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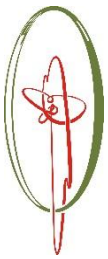

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Air Studios
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Structural and Ground Dynamics

Ref: AKS/3400/R1/i1 (01/02/16)

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CLIENT

Air Studios

(I) LIMIT OF LIABILITY and CONDITIONS OF USE

- This report has been prepared by Civil Engineering Dynamics Ltd, within the scope of our quotation to the client for the project concerned. We accept no responsibility for data presented by other bodies and no legal liability arising from the use of this report by any other party.
- Information contained within this report should not be referred to or quoted in any context other than the site for which the report was commissioned.

(II) SCOPE OF REPORT

- To investigate structural and ground dynamics issues that could arise at Lyndhurst Hall, London NW3 5NG in relation to a proposed development comprising basements at an adjoining property known as 11 Rosslyn Hill, Hampstead.

1. INTRODUCTION

1.1. Air Studios operate world class recording facilities at their site known as Lyndhurst Hall, in Hampstead, London NW3.

1.2. Civil Engineering Dynamics (CED) were commissioned by Air Studios to investigate dynamics, in particular structural and ground dynamics issues that may arise from the proposed development comprising basements at an adjoining site known as 11 Rosslyn Hill.

1.3. The investigation included a desk top review, site visits and measurements.

1.4. Site noise and vibration measurements in December 2015 coincided with a period within which trial pits for an archaeological investigation were planned by the neighbour's development team, and so measurements also include samples of that activity.

1.5. This report presents the outcome of this investigation.

1.6. There is some overlap to topics raised by other experts reporting to Air Studios, and this report provides primary and supplemental information.

2. ISSUES IDENTIFIED

2.1. A number of issues became apparent, which have a potential for significant adverse consequences to the performance of the studios, and merit detailed analysis.

2.2. The issues relate to potential for either long term impacts and/or those arising during a construction phase.

2.3. The issues relate to changes in ground dynamics, structural dynamics and the coupled effects. Some issues relate to structural movements and consequences to acoustic integrity. Others relate to limited performance of base isolated studios and their vulnerabilities.

2.4. The issues are listed as follows and subsequently elaborated in the report.

2.4.1. Groundborne noise and vibration from Railway Tunnels – Increased Impact.
2.4.2. Acoustic Integrity of Building Fabric - Structural damage can impair the sound attenuation performance between studios and to the external environment and vice versa.
2.4.3. Base Isolated Studios – Structural movement that can alter the dynamic characteristics of base isolated structures.
2.4.4. Base Isolated Studios – Limitations in Dynamic Performance.

2.5. It is important to recognise that a recording studio, is no different to any other product or service, with a diverse range of quality ranging from the bare minimum standard to a top world class facility sought out by the most discerning clients. The report begins by addressing this very important issue.

3. RECORDING STUDIO ACOUSTIC DESIGN AND PERFORMANCE CRITERIA

3.1. The acoustic requirements for the studios were designed by Sandy Brown Associates (SBA) during 1991 when the listed building, originally a chapel, was altered to accommodate studios.

3.2. It is instructive to review the design specification for the studios obtained from the Archives.

3.3. Table 3.3 shows SBA[1]'s suggested background noise and criteria for intrusive noise.

Area	NR (Noise Rating)	dB(A) approx.
Main Hall	15-20	20
Studio 1	15-20	20
Booths	15	20
Controls	20	25
Video Floor	30	35

3.4. Schedule 1 from SBA[2] , reproduced in Table 3.4 refers to a Specification of Background Noise Levels including that from Mechanical and Electrical Services Plant and Equipment. It is further qualified that noise which is intermittent or tonal in character must not exceed a sound level 5 dB below the appropriate part of the NR curve otherwise specified.

General noise criteria:	
ROOM TYPE	NR LEVEL
LYNDHURST HALL	15
STUDIO 1	15
CONTROL ROOMS	20
BOOTHS	15
VIDEO FLOOR	30
CD MASTERING	20

3.5. Schedule 2 from SBA[3] , reproduced below refers to a Specification of Vibration levels from Mechanical and Electrical Services Plant and Equipment, to ensure that the total vibration in any part of the building :-

3.5.1. do not exceed the base curves given in BS6472: 1984 "Evaluation of Human Exposure to Vibration in Buildings, and

3.5.2. are not of a magnitude which cause the noise criteria in Schedule 1 to be exceeded.

3.6. The specifications are written in a form that requires expert judgement, for practical implementation.

3.7. Annex B provides a background noise sample taken within the Main Hall, which shows the design NR approach for the space is achieved.

[1] SBA - Air Studios: Lyndhurst Hall, Sound Insulation Report, Project ref 8915, dated 15th January 1991
[2] SBA – Air Studios: Schedule 1, Project ref 8915, dated 19th February 1991
[3] SBA – Air Studios: Schedule 2, Project ref 8915, dated 19th February 1991

4. GUIDANCE FROM POLICY, NATIONAL STANDARDS AND INDUSTRY

4.1. Guidance on Noise and Vibration during demolition and construction has been covered in a report by Vanguardia[4] representing Air Studios. The report acknowledges that original criterion for the design of Air Studios was not available from archives at the time of drafting that report.

4.2. A response by Cole Jarman[5] (CJ), acting for the Applicants queries the particular use of an $L_{Amax,S}$ criteria from Crossrail, where a lower value at 25dB is proposed for theatres, large auditoria/concert halls compared to 30dB for Sound Recording studios. The source document referred to, Crossrail Information Paper D10[6] provides a table headed 'Construction' and 'Operational' groundborne noise criteria, albeit construction is qualified to exclude the Tunnel Boring Machine. CJ[5] go on to say "*It represents a high standard*", (page 5, 2nd para).

4.3. This report does not revisit the guide values in any detail but draws attention to a consideration when interpreting groundborne noise limits from Nationally significant infrastructure projects, such as Crossrail or High Speed Two (HS_2).

4.4. The Noise Policy Statement for England (NPSE)[7] in para 2.18 reads "*There is a need to integrate consideration of the economic and social benefit of the activity or policy under examination with proper consideration of the adverse environmental effects, including the impact of noise on health and quality of life. This should avoid noise being treated in isolation in any particular situation, i.e. not focussing solely on the noise impact without taking into account other related factors.*" It will come as no surprise that this has in any case been an approach for public infrastructure projects preceding this publication.

4.5. It will be obvious that infrastructure projects which are Nationally significant could not be burdened by ensuring every receptor receives the highest standard. A balance must be struck between public interest at large and what can be argued as a reasonable limit to impact on receptors, taking into account economic realities. It is wrong to assume that infrastructure projects provide 'high' standards when it comes to addressing impact, as there is a broader public interest balance at play.

4.6. Interpreting guide values from such Nationally significant infrastructure projects in the context of extensions to a single residential property should therefore be undertaken with caution, and where they are referred to, it does not follow that they should be adopted at face value.

4.7. A high standard for the acoustic environment within the recording studios is what Air Studios set out to achieve, and commissioned experts, spending time and funds to create the facility.

4.8. Asking what is an acceptable noise burden to place on Air Studios, given excellent acoustics is key to their business, brings the issue of burden into focus.

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[4] Vanguardia – Potential Noise and Vibration effects of the Proposed construction for 11 Rosslyn Hill, Project number VC/101936, report dated 3rd June 2015

[5] Cole Jarman (CJ) – Response on behalf of Applicants dated 13th August 2015, Ref 14-0692 LO2-0 to Vanguardia report of 3rd June 2015

[6] Crossrail Information Paper, D10- groundborne noise and vibration, version 4 dated 03/04/08

[7] NPSE, defra, March 2010

4.9. It is helpful to extract some points from BS8233[8]. Para 7.7.4 states "*It is advisable to consult a specialist acoustician for guidance on the design of specialist spaces such as recording studios, cinemas, concert halls and opera houses.*" Air Studios had employed SBA in 1991, a specialist in this field, and who had set forth a design criteria given in section 3, that they as experts deemed appropriate for the studio use.

4.10. A clause in Annex D.3 of the above standard states "*The intrusion of relatively low levels of noise can seriously interfere with the enjoyment of the performance and distract the performers*." Important clients or certain functions with an invited audience involve performances being appreciated live and not just recorded in isolation. Significantly the performers, whether they be before an audience in a concert hall or within a recording studio environment, are still performers that can be adversely distracted by intrusive noise and/or vibration.

4.11. A clause in Annex D.4 (cross referenced to D3) "*For some infrequent intrusive noises, the requirements are sometimes relaxed on the grounds that a retake is possible, but this can result in higher operating costs*." This clause notes the consequence to higher operating costs, but at Air Studios, we understand that studio time slots are managed carefully, and overruns are difficult if not in some cases impossible to accommodate.

4.12. A clause in Annex D.6 states "*Projects involving groundborne noise from underground trains, plant or industrial sources usually require expert advice.*" The issues of groundborne noise will be addressed as a major topic in subsequent sections.

4.13. A clause in Annex D.7 states "*Projects involving low-frequency noise usually require expert advice as accurate measurement is difficult and there is a shortage of reliable data below 100 Hz*" This will have relevance to uncertainty which will be referred to in subsequent sections.

4.14. There are many specific details at the Air Studios' facility which show that great care has been taken to minimise intrusion from their own plant and equipment, such as resiliently supported equipment and resiliently supported mechanical services pipe and ductwork, resiliently isolated mechanical relays for lift electronic control, and the more obvious interventions such as floated structures for the studios, etc.

4.15. Often Councils are faced with petitioners that invent sensitivity, and argue low levels of intrusion, when their own arrangements fail to meet those standards. The case of Air Studios stands apart, where they can demonstrate that from 1991 they set out with relevant expert advice to achieve at great expense the high standards that their discerning clients demand. It is difficult to argue that when recording is under way, that they should be burdened with less.

4.16. There is other industry specific guidance, such as from the BBC[9] which provide background noise criteria according to area use, which are more stringent than those given by SBA. The BBC paper also provides details on measurement method, tolerances, etc.

4.17. Upholding the design target metrics of SBA will require technical dialogue to ensure they are applied and assessed with procedures to safeguard intrusion from noise and vibration from the range of sources, taking account of National Standards and Industry best practise.

[8] BS8233:2014 Guidance on sound insulation and noise reduction for buildings
[9] BBC R&D White Paper WHP 021, Jan 2002, Acoustic Committee Note 1992/1- Criteria for Background Noise Levels

5. GROUNDBORNE NOISE AND VIBRATION FROM RAILWAY TUNNELS

5.1. It is evident from site maps[10] that railway tunnels exist in the area, as depicted in Fig 5.1, and it is also known that the Northern Line tunnel alignment is nearby**.**

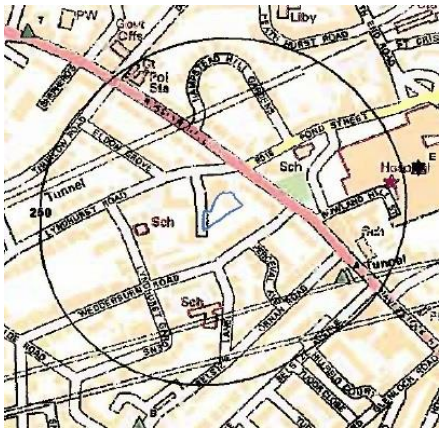
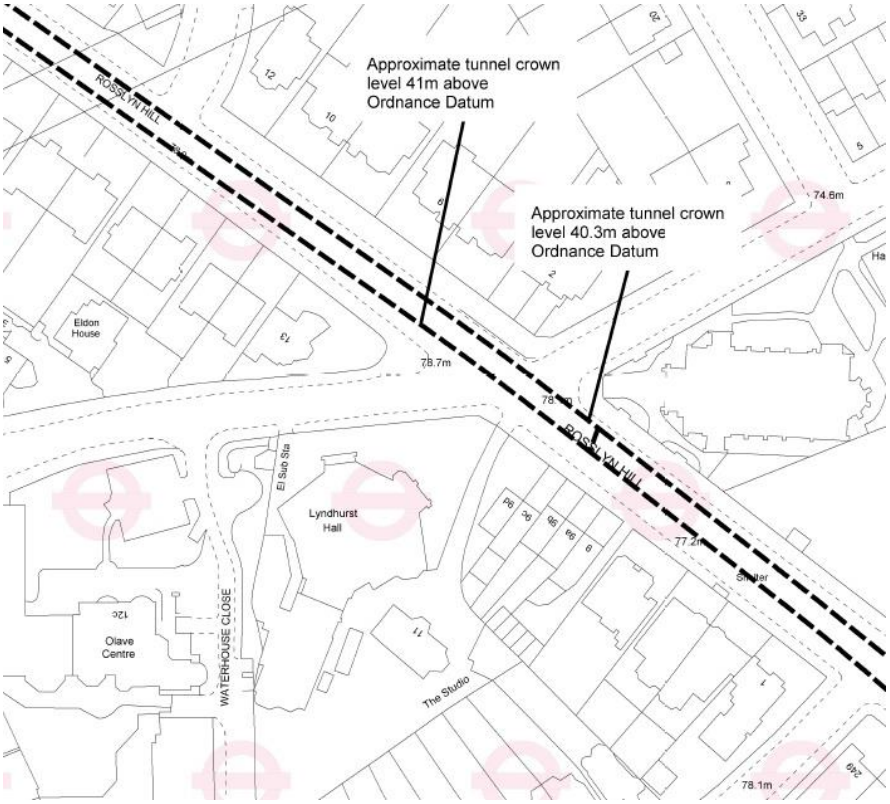


Fig. 5.1

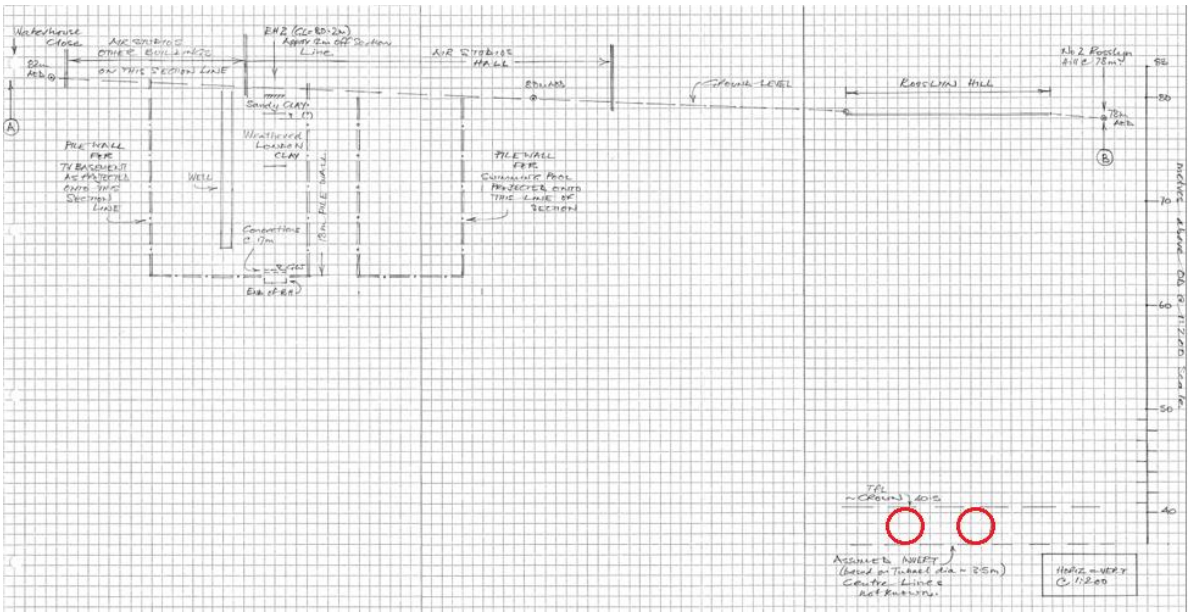
5.2. The response to enquiries with TFL (Annex C) identify the alignment and depth of the Northern Line Tunnels, of which there are two, one for each direction of travel. An extract of the drawing obtained is shown below in Fig[11] 5.2. This drawing must be read in conjunction with the accompanying letter sent by LUL, also noting that all dimensions and LUL asset locations are approximate. This drawing is for planning purposes only. For more accurate tunnel location information, a survey will need to be undertaken.



[10] Alan Baxter & Associate (ABA) – Basement Impact Assessment rev A, Dated 7th August 2015

[11] Figure, Plate or Table numbers are not subsequently captioned since they match clause numbering (CED convention)

5.3. To help put the proximity of these tunnels in context with geotechnical information, a sketch plan and section[12] is given in Annex D. The section, reproduced in Fig 5.3, shows the outline of the existing extent of Lyndhurst Hall building, and the proposed basements within a piling outline at 11 Rosslyn Hill. The approximate location of the tunnel is given, taken from the LUL drawing for which their conditions of use must also be noted.



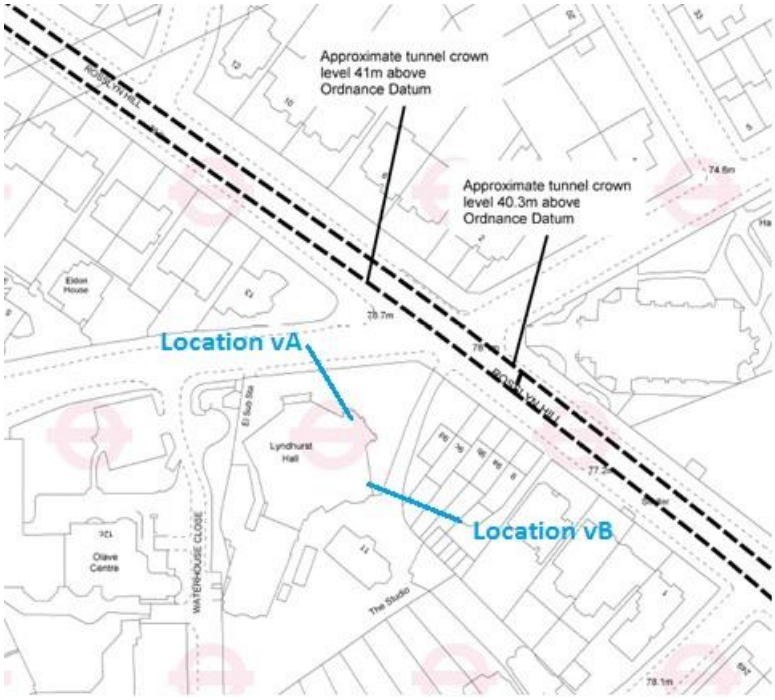
[12] Prepared courtesy of Dr DeFreitas, First Steps Ltd, email received 1st December 2015

6. SITE SURVEY DEPLOYMENT

6.1. The objective of the survey was to identify groundborne noise and vibration from railways in tunnels.

6.2. The vibration survey was undertaken in the area of Lyndhurst Hall, closest to the Northern Line tunnels. It happened that groundworks to create trial pits for an archaeological investigation were planned in the period when the railway tunnel vibration survey was planned, and so measurements included that activity as well. This is covered in Section 12.

6.3. Vibration Measurement locations, in the context of the Northern Line tunnels are shown in Fig 6.3.



6.4. Noise measurements were taken at various locations within Lyndhurst's Main Hall, and within other studios as and when accessible.

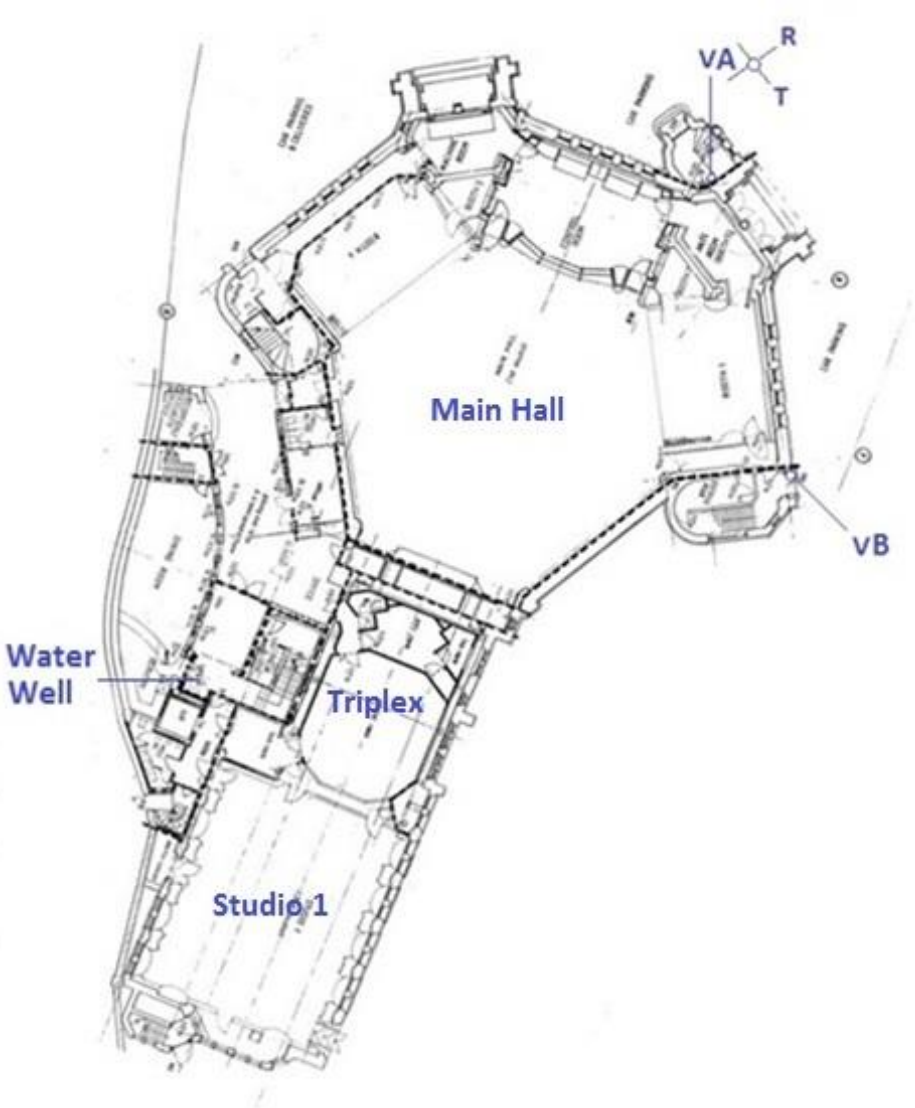
6.5. Vibration instrumentation comprised 4 CED Lance accelerometers, connected to a Lance signal conditioner, fed to a NI Data Acquisition unit sampling upto 2560 per second controlled by a Virtual Instrument operating on a Laptop. Noise measurements were taken with Bruel & Kjaer 2238 and 2250 type 1 sound level meters. Vibration and noise measurements were verified using portable Bruel and Kjaer calibrators, type 4294 and type 4231. Equipment details with serial numbers are provided in Annex E.

6.6. The equipment was deployed on Monday 7th December and removed on 14th December 2015.

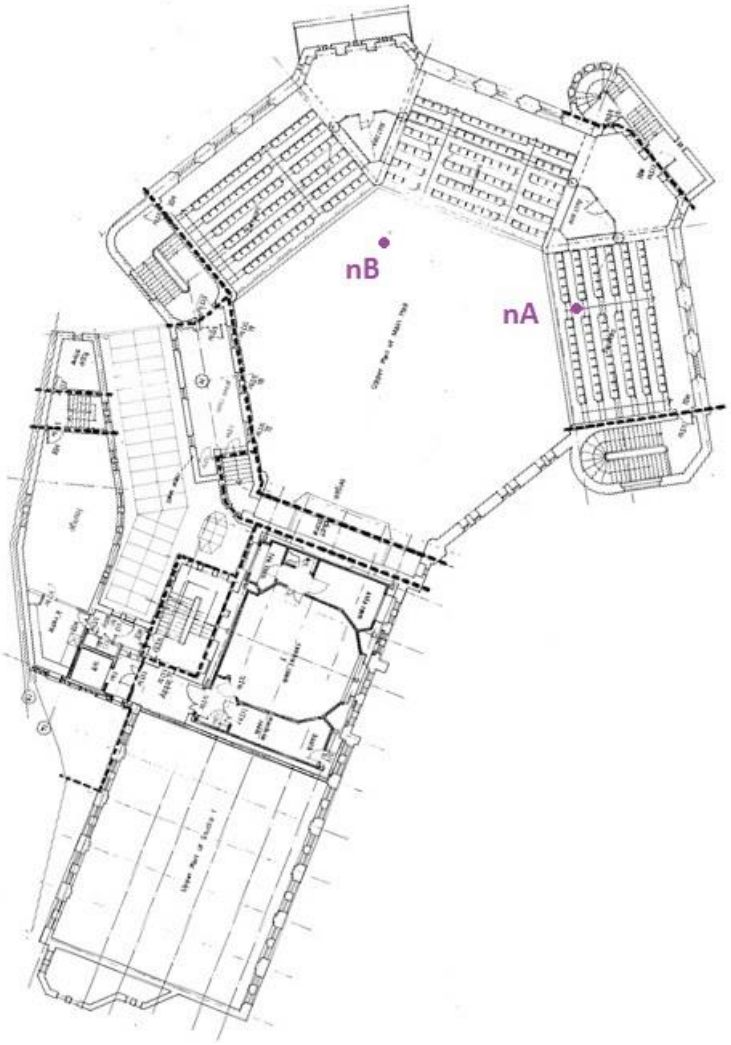
6.7. There were no inclement weather conditions to report for samples shown.

6.8. Water level depth within a well at Air Studios was measured from floor level as 3.15m on 7th Dec 15:30 and 3.25m on 14th Dec at 10:00. The fluctuation of water level depth with time and influence on vibration propagation from tunnels is outside the scope of this investigation.

6.9. A close up of the building is shown in Fig. 6.9, giving exact monitoring locations and sensor orientation. Sensors at locations ‘A’ and ‘B’ were placed at building ground level. Sensors at location ‘A’ include Vertical, Radial (orthogonal to tunnel) and Tangential (parallel to tunnel). Location ‘A’ utilised an engineering grade plastic cube glued with rapid araldite to the concrete floor, which provided orthogonal monitoring surfaces with steel discs for magnetic attachment. Location ‘B’ comprised a vertical sensor closer to the adjoining site but slightly more distant from the tunnel. Location ‘B’ utilised a heavy metal sonde with three feet parked on a stone threshold adjacent to the masonry wall. The surfaces were checked to ensure there were no laminations or surface debris. The building plan is shown approximately orientated according to the grid on OS maps.

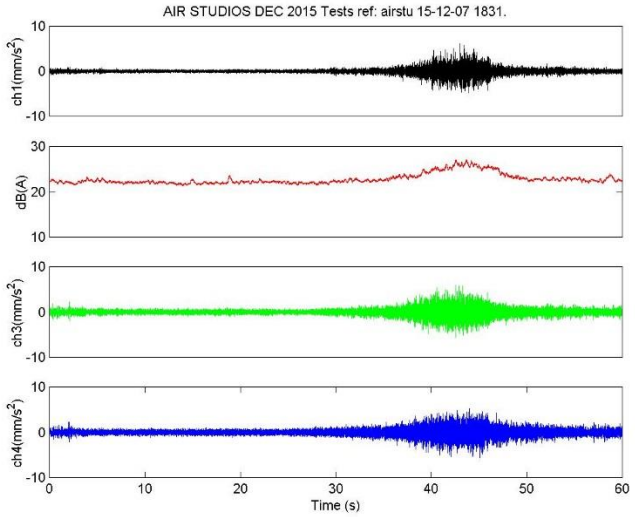


6.10. Noise measurements were taken at locations nA and nB shown in Figure 6.10. Location nA sampled on an upper tier whilst location nB was at ground level of the Main Hall. The microphone was placed on a tripod at a height of 1.45m, and was placed at least 3.5m from the nearest wall surface.

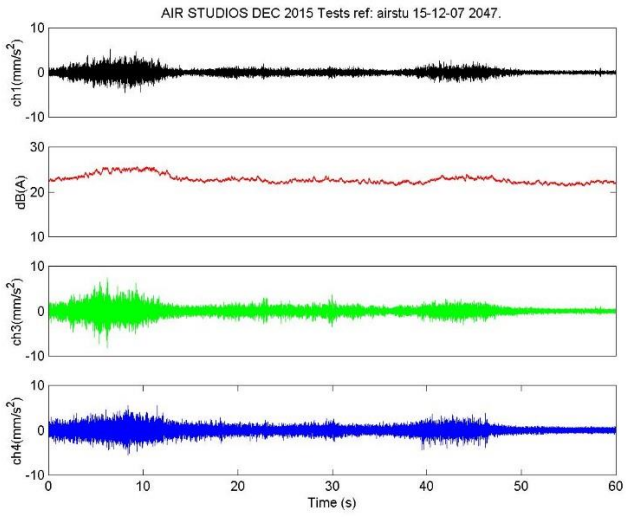


7. SITE SURVEY RESULTS – Northern Line

7.1. Fig 7.1 shows a 60 second sample that was judged to include an underground rail source. The date and time of the event are shown in the title to the figure. Channel 1 (black trace) in this arrangement refers to radial vibration measurements at location vA, with channel 3 (green trace) referring to vertical measurements at location vA with channel 4 (blue trace) referring to vertical measurements at location vB. The vibration measurements provide acceleration, time histories, band limited between 1 Hz to 1kHz. The DC output signal from the B&K 2238 noise meter at location nA, is shown in channel 2 (red trace) which is proportional to the 'A' frequency weighted, Fast time weighted Sound Pressure Level[13]. This output from the noise meter is delayed by 0.8 seconds, and accounting for that, the vibration and groundborne noise signatures are correlated.



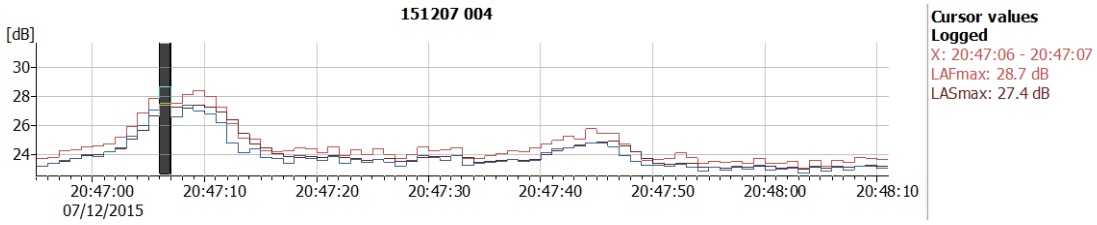
7.2. Fig 7.2 shows a sample at 20:47 in which there are two train sources, the stronger of the two events is likely to be due to a train in the closest tunnel of the Northern Line (NL), and the weaker signal for a train moving in the opposite direction in the furthest tunnel. The strength of the noise signature also follows the strength of the vibration signature. We can see that the events each last approximately 10 seconds.



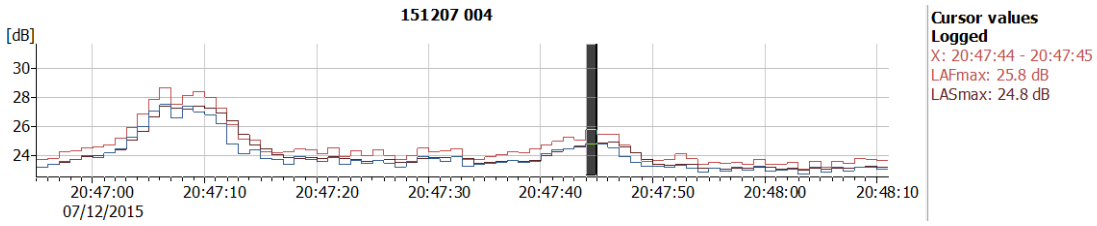
[13] (dB ref 20 μPa)

7.3. The Main Hall was not in use for live recording during the sampling referred to, and so access was not prevented to others in the building, although the samples shown relate to quiet periods with no intrusion from occupants. Low level background lighting was on as for the most sensitive work, the metal halide lights are not used, albeit they are replaced annually to reduce any noise implications from their use. The heating and ventilation plant was not disengaged, which only happens in the Main Hall when there is live recording and so could be operational according to demand. Given that the groundborne noise within the Main Hall correlates to the vibration measurement on the structure, it is judged the noise measured is representative of the Northern Line trains and there was repeatability across various samples.

7.4. Fig 7.4 shows a simultaneous sample of noise measured at location nB at ground level in the Main Hall, using the B&K 2250 noise meter, for the event at 20:47 (see also Fig 7.2). Here each bar in the graph represents metrics for each second. The cursor is positioned in the graph for the stronger of the two events, with the corresponding metrics shown to the right.



7.5. Fig 7.5 repeats the previous graph, but with the cursor positioned on the weaker of the two traces, with the corresponding metrics shown to the right.



7.6. There was a subjective impression that groundborne train rumble at ground floor level of the Main Hall (Loc. nB) appeared louder than that witnessed on the upper deck (Loc. nA). It was also subjectively noted that the two train events, nearside and farside tunnels could be distinguished by the level of noise at ground level.

7.7. Table 7.7[14] provides a comparison of data from the two noise meters for the 20:47 event referred to. The measurements are simultaneous at the two locations. The measured difference across the different locations, and between nearside and farside tunnel events supports the subjective impressions. This example compares a pair of train events and two locations, to demonstrate that there are differences and to indicate the magnitude of difference. More data can be presented for statistical analysis for trends, but is beyond the scope of this report. The significance is however that whatever limit is chosen, it must recognise that the noise levels will vary in the space, and will be greater still were measurements taken close to a reflecting wall or other panel.

Metric	Event	Loc nA	Loc nB	Diff nB -nA
L_{AFmax}	Nearest NL Tunnel	25.6	28.7	3.1
	Furthest NL Tunnel	23.8	25.8	2
	Diff Nearest - Furthest	1.8	2.9	

7.8. Table 7.8[14] provides a comparison between two metrics L_{AFmax} and L_{ASmax} distinguishing between slow and fast time weighting provided by the B&K 2250 noise meter at Location nB. The difference between such metrics is dependent upon the nature of the source, demonstrated here for underground rail sources but can be much larger than the example given. The significance of the demonstration is that limits can be given in either metric, typically L_{AFmax} being more stringent whilst L_{ASmax} being more common and easier to read from a noise meter.

Event	L_{AFmax}	L_{ASmax}	Diff L_{AFmax} and L_{ASmax}
Nearest NL Tunnel	28.7	27.4	1.3
Furthest NL Tunnel	25.8	24.8	1

[14] Differences should be read to the nearest whole dB, as measurements suffer inherent uncertainty

8. MODIFIED IMPACT FROM UNDERGROUND RAILWAY DUE TO BASEMENTS

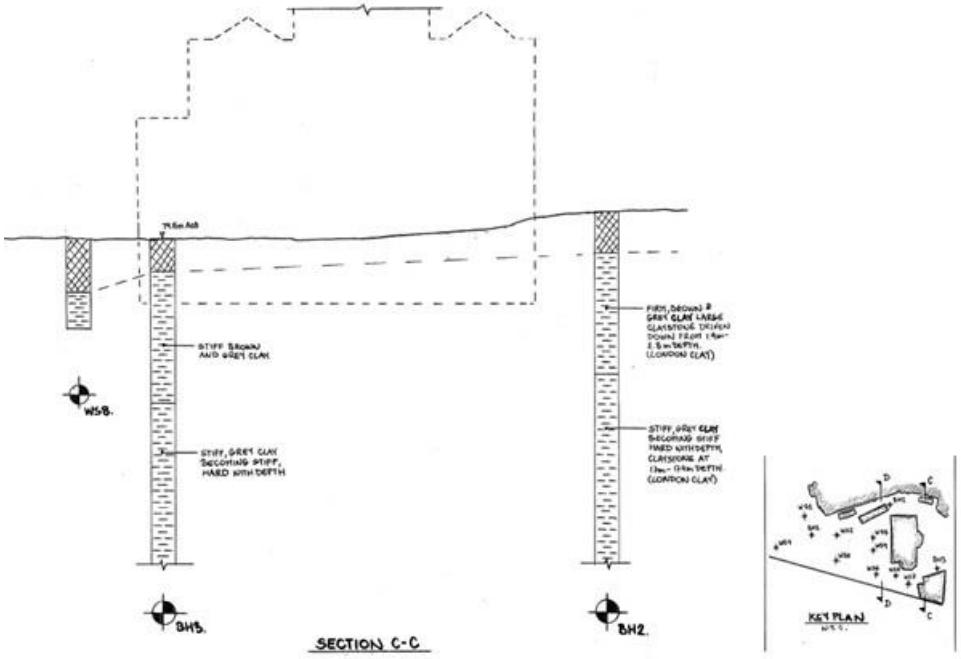
8.1. The preceding section shows that vibration and groundborne noise arises from underground trains within the Main Hall. The other studios, further away from the tunnels are floated structures in which this was to date not observed. The constraints on mitigation within a Listed building, have left the Main Hall unprotected from the effect of underground trains.

8.2. Whilst the vibration levels present at the specific locations are low, the magnified response of structural elements and other surfaces, which can act as 'loudspeakers', contribute to the groundborne noise being more evident.

8.3. The Main Hall due to its size, which can accommodate a full symphony orchestra represents a valuable studio space. When the intrusion from a train rumble or siren coincides with a quiet part of a cue (piece of music) or its tails (as the sound dies away to silence), it must on such occasions be re-recorded. Air Studios rarely perform post production to remove background noise in these situations, as the process is too obtrusive and would change the character of the recording.

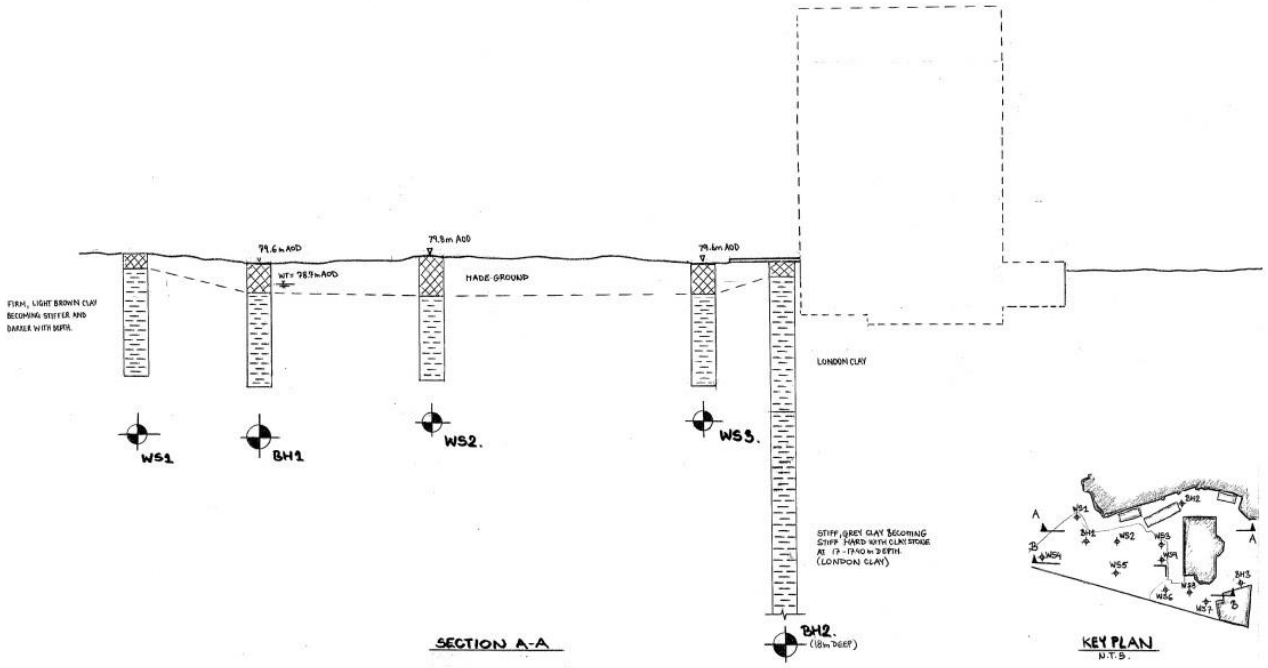
8.4. There are factors that alter groundborne noise from rail systems, of which a major factor is the characteristics of the transmission path.

8.5. The present outline of the building at 11 Rosslyn Hill exists in part of the transmission path. The extent of the building below ground is shown in Fig. 8.5, which is taken from Alan Baxter (ABA) drawing[15].

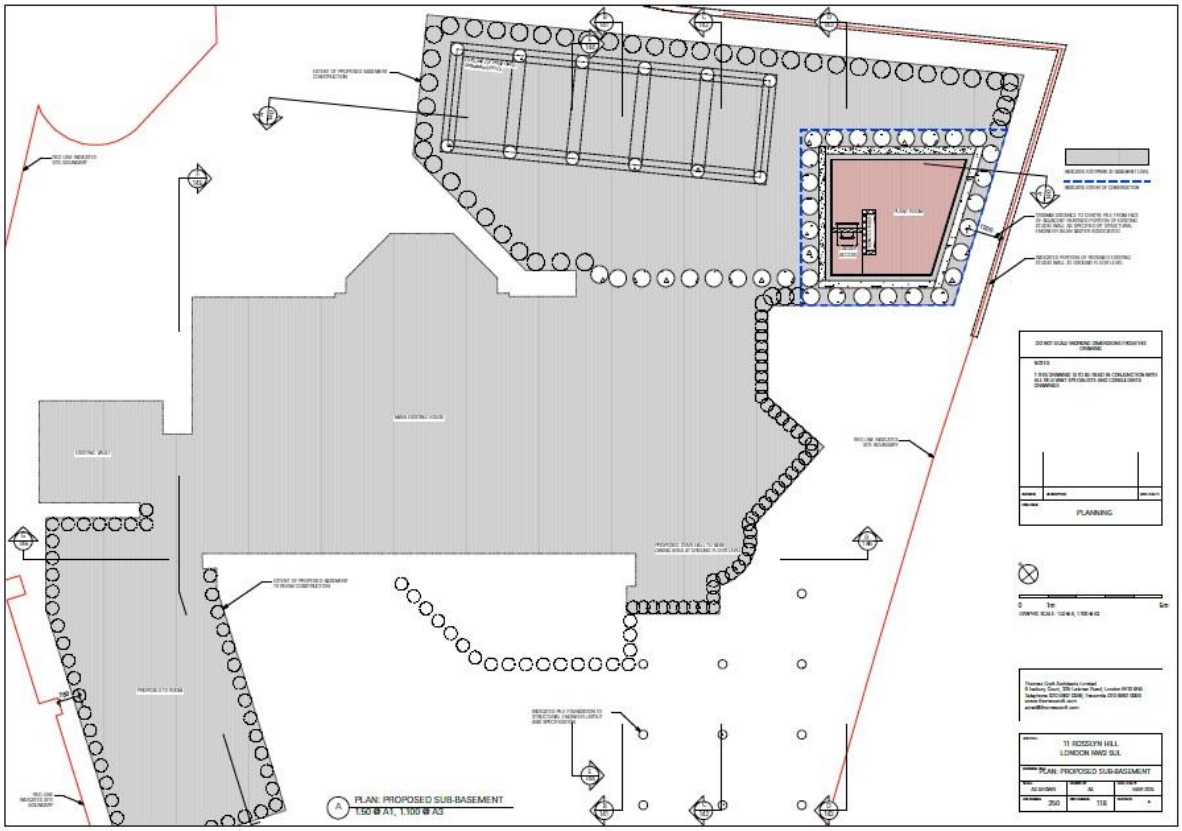


[15] ABA Geological Sections of Site Drg No 1693/01/S04, dated Feb 2014

8.6. An orthogonal section is shown in Fig 8.6 from an ABA drawing[16].



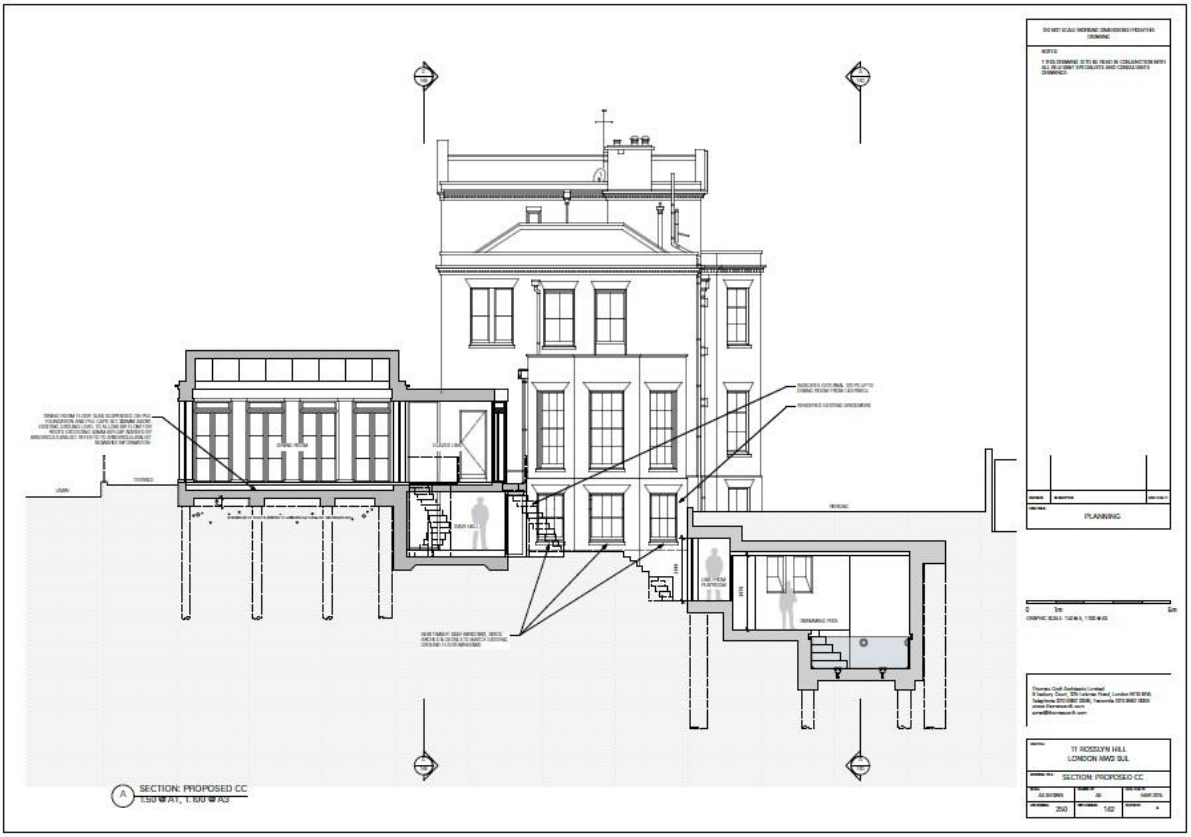
8.7. The outline of the proposed scheme[17] is shown in plan in Fig 8.7.



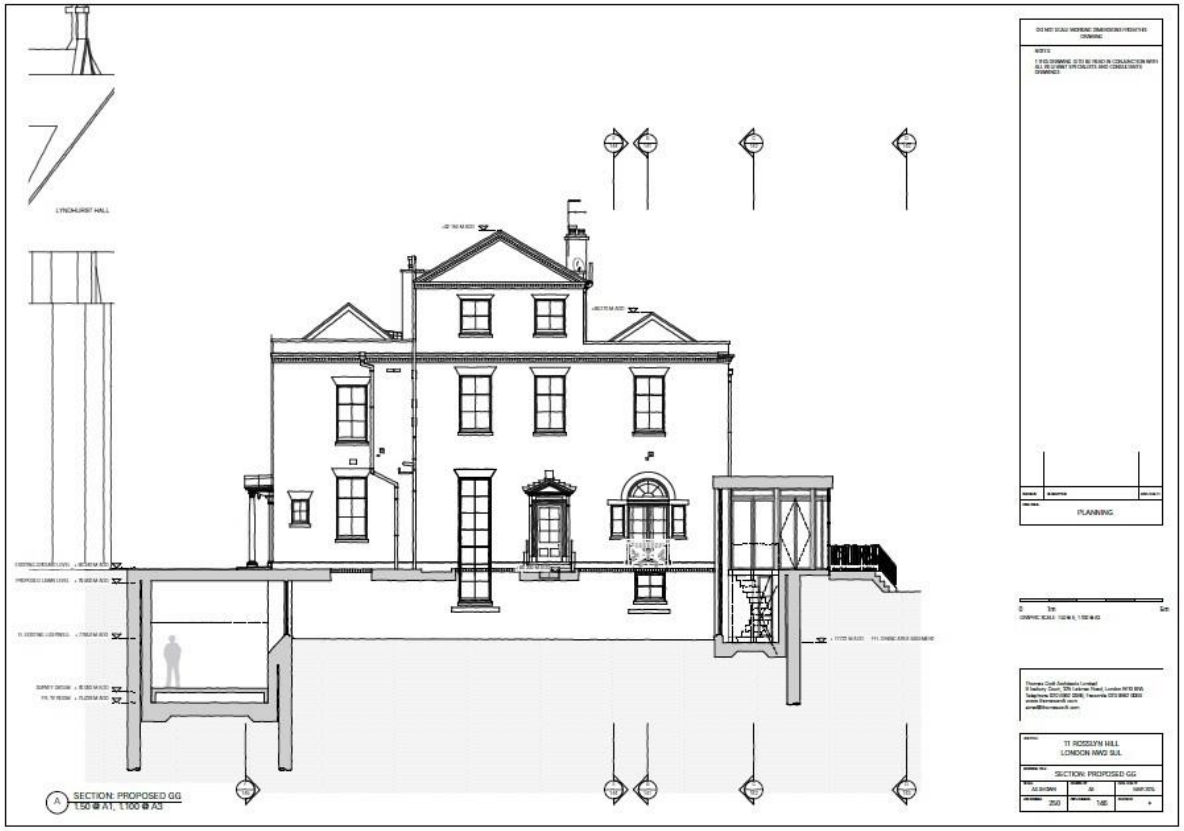
[16] ABA Geological Sections of Site Drg No 1693/01/S03, dated Feb 2014
[17] Proposed Drawings, Camden Planning Portal, Application Number 2015/7079/P

8.8. Fig. 8.8 shows Proposed section AA[17].

8.9. Fig. 8.9 shows proposed section CC[17].



8.10. Fig 8.10 shows proposed section GG[17], edited to remove parts of Lyndhurst Hall in the background, to focus on the adjacency of new Basement and piling at closest approach.



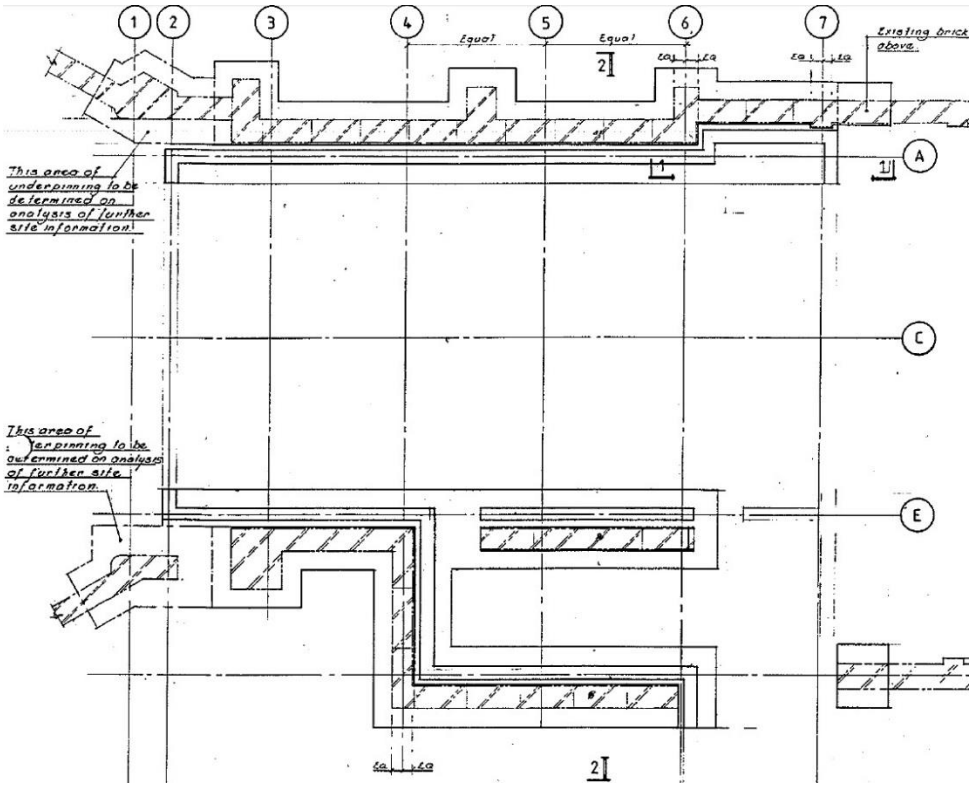
8.11. It is conceivable that the two proposed basements and their associated piling, can introduce more efficient ground transmission paths. They also bring themselves as conducting structures to a closer proximity to the tunnel source, not just by virtue of shorter distance, but also penetrating into soil layers that potentially themselves provide for stronger transmission.

8.12. An addendum report[18] by Dr DeFreitas of First Steps Ltd (FSL) provide geotechnical sections surmised from all the information presently available. Para 21A concludes "*stiffness of the London Clay will increase with depth but have a marked change at the junction of the grey with the brown clay*.". It also states that "*Calcareous nodules are present and form distinct horizons within the London Clay; they are an obstacle to piling*." Para 17A supports this assertion from analysis of different boreholes from which it is reasonable to expect these to be present across the site.

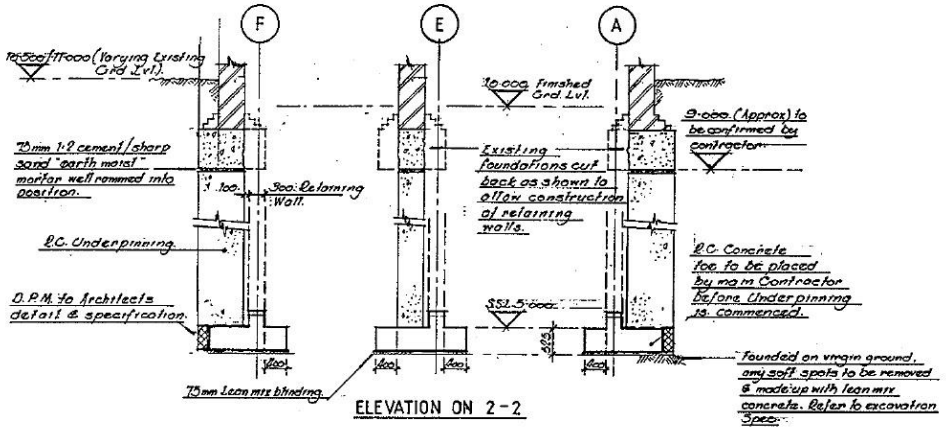
8.13. The case for better establishing the existing foundations at Air Studios has been made by Corbett & Tasker[19], and becomes all the more compelling to understand how and to what extent the Air Studios building and the limited parts which are underpinned, relate to changes in the ground dynamics properties with depth, and how the propagation from the tunnels will be modified by the introduction of neighbouring basement structures and piling.

[18] FSL, An Addendum Report on Geological and Hydrogeological issues for concern Arising from Planning Application, dated 11th January 2016
[19] Corbett & Tasker Report - Response to revised BIA for 11 Rosslyn Hill, dated 5th Oct 2015

8.14. Fig. 8.14 shows an archive drawing indicating the extent and depth of underpin, which is yet to be confirmed, as there are no as-built record drawings. It is evident that the only Trial Pit (TP1) from the applicants SI[20] which attempted to discover foundations of the East wall happened to miss the section with the underpin, having been excavated to the right of grid 7.

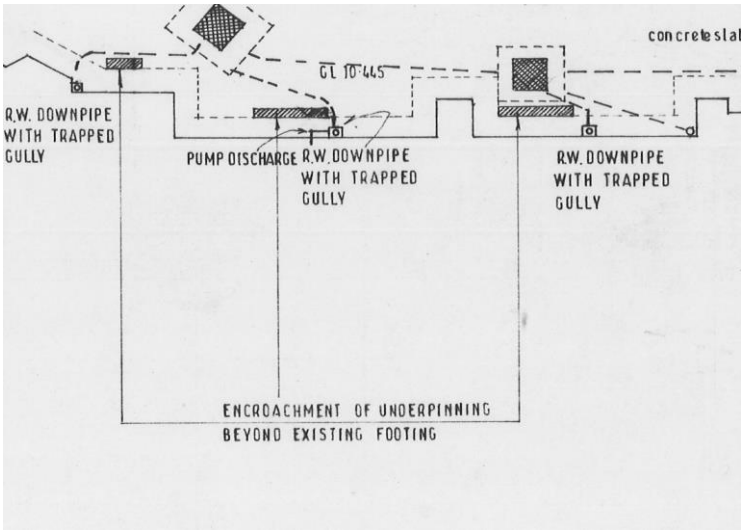


8.15. The section of the underpin shown in Fig 8.15, as with TP (1) of the SI shows that the wall on the East side adjoining the neighbours at 11 Rosslyn Hill, has corbelled brickwork and the concrete footing below also goes beyond, reducing the adjacency to the proposed piling and basement to the New Cinema Room. The depth of the underpin is indicative and reference to borehole information[18] shows that it bears in the brown weathered clay.



[20] ALAN BAXTER & ASSOCIATES (ABA) – Site Investigation Summary of Trial Pits, Drg 1693/01 SO2 Dated Jan 2015

8.16. Fig.8.16, an extract from an archive drawing[21] shows the existing drainage on the East side of Air Studios, which is in the area of the proposed Basement Cinema Room and also shows that the underpin encroaches beyond the line of the wall above.



8.17. From information to hand, it could appear that the Air Studios foundations are within the brown (weathered clay), and certainly the partial underpin. Although we cannot definitively assume this is the case throughout the building as only 1 trial pit has been excavated. Furthermore, the support details of the ground floor to the Main Hall are yet to be established.

8.18. It is clear that the proposed basement structures and piles, of which there are many, would bridge through to deeper stiffer grey (unweathered clay), and also make contact with stiffer horizons within. This may all provide more efficient transmission of groundborne noise and vibration from the tunnel structures to more strongly reach surface layers.

8.19. It is also conceivable that the immediately adjacent proximity of the TV (Cinema) Basement structure, being within 200mm of the Air Studios' foundation[19], potentially closer still, allows more efficient or direct coupling and transmission facilitated by the continuity of neighbouring structures. From that nearest the tunnels, i.e., the deep basement swimming pool/plant room structures and piling, via the existing building and on through the Cinema Basement structure and so conveniently 'short circuited' into the Air Studios building.

8.20. The new basement structures could change direct as well as influence reflected path transmissions.

8.21. The new basement structures introduce new dynamics, where the pile axial dynamics and soil structure interaction of basement box, although heavily damped in their coupling to the soil may still bring more energy to the surface layers.

8.22. The lateral impedance of the Air Studios foundation in the long interface to the Cinema basement room (see fig 8.10), will change, and that may adversely influence performance of the triplex of floated studios, the significance of which remains to be seen, but can only be assessed by detailed investigation.

[21] Heber-Percy & Parker Architects – Lyndhurst Hall, Drainage & Electrical Services SE Boundary, Drg 05 revD, April 1991

8.23. The groundborne noise intrusion from the underground trains is already evident within the Main Hall at a level that presents a problem and an increase in this intrusion will likely render this studio unusable.

8.24. There is a possibility that the transmission path may alter not just the magnitude, but spectral distribution in a way that certain frequencies become more troublesome than hitherto. Under this condition the change at specific frequencies can be more dramatic, as a resonant response can be very significant, compared to a situation where there is a frequency mismatch. This could give rise spectral components suffering a large multiple increase rather than just a fractional change.

8.25. Whilst these issues have greatest risk for the Main Hall, the limited performance of base isolation for the other studios (discussed in Section 10) could introduce a train induced issue in other studios in the building that have avoided this issue to date.

8.26. The Applicant's technical advisers have not provided any information to address these potential impacts, which has very serious consequences to the performance and therefore viability of the studios.

8.27. The relevance of such an issue can be read from BS B228, Part 2[22] Vibration, which states in section 8.7 "*The mechanisms which give rise to the propagation of vibration through media such as soil are complex. The magnitude of vibration is determined by the characteristics of the vibration source, the properties of the excavated ground, and the ground between the vibration source and receiver. Multi-layered soils and/or the presence of deep piled building foundations can further complicate and modify magnitudes and estimates.*" The text underlined here for emphasis is very explicit on this.

8.28. Guidance on modelling and predicting such changes is readily accessible in ISO 14837[23], Ground-borne noise and vibration arising from rail systems. Section 4.3 on Propagation states "*Consideration should be given to man-made structures in the ground (…) and the effect that they may have on propagation characteristics. It may be necessary also to consider the effect of ground water*. " This text reiterates the preceding paragraph and also draws attention to consider ground water, which is known to be very evident at this site.

8.29. The standard repeats this in Annex A providing a checklist of issues which under the subsection propagation path, para A3.1.e draws attention to " *Inhomogeneity's in the path - man-made (pipes, roads, other tunnels, ground anchors, piles, deep foundations, pre- or post-ground treatment)*."

8.30. The example of the Northern Line tunnels has been given, being the closest tunnel source. The possibility of changes in propagation from more distant Network Rail tunnels that exist to the NW and SE of the building should be explored. These are likely to support heavy freight, and will impart low frequency vibration that will benefit from low attenuation rates and better induce possible resonant responses of building elements. It remains to be seen if such will be strong enough to induce rattling and consequent noise from elements hitherto below such thresholds of mobilisation.

[22] BS 5228-2:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – Part 2 Vibration

[23] ISO 14837 Ground-borne noise and vibration arising from rail systems — Part 1: General guidance, dated 2005

8.31. The road surface on Rosslyn Hill is poor, as seen in Plate 8.31. Heavy lorries or busses running at speed across poor road surfaces are known to create nuisance to residents in some cases. The basement structures and piling could increase the vibration in adjacent properties that are within a zone of influence of any changes in ground propagation characteristics.

8.32. Depending upon the type of sound system used in the Home Cinema Basement room and were they to be mounted on the immediately adjacent new interface basement wall (see fig. 8.10), it may be necessary to mount any powerful loudspeaker (an electrodynamic shaker), in such a way to minimise structure-borne noise transmission of very loud events that exist in some movie tracks. Otherwise this has a potential to affect the un-isolated Main Hall, particularly given the 24/7 nature of the studio usage. It may be used late at night at a time coincident with typical use of a home cinema, and when background levels are lower.

8.33. Structural and ground dynamics are highly complex for the system comprising the underground rail sources, the transmission paths and the receivers, and there is significant uncertainty in modelling outcomes. It is not suggested that all of the possible mechanisms will conspire to cumulatively make the situation worse, there will be competing factors, which would need to be thoroughly modelled and calculated. The problem is that even after the most sophisticated analysis is undertaken, supplemented with an array of relevant site tests, which will help to reduce uncertainty, the net uncertainty that will remain will itself present a problem. So the question should arise, as to who or what entity should bear the burden of the net risk, and what if any are the remedies available.

8.34. The situation is in fact compounded because there is no plausible mitigation that could be implemented after the event.

8.35. This could culminate into a perilous situation for the studios with no obvious simple redress.

8.36. Given that there are no practical steps that are within the domain of Air studios to implement to reduce the impact, and given there are no plausible interventions, recognising also the constraints of a listed building, the avenues left would be legal redress. Even that predicament of legal action, would be uncertain and drawn out. As it is unlikely that an insurance company will pay out for the loss without an enormously protracted process, where insurance companies representing different parties would seek to identify breach of contractual obligations and try to establish which parties were responsible for which aspects of the problem.

8.37. It might be suggested that changes arose due to maintenance issues at the source, or due to operational changes by LUL. There are many factors that can alter groundborne noise and vibration from underground railways, but in all such cases, changes in the transmission path could increase the consequences.

8.38. Since the subject is complex, it will by this nature be a lengthy process to arrive at a ruling. In fact, it may prove easier to direct such legal action against the Council, since the risk and concerns were clearly and unequivocally brought to their attention at the outset, if it can be proved that they did not ensure this matter was thoroughly addressed as part of the planning process in the first place.

8.39. Of course in all this time, the reputational damage and loss of business is one consequence, the ability to find a viable use to keep a listed building as a functional use another challenge entirely.

8.40. There is a possibility that not only will Air Studios be adversely affected, but the residential terrace Block 9 Rosslyn Hill which is closer to the tunnel may already be experiencing or complaining about groundborne noise from the Northern Line, and or road traffic vibration. It is assumed the Council would as part of this disclosure, consider additional impacts that may arise to the various receptors there.

8.41. It should also be a matter of concern to the Applicants, that such changes could also increase the impact of groundborne noise from the tunnels to their own property, which may blight the environment they currently enjoy, and so require the Council to ensure the impact assessments are broader to cater for the issues to all parties that can be adversely affected, whether they realise it or not.

8.42. Given that LUL clearly state that the depth and alignment of the tunnel is indicative and not to be used for design purposes (Annex C), it would be prudent to accept their advice that a survey is commissioned to establish that accurately, as it is so relevant to the issues raised.

9. ACOUSTIC INTEGRITY OF BUILDING FABRIC

9.1. Building movements arising from settlement (or heave) induced by Basement construction both in the short and long term have the potential to compromise the sound attenuation between studios and significantly cause noise to break out through fractures in walls, or strain on the glass and localised detachment of secondary glazing.

9.2. Plate 9.2 shows an example of a crack on the West elevation in the cottage element of the site. Fortunately, it is not subject to strong noise levels on the inside.

9.3. Even hairline cracks in the fabric, of the type shown, could compromise the sound attenuation, as well as being difficult to repair and remain as unsightly scarring. Some cracks might arise in areas that are not immediately obvious, and so it may be hard to remedy a weakness in sound attenuation. Not only does such a compromise effect the sound attenuation between studios, but it could also allow noise to break out and effect neighbours.

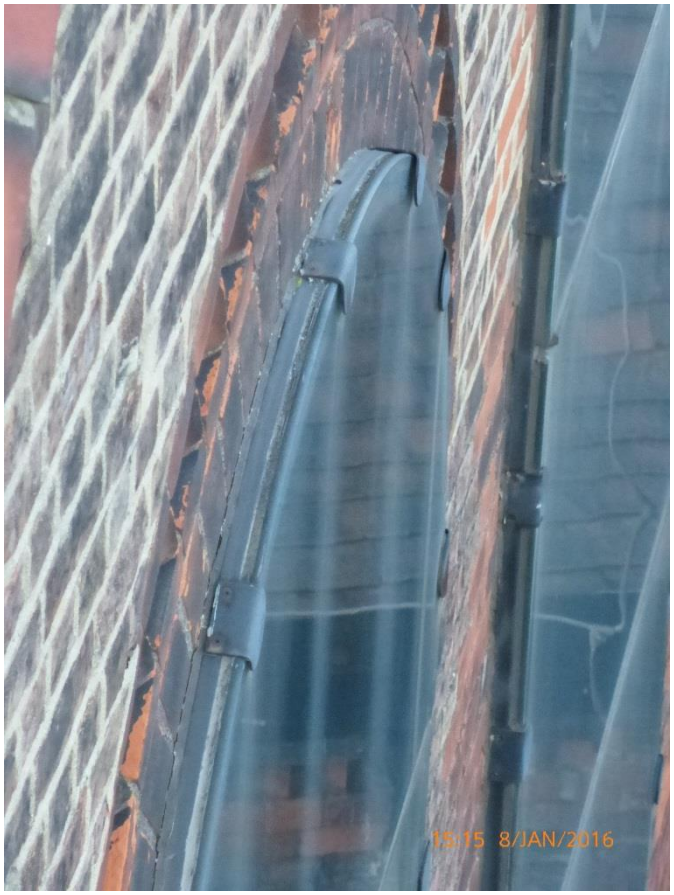
9.4. It is noted that floated studios will have an ability to a degree to articulate under support movements, although were stronger noise levels to break into the cavity between un-isolated and isolated parts through a crack, that could reduce sound attenuation between studios. To remain authentic, the actual text from the SBA[24] Blockwork to General Areas Acoustic Specification is quoted from, "*The sealed surface must be impervious.*",

9.5. The mortar pointing of areas of Lyndhurst Hall building that are accessible were found to be observationally hard and likely brittle and so less able to accommodate differential settlement. It will be necessary to test the mortar from adequate sampling to see if we can expect some accommodation or brittle mechanism under induced strain.

9.6. It is to be noted that the Air Studios building has partial underpinning and whilst that served the purpose to accommodate new loadings, the change in foundations across the site, lend themselves to a vulnerability with strain accumulating at such junctures.

[24] SBA Project ref 8915, Blockwork to General Areas Acoustic Specification, dated 17th April 1991

9.7. Induced strain could cause localised detachment of secondary glazing. The secondary glazing perimeter seals could have become hard with age and are vulnerable to building distortion. Plate 9.7 shows a close up of the perimeter detail, where the stress points from the retaining clips for the glazing are evident. Thermal loading under certain conditions can induce significant thermal strain, where the threshold to damage becomes easier to breach. Stained glass is in many areas already showing signs of distortion and strain.



9.8. There is a risk that settlement (or heave) induced by ground works, and possible changes to water levels, could bring Air Studios into a breach of a planning condition[25], "*No music shall be played on the premises in such a way as to be audible within any adjoining residential accommodation*" should such settlement even cause hairline cracking.

9.9. It may prove difficult for the Council to act to remedy a breach since they will be unsure if the breach has arisen due to an impairment of the acoustic integrity of the fabric of the building, caused by settlement arising from permission granted at an adjoining site, or if some other operational change at Air Studios could be robustly attributed to the breach. It is presumed that the highest sound levels within the studios are by now a matter of record, and is unlikely to be exceeded in the future. It can be assumed that Air Studios would try and find the cause of and remedy a situation, which they would wish for good neighbourly relations. However, defects in sound attenuation of a building are hard to trace and rectify, leading to an extended period of difficulty and a burden to the Council enforcement team.

[25]Camden Planning condition 08, ref PL/8905427/R3 dated 8th February 1991

9.10. Whilst hairline cracks might be regarded as negligible in a typical building damage classification, they are however potentially very severe in terms of impairing acoustic integrity for a fabric required to contain very high sound pressure levels.

9.11. Due to these reasons the burden on structural monitoring, adequate baselines from extended monitoring prior to any proposed works and the implementation of more conservative building movement limits are needed to safeguard acoustic integrity, which triggers a concern at a lower threshold compared to structural integrity.

9.12. The listed building of Air Studios, based upon various vulnerabilities including the large arched openings in its façade, and differential foundation arrangements still undetermined, and hard brittle pointing is likely to score high in the Sensitivity Assessment of Listed Buildings. The forgoing issues simply adding to the need for special care at this site.

10. BASE ISOLATED STUDIOS

10.1. Structural movements arising from settlement induced by basement construction, both in the short term and cumulatively arising over the long term could have the potential to alter the dynamic characteristics and therefore performance of base isolated structures, also referred to as floated structures or box within a box structure.

10.2. The studios that are isolated are able to accommodate some differential movement in the structure, due to the fact that they can articulate about the resilient supports. The studios will have been designed with air gaps to un-isolated structures. In practise these are often difficult to achieve, and so there can be situations where the design aim of air gaps is less than the optimum. Building Settlement cause movements where the already small air gaps can be reduced and bridged. The resulting short circuit, however small, can cause a disproportionate impact on performance. Such short circuits are difficult to trace and difficulties with access make them hard to remedy.

10.3. To remain authentic, the actual text from the SBA[26] Specification of Acoustic Performance states "*Ensure that you maintain a minimum 10mm gap between floating structures and all other structures and elements outside the floating structure.*" and *"Do nothing that could make a rigid connection between a floating structure and any other structure."*

10.4. Whilst a 10mm minimum gap has been called for, and is itself rather small to start with, experience shows that often the gaps achieved can be less, and so could under settlement be closed and create short circuits to the detriment of the acoustic performance of the studios. This compromises their ability to accommodate changes in source levels.

10.5. Differential settlement can also cause load redistribution on the bearings, and where the bearings are relatively stiff, such as the Tico bearings specified, they are more sensitive this.

10.6. Plate 10.6 shows an example of Tico bearings in use under the floating floor of studio 1. These show a mixture of support conditions from brick piers on a slab (right of view) to concrete beams (left of view), emphasising the potential for differential behaviour.

[26] SBA project Ref 8915, Specification of Acoustic Performance: Notice to all Trade Contractors, dated 17th April 1991

10.7. Plate 10.7 shows a close up of the Tico bearing.

10.8. SBA memo[27] states "*If the load imposed upon the pads is less than the minimum shown above then there is the possibility that the performance of the floor will be seriously reduced. Severe underloading may result in the floor actually magnifying train noise and vibration*."

10.9. The dead load deflections for the studio 1 floor, which use relatively stiff Tico CV/CM pads, is of the order of 7mm. It therefore does not require much differential settlement to cause load redistribution.

10.10. In the case of the Triplex of studios arranged one above the other, Tico CV/CA pads of 50mm thickness were specified for floor beams and type CV/CM pads also 50mm thick for ceilings. In both cases a dead and live load deflection of about 7mm was expected. In this context building distortion can cause load redistribution.

10.11. The floating floor above studio 1 ceiling, known as Mezzanine Level, is supported principally on Tico CV/CA pads 50mm thick, and again with a design deflection of 8mm.

10.12. The equivalent rigid body natural frequency for the design aim (although a vastly simplified concept) is likely to have been in the region of 15Hz or more for the studios in the triplex, Studio 1 and the mezzanine floor above. This does not factor the dynamics of the support structure or the multitude of modes for the floated box or floors themselves. It is certain that the studio isolation is only potentially effective at dealing with frequencies significantly above 20Hz and probably only selectively effective at certain frequencies of structureborne noise, and so remains vulnerable to groundborne noise and vibration sources.

10.13. In particular, it is likely that these studios will respond adversely to some spectral components of vibration from railways and construction activity rather than attenuate them. Their actual behaviour can be better understood by modelling and confirmed by field trials. This is a significant limiting factor and why it is imperative that the floated studios should not be presumed to be immune to external disturbance.

[27] SBA Memo numbered D203 dated 2/07/92

10.14. A control room is understood to be on softer Tico CV/LF/N bearings, double layer with total unloaded height of 67mm. Such areas are likely to target a lower simplified rigid body natural frequency, but the same limiting issues apply.

10.15. It has been highlighted that differential settlement can cause load redistribution on the isolators, and in consequence may also alter the support and therefore modal characteristics of the structure. The changes in performance may in fact be dramatic, where a source in the ground spectrum is now brought into or closer into resonance with a mode hitherto avoided.

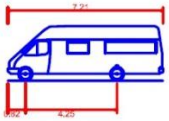
10.16. The base isolation is not optimum. Tico bearings are relatively stiff and give rise to high natural frequency systems, whereas the highest specification solutions adopt much softer isolators, and even steel coil systems. This implies that although the studios are floated, they have been done so using relatively stiff isolators, and whilst they appear to meet their present requirements, they are not necessarily capable of isolating all sources. They will be limited in their ability to cope with an increase in groundborne noise and vibration from rail systems or from certain construction processes.

10.17. It might be asked why a client aspiring to the highest standards did not adopt the softer systems for base isolation which have potential for better performance. Such isolators do require more space, which may have been a factor that prevented their selection, working within the physical constraints of a listed building.

11. SELECTED CONSTRUCTION ISSUES

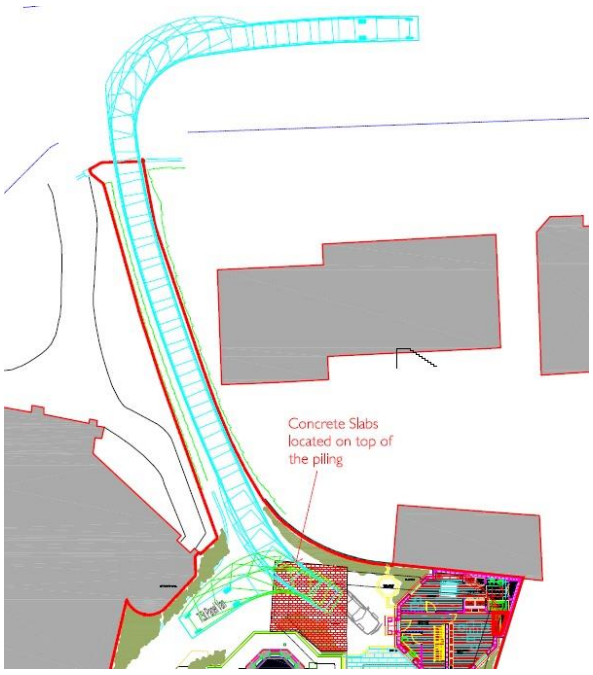
11.1. The construction and demolition issues related to noise and vibration have been addressed by a Vanguardia report[4]. This section selectively draws attention to some of the issues.

11.2. The Outline Construction Logistics Plan (CLP) from Paul Mew Associates[28] (PMA) shows in swept path analysis that vehicles will reverse on site. The proximity of such vehicles and reversing alarms to Air Studios, given their frequency of movements is to be considered. It is very surprising that the report makes the following commitment in paragraph 4.18. *"The largest delivery vehicle will be a 7.5 tonne panel van.",* which is shown as a diagram in Fig 11.2. The nature of the heavy civil engineering works, makes the commitment to this vehicle all the more surprising, although the following clauses in the report indicates that in practise a different arrangement may be required, Clause 1.9 States *"……..information provided in this Construction Logistics Plan should be seen as preliminary and subject to contractor alterations*." And Clause 3.25 states "……..*Construction vehicles accessing the site will need to be confirmed at a later date by the appointed contractors*." Such a provision is not unreasonable and the report implies further details forthcoming in a detailed CLP. But it should be appreciated at the outset that the restriction to the following vehicle alone is unrealistic.



7.5t Panel Van

11.3. The swept path analysis for a small tipper truck and the 7.5 tonne van were given in the report by PMA[28] , and a part of that diagram for the 7.5t Panel Van is reproduced in Fig 11.3. It shows such vehicles can turn on site. Longer vehicles will inevitably be necessary for such a project and it is unlikely that they could turn on site, and therefore implies a long reversing run on the access driveway, that not only creates a concern at the junction to the main road, but necessitate reversing alarms to be in operation for very much longer durations.



[28] PMA – Outline Construction Logistics Plan, ref P1284, dated March 2015

11.4. Lorries do create low frequency noise that couples through the air and ground which can induce windows to rattle when close, such as will be the case here. The vehicle type and frequency of movements is thus important.

11.5. BS5228[22] in para 8.7 dealing with sub-surface construction activities states "*Groundborne noise generated within a building is predominantly low frequency in nature and can be caused by the vibration of all the internal surfaces of that building*." Given the studios are floated on relatively stiff resilient pads (section 10), they are vulnerable to low frequencies which may be magnified rather than attenuated, and so becomes an issue for closer scrutiny.

11.6. Basement construction typically employ conveyor system for muck removal, and if deployed adjacent to Lyndhurst Hall will potentially create groundborne noise, requiring the need to consider localised isolation.

11.7. The horizons of calcareous nodules present in the ground[18] have the potential for increased groundborne noise and vibration fall out during CFA piling, which should not be overlooked. The proximity of CFA piling on this site noting the sensitivity of Air Studios still requires close attention, particularly to groundborne noise, which is hard to predict in the nearfield.

11.8. The building vibration limits during construction have been proposed[4], and the following can add a consideration. An SBA specification[26] states "*It is imperative that you do not allow debris to fall into any cavity between rigid and floating structure*." Mortar used in forming blockwork walls can on the cavity side be squeezed out of courses which can be loose and fall through the cavity. For studio cavity applications, ideally such excess should be removed during construction. For that which is overlooked, vibration could in this case exceed a threshold that agitates material which could be sufficient to make loose mortar fall and bridge critical gaps. These will be hard to locate and clear given they are hidden, yet they have a disproportionate effect on the performance of the floated studios.

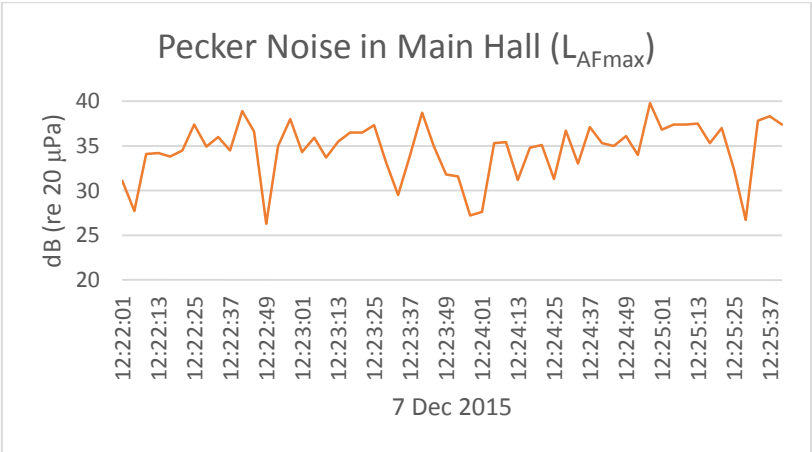
11.9. Dust generated from the works will have impact on soiling the building and glazing, as well as require increased maintenance on filter changes for the Mechanical service plant.

11.10. Some forms of site welding can cause Electromagnetic Interference (EMI), and recording studios although routinely guarding against EMI, may find certain, albeit temporary sources a further challenge.

12. SITE SURVEY RESULTS – Archaeological Trial Pits

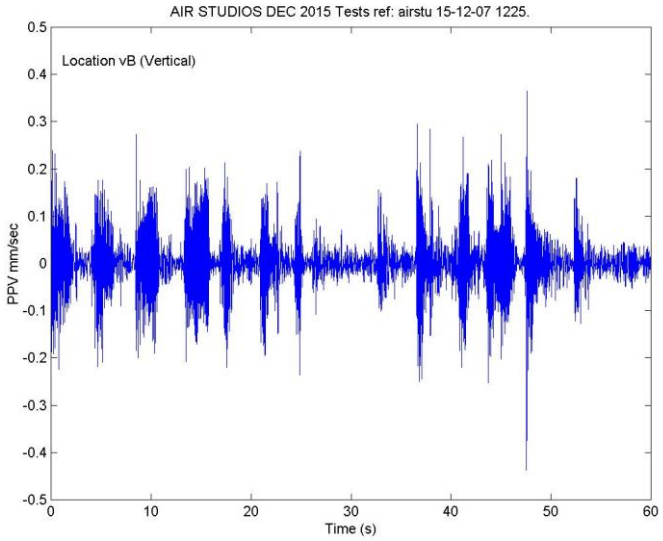
12.1. Section 7 provided site survey results of groundborne noise and vibration for the Northern Line Trains. This section provides a sample of results obtained during the Archaeological Trial Pit investigations, which use the site survey equipment deployment described in Section 6. The location of archaeological trial pits[29] is shown in Fig 12.1, along with the vibration sensor deployed at location vB oriented to vertical axis. The monitoring was not dedicated to sample this activity hence the limited equipment deployment in close proximity to these works.

12.2. Fig 12.2 shows noise measurements logged at 4 second intervals obtained at Location nA, on the upper tier within the Main Hall (refer to fig 6.10). In this sample the recording sign was not lit, so the heating and ventilation system can be assumed to be operational. The lighting was on, and adjacent studio 1 was in use. The Engineer was also on occasions seated at that location to witness the events, and this coincides with the data presented below. The site notes identify this to be due to the Pecker in use on Tr 1, with noise meter L_{AFmax} readings of 38dB, 39 dB and 40 dB unmistakably attributed to the pecker source. The vibration was also clearly perceptible through the mezzanine floor with a note highlighting that the building shakes. It is possible to see that the noise levels at moments subside to a lower level of 26dB in between pecking activity, and lower still in terms of an L_{AF90} metric (24dB) which is more representative of a background. The dynamic range from the lulls to highs within the same L_{AFmax} metric causes the noise from pecking to be highly intrusive, and a condition within which recording in the Main Hall would have been impossible.



[29] Pre-Construct Archaeology Ltd, Proposed Trench Locations, Fig dated 30/11/15

12.3. Fig 12.3 shows a vibration trace in terms of Peak Particle Velocity (PPV) for a sample taken at Location vB, in the vertical axis, whilst the pecker was in use, at Tr1. Equipment was being set up whilst this activity was under way, and so the levels recorded refer to the pecker being used within a large area depicted for Tr1, so it is conceivable that higher levels could arise when used closer in. The vibration in this sample reaches 0.44mm/sec Peak Particle Velocity (PPV) at a load bearing wall position at ground level. Magnified vibration levels at other locations are to be expected, and would support the subjected impression that on the upper tier within the Main Hall the vibration was clearly perceptible.



12.4. It is instructive to compare such samples with the provisional target levels put forward in the Vanguardia[4] report dealing with noise and vibration from construction activities. This is reproduced in Table 12.4. Although these pecker measurements were in an L_{AFmax} metric, for an impulsive source the difference between fast and slow weighting would be several dB, larger than seen for the underground trains. Even accounting for that, measurement of L_{AFmax} 40dB indicates that the Vanguardia re-radiated noise limit of 25dB L_{ASmax} was significantly breached, and could not have allowed any recording to take place. The vibration was only sampled at one position on the eastern boundary wall and in one axis, at building ground level. A sample read 0.44mm/sec which can be magnified on suspended floors, so it is reasonable to assume the Vanguardia occupants' vibration limit of 0.5mm/sec was approached if not breached at certain locations. Were the pecker in use at Tr 2 and were tri-axial measurements in place closer to that trial pit, then it is possible the Vanguardia structural vibration limit might also have been approached or exceeded, depending upon the actual proximity of the pecker and the nature of any obstructions and their coupling.

Construction Effect	Maximum Level not to be exceeded in all the studios (Vanguardia[4] Provisional Targets)
Internal Noise	NR20
Re-radiated noise	25dB L_{ASmax}
Vibration for occupiers	0.5mm/s
Structural Vibration	3.0 mm/s

12.5. It is to be noted that, at the outset Air Studios enquired upon the possible use of a pecker and were informed by the Applicants' representative that they did not expect to be going to a depth where they will be required to break up obstructions. Yet it was evident a pecker mounted on a small digger was being used to remove a concrete hardstanding near the surface, the spoil is shown in Plate 12.5 and level of hardstanding shown in close up.

12.6. It is significant to note that the Applicants' representative confirmed to seek to undertake the noisiest works between the hours of 8am and 10am on the days the studios were in use, having been informed that recording that particular week on the days of studio use would begin after 11am. It was therefore surprising to see the pecker, an obvious noisy activity, being used without regard to that arrangement, and persisting in use through the middle of that day during which studios were timetabled for use. Such breaches of a voluntary arrangement would understandably undermine confidence in any future arrangements. Experience shows that disturbance and disruption is almost guaranteed to take place, despite any prior arrangements given with the best of intentions or for expediency. There is therefore a net impact, which will not be eliminated and the evidence of arrangements failing on the small minor works here are a reasonable indicator to the future. Furthermore, the events show that even minor works are very intrusive and incompatible for recording studio use.

12.7. It is understood that Air Studios recorded the intrusion, and will be able to demonstrate such recordings to the Council.

13. GROUNDBORNE NOISE AND VIBRATION MONITORING CONSIDERATIONS

13.1. It is not within the scope of this report to discuss this in any detail. The following points are considerations that need to kept in mind when preparing the monitoring specification that would ultimately need to be developed and agreed.

13.2. It has already been suggested[4] that simultaneous internal and external airborne noise monitoring should form part of the monitoring strategy. Groundborne paths can generate noise within the Air Studios building, which might be attributed to airborne sources coming from directions unrelated to the site. It is therefore recommended that in addition, synchronised vibration measurements should accompany the noise measurements, and that vibration measurements should be deployed at strategic locations which help ascertain correlation to groundborne sources directly connected to the construction site. It is recognised that Vibration measurements will in any case be required to safeguard against nuisance to occupants, safeguard sensitive equipment and protect the building, although measurements for correlation with noise can require different considerations and choices.

13.3. There are other specialised measurements related to benchmarking that will be necessary to safeguard Air Studios, but are outside the scope of this report. These will need to be discussed should the planning application progress further.

14. CONCLUSIONS

14.1. The information submitted to the Council to date is not sufficient to enable CED to advise Air Studios that the Applicants' proposals will be policy compliant, in so far as structural dynamics, ground dynamics and coupled effects can affect Lyndhurst Hall.

14.2. The information does not enable CED to assess the extent of disturbance to their sensitive activities on account of groundborne noise and vibration, both from construction activities or from changes in ground dynamic transmission paths that could alter long term impact from the underground trains, or other traffic.

14.3. The settlement related issues, have potential adverse impacts on dynamic performance of the studios, and the acoustic integrity of the fabric of the building.

14.4. A case is made that the high standards of acoustics that were sought out with expert advice and achieved when the former chapel was converted into studios back in 1991, are the design standards that should be upheld and enforced.

14.5. What is certain is that the minor works undertaken in December 2015 in relation to the archaeological trial pits caused significant impact, and would have made recordings within the Main Hall impossible.

14.6. The arrangements that were promised in relation to the minor works of the Archaeological trial pits were not observed by the Applicants' contractor, and shows that whatever conditions might be sought, there will inevitably be adverse impact.

14.7. It is clear that there are significant risks to the activities of Air Studios, and the systems that will give rise to such outcomes are inherently complex, with high degrees of associated uncertainty.

14.8. The question remains what burden can be placed upon Air Studios, given there is little or no mitigation to remedy the outcomes described, many of which are irreversible, and certainly any that might be attempted come with further protracted consequences to the business and its reputation as a world class recording facility.

14.9. There are unacceptable risks to the recording studio facilities, particularly if the matters raised are superficially reviewed, since the mechanisms that can give rise to adverse impacts are complex, interrelated and will require expert analysis by specialists in geophysics and structural dynamics.

15. ANNEX A – Basic Guide on Acoustic Terminology

15.1. The decibel dB is derived as a logarithmic ratio of sound pressures (re 20μPa).

15.2. Measurement of sound levels involves a kind of averaging process in which the fluctuating pressure signal is squared, averaged and the square root obtained. This is known as rms averaging and takes place over a defined time interval. There are two standard averaging times, 1 second, known as 'S' response and 0.125 seconds known as 'F' response, which better reflects the response of the human ear.

15.3. The A weighting in Sound Pressure Level dB(A) makes the noise meter approximately match the human auditory response that varies according to the magnitude change of sound pressure and its differential sensitivity to different frequencies. dB(L) signifies linear or unweighted.

15.4. As the level of sound often fluctuates up and down, L_{eq} is a notional steady level, which over a given period of time delivers the same sound energy as the actual time varying sound over the same period. Fluctuating levels can thus by this metric be described in terms of an equivalent level. $L_{Aeq,T}$ shows the A weighted version, and the Time Period over which the equivalent level is determined is stated as T.

15.5. $L_{A90,T}$ is the A weighted noise level exceeded for 90% of the specified measurement period (T). It can be taken to indicate the background noise level.

15.6. L_{AFMax} is the maximum value that the A-weighted sound pressure level reached during a measurement period using a Fast time constant 'F'. The Slow time constant can also be used, signified 'S' (L_{ASMax}).

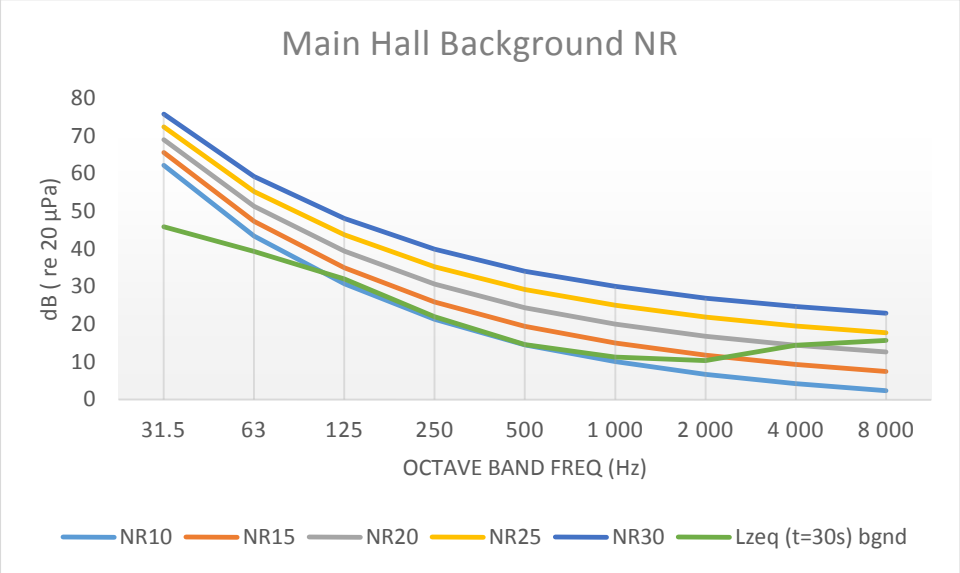
15.7. A doubling in the amount of energy in sound (e.g. putting two identical sound sources close together) causes an increase of 3 decibels, which is noticeable but certainly not a doubling in the perceived loudness. As a guide it takes a 10 dB(A) increase for a doubling of perceived loudness or a 10 dB(A) decrease for a perceived halving of loudness.

15.8. One third octave is a frequency band in which the ratio of the upper frequency limit to the lower frequency limit is equal to one third of an octave and provides better resolution than the octave band which is an interval where the upper frequency limit is double the lower frequency limit.

15.9. Noise Rating (NR) is a graphical method for rating a noise by comparing the noise spectrum with a family of noise rating curves.

16. ANNEX B: Main Hall – Background Sampling for NR.

16.1. Fig 16.1 below shows a background sample taken at location nB (see fig 6.10). It represents a quiet 30 second sample, on the evening of Monday 7th December 2015 at 8.50pm, when the hall was accessible and empty. The heating and ventilation system was not disengaged as there was no recording within the hall at the time, and so could be operational according to demand. Adjacent Studio 1 was in use, although the actual activity within is unknown. Background lighting was on, with the main Metal Halide lights switched off. The noise at and above 2kHz is influenced by instrument noise. The noise rating from this sample is below NR15. As it has similarities to background sample measurements taken by Vanguardia[4] at other times, no further samples are reported here.



17. ANNEX C : TFL Accompanying Letter and Drawing

Transport for London
London Underground

London Underground
Infrastructure Protection

3rd Floor
Albany House
55 Broadway
London SW1H 0BD

www.tfl.gov.uk/tube

Your ref:
Our ref: 20403-SI-N044

Dr Ather Sharif
CED
aks@vibration.co.uk

23 November 2015

Dear Ather,

Lyndhurst Hall Lyndhurst Road Hampstead London NW3 5NG

Thank you for your communication of 20th November 2015.

Attached is a 1:1250 plan @A4 showing the alignment and tunnel crown levels of the Northern line in relation to the above location.

Please note:

- the positions of the tunnels on this plan are indicative only and must not be used for design purposes
- for more accurate tunnel location information a survey will need to be undertaken
- this letter must be distributed with the drawing which it refers to

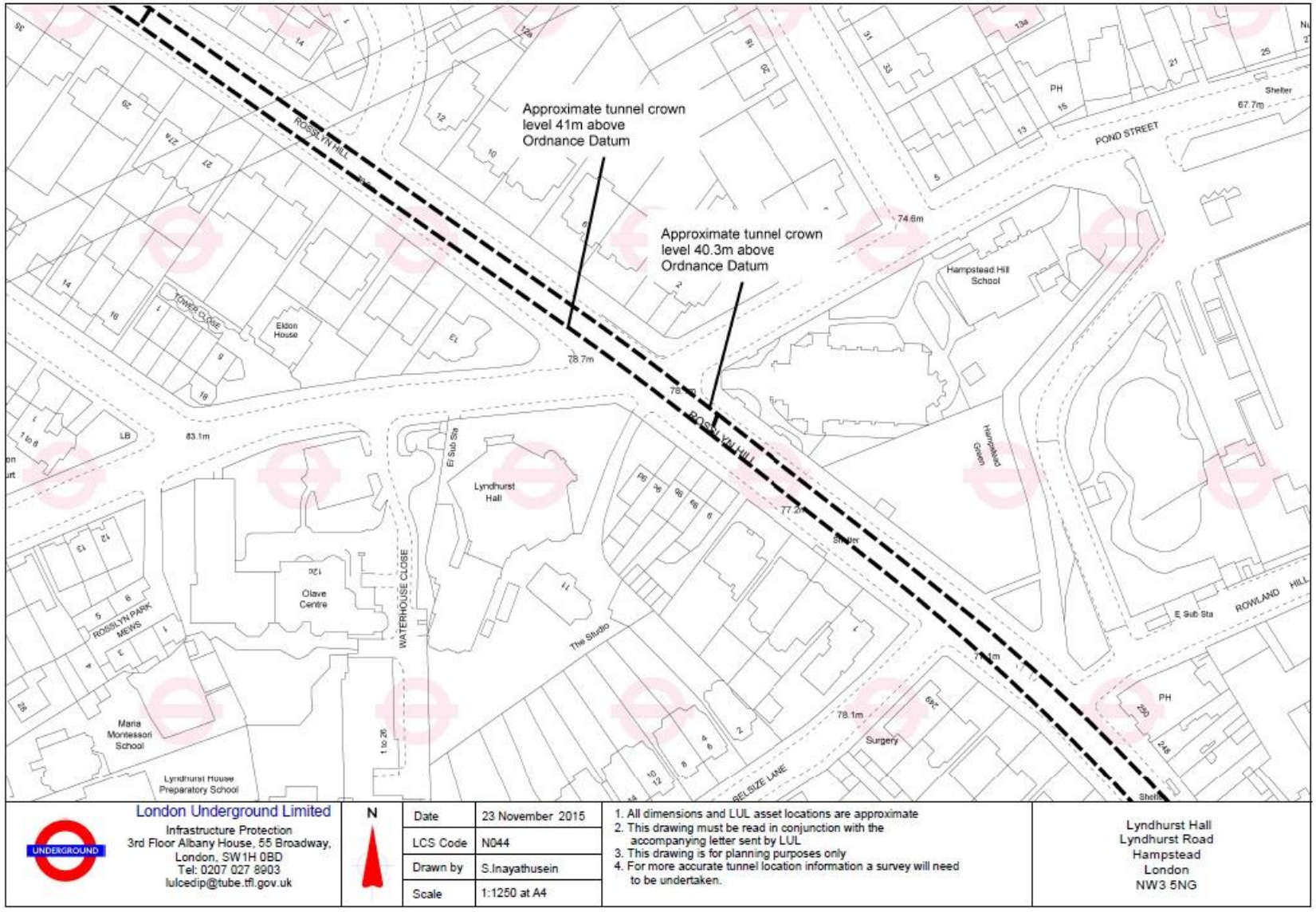
If you or any other intends undertaking, the following at the above location London Underground Infrastructure Protection must be provided with details of the proposals so that the safety of our railway can be assured:

- demolition
- structural works
- excavation
- boreholes or piling
- highway works above shaded areas

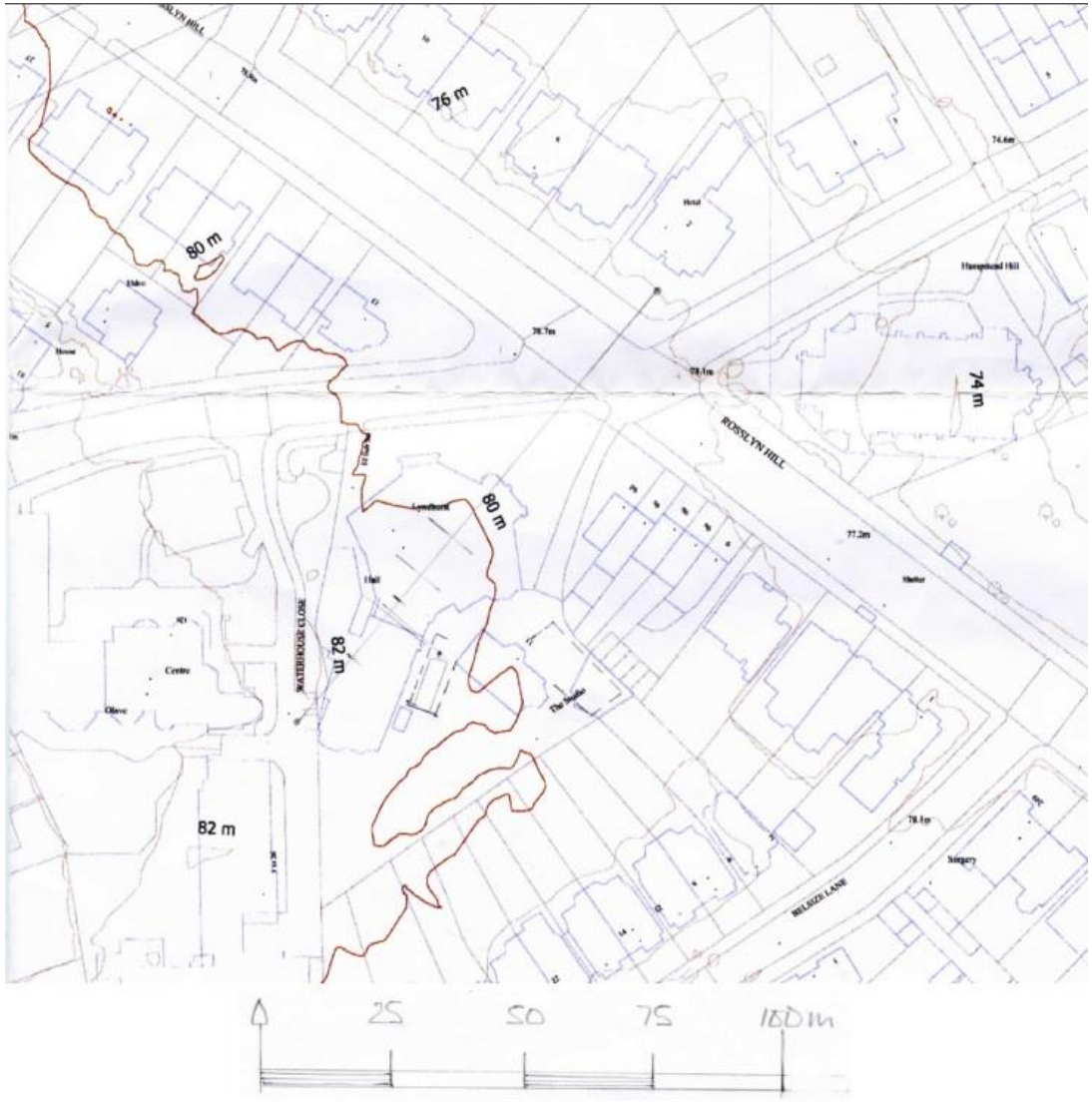
If I can be of further assistance, please contact me.

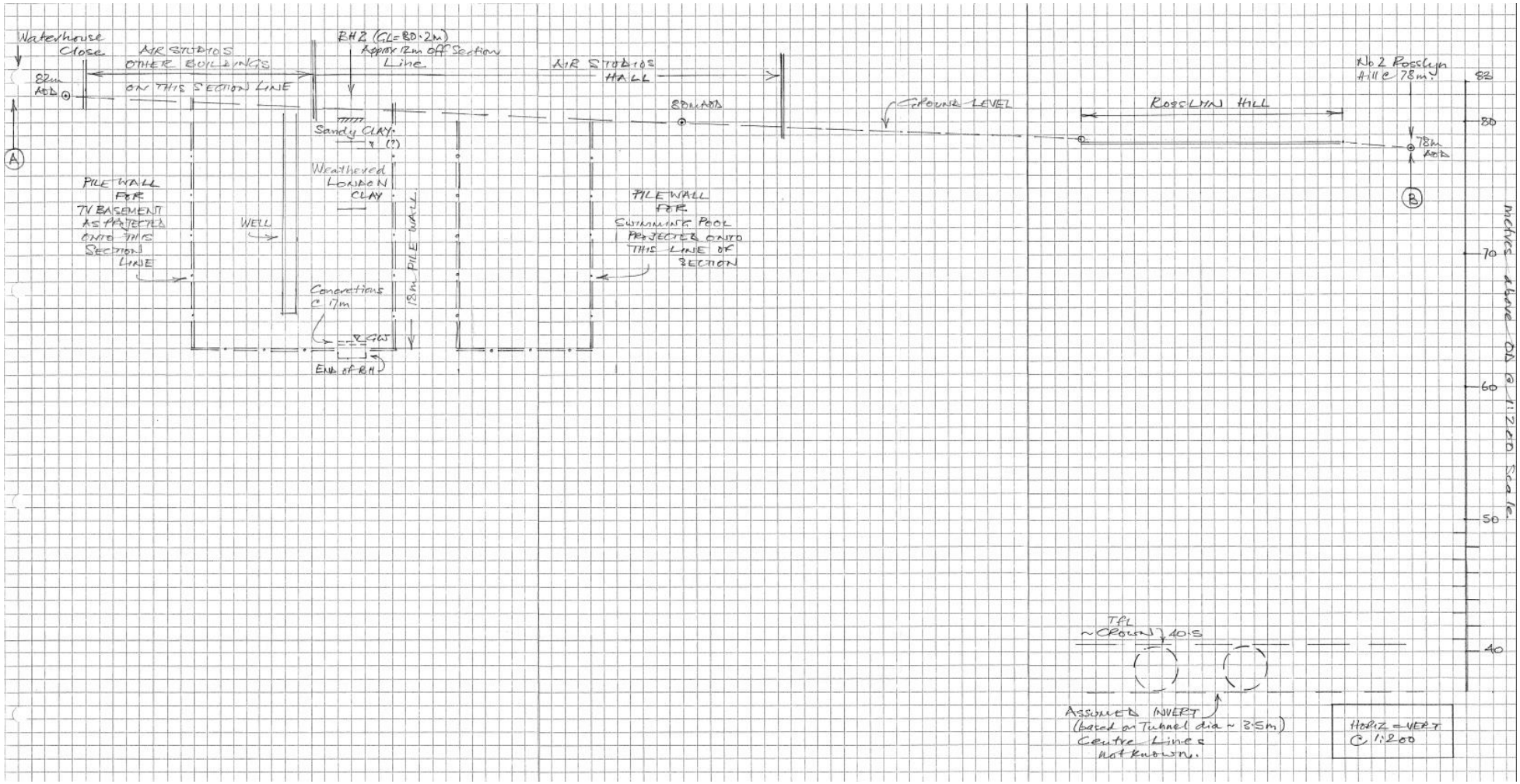
Yours sincerely

Shahina Inayathusein
Information Manager
Email: locationenquiries@tube.tfl.gov.uk
Direct line: 020 7918 0016


Approximate tunnel crown level 41m above Ordnance Datum
Approximate tunnel crown level 40.3m above Ordnance Datum
ROSSLYN HILL
POND STREET
ROWLAND HILL
BELSIZE LANE
WATERHOUSE CLOSE
TOWER CLOSE
ROSSLYN PARK MEWS
Elton House
Lyndhurst Hall
Olave Centre
The Studio
Maria Montessori School
Lyndhurst House Preparatory School
Hampstead Hill School
Hampstead Green
Surgery
E Sub Sta
PH
Shelter
74.6m
78.7m
83.1m
77.4m
78.1m
67.7m
London Underground Limited
Infrastructure Protection
3rd Floor Albany House, 55 Broadway,
London, SW1H 0BD
Tel: 0207 027 8903
lulcedip@tube.tfl.gov.uk
N
Date 23 November 2015
LCS Code N044
Drawn by S.Inayathusein
Scale 1:1250 at A4
1. All dimensions and LUL asset locations are approximate
2. This drawing must be read in conjunction with the accompanying letter sent by LUL
3. This drawing is for planning purposes only
4. For more accurate tunnel location information a survey will need to be undertaken.
Lyndhurst Hall
Lyndhurst Road
Hampstead
London
NW3 5NG

18. ANNEX D : Site Plan and Section including approximate location of LUL Tunnel





Section Provided by Courtesy of Dr DeFreitas, First Steps Ltd.

19. ANNEX E: Equipment List

19.1. Vibration

19.1.1. CED Lance accelerometers, type LC0116A , ch1 (s/n 106), ch2 (s/n 107), ch3 (s/n 108), ch4 (s/n 109)
19.1.2. CED Lance signal conditioner (s/n 4029)
19.1.3. National Instruments (NI) USB6343 X series data acquisition card (s/n 170F94D)
19.1.4. A Bruel and Kjaer (B&K) 4294 calibrator (s/n 1884114)
19.1.5. The accelerometers were calibrated at the start and checked at the end of each survey, with no drift.

19.2. Noise

19.2.1. A Bruel and Kjaer (B&K) 2250 type 1 noise meter (s/n 2626220)
19.2.2. A Bruel and Kjaer 2238 type 1 noise meter (s/n 2343771)
19.2.3. A Bruel and Kjaer 4231 calibrator (s/n 2309713)
19.2.4. The meters were calibrated at the start and checked at the end of the survey, with no drift.

20. ANNEX F: Abbreviations used for some Organisations

20.1. (ABA) Alan Baxter & Associate
20.2. (CED) Civil Engineering Dynamics
20.3. (CJ) Cole Jarman
20.4. (FSL) First Steps Ltd
20.5. (PMA) Paul Mew Associates
20.6. (SBA) Sandy Brown Associates