camden Development Policy (DP) 27: Basements and Lightwells.
- Camden Development Policy (DP) 23: Water.

2.4. The BIA should demonstrate that schemes:

a) maintain the structural stability of the building and neighbouring properties;

b) avoid adversely affecting drainage and run off or causing other damage to the water environment; and,

c) avoid cumulative impacts upon structural stability or the water environment in the local area

and evaluate the impacts of the proposed basement considering the issues of hydrology, hydrogeology and land stability via the process described by the GSD and to make recommendations for the detailed design.

2.5. LBC's Audit Instruction described the planning proposal as the *"Erection of a 7 storey block to provide 17 self contained residential (Class C3), (comprising 2 x studio, 5 x 2 bedroom, 6 x 3 bedroom, and 4 x 4 bedroom units) with associated roof terraces, plus new vehicular access and basement parking for 17 cars; new pedestrian access, refuse store and substation on front boundary; green roofs; communal open space and landscaping, following demolition of existing nurses' hostel (Sui Generis)."*

and confirmed that the basement proposals did not involve a listed building, although the following listed buildings (designated heritage assets) are in close proximity to the site: Lawn House (grade II), nos. 10-14 Elm Row (grade II); Christ Church Primary School (grade II), Hampstead Parish Workhouse, now known as Kendall's Hall (grade II), nos. 10, 12 & 14 New End (grade II).

2.6. CampbellReith was provided, on 24 May 2016, with a CD providing the following relevant documents for audit purposes:

· Basement Impact Assessment (BIA) dated May 2016 by Fluid Structures

This contained within its appendices the following information:

- Land Stability Assessment dated May 2016 by Soil Consultants.
- Hydrological Study dated May 2016 by Stephen Buss Environmental Consultancy Ltd.
- Ground Movement Assessment dated May 2016 by A-Squared Studios.
- Ground Investigation Report dated May 2016 by Soil Consultants.
- Construction Sequence Methodology undated by Belheim House Construction incorporating Temporary Works Proposals by Wentworth House Partnership.
- Movement Monitoring Method Statement dated April 2016 by Landscape Engineering Ltd.

2.7. CampbellReith was also provided with a letter prepared by Alan Baxter Associates, dated 7 July 2016, which contained an initial structural review of the BIA, together with a response prepared by the applicant's engineer, dated 22 July 2016. These letters are considered in the audit and presented in Appendix 3.

2.8. Following the initial audit, further queries were raised on behalf of a neighbour by the Geotechnical Consulting Group (GCG) (dated 4 August 2016) and Alan Baxter Associates (5 August 2016). Letter responses to the audit queries were received from A-Squared Studio and Stephen Buss Hydrogeology between 15 August and 3 October 2016 by email. This correspondence is presented in Appendix 3 and considered in this revised report.

3.0 BASEMENT IMPACT ASSESSMENT AUDIT CHECK LIST

Item	Yes/No/NA	Comment
Are BIA Author(s) credentials satisfactory?	Yes	BIA and Appendices.
Is data required by Cl.233 of the GSD presented?	Yes	
Does the description of the proposed development include all aspects of temporary and permanent works which might impact upon geology, hydrogeology and hydrology?	Yes	
Are suitable plan/maps included?	Yes	BIA Appendix G.
Do the plans/maps show the whole of the relevant area of study and do they show it in sufficient detail?	Yes	
Land Stability Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	BIA Appendix G, Section 3.
Hydrogeology Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	BIA Section Appendix H, Section 2.
Hydrology Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	BIA Section Appendix H, Section 3.
Is a conceptual model presented?	Yes	BIA Appendix H, Section 4.
Land Stability Scoping Provided? Is scoping consistent with screening outcome?	Yes	BIA Appendix G, Section 4.

Item	Yes/No/NA	Comment
Hydrogeology Scoping Provided? Is scoping consistent with screening outcome?	Yes	BIA Appendix H, Sections 3 & 4.
Hydrology Scoping Provided? Is scoping consistent with screening outcome?	Yes	BIA Appendix H, Sections 3 &4.
Is factual ground investigation data provided?	Yes	BIA Appendix G, Section 5 & Appendix J.
Is monitoring data presented?	Yes	BIA Appendix H, Section 4.4.
Is the ground investigation informed by a desk study?	Yes	BIA Appendix G, Section 5.
Has a site walkover been undertaken?	Yes	
Is the presence/absence of adjacent or nearby basements confirmed?	Yes	BIA Appendix H, Section 4.5.
Is a geotechnical interpretation presented?	Yes	BIA Appendix J, Section 5.
Does the geotechnical interpretation include information on retaining wall design?	Yes	BIA Appendix J, Section 5.5.
Are reports on other investigations required by screening and scoping presented?	N/A	
Are baseline conditions described, based on the GSD?	Yes	
Do the base line conditions consider adjacent or nearby basements?	Yes	
Is an Impact Assessment provided?	Yes	BIA Appendix G & H.
Are estimates of ground movement and structural impact presented?	Yes	BMA Appendix I.

Item	Yes/No/NA	Comment
Is the Impact Assessment appropriate to the matters identified by screen and scoping?	Yes	
Has the need for mitigation been considered and are appropriate mitigation methods incorporated in the scheme?	Yes	BIA Section 15, Appendix H, Section 6 & Appendix K.
Has the need for monitoring during construction been considered?	Yes	BIA Section 17 & Appendix M
Have the residual (after mitigation) impacts been clearly identified?	Yes	BIA Sections 18-21.
Has the scheme demonstrated that the structural stability of the building and neighbouring properties maintained?	Yes	Although GMA to be updated once construction sequence finalised and agreed as part of party wall awards.
Has the scheme avoided adversely affecting drainage and run-off or causing other damage to the water environment?	Yes	Although continued groundwater monitoring recommended.
Has the scheme avoided cumulative impacts upon structural stability or the water environment in the local area?	Yes	As above.
Does report state that damage to surrounding buildings will be no worse than Burland Category 2?	Yes	BIA Section 18.
Are non-technical summaries provided?	Yes	BIA Section 22.

4.0 DISCUSSION

4.1. 29 New End has a complicated planning application history which resulted in a June 2012 Application being approved at Appeal with a Condition that a Basement Impact Assessment (BIA) be submitted and approved by the London Borough of Camden. CampbellReith was provided with a CD containing the BIA documents by Savills (UK) Limited, Chartered Surveyors, dated 24 May 2016. CampbellReith was instructed to carry out an audit of this BIA information on 8 July 2016. Following the issue of the initial audit report, further information for review was provided to CampbellReith on between 28 July and 3 October 2016 as described in Section 2.

4.2. The BIA appears to be a revised document since it and all of its constituent appendices are dated May 2016. They have been carried out by well-known firms of consultants who possess suitable qualifications and experience.

4.3. The proposed development comprises the demolition of the former nurses home, which had no basement, and its replacement by a new seven storey reinforced concrete building which incorporates a basement for car parking, plantrooms and gymnasium. The ground slopes steeply from the rear (north) of the site towards the front (south) resulting in the basement depth at the front being approximately 4 metres and at the rear approximately 10 metres. The rear existing ground level is roughly level with the proposed second floor while the proposed front entrance area is level with the new ground floor. New End slopes downwards to the east and so the proposed basement will be approximately 2 metres below highway level rising to approximately 4 metres at the highway access to the building. On plan, the proposed basement is approximately 38 metres x 32 metres and to the east, south and west of the site are neighbouring residential properties (Grade II Listed in part) and gardens, public footpath and Christ Church.

4.4. A ground investigation was carried out by Soil Consultants Ltd (SCL) consisting of 4 no. boreholes to depths of up to 25 metres and 10 no. trial pits to expose existing foundations. These identified varying depths of Made Ground, up to 3.10m below ground level (bgl), overlying the sands and clay bands of the Bagshot Formation and Claygate Member, and augmented previous investigations carried out in 2010 and 2011. In total, 7 no. boreholes have been installed on the site, all with standpipes, and the latest standpipes have been monitored on four separate occasions. In addition to geotechnical appraisal carried out by SCL, further assessments of the ground conditions have been made by A-squared Studio Engineers Ltd and Stephen Buss Environmental Consulting Ltd.

4.5. The geology of the site, as described above, indicates granular soil layers and shallow groundwater; the BIA correctly identifies the consequential instability risks associated with these and considers mitigation measures in the Construction Sequence Methodology prepared

by Blenheim House Construction, supported by the Wentworth House Partnership (Appendix L of the BIA). The sequence is generally as follow:

- The basement is to be formed by secant piling with multiple levels of propping, progressive excavation to formation level, and then bottom up construction of the RC frame in conjunction with removal of temporary props. Additional bearing and tension piles will be installed where necessary to resist gravity and uplift actions. Sheet piles and gravity retaining walls will be constructed to facilitate the work.

- Prior, and during, the excavation works, a series of well points will be installed to maintain the equilibrium of the existing ground. Any encountered groundwater will drain into the public sewage system under licence to the Local Authority.

- Under slab drainage is to be installed throughout the substructure level.

4.6. The proposed development involves a large excavation on a sloping site surrounded by numerous properties. A great proportion of the ground movement realised in such construction depends on the way works are managed on site and good workmanship and are thus not quantifiable to model even in sophisticated FE methods. In order to maintain the stability and safety of the neighbourhood, it was considered that moderately conservative assumptions should be made in the assessments to account for unforeseen factors during the work.

4.7. A ground movement assessment (GMA) was prepared by A-squared Studio Engineers Ltd, which included prediction of likely ground movements using Plaxis 2D Finite Element (FE) modelling. The results of the Plaxis analysis were used to validate the implementation of empirical relationships between excavation and ground movement presented in CIRIA C580. Building damage has been predicted for affected structures on the basis of CIRIA relationships using the Oasys software package XDisp. The input and output data for the software packages was not provided. It is noted that a 3D FE model is being prepared by A-Squared and CampbellReith have been advised this confirms the assessments and conclusions described to date. It is recommended that this model is scrutinised by the Party Wall Surveyor once it is made available.

4.8. An initial review of the GMA identified a number of queries which have been responded to as described earlier. The initial queries and subsequent responses are summarised as follows:

- The building dimensions for New End Theatre, Lawn House, and Christ Church Cottage should be reviewed as smaller elements are more vulnerable to damage. New End Theatre appears to be closer to the edge of the excavation than assumed;

  In their latest submission, A-Squared confirm that they considered a reduced wall height for the theatre and the worst predicted category of damage remained Burland Category 1. It is also stated the position of the buildings relative to the proposed excavation have been located based on available ordnance survey data, therefore the distance between

the neighbouring structures to the proposed excavation is considered to be accurate. A plan has been presented showing the location of the theatre in relation to the proposed basement.

- It is understood that the outcomes of the Plaxis analysis were normalised against the excavation depth. Clarification of assumptions for for H in figure 4.2 of the GMA report was requested together with confirmation of the depth assumed for retaining walls piles;

  A-Squared have confirmed that the output was normalised against excavation depth and acknowledged curves for installation and excavation accept different height/wall length parameters. It is accepted that the ground movements due to installation effects are generally of second order compared to those due to excavation, however, it is recommended that the GMA is reviewed by the Party Wall Engineer following finalisation of the detailed design of the embedded retaining wall. An embedment of around 5m was assumed.

- Justification for the assumptions made in the GMA regarding stiffness of cohesive strata is required with confirmation that the SPT N_{60} design profile represents a 'cautious assessment';

  Figure 1 in A-Squared's letter response dated 12 August 2016 provides the adopted design profile. They note that the adopted design line presents a cautious assessment of the variation of SPT N60 with elevation, and that the assumed stiffness is considered to be conservative taking into account the anticipated level of strains in the retained ground mass in typical operating conditions. The undrained shear strength of the clay has been approximated based on SPT blow counts as, Su = 5 N60 (in kPa) with a stiffness which allows for small strain levels at working conditions behind the retaining wall is Eu/Su = 500. A-Squared note that the adopted drained stiffness profile is nominally 10 MPa less than what could be taken at face value from available data. A sensitivity check undertaken by A-Squared shows greater ground movements where the stiffness of the soil and structural elements are reduced by half. Although predicted deflections increase, the anticipated damage does not exceed Burland Category 2 for Lawn House.

- It should be clarified what allowance has been made for ground movements during enabling works, i.e. grubbing out of foundations/ substructures and re-profiling of the site including temporary batters;

  A-Squared have confirmed that the GMA does not explicitly incorporate movements due to localised removal of obstructions or grubbing out of existing structures which are dependent on the methodology adopted to undertake the works and the level of workmanship involved. They further note that excavations to remove obstructions in sensitive areas (i.e. adjacent to Lawn House) will be shallow and will not intercept a 45° line extended from the underside of the existing building foundation level. In this respect, it would be anticipated the effects of localised excavations to remove obstructions would be small. Notwithstanding, this A-Squared recommended that the methodology to remove obstructions is reviewed by the Engineer and Construction team at the time they

[the obstructions] are identified to ensure that unacceptable ground movements do not result from the works'.

- Temporary works drawings appear to show sheet pile walls to act as a cantilever (e.g. section A, stages 2A and 2B). It should be confirmed whether this has been incorporated into the assessment;

  It has been confirmed that the sheet piling in the temporary phase has been incorporated as part of the FE assessment. It is noted that the foundation level of Lawn House has been conservatively assumed to be at +118.8m AOD in the finite element analyses, to provide additional degree of conservatism when assessing the ground movements due to temporary works. It is also noted that the Wentworth House drawings refer to the provision of strutting to sheet piling where required. It is recommended that the temporary propping is considered during detailed refinement of the construction sequence, such that the risk of ground movements associated with temporary works in critical areas can be mitigated. A-Squared suggest further possible mitigation comprising the hit-and- miss installation of working platforms.

- It is noted that the proposed retaining walls in east-west direction, i.e. adjacent to Lawn House and Christ Church Cottage, are not retained by any structural element, and thus, form cantilever walls of up to 6.5m high. The GMA assumes excavation in front of a 'high-stiffness' wall which would require them to be propped at all time.

  A-Squared have reiterated that the 2D finite element model was used as a means to select the relevant CIRIA curve. It is assessed that the deformation of the proposed retention system is generally enveloped by the CIRIA curves, even though some portions of the permanent wall cantilever up to 6m. Notwithstanding the above, a simplified sensitivity check on the effect of adopting a "Low Stiffness" wall was carried out by A-Squared and suggests the maximum predicted Damage Category for Lawn House is Category 2 – Slight. This is within the existing maximum damage category assessed for Lawn House, albeit the position of the damage category coordinate is located further within the Slight damage contour interval.

- It is noted that the GMA uses the assumption of 'contiguous piled wall', whilst the proposed construction consists of 'secant' walls that are known to exhibit larger ground movements. It is not considered that this represents a 'cautious assessment'.

  In their response, A-Squared note that the adopted reduced installation effects were considered appropriate based on the proposed pile construction methodology incorporating the use of full length temporary casing during pile construction to reduce ground movements.

  They also state that sensitivity analyses were carried out to assess the damage category predicted at Lawn House if the full secant pile installation effects were adopted for the analyses. The sensitivity analyses indicate that the Damage Category for Lawn House (previously identified to be the most critical structure in terms of building damage category) remains within the predicted Category 2, whereas the previously the damage

category is predicted to be identified in the GMA was estimated to be straddling the Category 1/Category 2 boundary.

4.9. The methodology adopted in the GMA was queried by ABA and the GCG. Subject to the resolution of the queries noted above, the approach taken was considered appropriate at this stage. It is understood that A-Squared are producing a 3D FE model and that this supports the conclusions drawn to date. It is considered that significant analysis and sensitivity checks have been undertaken to justify that the proposed basement can be constructed in a manner to control ground movements and damage to surrounding structures. It is recommended that that GMA is revisited, once the final construction sequence is known, and agreed with the Party Wall Surveyor.

4.10. Matters such as ground movement are highly dependent on the construction and propping sequences which will be determined by the Contractor. Due to the sensitivity of the nearby structures, it is recommended a refined GMA and building damage assessment be undertaken once a contractor has been appointed. This should use appropriate methods of analysis and a reasonably cautious assessment.

4.11. It is proposed in the BIA that adjacent properties are monitored by one or two (depending on location) wirelessly controlled bi-planar inclinometers. Additionally Lawn House will be covered by separate level monitoring using traditional survey techniques. This is accepted at this stage although the final monitoring regime should be agreed with the neighbours party wall surveyors. ABA recommend that inclinometers are installed in the retaining wall and we would concur with this suggestion.

4.12. The interpretation in the BIA Hydrology Report of two distinct groundwater bodies beneath the site is agreed although, on the basis of the response zone for BH103 being isolated in a deeper sand layer, it was queried whether the groundwater elevation recorded in BH103 actually reflects a discrete water bearing sand/granular lens that is hydraulically isolated from the upper aquifer. It was our understanding that the groundwater elevation in BH103 is used to inform both the 'base case' and constant head applied in the numerical model. Clarification was sought on whether of whether the CSM and numerical model assumptions remain valid if BH103 data is not representative of the upper aquifer. Stephen Buss Environmental Consultancy's response confirms that on the basis of new evidence which is detailed in the letter in Appendix 3, the conclusions in the BIA remain valid and that the assessment is considered conservative.

4.13. It is noted that the Conceptual Site Model assumes a uniform aquifer thickness with uniform properties with groundwater continuously discharging downstream. Based on the data reviewed, it is considered feasible that the upper aquifer could be of limited lateral extent and that the development may result in excavation and removal of a large proportion of the aquifer. This could potentially cut off / remove the existing downstream groundwater discharge pathway

for the upper aquifer, potentially increasing the impact of the proposed basement. It is acknowledged that Fluid Structures have advised their intention to adopt a deep borehole soakaway. It was requested that this was addressed in the hydrogeological assessment including potential impacts to the pavement vaults referred to in ABA's letter of 7 July and the cellar to the Duke of Hamilton pub. The full response is detailed in SBEC's letter in Appendix 3, however, in summary it is stated that '*there are likely to be no locations in the vicinity where the local water table is within 0.20m of ground level, due to drainage from substructure infrastructure…the rise in levels is minor and likely to be ameliorated by near-surface high permeability drainage along pipe trenches'.* With regards to the soakaway, it is confirmed that this is only proposed in the deep aquifer.

4.14. It is agreed that the proposed development could result in adverse effects with impacts on local basements / properties unless the infiltration is limited. Again, the uncertainty regarding the lateral extent of the upper aquifer and any downstream groundwater discharge mechanism therein raises the possibility of infiltration drainage gradually saturating the laterally limited sand unit (upper aquifer) and increasing potential for localised impacts / flooding. In their response, SBEC state that discharge is not proposed in the upper aquifer and from the interpretation of the hydraulic gradient and flow of groundwater, the discharged water is not expected to linger close to the site. The revised infiltration drainage scheme would effectively minimise impact to the upper aquifer and therefore reduce the likelihood of impacting the surrounding structures / basements. It should be noted a discharge consent from the Environment Agency (EA) is required.

4.15. Additionally, applying the parameter values in the text (A*K*I, 1.2*50*2.5*0.05) supports a value for the base flow of 7.5m^3/d not the 26m^3/d quoted in the original text. It was requested that this and the items described above were clarified and details of the modelling software and input parameters provided. Installation details for BHA and BH2 were also requested. Clarification on the modelling software and parameters used is provided together with a summary of the borehole installation details (refer to Appendix 3). The model appears reasonable and impacts are considered to be minimised. Whilst it is possible in the long term a combination of upward leakage and groundwater flow from upstream sources could cause some localised rise in shallow groundwater levels, these will be mitigated by the measures proposed.

4.16. The Hydrology Report also identifies a mitigation measure to protect basements to the west of the development site (Lawn House, The Duke of Hamilton pub and 27 New End) from additional groundwater ingress should groundwater levels rise due to the proposed basement, by the introduction of piezometers installed through the rear basement retaining wall, connected to groundwater bypass pipework within the proposed building, and back into the ground via a French drain constructed along the front boundary wall. Although a schematic section of this proposal is shown on Fluid Structures drawing no. BIA/015 P1, we agree with

ABA that further information should be provided including consideration of the longevity of such a system involving piezometer heads and their distribution along a 32 metre long wall as only 2no. heads are proposed. Further construction details are also requested of the infiltration "French drain" trench. Although details are provided, SBEC's response in Appendix 3 states this is no longer proposed due to further investigation of the groundwater situation and level of risk at the Duke of Hamilton Pub which indicates the neighbouring basements are not at risk from rising groundwater levels. However, it is recommended that long term groundwater monitoring should be undertaken to validate the current assessment and inform drainage design.

4.17. The Hydrology Report confirms that the development will increase the area of hardstanding but proposes to attenuate the additional surface water discharge into the drainage system by the use of a green roof and, possibly, infiltration SUDS. The introduction of the latter proposal appears to increase the potential for increased water ingress into the existing basement of the Duke of Hamilton pub and clarification of the proposed methodology to be incorporated is requested. Details of this are included in SBEC's letter which confirms that soakaway drainage will be via a borehole soakaway.

4.18. A late query concerning the presence of a well in the basement of a nearby property was forwarded by LBC on 5 October 2014. From the development plan and the OS map, the historic pump seems to be outside the basement area, so if its disturbed at all it will be part of the wider ground works. This is not considered to be an issue for the basement itself. The statement on Pg 8 of the SI report which states that '..this feature if still present may require remedial work such as capping off or grouting before construction of the lower basement slab' with reference to the pump and possible presence of a well in the north west corner was noted. This was not highlighted in the audit, given we are already aware that the development will encounter groundwater and permeable strata during the excavation/construction. Additional risks from this feature are not foreseen given the mitigation measures already proposed in the BIA supporting documents. However, in accordance with best practice, it is recommended the remedial work suggested in the SI report be undertaken.

4.19. The responses to the hydrogeology and hydrology queries are considered adequate. It is recommended that mitigation measures, such as the proposed dewatering scheme, should be implemented (which assumes that the downstream discharge is carefully considered so as not to create additional impacts). It is also recommended that continued groundwater monitoring into winter as the project progresses be undertaken with the data reviewed against the model outcomes and conclusions to ensure that mitigation measures remain adequate. The results of the additional monitoring and confirmation that the conclusions remain valid should be included in the BCP.

4.20. We concur with ABA that the horizontal loads imparted to the structural frame by the retaining walls must be evaluated but consider this is a normal part of detail design development.

4.21. It is accepted that the site is not located within the catchment area of the Hampstead Heath pond chain.

4.22. It is accepted that the development site has no anticipated risk of groundwater or fluvial flooding and has no past history of flooding.

5.0 CONCLUSIONS

5.1. The BIA and its constituent appendices have been carried out by well-known firms of consultants using individuals who possess suitable qualifications.

5.2. The BIA has confirmed that an existing former nurses home will be demolished and replaced by a seven storey residential building including a basement. The site slopes steeply from rear to front resulting in a 4 metre deep basement at the front and a 10 metre deep, three storey basement at the rear. The proposed basement is approximately 38 metres x 32 metres on plan and is surrounded by listed buildings.

5.3. The BIA identifies that the proposed basement will be founded within the sands and clay bands of the Bagshot Formation and Claygate Member.

5.4. A number of queries were raised on the hydrogeological and hydrology assessments in relation to the impact of the basement and proposed drawings on the groundwater table in relation to the impact of the basement and proposed SUDs drainage on groundwater levels. The responses to these were received in a letter from Stephen Buss Environmental Consultancy which is included in Appendix 3. The responses largely address the queries raised nominal risen and deep BIA strata confirming that any rise in groundwater levels would be nominal and not affect nearby basements, and that soakaway drainage would be via a deep borehole soakaway so as not to raise the shallow groundwater level further. However, it is recommended that continued groundwater monitoring be undertaken to confirm the conclusions remain valid and the mitigation measures proposed are adequate. The results and confirmation of the validity of the assessment should form part of the party wall awards.

5.5. It should be noted a discharge content would be required from the EA to discharge water into the lower aquifer as discussed in Section 4.

5.6. It is accepted that the site is not located within the Hampstead Heath pond chain catchment area, has no anticipated risk of groundwater or fluvial flooding and has no past history of flooding.

5.7. Whilst responses to the queries regarding the GMA have been received, the full input and output data used in the analysis has not been provided as requested. However, the queries raised have been addressed through discussions and email as described in Section 4. It is acknowledged that the assessment has demonstrated ground stability can be maintained and building damage controlled although the analyses and assessments required to be refined and, where necessary, revised once the final construction sequence and methodology are agreed. The GMA and building damage assessments should be scrutinised as part of the agreement of the party wall awards. Detailed monitoring proposals may also be agreed at this stage.

5.8. It is accepted that the BIA and supporting documents adequately identify the potential impacts arising out of the basement proposals and subject to the agreement of party wall awards, describe suitable mitigation measures.

Appendix 1: Residents' Consultation Comments

Residents' Consultation Comments

Surname	Address	Date	Issue raised	Response
Henderson	Lawn House, 12 Hampstead Square	07/07/16	Alan Baxter Associates letter report reviewing the effects of BIA proposals on Lawn House.	See Audit paragraphs 4.4 to 4.19
		04/08/16	Geotechnical Consulting Group letter raising queries with respect to GMA.	See Audit paragraphs 4.4 to 4.11
		05/08/16	ABA letter with remaining queries regarding GMA and structural design.	See Audit paragraphs 4.4 to 4.19
Unknown – forwarded by Camden	Unknown	05/10/16	Presence of well in near by building	See Audit paragraph 4.18

Appendix 2: Audit Query Tracker

Audit Query Tracker

Query No	Subject	Query	Status	Date closed out
1	Stability	Details of sheet pile installation to minimise damage to adjacent structures.	Closed - responses received from Fluid Structures (22 July) and A-Squared Studio (12 August) refer to the 'silent piling techniques' and the removal of obstructions. The methodology should be confirmed as part of the party wall awards.	12/09/16
2	Stability	Ground movement assessment to be resubmitted in accordance with requirements of item 4.7 (of the initial audit).	Closed – see Section 4.	30/09/16
3	Hydrogeology	Clarification of items 4.8 to 4.12 (initial audit) and details of modelling software and input parameters.	Closed – see Audit paragraphs 4.11 to 4.17 and Stephen Buss letter response in Appendix 3. Further monitoring recommended.	12/09/16
4	Hydrogeology	Installation details for BHA and BH2.	Closed – see Audit paragraph 4.14 and letter response in Appendix 3.	12/09/16
5	Hydrogeology	Details of longevity of piezometer installation and its distribution. Construction details of French drain.	Closed – see Audit paragraph 4.15	12/09/16
6	Hydrology	Clarification of infiltration SUDS methodology.	Closed – see letter response in Appendix 3.	12/09/16
7	Hydrogeology	Groundwater monitoring to be undertaken through the winter up to construction to confirm the validity of the conclusions in the Hydrology and hydrogeology assessments.	Closed - Long term monitoring results and confirmation that conclusions remain valid to be confirmed as part of party wall awards.	12/09/16
8	Hydrology	Discharge consent from the EA with respect to the deeper aquifer	To be agreed with the EA.	N/A

Appendix 3: Supplementary Supporting Documents

SCANNED LETTER BY EMAIL

Alan Baxter
INTEGRATED DESIGN

Our Ref: 1675/62/JGa/gg

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Jane Henderson
Lawn House
12 Hampstead Square,
London
NW3 1AB

7 July 2016

Dear Jane,

29 New End, Hampstead, NW3 1JD

As requested we have carried out an initial structural engineering review of the BIA report provided for the proposed development on this site.

The proposal is to redevelop this site by replacing the existing 1950's nurse's home with a new residential building. The new building comprises seven storeys including a basement level car park. The site slopes up approximately 8m from front to back – this means that there is a single storey (basement level car park) of the new building below ground level along the front which increases to three storeys below ground level along the rear. Above ground floor level the building is set back from the sides presumably to allow natural light down to the lower residential floors.

The new building structure is proposed to be reinforced concrete framed supported on piled foundations. The new building excavation below ground level is proposed to be created using a 750mm diameter secant piled retaining wall around the perimeter. The piled retaining wall is generally restrained by the basement level and ground floor level slabs. Where the building is set back from the sides the piled retaining wall cantilevers (i.e. not restrained) up to approximately 6-7m above the ground floor slab.

Here are our general comments/queries of the key engineering issues in relation to the potential impact of the proposed development on the buildings around the site.

- The boreholes, which were carried out at two separate times, indicate notable variations in the soil descriptions over quite short distances. This may be due to different interruptions by the site investigation firms. We suggest that the data is reviewed by a geotechnical consultant.

- The ground movement predictions around the new building have been carried out using the CIRIA C580 guidance and also modelled using a 2d finite element computer analysis programme (Plaxis). The CIRIA guidance relies on certain

assumption being made in relation to the ground conditions, form and shape of the basement, installation of the piled retaining wall, the stiffness of the piled retaining wall, the restraint to the piled retaining wall and the stiffness of the temporary propping system. As such, the CIRIA approach can only give some very initial indication of movements, but in our view they should not be relied on for this project as it is not directly applicable. The output from the computer analysis also depends on the data input in relation to ground conditions, stiffness of the piled retaining wall and the stiffness of the temporary and permanent restraint to the piled retaining wall. This is an unusual basement with significantly different ground levels around each side of the basement, as well as the piled retaining wall being designed to cantilever up to approximately 6-7m above the ground floor slab along the sides and part of the rear of the basement. These factors will lead to unusual ground movements, which are likely be significantly larger in places than the values predicted using the simplified approach set out in the CIRIA guidance.

It is not clear to us what data has been inputted into the Plaxis programme. However, based on our experience of other sites which have different ground levels on either side of the basement, the predicted movements are lower than we would expect to see even if the deflections of the cantilevered perimeter wall are not taken into account. Therefore, we recommend that an independent check of the ground movements is carried out by a geotechnical specialist to verify the ground movements predicted in the BIA. We suspect that they may be an underestimate and, if so the movements to Lawn House in particular will increase.

- The BIA predicts that Lawn House is likely to undergo the largest movement due to the basement construction, which could potentially lead to cracks occurring that are up to 5mm wide (Category 2 change). This obviously depends on the ground movements predicted in the BIA, which should be verified as noted above. Category 2 is the maximum damage category that Camden permits, but this may be an underestimate.

- It appears from the information provided in the BIA that the first and second floor slabs are to be used to restraint the piled retaining wall along the rear of the building. However, it's not clear how these horizontal forces are resolved. Also it's not clear how the piled retaining wall is proposed to be restrained adjacent to the light well, ventilation shaft, lift shaft and stair core along the sides of the basement.

- It is unclear how all the lateral loads from earth pressures are being resolved particularly between the Church and New End. The Engineers need to identify the lateral loads applied at each floor level and demonstrate how they are supported, both in the temporary and permanent case. Also, the lateral loads at New End need to be assessed.

- In the sequence of construction details are required to indicate how the sheet piles are to be installed in order to avoid damaging the listed masonry retaining wall

buttresses along Lawn House. Also, it does not appear that the deflection of the sheet piled retaining wall been considered when predicting the ground movements.

- As part of the movement monitoring regime the west side of Lawn House and east side Christ Church Cottage should also be monitored to measure the differential movements across these buildings. Also Inclinometers should be installed in the piled retaining walls to measure the deflection of the walls.

- What trigger levels are being proposed as part of the movement monitoring regime, and what is the action plan if the trigger levels are reached.

-The ground water assessment suggests that this may not be a major concern. However, it could increase ground water levels particularly close to New End and could cause problems with the pavement vaults on the opposite side of the road.

- The BIA looks into the possibility of using a soakaway infiltration system to discharge rainwater into the ground as part of the SuDS strategy. If this is being proposed details of the proposals should be provided. It would seem logical to avoid putting additional groundwater upstream of the basement.

- A schematic of the relief drainage system has been included in the BIA. Details of this system should be provided as well as the locations of the infiltration trenches along the front of the site?

This is a very unusual and complex basement. It is very important that all lateral pressures are carefully considered and the ground movement analysis accurately reflects the proposals. The CIRIA approach is in our view not appropriate for this project.

We look forward to responses on the comments/queries noted above; however, the key point to consider in our view is a geotechnical specialist carrying out an independent check to verify the ground movements predicted in the BIA.

I have copied this to Simon Levy and I assume that you will pass these comments on to others. Please call me if you wish to discuss the comments.

Yours sincerely,

Jim Gardiner
for Alan Baxter Ltd

24397/RWS

22 July 2016

FLUID.STRUCTURES
ENGINEERS AND TECHNICAL DESIGNERS

Mr Niki O'Hara
New End LLP
C/o The Linton Group
8 Headfort Place,
London. SW1X 7DH

Dear Niki,

Ref : 29 New End, Comments dated 7 July relating to BIA (Rev '0' issued May 2016)

We have reviewed the comments provided by Alan Baxter Associates under cover of their letter of 7 July to Jane Henderson, with the design and construction team, and provide the collated responses below. Text in italics is reproduced from the ABA letter.

The proposal is to redevelop this site by replacing the existing 1950's nurse's home with a new residential building . The new building comprises seven storeys including a basement level car park. The site slopes up approximately 8m from front to back - this means that there is a single storey (basement level car park) of the new building below ground level along the front which increases to three storeys below ground level along the rear. Above ground floor level the building is set back from the sides presumably to allow natural light down to the lower residential floors.

The new building structure is proposed to be reinforced concrete framed supported on piled foundations. The new building excavation below ground level is proposed to be created using a 750mm diameter secant piled retaining wall around the perimeter. The piled retaining wall is generally restrained by the basement level and ground floor level slabs. Where the building is set back from the sides the piled retaining wall cantilevers (i.e. not restrained) up to approximately 6-7m above the ground floor slab.

Here are our general comments/queries of the key engineering issues in relation to the potential impact of the proposed development on the buildings around the site.

- *The boreholes, which were carried out at two separate times, indicate notable variations in the soil descriptions over quite short distances. This may be due to different interruptions by the site investigation firms. We suggest that the data is reviewed by a geotechnical consultant.*

Soil Consultants have confirmed that the borehole records contained in their report have been compiled after drawing together various strands of information which have included the results of drilling observations with regard to ground water inflows, in-situ and laboratory testing and their engineers descriptions of the recovered soil samples. As part of the design process these have also been reviewed by the other members of the design and construction team, including A-Squared Studio. The soils are known to be stratified to a degree, as recorded in the GI.

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- *The ground movement predictions around the new building have been carried out using the CIRIA C580 guidance and also modelled using a 2d finite element computer analysis programme (Plaxis). The CIRIA guidance relies on certain assumption being made in relation to the ground conditions, form and shape of the basement, installation of the piled retaining wall, the stiffness of the piled retaining wall, the restraint to the piled retaining wall and the stiffness of the temporary propping system. As such, the CIRIA approach can only give some very initial indication of movements, but in our view they should not be relied on for this project as it is not directly applicable. The output from the computer analysis also depends on the data input in relation to ground conditions, stiffness of the piled retaining wall and the stiffness of the temporary and permanent restraint to the piled retaining wall. This is an unusual basement with significantly different ground levels around each side of the basement, as well as the piled retaining wall being designed to cantilever up to approximately 6-7m above the ground floor slab along the sides and part of the rear of the basement. These factors will lead to unusual ground movements, which are likely be significantly larger in places than the values predicted using the simplified approach set out in the CIRIA guidance.*

Early on in the GMA process, the atypical nature of the proposed development and setting was recognised. The GMA methodology was developed with this in mind and the finite element analysis was used as a tool to help capture more realistic patterns of ground deformation. These patterns of ground movement were then compared to the CIRIA curves (which represent an upper bound to the data base of recorded ground movements), which indicated that the patterns of movement were reasonably similar. This provided confidence that the magnitudes of movement predicted by the adopted combination of installation and excavation curves from CIRIA were not unrealistic and would provide a conservative estimate of movement.

Regarding the output from the finite element analysis, it is evident that the analyses will be subject to interpretation of ground conditions, material parameters and simplifications of geometry. Notwithstanding, this line of argument can be applied to all engineering analyses, whether simplified or complex.

It is evident that the patterns of ground movement will not be the same as for a standard rectangular excavation. Notwithstanding, the basis for the conclusion that ground movements are likely to be 'significantly larger' is unsubstantiated.

- *It is not clear to us what data has been inputted into the Plaxis programme. However, based on our experience of other sites which have different ground levels on either side of the basement, the predicted movements are lower than we would expect to see even if the deflections of the cantilevered perimeter wall are not taken into account. Therefore, we recommend that an independent check of the ground movements is carried out by a geotechnical specialist to verify the ground movements predicted in the BIA. We suspect that they may be an underestimate and, if so the movements to Lawn House in particular will increase.*

The material parameters used in the Plaxis analysis are provided in the GMA report. The finite element analysis carried out reflected a realistic sequenced construction, incorporating:

a) stress history
b) steady state seepage analyses of current and temporary dewatering scenarios
c) sequenced installation of temporary and permanent structural members
d) assessment of short term and long term performance

e) asymmetric ground levels

The analyses were carried out in 2D, which considers movement in-the-plane of analysis only. In this respect, the in-plane movements are considered to be conservative. Out-of-plane movements are not captured explicitly. A 3D model has been developed which enables the effects of out-of-plane forces to be assessed directly.

Notwithstanding the above in the context of the analyses performed for the existing GMA the movements, particularly with regards to Lawn House should be conservative as the north and south walls of Lawn house are parallel to the plane of analysis. Tensile strains developed in the ground due to extension and flexural behaviour will thus be conservatively estimated by the adopted CIRIA analyses. It is considered that 3D effects will be on the whole beneficial and therefore primarily indicate an overall reduction in ground movements in the vicinity of Lawn House.

- *The BIA predicts that Lawn House is likely to undergo the largest movement due to the basement construction, which could potentially lead to cracks occurring that are up to 5mm wide (Category 2 change). This obviously depends on the ground movements predicted in the BIA, which should be verified as noted above. Category 2 is the maximum damage category that Camden permits, but this may be an underestimate.*

It should be recognised that the predicted damage categories for Lawn House described in the BIA are either in Category 1 or on the margins of the lower bound for Category 2. Therefore the likelihood of cracks of 5mm is very low, as Category 2 correlates to a range of anticipated cracking from approx. 1mm at the lower bound to approx. 5mm at the upper bound.

It is also noted that an earlier GMA prepared for the project by a well-regarded geotechnical engineering consultancy using a different methodology for the analyses estimated the same damage category for Lawn House.

All analyses of ground movement and building damage will be subject to interpretation. It is the nature of geotechnical engineering that there will always remain some uncertainty. In this respect, the risk mitigation measure is to employ monitoring during construction to enable early identification of adverse ground performance.

- *It appears from the information provided in the BIA that the first and second floor slabs are to be used to restraint the piled retaining wall along the rear of the building. However, it's not clear how these horizontal forces are resolved. Also it's not clear how the piled retaining wall is proposed to be restrained adjacent to the light well, ventilation shaft, lift shaft and stair core along the sides of the basement.*

The basement structure is a wholly monolithic insitu reinforced concrete construction free of building movement joints, therefore all lateral forces are shared by diaphragm action and passed into the perimeter retaining walls which act in passive pressure and in shear. The piled retaining walls are lined by insitu RC, which spans horizontally and/or vertically across voids where necessary, and are also buttressed adjacent to Lawn House by basement RC wall.

- *It is unclear how all the lateral loads from earth pressures are being resolved particularly between the Church and New End. The Engineers need to identify the lateral loads applied at each floor level and demonstrate how they are supported,*

both in the temporary and permanent case. Also, the lateral loads at New End need to be assessed.

Please refer to previous point and to the temporary works proposals included in the BIA.

- *In the sequence of construction details are required to indicate how the sheet piles are to be installed in order to avoid damaging the listed masonry retaining wall buttresses along Lawn House.*

The temporary sheet piles indicated adjacent to Lawn House would be installed working progressively along the line of the piling using a pile press rig (e.g. by Giken, Tosa) mounted on the sheet piles, with piling commenced from a reaction stand as is conventional for this technique.

- *Also, it does not appear that the deflection of the sheet piled retaining wall been considered when predicting the ground movements.*

This is not the case and allowance for this has been made in the GMA included in the BIA. The temporary sheet pile wall was incorporated in the 2D FE section, which was in turn used to justify the selection of the appropriate CIRIA curves.

- *As part of the movement monitoring regime the west side of Lawn House and east side Christ Church Cottage should also be monitored to measure the differential movements across these buildings. Also Inclinometers should be installed in the piled retaining walls to measure the deflection of the walls.*

We do not believe this is necessary

- *What trigger levels are being proposed as part of the movement monitoring regime, and what is the action plan if the trigger levels are reached.*

Trigger levels and action plan will be established in conjunction with the contractor and with review of the baseline monitoring which has been underway over recent weeks and months and will be concluded shortly. Levels will be set with the objective of ensuring that investigations of possible causes of unexpected movement, and planning for any changes in the works, are triggered at “amber” level, significantly below “red” level where significant damage may occur

- *The ground water assessment suggests that this [groundwater] may not be a major concern. However, it could increase ground water levels particularly close to New End and could cause problems with the pavement vaults on the opposite side of the road.*

This has been considered in the Hydrogeological report included in the BIA and is not expected to be an issue.

- *The BIA looks into the possibility of using a soakaway infiltration system to discharge rainwater into the ground as part of the SUDS strategy. If this is being proposed details of the proposals should be provided. It would seem logical to avoid putting additional groundwater upstream of the basement.*

The team concur with the point, as this has been specifically investigated and ruled out. No shallow infiltration systems are therefore being considered as part of the SUDS strategy. A deep borehole soakaway is proposed which would discharge into permeable strata well below proposed basement level.

- *A schematic of the relief drainage system has been included in the BIA. Details of this system should be provided as well as the locations of the infiltration trenches along the front of the site?*

One infiltration trench is proposed to run parallel to New End within the site boundary, as indicated on the schematic section in the BIA, should final groundwater monitoring and detailed design conclude this is necessary. The trench, if required, will extend the along the majority of the frontage so as to mimic the existing downslope groundwater flows

- *This is a very unusual and complex basement. It is very important that all lateral pressures are carefully considered and the ground movement analysis accurately reflects the proposals. The CIRIA approach is in our view not appropriate for this project.*

As discussed above, the adopted procedure has supplemented the CIRIA-based assessment with additional finite element analyses to capture the effects of the atypical setting and ensure the robustness and conservatism of the GMA. The methodology has incorporated both empirical and analytical approaches. It is considered that the analysis as presented are appropriate and that the estimated building damage categories are representative of the proposed scheme and its various complexities.

- *We look forward to responses on the comments/queries noted above; however, the key point to consider in our view is a geotechnical specialist carrying out an independent check to verify the ground movements predicted in the BIA.*

An independent review of the BIA is being implemented by London Borough of Camden and their retained consultant. In light of this, and the consistency of the results of this detailed work with previous assessment by other parties, we understand there is no intention to commission further parties to verify the movements predicted in the BIA

We trust the above is of assistance.

Yours sincerely

Ralph Swallow

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12th Aug 2016

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For the attention of **Mark Rushgrove**

Ref: 29 New End
Response to GMA queries

Dear Mark,

Please find enclosed our response to Campbell Reith's queries regarding the Ground Movement Assessment completed for the proposed 29 New End project. Specifically, these responses refer to the queries outlined in Paragraphs 4.7 and 4.8 of the Basement Impact Assessment Audit (revision D1).

Response to Para. 4.7:

Item 1: The building dimensions for New End Theatre, Lawn House, and Christ Church Cottage should be reviewed as smaller elements are more vulnerable to damage. New End Theatre appears to be closer to the edge of the excavation than assumed;

The length of the wall segments are subdivided by Xdisp into sub-lengths of approximately 1m. So it is considered that damage to shorter lengths are appropriately accounted for in the analyses.

The geometry of the neighbouring buildings have been reasonably simplified/idealised.

Very short wall segments, e.g. less than say 1m to 2m, are not considered to be well represented by the Burland method. In these cases it is considered that wall elements are unlikely to behave as an elastic beam subject to bending/shear mechanisms given the large wall height to length ratio.

The position of the buildings relative to the proposed excavation have been located based on the available ordnance survey data and geo-referenced location of the proposed substructure layout. It is assessed that the distance of the neighbouring structures to the proposed excavation is accurate as incorporated into the Xdisp analyses.

Item 2: It is understood that the outcomes of the Plaxis analysis were normalised against the excavation depth. It should be clarified what was assumed for H in figure 4.2 of the GMA report, as it is not the same for prediction curves for installation and excavation. Also, it should be confirmed what depth was assumed for retaining walls piles;

Normalisation of the finite element output was with regards to the retained height of the excavation. At Lawn House this height was taken as the difference between +118.8m AOD and +109.0m AOD. It is recognised that the curves for installation and excavation accept different height/wall length parameters. Though it is assessed that the ground movements due to installation effects are generally of second order compared to those due to excavation.

The embedment depth of the wall was assumed to be between approximately 4m and 5m, where the retained height was ranging between circa 9m to 11m.

It is recommended that the GMA is reviewed by the Engineer following finalisation of the detailed design of the embedded retaining wall elements.

Item 3: Justification for the assumptions made in the GMA regarding stiffness of cohesive strata is required with confirmation that the SPT N60 design profile represents a 'cautious' assessment;

Figure 1 provides a review of the SPT N_{60} results used to develop the adopted design profile. It is considered that the adopted design line presents a cautious assessment of the variation of SPT N_{60} with elevation, particularly with regards to the results within the retained height of the excavation. Notably, BH101 tended to indicate a lower trend, though it was considered to be an outlier for the assessment.

The drained Young's modulus of the cohesive Claygate Beds was assumed to be approximately 50 MPa at the surface (circa +102m AOD, approximately 17m below ground surface at the Lawn House section) and increasing at a rate of 2 MPa per meter. This was considered to be a conservative estimate of the stiffness of these beds, which makes an allowance for the anticipated level of strains in the retained ground mass in typical operating conditions.

The undrained shear strength of the clay may be approximated based on SPT blow counts as, $s_u = 5\ N_{60}$ (in kPa). A typical rigidity index for overconsolidated clays in London, which allows for small strain levels at working conditions behind the retaining wall is $E_u/s_u = 500$. The SPT N_{60} at the top of the beds is approximately $N_{60} = 30$ and increasing at a rate of approximately 1 N_{60} /m. Thus, based on the preceding discussion, the adopted drained stiffness profile is conservative and nominally 10 MPa less than what could be taken at face value from the available data. The adopted stiffness profile is considered to be cautious in this respect.

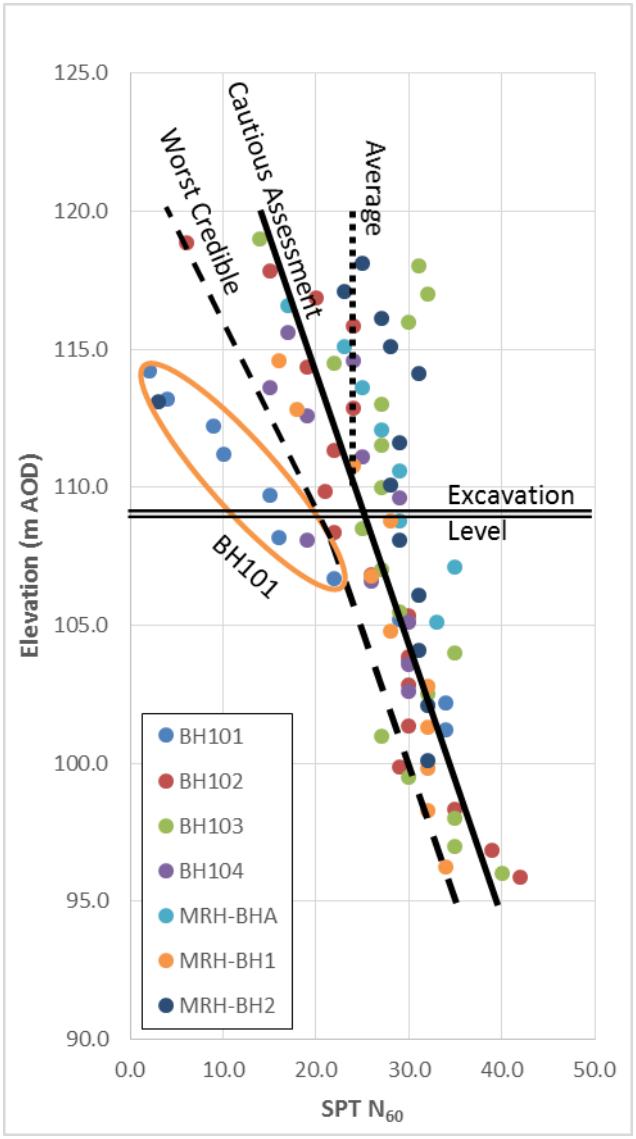

Figure 1: Select SPT-N60 profile

Item 4: It should be clarified what allowance has been made for ground movements during enabling works, i.e. grubbing out of foundations/ substructures and re-profiling of the site including temporary batters;

The GMA incorporates movements due to demolition of the existing Nurses Home and deformations due to reprofiling the existing ground surface to meet the proposed excavation sequence as part of the 2D FE modelling.

The GMA does not explicitly incorporate movements due to localised removal of obstructions or grubbing out of existing structures. The ground movements associated with such works are considered to be dependent on the methodology adopted to undertake the works and the level of workmanship involved.

Based on reviewing the Contractor's proposed Construction Sequence drawings, it is assessed that excavations to remove obstructions in sensitive areas (i.e. adjacent to Lawn House) will be shallow and

will not intercept a 45° line extended from the underside of the existing building foundation level. In this respect, it would be anticipated the effects of localised excavations to remove obstructions would be small.

Notwithstanding, it is strongly recommended that the methodology adopted to remove obstructions is reviewed by the Engineer and Construction team at the time they [the obstructions] are identified to ensure that unacceptable ground movements do not result from the works.

Item 5: Temporary works drawings appear to show sheet pile walls to act as a cantilever (e.g. section A, stages 2A and 2B). It should be confirmed whether this has been incorporated into the assessment;

The sheet piling in the temporary phase has been incorporated as part of the FE assessment.

Given the estimated underside of the existing walls of Lawn House (circa +117.1m AOD – refer Engineer's Section D-D' in BIA), it is expected that the proposed temporary retention of the sheet pile walls will not lead to excessive ground deformations, as the foundation of the Lawn House are not expected to be significantly undermined. As an aside, it is noted that the foundation level of Lawn House has been conservatively assumed to be at +118.8m AOD in the finite element analyses, to provide additional degree of conservatism when assessing the ground movement due to temporary works.

It is recommended that the location of nearby temporary propping be considered again during detailed refinement of the construction sequence, such that the risk of ground movements associated with temporary works in critical areas can be mitigated. Additionally, consideration to carrying out hit-and-miss installation of working platforms, etc. could also be considered to reduce the risk of excessive ground movements occurring.

Item 6: It is noted that the proposed retaining walls in east-west direction, i.e. adjacent to Lawn House and Christ Church Cottage, are not retained by any structural element, and thus, form cantilever walls of up to 6.5m high. The GMA assumes excavation in front of a 'high-stiffness' wall which would require them to be propped at all times.

With regards to Christ Church Cottage, the foundation levels of this building are at approximately +115m AOD (refer Section A-A of Engineer's Building Foundation Sections in BIA). Thus, although the adjacent basement wall of the New End development will be topped-off at approximately +120m AOD, the top 5m of the wall will effectively be only retaining Christ Church foot path. In this respect it is considered that the cantilever at this location is less critical than that adjacent to Lawn House.

The 2D finite element model was used as a means to select the relevant Ciria curve. It is assessed that the deformation of the proposed retention system is generally enveloped by the Ciria curves, even though some portions of the permanent wall cantilever up to 6m.

In the short term the walls are propped with temporary propping at two levels. In the long term, the retaining walls are propped at basement level and ground floor for all walls. Approximately, the middle third of the northern retaining wall is also propped at the first floor level in the final condition.

It is noted that the locations where the wall is cantilevering the maximum distance are near to the return walls of the excavation. So it is assessed that the deflections predicted from the 2D analyses are probably

higher than what may be expected in reality due to the 3D effects related to soil arching. Additionally, the ground level reduces significantly toward the south of the development, thus further reducing the potential for full plane strain conditions to develop.

Finally, the pile wall will be made integral with a thick internal lining as part of the permanent works build up (increasing total build up to approximately 1100mm in front of Lawn house). This wall will be heavily reinforced (not only due to the cantilever condition, but also for crack control reasons, etc.). This internal lining will also act to redistribute the loads around the structure through its ability to span bi-axially.

Notwithstanding the above, a simplified sensitivity check on the effect of adopting a "Low Stiffness" wall was assessed as part of the GMA for Lawn House. As shown in Figure 2, the maximum predicted Damage Category is Category 2 – Slight. This is within the existing maximum damage category assessed for Lawn House, albeit the position of the damage category coordinate is located further within the Slight damage contour interval.

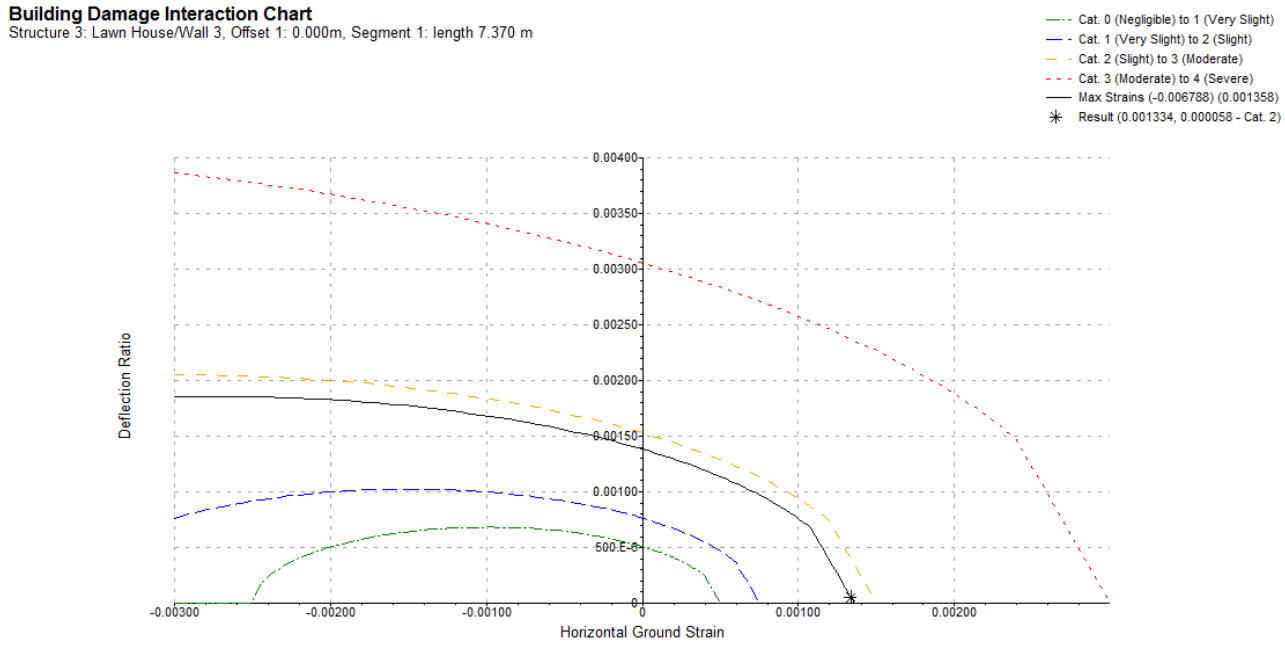

Figure 2: Damage category on the assumption of a "Low Stiffness Wall" at Lawn House.

Item 7: It is noted that the GMA uses the assumption of 'contiguous piled wall', whilst the proposed construction consists of 'secant' walls that are known to exhibit larger ground movements. It is not considered that this represents a 'cautious assessment'.

The adopted reduced installation effects were considered appropriate based on the proposed pile construction methodology, incorporating the use of full length temporary casing during pile construction to reduce ground movements.

This selection was partly informed based on a recent paper by Ball and Langdon (2014) that provides records of installation induced ground movement for cased CFA piles to retain a two-storey basement excavation in approximately 8m of made ground and terrace gravels. Based on their monitoring, they demonstrate that the maximum deflection ratios for installation can be limited to approximately 0.02%, which is approximately half of the maximum value quoted for contiguous pile walls in Ciria.

Additionally, it is evident from Ciria C580 that the estimated horizontal ground movements due to secant pile wall installation are primarily based on historical ground movement records obtained during the construction of the Bell Common excavation (circa 1982-1983). It is worthwhile noting that the Bell Common secant pile wall was:

- Constructed with the use of a bentonite support fluid (inferred from Gunn et al, 1992) to restrain the pile borehole. Temporary casing were not employed.
- Partly retained London Clay with a high coefficient of Earth Pressure in the order of 1.5 to 2.0 (Gunn et al, 1992).

It was assessed that these conditions, which form the basis of the horizontal ground movement predictions of secant pile walls in Ciria C580 were sufficiently different from what may be expected at the New End development site. On this basis it was assessed that the installation effects due to a contiguous pile wall may provide a more realistic estimate of installation induced ground movements.

Notwithstanding the above justification, sensitivity analyses were carried out to assess the damage category predicted at Lawn House if the full secant pile installation effects were adopted for the analyses. The sensitivity analyses indicate that the Damage Category for Lawn House (previously identified to be the most critical structure in terms of building damage category) remains within the predicted Category 2 – Slight range (Figure 2). Albeit, whereas previously the damage category identified in the GMA was estimated to be straddling the Category 1/Category 2 boundary, the damage coordinate is now centred within the Slight damage range. Nevertheless, there does not appear to be orders of magnitude differences in ground strain and thus building damage, due to the selection of a much more conservative pile installation effect.

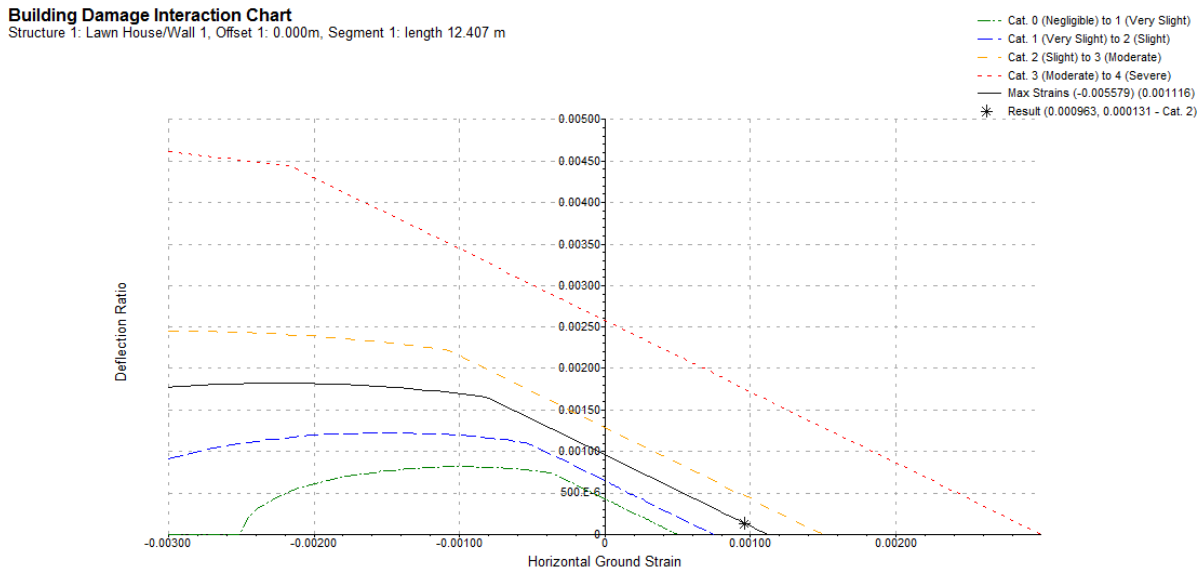

Figure 3: Damage Category at Lawn House based on full secant pile installation effects. Overall damage category does not change from existing GMA damage category.

Response to Para. 4.8:

Item 1: The methodology adopted in the GMA is queried by ABA. Subject to the resolution of the queries noted above, the approach taken is considered appropriate at this stage. However, it is recommended that the GMA is reviewed and, if necessary, revised to reflect the finally adopted construction methodology. At that stage, consideration should be given to importing the movements

predicted in the FE analysis for the damage assessment since the maximum movements in propped walls occur at depth.

The methodology adopted for this GMA was to use the finite element method to justify the selection of a representative Ciria curves. This was considered to be suitable given some of the atypical features of the development site (i.e. asymmetric ground levels, sub-soils, etc.). Notwithstanding, it has been demonstrated that even employing significantly more conservative selections of wall stiffness or installation effect do not necessarily correlate with an overall increases in the predicted Damage Category.

The finite element results were not used directly in the assessment, because it was assessed that the adoption of a more simplified method of analysis based solely on Ciria data would provide improved transparency regarding how the estimated building damage categories were evaluated. It is recognised that additional finite element modelling may be required to satisfy various stakeholder requirements, particularly with regards to identifying the effects of out-of-plane actions, etc., which cannot be explicitly accounted for in the 2D method adopted to date.

It is acknowledged that there are varying avenues by which a GMA can be approached. We consider that the approach taken to date provides an appropriate level of analysis and site-specific consideration, which is commensurate with the scale of the proposed development. Additionally, we have aimed to tie together both analytical methods of analysis, with a database of empirical records of ground movement, to provide a robust assessment of potential ground movement.

References:

1. Ball, R., Langdon, N., 2014, *Prediction of party wall movements using Ciria report C580*, Ground Engineering.
2. Gunn, M.J., Satkunananthan, A., Clayton, C.R.I., 1992 *Finite element modelling of installation effects*, ICE conference on retaining structures, pp 46 – 55.

For on behalf of A-squared Studio Engineers Ltd

Daniel Schutt
BEng, MSc, DIC
Associate

AUTHOR

Alex Nikolic
BEng(Hons) MSc DIC CEng MICE MSt(Cantab)
Director

APPROVER

RE: 29 New End
daniel.schutt
to:
LizBrown
16/09/2016 16:40
Cc:
alex.nicolic, "'Fowler, David'", tony.suckling, camdenaudit, FatimaDrammeh, "'Ralph Swallow'", mrushgrove
Hide Details
From: <daniel.schutt@a2-studio.com> Sort List...
To: <LizBrown@campbellreith.com>
Cc: <alex.nicolic@a2-studio.com>, "'Fowler, David'" <David.Fowler@camden.gov.uk>, <tony.suckling@a2-studio.com>, <camdenaudit@campbellreith.com>, <FatimaDrammeh@campbellreith.com>, "'Ralph Swallow'" <ralph@fluidstructures.com>, <mrushgrove@thelintongroup.co.uk>
History: This message has been replied to.

1 Attachment

image001.jpg image002.jpg 160915_CR_A2Response_00.pdf

Good Afternoon Liz,

Please find attached responses to your additional queries.

Please advise if you require any further information/clarification

Best Regards,

Daniel Schutt
BEng (Hons) MSc DIC
Associate

A-squared | Studio

One Westminster Bridge Rd ½ London SE1 7XW
www.a2-studio.com

From: LizBrown@campbellreith.com [mailto:LizBrown@campbellreith.com]
Sent: 13 September 2016 12:01
To: daniel.schutt@a2-studio.com
Cc: alex.nicolic@a2-studio.com; Fowler, David <David.Fowler@camden.gov.uk>; tony.suckling@a2-studio.com; camdenaudit@campbellreith.com; FatimaDrammeh@campbellreith.com
Subject: 29 New End

Daniel

Thank you for the additional information supplied in response to our BIA audit. I have a few questions remaining and would be grateful if you could come back to us as soon as possible.

Response to para 4.7 - Item 1

Our query with respect to the length of the elements was in relation to wall lengths and heights. We had the impression that width and height of the New End Theatre are less than assumed in your modelling (i.e. is it appropriate to take 7.9m when it is a single storey structure with a pitched roof?). It would also appear from KSR drawing NEN - PL - 003 that the theatre is only 2 -3 m from the proposed basement.

Response to para 4.7 - Item 3

You refer to cohesive soils below 102m OD. The factual information supplied by SCL shows a significant cohesive layer below 112m OD. Can you please clarify the ground model (that presented in Tables 2.1 and 2.2 does not give elevations and Fig 2.3 is difficult to interpret).
Is there a possible explanation for the 'outlier' in the data exhibited by BH101? It is difficult to ignore it if it cannot be explained.

Response to para 4.7 - Items 5 & 6

I am confused as to whether walls are propped or are to act as cantilevers, and have some other queries.

Item 5 - paras 1 & 2 - you note that the sheet pile walls have been considered in the FEA and then state that 'it is expected that the proposed temporary retention ..... will not lead to excessive ground deformations'. Is that confirmed by the FEA?

Item 5 - para 3 - when you refer to nearby propping, does this mean the sheet pile walls are not cantilevers?
Item 6 - para 3 - this suggests that all walls are propped in the permanent and temporary case which appears to contradict the paragraphs above and below.
Item 6 - para 4 - whilst we concur that 2D analyses tend to overestimate ground movements, your modelling at the moment does not allow for the re-entrant corners in the SW and NW. How might this affect the damage predictions?

Finally, Fluid Structures note in their letter dated 22 July that a 3D model has been developed. Can you confirm the results of that modelling?

Can you also confirm the mitigation measures that have been incorporated to minimise potential damage as required by CPG4.

It should be noted that CampbellReith has not undertaken a detailed check but has reviewed the submitted information for clarity, reasonableness and robustness. Due to the geometry of the site and the sensitivity of the surrounding structures, we will be recommending that a Basement Construction Plan is prepared in which a more detailed analysis will be required together with an independent detailed check.

If you have any questions on the above, please don't hesitate to contact me.

Regards,
Liz Brown
Partner

CampbellReith
consulting engineers

Friars Bridge Court,
41-45 Blackfriars Road,
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RE: 29 New End
daniel.schutt
to:
LizBrown
03/10/2016 17:24
Cc:
alex.nicolic, camdenaudit, "'Fowler, David'", FatimaDrammeh, mrushgrove, "'Ralph Swallow'", tony.suckling
Hide Details
From: <daniel.schutt@a2-studio.com> Sort List...
To: <LizBrown@campbellreith.com>
Cc: <alex.nicolic@a2-studio.com>, <camdenaudit@campbellreith.com>, "'Fowler, David'" <David.Fowler@camden.gov.uk>, <FatimaDrammeh@campbellreith.com>, <mrushgrove@thelintongroup.co.uk>, "'Ralph Swallow'" <ralph@fluidstructures.com>, <tony.suckling@a2-studio.com>

0 Attachment

image001.jpg image002.jpg

Good Afternoon Liz,

With regards to your additional queries I can confirm the following:

- Reducing the wall height for the New End Theatre does not affect the assessed damage category for the building facades. The supplementary analysis considers a wall 3.5m high, which is commensurate with the average façade height of the south wall (fronting the road), not accounting for the pitched roof. The predicted damage categories remain the same, with the worst case being Category 1 - Very Slight.

- The original FE analyses predict approximately 17mm. The FE analyses have incorporated a cantilever wall at the relevant cross-sections of analysis.

Best Regards,

Daniel Schutt
BEng (Hons) MSc DIC
Associate

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From: LizBrown@campbellreith.com [mailto:LizBrown@campbellreith.com]
Sent: 30 September 2016 11:12
To: daniel.schutt@a2-studio.com
Cc: alex.nicolic@a2-studio.com; camdenaudit@campbellreith.com; 'Fowler, David' <David.Fowler@camden.gov.uk>; FatimaDrammeh@campbellreith.com; mrushgrove@thelintongroup.co.uk; 'Ralph Swallow' <ralph@fluidstructures.com>; tony.suckling@a2-studio.com
Subject: RE: 29 New End

Daniel

Thank you for the clarifications and additional information you sent through on 16 September. As discussed, I have just a few remaining questions. An email response will be sufficient:

With respect to para 4.7 - Item 1, Figure 2.18b of CIRIA C580 indicates that vertical strain becomes more critical as the ratio of L/H increases (i.e. as height reduces in relation to length). Can you therefore confirm that the predicted damage category for the theatre is not changed by considering the smaller wall heights that exist in places.

Para 4.7 - Item 3 - you note that reducing the soil and wall stiffnesses results in 25mm movement. Your previous GMA did not quote any absolute values to which I can compare this. In respect of the cantilever vs propped walls. I note that the sequence drawings state the sheet piles will be propped where necessary, so that item is closed out. However, can you please make a clear statement that your FE analysis allows for the permanent retaining wall to cantilever approximately 6.50m in the vicinity of Lawn House as shown by Fluid Structures' drawings.

Thanks,

Liz Brown
Partner

CampbellReith
consulting engineers
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SE1 8NZ

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From: <daniel.schutt@a2-studio.com>
To: <LizBrown@campbellreith.com>
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Date: 16/09/2016 16:40
Subject: RE: 29 New End

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Please advise if you require any further information/clarification

Best Regards,

Daniel Schutt
BEng (Hons) MSc DIC
Associate

A-squared | Studio

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Sent: 13 September 2016 12:01
To: daniel.schutt@a2-studio.com
Cc: alex.nicolic@a2-studio.com; Fowler, David <David.Fowler@camden.gov.uk>; tony.suckling@a2-studio.com; camdenaudit@campbellreith.com; FatimaDrammeh@campbellreith.com
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If you have any questions on the above, please don't hesitate to contact me.

Regards,
Liz Brown
Partner

CampbellReith
consulting engineers
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Stephen Buss Environmental Consulting

David Fowler

Principal Planner

London Borough of Camden

19 August 2016

29 New End, London NW3 1JD

Dear David

I am writing in response to the basement impact assessment audit recently completed by CampbellReith, to provide clarification of points that are made in the hydrogeology and hydrology section of the BIA for 29 New End, London NW3 1JD.

I would also like to present a significant body of new data collected since the BIA was written. To reduce the uncertainties that were identified in the BIA the applicant has collected a much longer time series of data; the older boreholes BH1, BH2 and BHA have been found and dipped; a new multi-level borehole, BH105, has been constructed in the car park of the Duke of Hamilton pub; and a constant head test was undertaken on BH102 to better understand the potential for using a soakaway in the deep aquifer.

For ease of review I have structured this letter in the as with the audit query tracker in Appendix 2 of the CampbellReith audit.

Query No 3: Clarification of items 4.8 to 4.12 and details of modelling software and parameters.

I assume that referring to 4.8 is a typo as points 4.8 and 4.9 are not related to hydrogeology.

Item 4.10 raises a question about the representativeness of data from borehole BH103, when making conclusions about the upper aquifer. I feel that evidence from BH103 is not the only indication of a shallow water table at c. 113 to 114 m AOD. This is especially the case now, given the new data, and I have listed my evidence below; more recent monitoring data is presented in Table 1 of this letter.

- BH103 comprises a short (2 m length) standpipe between 110.5 and 108.5 m AOD. The standpipe is open across a sand unit from which there was the first water strike during drilling at 109.9 m AOD. Rest water level is at c. 114.3 to 114.4 m AOD.
- BH102 struck water at 113.15 m AOD, near the base of a sand unit, and the water rose to 113.55 m AOD after 20 minutes; however, this inflow was cased and sealed out of the borehole and there is no further record. It is not unreasonable to expect this to be representative of a water table at 113.55 m AOD or a little higher.

- BHA has now been monitored simultaneously with the other boreholes and the rest level is c. 114.2 m AOD to 114.6 m AOD.
- BH2 has also now been monitored simultaneously with the other borehole and the rest level is c. 113.5 m AOD.

Based on these new levels, the hydraulic gradient is actually lower than anticipated in my previous report. I had assumed that the BH103 to BH2 gradient was 0.037, whereas in August 2016 it was 0.031. The consequences of this are: 1) the assumption in my model is too conservative, so any groundwater level rise will be less than predicted, and 2) baseflow beneath the building is less than anticipated.

A useful point to note at this stage is that an engineer on site spoke to the landlord of the Duke of Hamilton pub who had recently discovered that the water ingress to his cellar is related to surface water, not shallow groundwater.

This is reinforced by the findings of monitoring in the shallow borehole BH105, which was specifically constructed in July 2016 to monitor any groundwater that might be at or near the cellar floor. Site engineers surveyed the cellar floor at c. 113.78 m AOD, and the base of the shallow borehole BH105 is 112.25 m AOD. The shallow borehole has, so far, been consistently dry. Also no sandy horizons were identified in the borehole to 13 m depth (103.75 m AOD); the stratigraphy here is entirely clayey.

To summarise, I feel that evidence for a water table in the upper sand aquifer is now robust and it shows that the original estimate, used in scoping calculations and the model, was a little conservative. Therefore the conclusions of the BIA report may stand. The cellar has now been surveyed at an elevation 0.78 m above that which I had originally assumed, so the impact assessment becomes more conservative.

Item 4.11 requests 1) a discussion of how the basement will intercept the discharge through the upper aquifer, and 2) a review of the potential impacts of the proposed soakaway discharge to the deep aquifer.

Intercepting discharge

It is noted in the audit that the excavation will cut off a significant amount of flow in the upper aquifer. The estimate of flow in the upper aquifer in the audit, 7.3 m^3/day, is correct and I apologise for the typo in the BIA report. I have looked back at the MODFLOW model results and this gives a corresponding flow beneath the site of 6.6 m^3/day so this is in good agreement with the (amended) scoping calculation.

Hence the question in the audit about the interception of flows, and redirection around the basement, is answered in part by the model. The model results shown in Figure 5.4 in the BIA indicate the effect of introducing the basement to heads. If the groundwater level were to reach ground surface it would be to the east and south east where the ground surface is lowest. Groundwater levels are expected to rise by 0.5 m at BH102 and 0.4 m at BH2. But the unsaturated zones at these boreholes are 5 m or more in thickness. Moving further from the basement, where the groundwater level may reach ground surface (Environment Agency LIDAR data is not available for this area so I cannot tell exactly where this), the change in groundwater level becomes less than 0.2 m. I suggest that there are likely to be no locations in the vicinity where the local water table is within 0.2 m of ground level, due to drainage from subsurface infrastructure.

Clearly the model does not represent all of the complexity of the geometry of the water table and the topography here. But the key point I would like to emphasise is that the model shows heads rising most where there is a thick unsaturated zone close to the basement. Further away, I

suggest that the rise in levels is minor and likely to be ameliorated by near-surface high permeability drainage along pipe trenches etc.

Soakaway design

Despite including the modelling results for this scenario in the BIA, we are not proposing to construct a soakaway in the shallow aquifer, just the deep aquifer. The actual SUDS design was not finalised when the BIA was written.

In March 2016, a constant head test was undertaken on BH102 to assess whether the deep aquifer was likely to be able to accept sufficient water to make it useful for a soakaway discharge. BH102 was chosen for this test because: where it intercepts the lower aquifer, the aquifer is more sandy than silty; it is better to discharge water in the back garden to get a higher head on the soakaway; and it is relatively far from the pavement vaults at 10, 12 and 14 New End.

In this test a constant flow rate of 0.25 l/s, when applied to BH102, maintained a constant head at close to ground level. Test data collected is shown in Figure 1. No other groundwater levels were monitored.

A radial flow model, using the Theis equation, of the rise in groundwater level ('draw-up') has been developed for the deep aquifer (Figure 2). It has been calibrated to match the result of the constant head test, cited above, and the following parameters are suggested: transmissivity of 2.6 m^2/day for a storage coefficient of 10^{-5}. The model is intended only to demonstrate a rough fit, as there are more complexities in this situation than described in the simple Theis equation: one key observation is that the draw-up very quickly stabilised; so in the aquifer there must have been a discharge boundary condition (perhaps into road drainage, granular fill in pipe trenches, or downwards into a lower aquifer).

This model can be used to estimate the rise of groundwater level at 69 m from the discharge – which is the distance from BH102 to the pavement outside 10, 12 and 14 New End. After 110 minutes (the duration of the test) the modelled rise is expected to have been 1.5 m. After 12.75 hours (the longest duration of the 100 year storm that would lead to a discharge of 0.25 l/s) the modelled rise is 2.7 m. (This is expected to be an upper estimate as the head in the soakaway will have been stable for all that time, rather than rising as predicted by the model.)

I estimate that the floors of the pavement vaults are at 108.4 m AOD. BH101 is closest to the pavement vaults, with an average rest water level of 107.25 m AOD. The hydraulic gradient in the lower aquifer, from BH102 to BH101, was 0.032 before March 2016. If this gradient is extrapolated linearly to the pavement vaults, at 32 m from BH101, then the level at the pavement vaults is expected to be 106.2 m AOD, about 2.2 m below the floors. Seasonal variation is small in this aquifer, with an average range of c. 0.23 m. It seems reasonable, therefore, to assume that under present conditions the groundwater level will never be less than 2.1 m below the pavement vaults.

The borehole log of BH101 indicates that the top of the lower aquifer layer is at 105.1 m AOD. Above this is a silty clay. This is broadly the same geology and levels as in BH102 (see Figure 4.3 of the original BIA), which suggests that the stratigraphy is level here. Strata may camber but assuming that the stratigraphy is level is conservative. Therefore the pavement vaults are separated from the lower aquifer by a little more than 3 m of silty clay.

So during the 100 year storm, 12.75 hours of discharge at 0.25 l/s appears likely to lead to the groundwater level beneath the pavement vaults rising to c. 0.6 m above the level of the bases of the vaults. But the aquifer (in which that head change has occurred) and the pavement vaults are separated by 3 m of silty clay. Therefore whilst the water pressure may be rising below the vaults, the actual upward flow of water is likely to be very low and would need to saturate the porosity of the unsaturated zone before it reaches the base of the vaults.

Item 4.12 refers to the risk of infiltration to the upper aquifer causing break-out of water at the ground surface.

I agree that this is a risk and this is the main reason we do not propose to discharge any rainwater to the upper aquifer. The lower aquifer, where rainwater is intended to be discharged, seems to be more persistent in logs.

Also I note that the hydraulic gradient under current conditions is about 0.03 – indicating that the groundwater in that aquifer is flowing. Hence I do not expect the discharged water to linger close to the site, so the risk assessment described above applies.

A review of the modelling software and parameters is requested, partly in response to a perceived difference in estimated baseflow beneath the site.

The audit identified a typo in the BIA and I have dealt with the new value for baseflow above. Hopefully the text above provides enough description but I would be pleased to provide the model, or discuss specific points further, if required.

Query No 4: Installation details for BHA and BH2.

Construction details for BHA, BH1 and BH2 are contained in a 2010 site investigation by MRH Geotechnical, and I am not at liberty to provide it to you as it was not produced for the current applicant. However, I can summarise the findings:

- BH1 was drilled using the shell and auger technique in July 2010. Ground level is 115.8 m AOD, and a piezometer was installed at the base of a sand layer at 8.8 m depth (107.0 m AOD).
- BH2 was constructed using shell and auger in July 2010. Ground level is 119.1 m AOD, and a piezometer was installed in a thick silty sand layer at 8.8 m depth (110.3 m AOD).
- BHA was constructed using a mechanical auger in January 2011. Ground level is 119.8 m AOD, and a piezometer was installed in a thick silty sand layer at 8.8 m depth (111.0 m AOD).

Query No 5: Details of longevity of piezometer installation and its distribution. Construction details of French Drain.

The principal behind the proposed dewatering system was that the very top of the water column, if groundwater levels rise behind the basement, is skimmed off and piped to a location downgradient of the basement. In this way we would aim to protect neighbouring basements without disturbing groundwater levels more than necessary. Now that we have investigated the groundwater situation and the level of risk at the Duke of Hamilton Pub further it is clear that this is a redundant system, as neighbouring basements appear to not be at risk from rising groundwater levels. Hence we propose to not include this in the final design.

Query No 6: Clarification of infiltration SUDS methodology.

There is more detail on the SUDS methodology in the SUDS report that was submitted to the Council with the BIA (though the BIA was written first). The appropriate section is as follows:

7.0 SUDS HIERARCHY – DISCHARGE TO THE GROUND

Infiltration testing within boreholes indicated the site was marginal for construction of conventional shallow soakaways. Furthermore, numerical analysis was undertaken (Stephen Buss Environmental, Appendix B) which indicated that such a soakaway could present a low risk of groundwater flooding to the cellar of the Duke of Hamilton public house approximately 50 m to the west of the site. The landlord of the public house reports that incidents of water ingress do occur pre-development at the existing cellar, and have done for some time. No formal records of these incidents are available.

A further stage of infiltration testing was implemented in March 2016 to establish the suitability of deep strata for acceptance of surface water discharge to the ground. This has been found viable at a rate of circa 0.3 litre/sec (26 cum/day). It is therefore proposed to provide adequate in-line tanked attenuation to accommodate a 1:100 year rainfall event, plus 30% climate change allowance, so as to enable discharge of surface water to the deep strata by a borehole soakaway sited to the north of the new building.

In event of surcharge of the borehole soakaway and attenuation a drain will divert any excess flow in accordance with the SUDS hierarchy.

I trust that this letter provides enough detail for you to be able to move the application forward. Please do contact me if you need any further details.

Yours sincerely

Dr Stephen Buss

Hydrogeologist / Owner

THE GEOLOGICAL SOCIETY
CGeol
CHARTERED GEOLOGIST
Fellow No. 10004065

Table 1. Groundwater level measurements from 2016

	Depth to water level in borehole (m)										
	03/02/2016	25/02/2016	11/03/2016	23/03/2016	29/04/2016	13/05/2016	27/05/2016	09/06/2016	30/06/2016	26/07/2016	03/08/2016
BHA	-	-	-	-	-	-	-	5.63	5.60	5.22	5.50
BH1	-	7.40	7.40	7.41	-	-	7.40	7.30	7.30	-	7.33
BH2	-	-	-	-	-	-	-	-	5.60	5.57	5.60
BH101	-	-	-	8.57	8.37	8.46	8.70	8.50	8.30	8.30	8.40
BH102	11.76	11.74	12.17	11.85	9.34	-	9.33	9.32	9.15	9.23	9.20
BH103	6.15	6.15	6.14	6.15	6.07	6.15	6.15	6.13	6.10	6.02	6.10
BH104	8.65	8.66	8.65	8.67	8.55	8.65	8.60	8.63	8.50	8.60	8.63
BH105 (deep)	-	-	-	-	-	-	-	-	-	7.40	7.10
BH105 (shallow)	-	-	-	-	-	-	-	-	-	dry	dry

		Elevation of water level in borehole (m AOD)										
	Datum	03/02/2016	25/02/2016	11/03/2016	23/03/2016	29/04/2016	13/05/2016	27/05/2016	09/06/2016	30/06/2016	26/07/2016	03/08/2016
BHA	119.80	-	-	-	-	-	-	-	114.17	114.20	114.58	114.30
BH1	115.80	-	108.40	108.40	108.39	-	-	108.40	108.50	108.50	-	108.47
BH2	119.10	-	-	-	-	-	-	-	-	113.50	113.53	113.50
BH101	115.70	-	-	-	107.13	107.33	107.24	107.00	107.20	107.40	107.40	107.30
BH102	120.35	108.59	108.61	108.18	108.50	111.01	-	111.02	111.03	111.20	111.12	111.15
BH103	120.50	114.35	114.35	114.36	114.35	114.43	114.35	114.35	114.37	114.40	114.48	114.40
BH104	117.10	108.45	108.44	108.45	108.43	108.55	108.45	108.50	108.47	108.60	108.50	108.47
BH105 (deep)	116.75	-	-	-	-	-	-	-	-	-	109.35	109.65
BH105 (shallow)	116.75	-	-	-	-	-	-	-	-	-	dry	dry

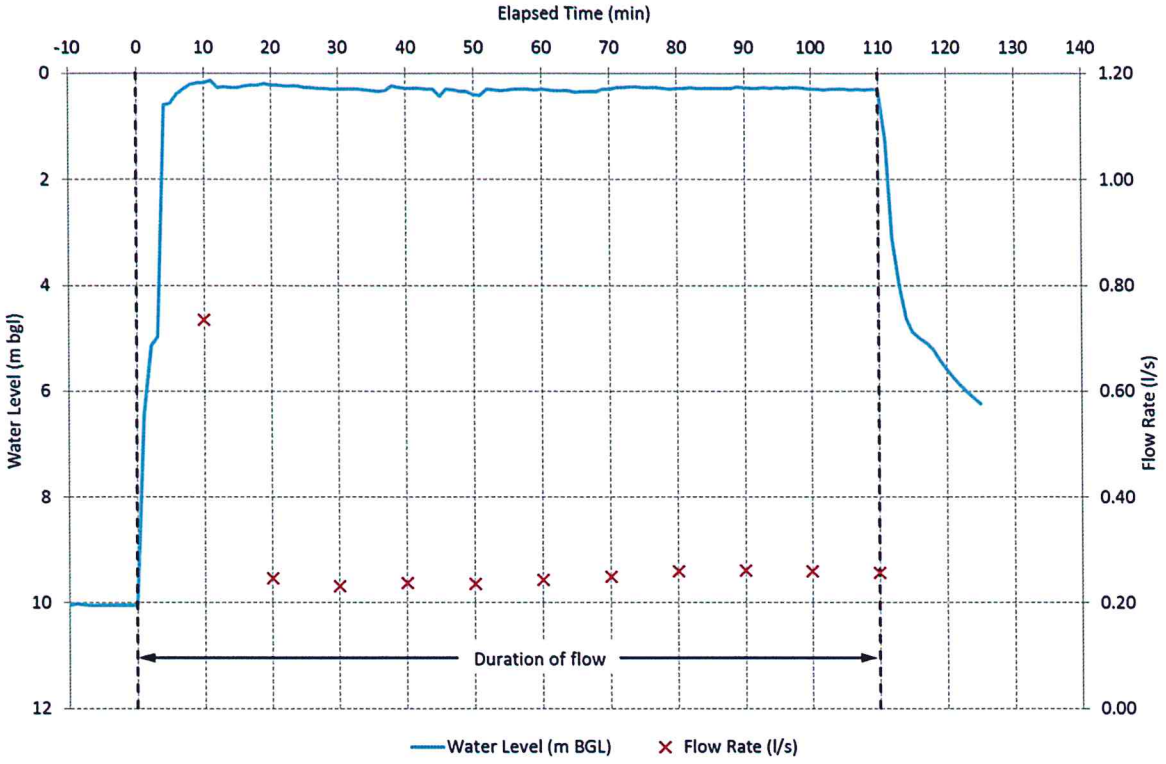

Figure 1 Constant head test results

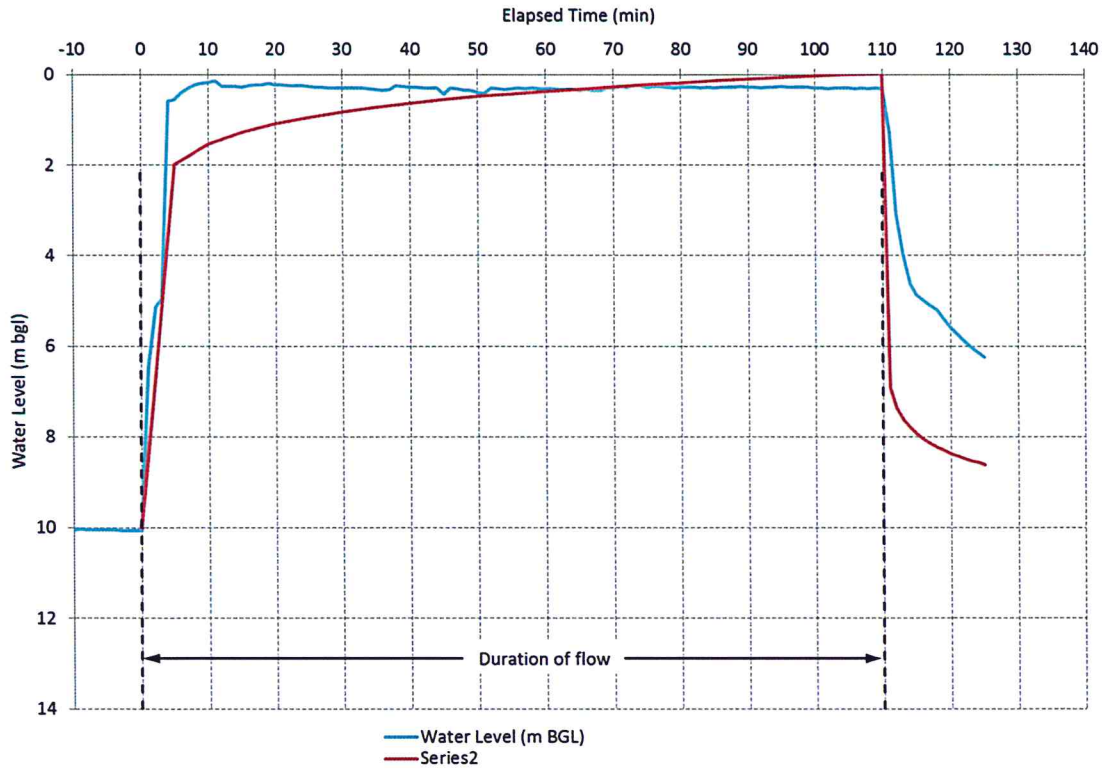

Figure 2 Modelled constant head test results

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