NRE3.2

Proof of Evidence – Vibration (Mr Lynden Spencer-Allen)

(Inquiries Procedure (England & Wales) Rules 2004)

January 2022

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CAMBRIDGE SOUTH INFRASTRUCTURE ENHANCEMENTS VIBRATION PROOF OF EVIDENCE

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1. INTRODUCTION

1.1 Qualifications and Experience

1.1.1 My name is Lynden Spencer-Allen.

1.1.2 I am employed by Ramboll UK as a Director with responsibility for vibration engineering. I am a chartered civil engineer with 17 years' experience following graduating with a Master of Engineering degree from University of Cambridge (UoC). For the last 12 years I have specialised in vibration engineering.

1.1.3 A particular area of expertise for me is the design and assessment of science buildings for low vibration environments. I have a detailed knowledge of the Cambridge Biomedical Campus having been involved in the design of three buildings on the site. In particular, I provided vibration measurement surveys for the University of Cambridge Anne McLaren Building (AMB) and have provided vibration consultancy advice for potential new developments at the Medical Research Council (MRC) Laboratory of Molecular Biology.

1.2 Involvement in the Scheme

1.2.1 I have been involved with the Cambridge South Infrastructure Enhancements Project (CSIE Project) since September 2020 when Ramboll were instructed to carry out the scoping of the vibration chapter of the environmental statement. We were subsequently appointed in December 2020 to complete the vibration chapter of the Environmental Statement (ES).

1.2.2 I was responsible for the work undertaken by Ramboll during the periods above and had direct involvement in reviewing and approving the ES chapter.

1.2.3 Since the Transport and Works Act Order (TWAO) submission I have been involved in ongoing stakeholder engagement with the MRC and UoC to discuss their objections. I have developed and refined analyses and mitigation options and written technical notes that have been issued to MRC and UoC.

1.3 Scope and Structure of the Evidence

1.3.1 The proof of evidence is structured as set out below.

1.3.2 Section 2 provides an overview of the CSIE Project and the key aspects for vibration;

1.3.3 Section 3 sets out the legislative and policy context;

1.3.4 Section 4 gives a background to the stakeholder engagement undertaken through the ES; and since submission of the TWAO;

1.3.5 Section 5 contextualises the vibration sensitivity of the key receptors;

1.3.6 Section 6 sets out the findings of the ES and further assessment work for the receptors with a predicted significant adverse impact;

1.3.7 Section 7 summarises the two objections raised relating to the proposes from a vibration perspective;

1.3.8 Section 8 provides a response to the specific aspects raised in the Objectors' objections and statements of case regarding effects from vibration; and

1.3.9 Section 9 sets out the conclusions of the proof of evidence.

1.3.10 The technical detail contained within the Environmental Statement Chapter 6.1 is not reproduced within this document but relevant aspects are summarised within their respective chapters.

2. CSIE PROJECT OVERVIEW

2.1 Summary

2.1.1 The CSIE Project will deliver a new passenger railway station and associated infrastructure required to maintain capacity and train performance. Key elements of this comprise:

a) A new railway station with four platform faces including forecourts, pedestrian and cycle access paths, new interchange for taxi and pick up/drop off points, cycle parking spaces, and limited parking for staff/contractors and blue badge holders, together with associated works. The new station will be located between the Cambridge Biomedical Campus (CBC) and Hobson's Park and bordered to the north by the Cambridge Guided Busway;
b) introduction of 2 additional loop lines on West Anglia Main Line (WAML) for the purpose of enabling trains to access the eastern and western platforms in the area of the new station and associated Overhead Line Equipment and signalling;
c) track replacement/modification/additional loop line to the WAML;
d) new Overhead Line Equipment and improvement works at Shepreth Junction and replacement of the GSMR mast;
e) new permanent rail systems compound and associated works to the south-west of Addenbrooke's Road (Nine Wells Bridge);
f) attenuation ponds and drainage works;
g) closure of Dukes No.2 Level Crossing and Webster's Level Crossing over the WAML at Shelford and extinguishment of the existing private access rights over the crossings together with provision of alternative access measures; and
h) replacement open space provision.

2.1.2 Full details of the scheme and its component parts are available in the Proof of Evidence authored by Mr Andy Barnes (NRE1.2).

2.2 Key aspects for vibration

2.2.1 Railways and associated infrastructure can create sources of vibration which can propagate through the ground. The existing railway line has been present for well over 100 years and is already a source of vibration and nearby development has needed to account for the effects of the vibration.

2.2.2 The CSIE Project will create modifications to the existing railway lines and construct new station infrastructure. The key vibration aspects are therefore:
- What are the vibration sensitivities of the receivers?
- What new or elevated sources of vibration are created as a result of the project?
- Are any of these of sufficient magnitude to have a significant effect on the receivers nearby?

2.2.3 The vibration sensitive receptors near to the CSIE project can be grouped as follows:
- Residences near to Shepreth Branch Junction;
- Scientific research institutions on the Cambridge Biomedical Campus;
- Hospital facilities on the CBC;
- Residences near to the area of the station development, albeit these are much further away than the more sensitive CBC receivers.

2.2.4 These receptors are shown on Figure 2 below. Potential vibration impact can occur during both the construction and operational phases and both have been assessed.

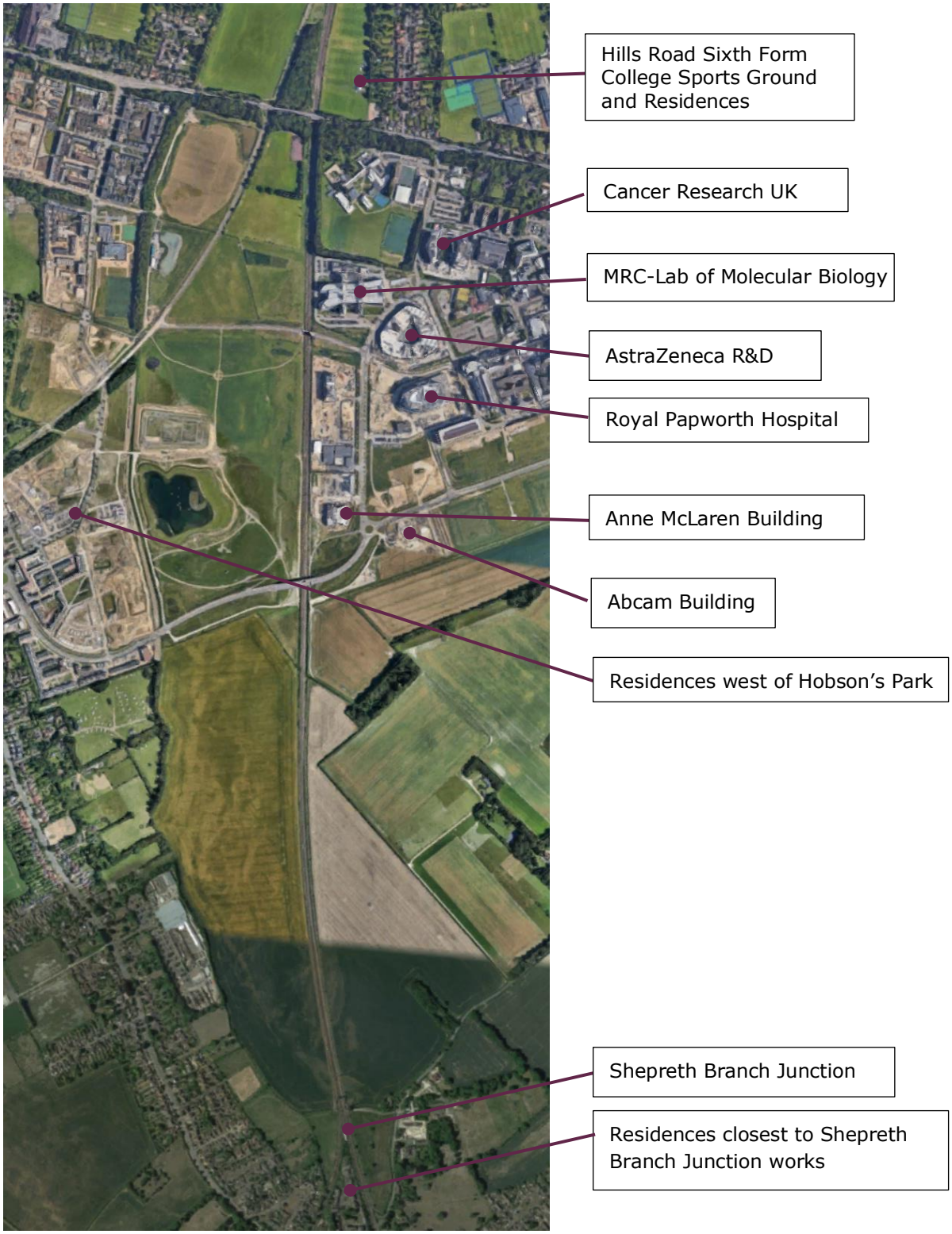

Figure 2 – Overview of the area of the CSIE Project development for context

2.2.5 New and elevated sources of vibration identified

2.2.5.1 The environmental statement[1] provides further detail, but the following aspects were identified as key sources of new or elevated vibration levels:

- Line speed increases through the existing Shepreth Branch Junction on the Royston lines from 30mph to 50mph (refer to ES Chapter 6 6.2.13);
- Construction works to facilitate the above line speed improvements including overhead line equipment works and track geometry changes (refer to ES Chapter 6 6.2.11);
- The change of track layout in the area of the new station to create two bay platforms, in particular the addition of switches and crossings into areas that are currently plain line track (refer to ES Chapter 6 6.1.7 and 6.1.8);
- Construction works in the vicinity of the station area, especially near to scientific research buildings (refer to ES Chapter 6 6.1.3).

2.2.6 Vibration Sensitivity of the Receivers

2.2.6.1 The groups of receivers identified include residential receptors, hospitals and scientific research institutions. These are considered further below.

2.2.6.2 Sensitivity of Residential Receptors

2.2.6.3 The vibration sensitivity of humans in residential settings are well reported and British Standards set out the approach for such assessments.

2.2.6.4 The identified receptors that fall in this category are:

- Residences near Shepreth Branch Junction;
- Residences near Hills Road Sixth Form College Sports Ground;
- Residences west of Hobson's Park.

2.2.6.5 For each of the receptors a Variable Dose Value[2] assessment is undertaken as set out in ES Chapter 6 section 6.2.58 and Table 6-8. This sets out the Lowest Observable Adverse Effect Level (LOAEL) and Significant Observable Adverse Effect Level (SOAEL) as per the ANC Red Book[3].

2.2.6.6 Sensitivity of Hospital Receptors

2.2.6.7 The vibration sensitivity of hospitals is also well defined through the NHS technical standards. These apply to the Royal Papworth Hospital building. Addenbrooke's Hospital is further away and was scoped out of the assessment due to the distance from the railway.

[1] TWAO submission NR 16 Volume 2 Environmental Statement Chapter 06 Acoustics Assessment Part 2 (Vibration) and Volume 3 Appendix 06.1 Acoustics Assessment Part 2 (vibration) included as Core Document NR16

[2] Vibration dose value is the method for assessing vibration effects on humans as set out in BS 5228-2. It allows the magnitude of vibration and the length of time the vibration occurs for to be combined and compared with thresholds of annoyance in humans.

[3] Association of Noise Consultants, Measurement & Assessment of Groundborne Noise and Vibration, 3rd Edition. This publication is considered best practice in relation to the assessment of vibration effects on buildings. Relevant extracts are contained in Appendix A as only printed versions of this are available.

2.2.6.8 The sensitivity of the Royal Papworth Hospital is governed by the medical imaging area at ground floor as set out in the ES Chapter 6 section 6.2.44. For this area the requirements of Health Technical Memorandum 08-01 are used to define the level of sensitivity.

2.2.6.9 Sensitivity of Scientific Research Receptors

2.2.6.10 The vibration sensitivity of scientific research institutions can vary widely dependent on the type of scientific work being undertaken. Consultation with the identified buildings has been used to establish the degree of sensitivity of the facilities which have also been measured as part of baseline vibration surveys in each building. The buildings typically have a general requirement for low vibration with areas of more onerous sensitivity for small areas; typically, high powered microscopes and other forms of imaging.

2.2.6.11 The scientific facility receptors are many times more sensitive than residential receptors and dominate the assessment of the CBC area.

2.2.6.12 The receptors relevant to this category are:
- Astrazeneca R&D building
- UoC AMB
- MRC LMB
- Abcam Building
- Cancer Research UK

2.2.6.13 The sensitivity of each of these receptors and background to that sensitivity are set out in the ES Chapter 06 section 6.2.35 to 6.2.46.

2.2.7 Significant Effects due to New and Increased Vibration Levels

2.2.7.1 Each of the identified receptors was assessed for the construction and operational phases in the environmental statement. A summary of the findings after accounting for CSIE Project mitigation are set out below. These are divided into receptors for which a potential significant adverse effect is predicted and those for which there is no significant adverse effect predicted in the Environmental Statement. The receptors with potential significant adverse effects noted below are considered further in this proof of evidence.

2.2.7.2 Receptors with a predicted potential significant adverse effect in the Environmental Statement

2.2.7.3 The **construction works in the Shepreth Branch Junction** area were found to potentially have a significant adverse effect on the nearest residential receptor for short periods whilst some activities are taking place;

2.2.7.4 A potential significant adverse effect was predicted for the **Medical Research Council Laboratory of Molecular Biology** in both the construction and operational phases with a commitment from Network Rail to mitigating the operational phase impacts through the GRIP4 design stage; and

2.2.7.5 A significant adverse effect is predicted on the **University of Cambridge Anne McLaren Building during some aspects of the construction phase** but not in the operational phase**.**

2.2.7.6 These receptors are addressed in more detail within Section 5.2.4.

2.2.7.7 Receptors with no significant adverse effect predicted

2.2.7.8 The Shepreth Branch Junction line speed improvements are predicted to cause an increase in the vibration levels but these are lower than the level to cause significant adverse effects on the residential receptors;

2.2.7.9 No significant effect is predicted for the residential receptors near to the new station area;

2.2.7.10 No significant effect is predicted for the Royal Papworth hospital during the operational or construction phases; and

2.2.7.11 No significant effect during the construction or operational phases is predicted on the Heart and Lung Research Institute, Abcam, AstraZeneca R&D building and the Cancer Research UK building;

2.2.7.12 These receptors are not further detailed in this proof of evidence as no objections relating to the vibration effects for them have been received.

3. LEGISLATIVE AND POLICY CONTEXT

3.1.1.1 The following legislation is relevant to the assessment of vibration effects and has informed the assessment:

- The Control of Pollution Act 1974 (Ref B26), which was introduced to regulate a wide range of polluting activities, including noise and vibration. Parts of the Act have since been superseded by the Environmental Protection Act 1990
- The Environmental Protection Act 1990 (EPA 1990) (Ref B27)

3.1.1.2 The legislation above provides a high-level requirement for the control of vibration but do not set specific requirements for vibration. In addition, *"there are no existing statutory semantic scales that relate magnitudes of noise and vibration to levels of significance in the UK"* (ANC Red Book[4], 3rd Edition).

3.1.1.3 National and local planning policy do set out more specific requirements for the assessment of noise and vibration albeit these are typically more detailed for noise than for vibration. For example, the National Planning Policy Framework (Ministry of Housing, Communities and Local Government, 2021, Ref D1) only references vibration in the context of mineral extraction sites. The Cambridge City Council Local Plan[5] refers to vibration as a potential nuisance in relation to human quality of life. Legislation and policy documents do not cover the situation when the vibration sensitivity of a receptor is governed by very low vibration requirements that are lower than human perception.

3.1.1.4 In the absence of specific legislation in relation to very vibration sensitive facilities the principles of Agent of Change are applied:

3.1.1.5 "[…]. Existing businesses and facilities should not have unreasonable restrictions placed on them as a result of development permitted after they were established. Where the operation of an existing business or community facility could have a significant adverse effect on new development (including changes of use) in its vicinity, the applicant (or 'agent of change') should be required to provide suitable mitigation before the development has been completed." (Paragraph 187, National Planning Policy Framework, Ministry of Housing, Local Government and Communities, 2021)

3.1.1.6 This principle has been used as the basis for the assessment of the onset of significant adverse effects on sensitive facilities which are more onerous than would be required for human occupation alone.

3.1.1.7 The ES chapter sets out the detail of the approach taken to establish the effects on both very sensitive buildings and other receptors including the British and International standards used (ES Chapter paragraphs 6.2.47-6.2.62).

[4] Association of Noise Consultants, Measurement & Assessment of Groundborne Noise and Vibration, 3rd Edition. This publication is considered best practice in relation to the assessment of vibration effects on buildings. Relevant extracts are contained in Appendix A as only printed versions of this are available.

[5] Local Policy: Cambridge City Council (CCiC) Cambridge Local Plan (October 2018) Policy 35: Protection of human health and quality of life from noise and vibration (Ref D6)

4. ENGAGEMENT WITH STAKEHOLDERS

4.1.1.1 Specific stakeholder consultation with reference to vibration impacts was undertaken during the production of the Environmental Statement scoping document and the ES chapter itself. This included consultation with the local authority Environmental Health Officers and building stakeholders.

4.1.1.2 Due to the enhanced sensitivity and criticality for the scientific facility receptors this engagement typically had two or three phases:

- Baseline vibration survey access agreements and discussions with building users during survey periods
- Agreement of the building vibration sensitivity with reference to Vibration Criteria (VC) levels
- Presentation of the findings of the assessment where a significant impact was predicted

4.1.1.3 For each of the stakeholders a good understanding of their sensitivity has been established and agreed. A summary of the consultation is set out below.

Table 4-1 - Summary of consultations during the ES production

Consultee/Contact/Date	Summary of Consultee Issue	How Addressed?
Cambridge City Council EHO/ Adam Finch/ 16/10/20	In agreement with proposed baseline locations proposed and need to liaise with CBC building users to agree the sensitivity requirements	No action for baselines Consultation with CBC building users carried out as set out below
South Cambridgeshire District Council EHO/ Nick Atkins/ 19/10/20	Review of proposed baseline locations for SCDC area. If Shepreth Branch Junction impacts require it, a baseline monitoring location near Davey Crescent/ Granham's Close should be added	A baseline monitoring location for Granham's Close was included and this formed part of the assessment of the construction and operational impact of the proposed development
MRC Laboratory of Molecular Biology/ Stephen Holmes/ 15/01/21 23/03/21	Vibration baseline locations close to electron microscope suite (to east of building) and a general lab space to the west would be acceptable. Equipment sensitivity requirements set out for use in the impact assessment Would like to be updated on the baseline measurements and assessments to agree results and requirements for mitigation	Baseline locations refined to align with requirements. Vibration sensitivity requirements used in the assessment Presentation of findings of impact assessment to Steve Holmes on 23/3/21. The need for mitigation of operational impacts was agreed but that this would need to be finalised based on the detailed design phase.
University of Cambridge Anne McLaren Building/ Deborah Griffith/ 16/02/2021	[16/2/21] Proposed baseline monitoring location, equipment sensitivity requirements advised	Due to operational restrictions it was not possible to take measurements in the building. Permission was granted to use previous data collected during the commissioning of the building for the assessment. The building

Consultee/Contact/Date	Summary of Consultee Issue	How Addressed?
		sensitivity was also confirmed by the building users.
Royal Papworth Hospital/ Adam Olivant/ 25/02/2021	Proposed baseline monitoring location, equipment sensitivity requirements	Baseline location refined to align with requirements Equipment vibration sensitivity requirements incorporated into the assessment
AstraZeneca R&D Centre/ Andrew Smith/ 10/02/2021	Proposed baseline monitoring location, equipment sensitivity requirements	Baseline location refined to align with requirements Equipment vibration sensitivity requirements incorporated into the assessment
Abcam building/ Graham Flack/ 04/02/2021	Proposed baseline monitoring location, equipment sensitivity requirements	Baseline location refined to align with requirements Equipment vibration sensitivity requirements incorporated into the assessment
Cancer Research UK building/ Colin Weir/ 29/01/2021	Proposed baseline monitoring location, equipment sensitivity requirements	Baseline locations refined to align with requirements. Equipment vibration sensitivity requirements incorporated into the assessment
University of Cambridge Anne McLaren Building/ Deborah Griffith/ 07/05/2021	Summary of results from assessment for Anne McLaren Building provided via email with offer of presentation of the findings.	Information provided on results of assessment. Offer of presentation of the findings was not taken up.
AstraZeneca R&D Centre/ Andrew Smith/ 07/05/2021	Summary of results from assessment for AstraZeneca R&D Centre provided to AZ via email. Confirmation from AZ of no comments received 10/5/21	No Action

4.2 Engagement with stakeholders since TWAO submission

4.2.1 Further engagement has been held with the two parties who object to the Order based on effects from vibration, MRC and UoC, since the TWAO submission. This engagement is set out below for each stakeholder.

4.2.2 Further Engagement with University of Cambridge

4.2.2.1 A meeting was held with UoC on 24th September 2021 where the objections and statement of case were discussed and an update on the work being carried out to answer the points raised in those documents was provided.

4.2.2.2 A response to the UoC points including additional technical analysis and information was submitted on 14th October 2021 as Technical Note 5 (Appendix B).

4.2.2.3 A further engagement meeting to run through the response document and discuss any residual points took place on 4th November 2021. Technical Note 8 providing information that was discussed in the meeting was issued following the meeting and is shown in Appendix C.

4.2.2.4 A technical meeting between the author and UoC vibration consultant took place on 8th November 2021 to discuss the detail of the technical points being raised and responses to them. From this a summary of the technical points of agreement was produced.

4.2.2.5 Additional information was provided to the UoC vibration consultant on 1st December 2021 in relation to the remaining operational phase queries that had been agreed. This was contained within Technical Note 9 which is included as Appendix D. As of 6th January 2022, no response disputing the additional technical evidence has been received.

4.2.2.6 Further information on the construction phase has been requested by UoC which is not currently available due to the stage of the project. Engagement with J Murphy and sons, the contractor, is ongoing to seek to provide additional clarity but has not been available as of 6th January 2022.

4.2.2.7 Proposed Heads of Terms for a legal agreement between Network Rail and University of Cambridge were issued in December 2021 to UoC. This included commitments to control vibration during construction. As of 6th January 2022, revisions to the proposed Heads of Terms have been received from UoC on 23rd December 2021 and are being reviewed by the Network Rail team prior to responding to UoC

4.2.3 Further Engagement with Medical Research Council

4.2.3.1 A meeting was held with MRC on 24th September 2021 where the objections and statement of case were discussed and an update on the work being carried out to answer the points raised in those documents was provided.

4.2.3.2 A response to the MRC points including additional technical analysis and information was submitted on 14th October 2021. This was covered in vibration technical note 7 which is included as Appendix E.

4.2.3.3 Weekly engagement meetings with MRC have occurred through later October and November with vibration discussed on the following dates:

- 21st October 2021
- 11th November 2021
- 18th November 2021
- 9th December 2021

4.2.3.4 At the meeting on 11th November 2021 an update on the findings of an additional vibration survey carried out to the north of the MRC LMB was presented. This survey was intended to validate the conclusions of the operational phase assessment in Technical Note 7 which found that further mitigation was not necessary beyond that proposed in the ES. The survey findings provided evidence to support that conclusion and were issued to MRC on 15th November 2021 and are included as Appendix F.

4.2.3.5 A technical meeting with the MRC LMB vibration consultant was held on 16th November 2021 to discuss the findings of the survey and assessment in more detail. The outcome of this was that, subject to final confirmation from them, there was agreement that no significant adverse effect during the operational phase was expected.

4.2.3.6 For the construction phase the technical assessments carried out were reviewed with the MRC vibration consultant. Additional detail was requested to be provided and this was included in Technical Note 10 which is included as Appendix G.

4.2.3.7 As of 6th January 2022 the author's understanding is that MRC are satisfied with the technical assessments carried out which demonstrate that no significant adverse impact should results from the operational and construction phases and that the mitigation to achieve this will be secured through a legal agreement between Network Rail and MRC which is being finalised.

5. UNDERSTANDING THE LEVEL OF SENSITIVITY

5.1 Terminology

5.1.1 To understand the terminology and approach it is important to give some context to the vibration levels that are being used in the assessment and that have been agreed with the stakeholders.

5.1.2 Table 5-1 shows the vibration levels used in the assessment relative to each other.

5.1.3 It is easiest to contextualise vibration levels by starting at the level that humans can just perceive. This is the level just below which you design operating theatres in hospitals such that the surgeons are not impacted by vibration.

Table 5-1 – Vibration levels used in the assessment

Vibration Criterion	Value
ISO-1 (human perception)	100μm/s
VC-A	50μm/s
VC-B	25μm/s
VC-C	12.5μm/s
VC-D	6.25μm/s

The vibration levels refer to the velocity as measured in one third octave bands from 1Hz to 80Hz

5.1.4 For normal office environments you allow vibration levels from four to eight times higher than human perception. For stairs and walkways you allow even higher levels up to 36 times human perception.

5.1.5 For laboratories the vibration requirements generally start below human perception and use a different scale – the Vibration Criteria (VC) curves.

5.1.6 These start at VC-A which is a level approximately half of human perception. VC-B is half that level, VC-C half again etc. VC levels are defined as low as VC-G but with VC-E being a level typically associated with ultra-low vibration levels.

5.1.7 For the two buildings with significant impacts predicted the vibration levels required are between VC-A/VC-C for the AMB and VC-B/VC-D for the MRC LMB. These correspond to between half the level of human perception down to 1/16th of human perception.

5.2 Short term vs long term events

5.2.1 Human perception in relation to occasional vibration events is different to continuous vibration and humans will tolerate higher levels of vibration if they are only occasional. There are established methods for evaluating this, principally the Vibration Dose Value.

5.2.2 There is no parallel for VC levels however; in fact, VC criteria are not defined in terms of their time basis. There is no established definition of whether the VC criteria should apply to vibration levels measured over 1s, 1 minute or 1 hour. Measuring vibration for comparison with the VC criteria requires the data to be averaged over a time period since the criteria are based on root mean square (RMS) levels. The appropriate averaging period is not part of the definition of the VC curves.

5.2.3 This latter point is important for railway induced vibration since the passage of a train is only for a short period of time and any averaging over long periods would reduce the impact further. For construction vibration the effect can be even more pronounced with impact type vibration potentially only occurring for less than 1s.

5.2.4 In the ES the most onerous approach of using the highest 1s vibration levels has been used. For some sensitive spaces that can be a conservative approach as the equipment may not be affected by a single short duration event. Often the criteria are established to prevent resonant build-up of vibration levels and short term events may not occur for long enough to cause such resonance. Using this approach ensures that any potential impacts from vibration are overestimated (and appropriately mitigated) rather than underestimated.

5.3 Occasional Exceedances

5.3.1 The design of most research facilities is based on the premise that typical, regular activities would not exceed the design criteria. This ensures a consistent research environment that allows the users confidence in running experiments. In most cases the goal is not to prevent any exceedances of the vibration criteria but to ensure these are sufficiently infrequent or occur only with prior warning to allow them to be planned for.

5.3.2 Planning a facility with no exceedances of a given criteria is unusual as it places very significant operational constraints and would normally require a significant overdesign of the criteria. It is the author's understanding based on discussions with the MRC and my original involvement in the AMB vibration survey that the intention of the design of both the AMB and LMB was not to avoid any exceedances of the criteria but rather to design for typical activities that occur. The animal facilities in the AMB are understood to have been intended to avoid exceedances of the VC-A criterion even for occasional foreseeable events.

6. FINDINGS OF THE ENVIRONMENTAL STATEMENT AND FURTHER ASSESSMENT WORK

6.1.1 The Environmental Statement Chapter 6 and associated appendices set out the detail of the assessments undertaken for all the identified receptors. As set out in section 2.2 many of the receptors were not found to be significantly affected as a result of the construction or operational phases. On this basis and since there have been no objections relating to these receptors, this proof of evidence does not provide further detail on those receptors.

6.1.2 In the following sub-sections the assessment for each of the three receptors where significant residual effects are predicted are set out in more detail.

6.2 Residential Receptors near to Shepreth Branch Junction Construction Works

6.2.1 The assessment of the impact of construction works on residential receptors near to Shepreth Branch Junction shows significant adverse effects in two cases:

- When large earthworks operations are undertaken within 30m of a residential receptor;
- When vibratory piling techniques are used at a greater offset and potentially up to 125m away.

6.2.2 Figure 3 shows an extract from the ES Appendix 6.1 showing the relevant offsets from the nearest residential receptors and overlaid with the extent of construction works currently anticipated.

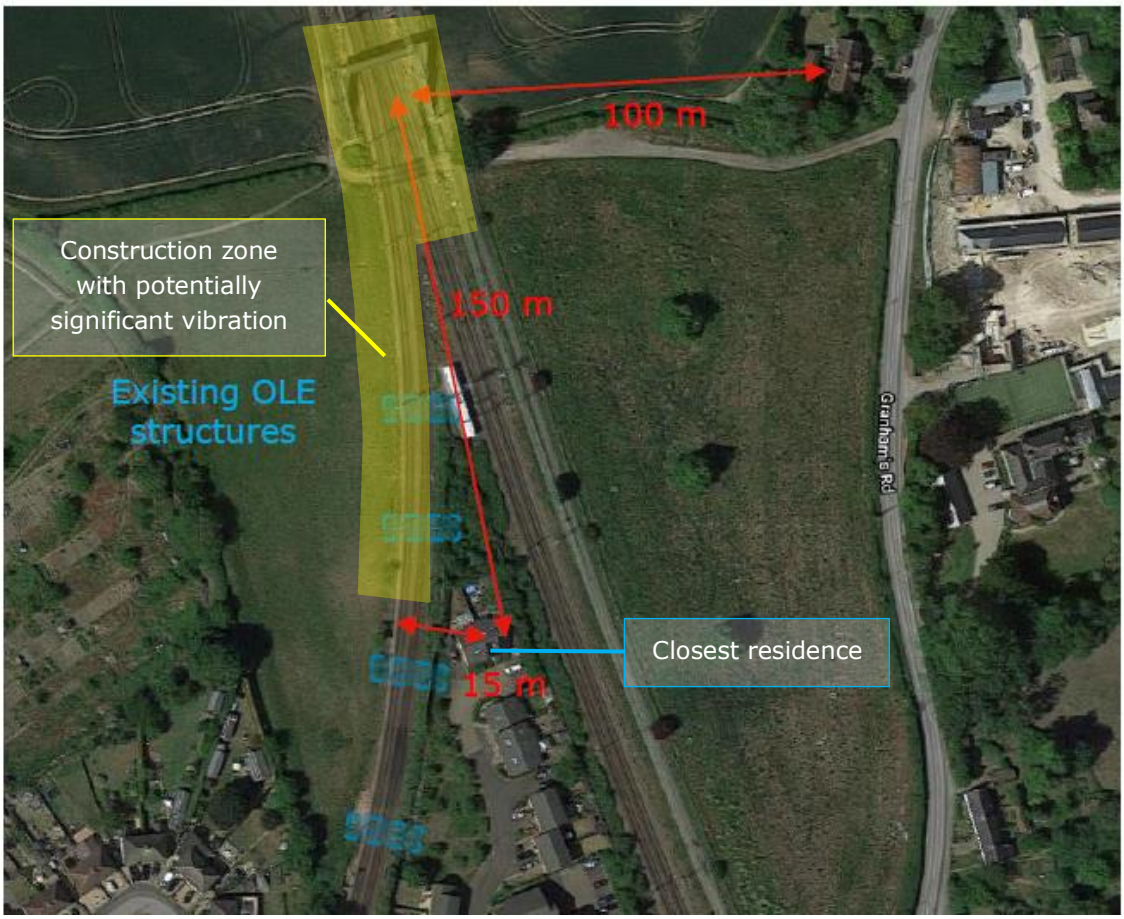

Figure 3 – Figure 6-25 from ES Appendix 6.1 showing the offsets from residential receptors near Shepreth Branch Junction with the likely extent of construction works annotated in yellow

6.2.3 The 30m offset for earthworks is expected to impact on one residence on Abberley Woods. All other residences are a greater distance away and hence the use of vibratory piling is the only potential construction activity that could cause significant adverse effects.

6.2.4 The use of vibratory piling for overhead line foundations is favoured due to the speed of construction. This is especially the case where works must be undertaken in a possession[6] of the railway.

6.2.5 The ES concludes that vibratory piling should be avoided except where it can be demonstrated it is far enough from residential receptors to avoid significant adverse impact or where there is no alternative due to the requirements for works to be completed within a possession of the railway.

[6] A possession is where trains are stopped from running and maintenance work takes place on the track. These are organised a long time in advance and have a finite time period to avoid disruption to the operations of the railway.

6.2.6 The choice of vibratory piling technique can lead to far lower vibration energy imparted to the ground than some methods and those used in the ES assessment that are available from published sources. The use of a Movax has been under consideration which offers the potential for much lower vibration levels and a smaller offset being possible. This can be further investigated by the contractor to establish the appropriate offset limit.

6.2.7 The ES concluded a potential significant adverse effect from this activity in the absence of more specific detail on the equipment proposed to be used. One residence is very close to the area of construction works and is likely to be the only property with levels sufficient to result in a significant adverse effect. Given the short duration of works (expected to be less than 2 days in the immediate vicinity) for the installation of overhead line equipment foundations it is considered that) forewarning and communication of the timings of works would be sufficient to mitigate adverse impact. If the selected piling method has lower vibration levels that that used in the assessment this may not be necessary.

6.2.8 The Code of Construction Practice Part B is the appropriate method to establish the detailed mitigation methodology and where any residual significant impact can be addressed, however it is clear from the above that this is achievable.

6.3 University of Cambridge Anne McLaren Building

6.3.1 Sensitivity of the receptor and baseline measurements

6.3.1.1 The Anne McLaren Building houses scientific research activity that is very sensitive to vibration. The specific requirements were established through engagement with the stakeholders as requiring VC-A for the building across most of the building with one area requiring VC-C on the ground floor at the south-east of the building.

6.3.1.2 These requirements are included in the ES and form the basis of the assessment.

6.3.1.3 Baseline vibration measurements were not possible to undertake during the production of the ES due to restrictions on access to the building at the time. Instead, vibration survey data collected by Ramboll from when the building was being commissioned was agreed to be used with the University. This survey data showed the VC-A criterion was being achieved over a 60 hour period in which video footage was used to correlate train pass-bys and the vibration levels within the building. VC-C was typically being achieved but there were some short term exceedances of the criterion during freight train pass-by events which was within the expected operating parameters. Limited freight trains passed during the survey period with the two that passed by causing an exceedance of the criteria for less than 10s for each event.

6.3.2 Construction stage impacts

6.3.2.1 The ES examined the likely construction vibration based on the techniques anticipated at that time. The AMB is situated as shown in Figure 4. The AMB is a minimum of 165m from the new station and 50m from the current track.

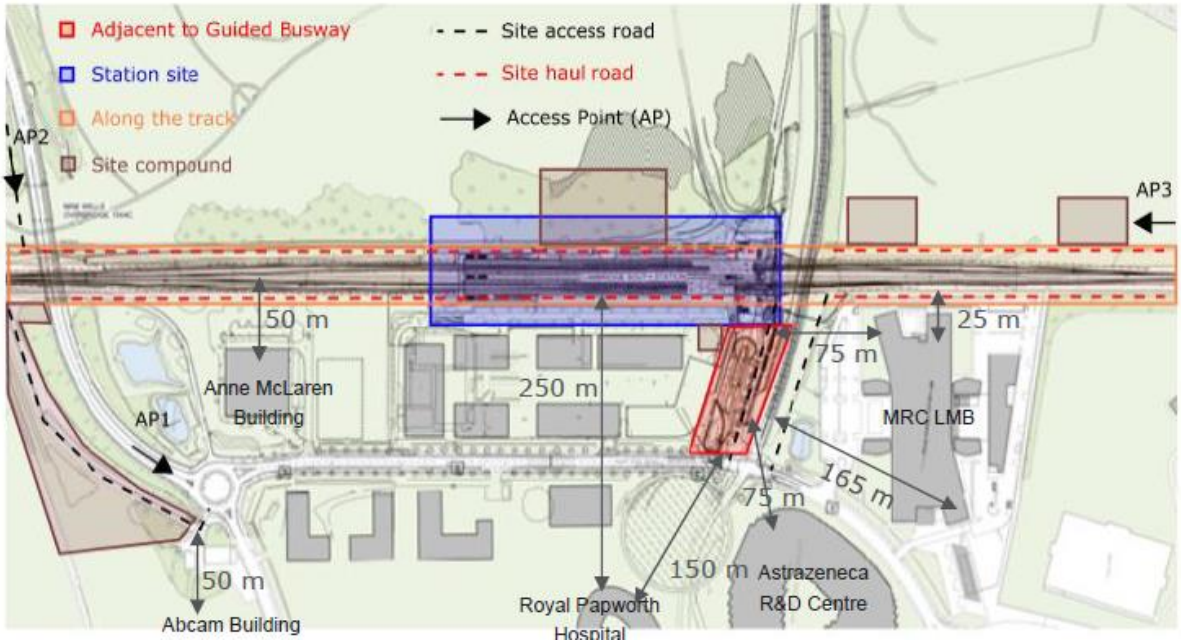

Figure 4 – Extract from ES Figure 6-23 showing the location of the AMB in relation to the construction activities

6.3.2.2 There are three primary aspects to be considered for the AMB in relation to construction vibration:

- The station construction area;
- The haul roads to the east and west of the track;
- The track and overhead line works to the south of the station area and nearest to the AMB.

6.3.2.3 Two distance offsets were used to establish the likely vibration levels corresponding to these areas: 50m for the haul road and track works and 150m for the station area.

6.3.2.4 Table 6-2-5 in the ES Appendix 6.1 tabulated a variety of construction activities in terms of their Peak Particle Velocity (PPV) levels at these two offsets. This is reproduced in Appendix H.

6.3.2.5 PPV is the typical assessment methodology for construction vibration and is the parameter in which data is published such as in BS5228-2. It is not an ideal parameter to be compared to the VC criteria however since there is no frequency information which is important for comparing with VC-A and VC-C, in this case. However, an approximate comparison can be made. In order to compare PPV with the VC criteria an approximate conversion is required and this is set out in Appendix I.

6.3.2.6 This conversion results in VC-A corresponding to a PPV of 0.14-0.19mm/s and VC-C 0.035-0.05mm/s

6.3.2.7 Predicted vibration levels within the building

6.3.2.8 The PPVs presented in the ES are those for vibration levels in free-field – ie as if the building was not present. The vibration levels within the building at ground floor level will be lower than the free-field levels would be. However, there is also expected to be an amplification from the levels measured at ground floor and typically the reduction in vibration levels from free-field into the building are offset by amplifications onto upper floors. This simplification is used as a first-order estimate appropriate to the assessment of the number of different buildings required as part of the ES.

6.3.2.9 This effect has been set out in more detail in Technical Note 5 that was issued to UoC as part of the post TWAO submission engagement and this is included in Appendix B. That analysis concludes that this approach is appropriate for upper floors but that a vibration level reduction by a factor of 2 could be applied to the ground floor. This means the vibration level measured in the building would be half that predicted through the BS5228 methods. This reduces the impact of each activity for the ground floor and this has been accounted for in Technical Note 5 and below.

6.3.2.10 Predicted Impacts from the Station Area

6.3.2.11 Table 6-2-5 (Appendix H) shows that at 150m offset all activities except for vibratory pile driving create vibration levels lower than 0.19mm/s. Vibratory pile driving was therefore excluded as an option due to the sensitivity of the surrounding receptors but included in the table for reference only.

6.3.2.12 The more sensitive VC-C area was not separately assessed in the ES but has been addressed in Technical Note 5 issued to UoC in October 2021 and included as Appendix B. An extract is shown below where the relevant construction activities have been scheduled out.

Table 5-1 – AMB predicted PPV levels for the construction activities identified

Legend			BS 5228-2 2009: Code of practice for noise and vibration control on construction and open sites		Table D.6 BS 5228-2 2009, historic data 95th %-ile	Transportation and Construction Vibration Guidance Manual (September 2013) - California Department of Transportation Division of Environmental Analysis			From previous measurements	
>0.38mm/s			Vibratory compaction (steady state)	Vibratory compaction (start up and run down)	Rotary Bored piling	Vibratory roller	Large Bulldozer	Loaded trucks	360-degree excavator operating	360-degree excavator digging
0.19 mm/s < PPV< 0.38 mm/s ie VC-A equivalent at gr										
0.1 mm/s <PPV< 0.19 mm/s ie VC-A equiv at upper flo										
PPV < 0.1 mm/s ie VC-C equiv at ground floor										
	Distance from activity [m]	*Construction Zone*	PPV [mm/s]							
Anne McLaren Building	50	Track Works	0.19	0.27	N/A	0.18	0.20	0.17	0.16	0.27
	90	Track Works	0.08	0.13	N/A	0.08	0.09	0.08	0.08	0.13
	150	Station Area	0.04	0.07	0.03	0.04	0.05	0.04	0.04	0.06
	200	Station Area	0.02	0.05	0.02	0.03	0.03	0.03	0.03	0.04

Figure 5 – extract from Appendix B (Technical Note 5) which shows the updated construction vibration assessment for AMB

6.3.2.13 The PPV levels in this table are predicted free-field levels for four distance offsets relating to the distance of construction activity. As they are free-field levels they need to be compared with the PPV-VC criteria equivalents after allowing for the building effect which is set out below. For the station area construction offset distance the bottom two rows are relevant.

6.3.2.14 For ground floor VC-A areas the expected reduction of vibration levels into the building is between 2 and 4 times and hence allowable PPVs of 0.28-0.76mm/s[7]. It is seen that all activities of 50m away or more are below this range and therefore exceedance of VC-A at ground floor is not expected.

6.3.2.15 For upper floor VC-A areas the expected reduction of vibration levels into the building is to be compared with free-field PPV levels[8] and so a range of 0.14-0.19mm/s is used. It is seen that all activities from the station area are below these levels.

6.3.2.16 For the ground floor VC-C area the expected reduction of vibration levels into the building is between 2 and 4 times and hence allowable PPVs of 0.07-0.2mm/s[9]. The VC-C area is 200m from the station area construction and all the results in this row are below this range and therefore exceedance of VC-C due to station construction is not expected.

6.3.2.17 Predicted Impacts from the Haul Road/Track Works

6.3.2.18 The haul road and track works are significantly closer to the AMB than the station area. Technical Note 5 in Appendix B (Figure 5 reproduced above) provides a refined analysis of the construction vibration impacts. The upper two rows show the relevant offset distances for the closest track works to the building. 50m is the closest distance to the building for comparison with the VC-A criteria and 90m is the closest distance to the VC-C area.

6.3.2.19 For ground floor VC-A areas the expected reduction of vibration levels into the building is between 2 and 4 times and hence allowable PPVs of 0.28-0.76mm/s. It is seen that all activities of 50m away or more are below this range and therefore exceedance of VC-A at ground floor is not expected.

6.3.2.20 For upper floor VC-A areas the expected reduction of vibration levels into the building is to be compared with free-field PPV levels and so a range of 0.14-0.19mm/s is used. It is seen that some construction activities may exceed this range and the remainder are within this range. For any construction activities that produce vibration within the frequency range amplified by the building upper floors there is a risk of exceedance of the criteria. The maximum predicted exceedance is a factor of 2. Further from the construction activity this potential exceedance would be lower; the 90m offset row shows all the activities are expected to be below the range.

6.3.2.21 For the ground floor VC-C area the expected reduction of vibration levels into the building is between 2 and 4 times and hence allowable PPVs of 0.07-0.2mm/s. The VC-C area is 90m from the closest track works and this range is compared to the values within the second row of the table. It is seen that the activities are within the range above. There is therefore a risk that some activity could exceed the VC-C level marginally.

[7] These values are calculated by multiplying 014mm/s-0.19mm/s as shown in Appendix I by the building attenuation factor of 2-4

[8] This is a function of the attenuation factor at ground floor being offset by amplification of vibration at some frequencies on upper floors. At the frequencies expected to be amplified these two effects approximately cancel each other and so free-field levels can be used as the likely levels at upper floor levels. This will be conservative where the construction vibration activities are at different frequencies to the upper floor amplification. This is likely to be the case for non-vibratory vibration activities.

[9] These values are calculated by multiplying the range of 0.035-0.05mm/s by the building attenuation factor of 2-4

6.3.2.22 The original ES assessment concluded significant adverse effect was likely. The refined analysis has however shown that the potential exceedances of the criteria are smaller than set out within the ES chapter but that they could still occur. There is therefore still a potential for significant adverse effects based on the definitions within the ES.

6.3.3 Construction Stage Mitigation proposed

6.3.3.1 The ES proposed that best practicable means should be implemented to mitigate the impact of construction vibration and that the detailed proposals would be included within the Code of Construction Practice part B.

6.3.3.2 The key BPMs proposed were:

1. No vibratory piling;
2. Well-constructed and maintained haul road;
3. Low vibration construction techniques;
4. Enhanced consultation and engagement; and
5. Vibration monitoring with real-time feedback

6.3.3.3 Given the relatively short duration of activities with potential significant adverse impact (haul road construction and track works in the area closest to the AMB) this approach is considered to be appropriate for buildings with this level of sensitivity. This is based on experience that shows that enhanced liaison and prediction of periods of elevated vibration can often be accommodated especially when it is for short periods of time.

6.3.3.4 However, it is since acknowledged that the University consider that the VC-A criterion should not be exceeded at any time due to the potential adverse impact of any higher vibration levels on the animal facility within the building. Technical Note 5 includes a review of the vibration criteria to assess the evidence relating to exceedances of VC-A in relation to animal facilities. It is found that there is very limited evidence on the impact of vibration on animal research. The research that has been published[10] involves much higher vibration levels than the VC-A criterion. One published paper referenced in the UoC Statement of Case (Core Document ref E3) sets out a vibration threshold which should not be exceeded. This threshold is also higher than VC-A by a factor of between 2 and 10 times[11] at different frequencies. It is therefore considered unlikely that some exceedance of VC-A would result in harm provided the exceedances are not above the limits within the published paper.

6.3.3.5 On this basis the following approach has been set out for discussion with UoC:

- VC-A is applied as the criteria and vibration levels during construction mitigated through the use of best practice approaches
- Where it is predicted that vibration levels could exceed this and the length of time and resulting levels have been minimised to practical standards, the levels should not exceed the level of 0.025g RMS[12] as set out in paper 3 of the University of Cambridge Statement of Case (Core Document Ref E3).

[10] Refer to Appendix B Technical Note 5 section 6.2.3

[11] Refer to Appendix B Technical Note 5 section 6.2.3.3

[12] This is an alternative measure for vibration amplitude that is set out in the published paper referenced in the UoC Statement of Case. It relates to the acceleration levels and relates them to the acceleration due to gravity, g

6.3.3.6 As of 6th January 2022, UoC are not in agreement that any exceedance of VC-A would be acceptable.

6.3.4 Operational Phase Impacts

6.3.4.1 The operational phase assessment focussed on the introduction of switches and crossings (S&C) into the railway in an area which is currently plain line. This creates a localised source of higher vibration levels when trains pass over. The location of the new S&C was possible to locate a significant distance from AMB, being over 150m away.

6.3.4.2 An amplification level associated with S&C was measured as part of a vibration survey carried out at Shepreth Branch Junction further to the south. This approach was chosen to:

- Give measurements on a similar geology to the site;
- Give measurements where the line speed is 90mph, the same as for the site; and
- To give frequency dependent values for amplification rather than single value levels as typically in published data.

6.3.4.3 The amplification from plain line track to S&C could then be applied to the vibration levels measured within the AMB from the baseline measurements. This was also modified to allow for the additional distance away that the S&C is compared to the distance to the track currently.

6.3.4.4 This additional distance reduction was carried out on the assumption of a line source[13] effect on a conservative basis.

6.3.4.5 The study found that the VC-A and VC-C criteria would both be achieved in the operational phase and therefore the impact of the development was concluded to not be significant for the operational phase.

6.3.4.6 It should be noted that this was based on the impact of freight trains being scoped out of the assessment since they are sufficiently infrequent to be discounted. This is considered an appropriate approach for sensitive facilities given the low number of freight train slots in the timetable and that many of these do not run; in the 60 hour baseline survey only two freight trains were measured.

6.3.4.7 However, as for the construction phase assessment, it is since acknowledged that the University have set out that the VC-A criterion should not be exceeded at any time due to the potential impact of any higher vibration levels on the animal facility within the building.

[13] A line source propagates as a wavefront through the soil and does not attenuate geometrically in the soil; it only attenuates through material damping. This is compared to a point source which spreads in ever increasing radius circles. These circles have larger circumferences in which the wavefront is spread leading to significant geometrical attenuation in addition to the material damping.

6.3.4.8 As an extra-over approach in recognition of this, the impact of freight trains has been assessed in addition. The detail of this assessment is included in Technical Note 5 in Appendix B. The conclusion is that freight trains are not predicted to cause an exceedance of the VC-A criterion and no significant adverse impact would result if this was included in the assessment.

6.3.4.9 Technical Note 5 also concludes that there is no significant adverse impact from freight trains in relation to the VC-C area. In the conservative scenario modelled, the vibration levels when freight trains pass over the new S&C are very slightly higher than the current baseline levels when a freight train passes next to the site. With the proposed large radius S&C the levels are expected to be lower than this and not exceed VC-C in that area of the building due to trains passing over the S&C.

6.3.4.10 In addition to the effect of the switches and crossings, UoC have questioned the potential impact of the new track being closer to the AMB then the existing track. Technical Note 9 (see Appendix D) was issued to provide evidence that this would not cause a significant adverse effect.

6.4 Medical Research Council Laboratory of Molecular Biology

6.4.1 Sensitivity of the receptor and baseline measurements

6.4.1.1 The MRC LMB is a large building that houses a variety of research equipment. It was designed to achieve the required vibration levels in proximity to the railway and there is a hierarchy of sensitivity with the most sensitive equipment being furthest from the railway.

6.4.1.2 The vibration criteria for the LMB were agreed during the stakeholder engagement to be VC-B for the wings nearest the railway line and VC-D for the north east wing where the most sensitive imaging equipment is. For both of these the highest 1s RMS levels were agreed to be the metric to be used for assessment.

6.4.1.3 Baseline measurements were carried out in two locations within the building to determine the current vibration levels and provide the input for vibration predictions.

6.4.2 Construction Phase Impacts

6.4.2.1 The ES found that some construction activities could lead to elevated vibration levels and potentially lead to a significant adverse effect.

6.4.2.2 The ES proposed that best practicable means should be implemented to mitigate the impact of construction vibration and that the detailed proposals would be included within the Code of Construction Practice part B.

6.4.2.3 The key BPMs proposed were:

1. No vibratory piling
2. Well constructed and maintained haul road

3. Low vibration construction techniques
4. Enhanced consultation and engagement
5. Vibration monitoring with real-time feedback

6.4.2.4 Given the relatively short duration of activities with potential significant adverse impact (haul road construction and track works in the area closest to the LMB) this approach is considered to be appropriate for buildings with this level of sensitivity. This is based on experience that shows that enhanced liaison and prediction of periods of elevated vibration can often be accommodated especially when it is for short periods of time.

6.4.3 Operational Phase Impacts

6.4.3.1 The operational phase assessment for the LMB was carried out using the same methodology as AMB but the key difference is that the switches and crossings are very close to the LMB. The result of this was a prediction that the VC-D criterion for the northeast wing could be exceeded. The VC-B criterion for the wings to the west was not predicted to be exceeded. Due to the exceedance in the northeast wing a significant adverse effect was concluded.

6.4.3.2 The results were presented to MRC during the production of the ES and a commitment to mitigating the vibration levels was set out. The approach to mitigation required the next level of detail on the design proposals.

6.4.3.3 In October 2021 Technical Note 7 was issued to the MRC LMB which provided an update on the mitigations being considered along with a refined analysis of the predicted vibration levels. This technical note is included as Appendix E.

6.4.3.4 The conclusion of the technical note is that the proposed large radius geometry of the new S&C and the refined analysis method results in a much lower vibration level prediction for the LMB. The reduction is of sufficient magnitude that the predictions are below the agreed criteria and that no significant adverse impact would result in the operational phase.

6.4.3.5 Due to the criticality of this assessment the methodology was validated through further site surveys that were carried out to the north of the LMB in late October 2021. The results supported the refined analysis and were presented to MRC in November 2021 with the slides presented and subsequently issued to them shown in Appendix F.

7. OBJECTIONS RAISED

7.1 Summary of Objections Relating to Vibration

7.1.1.1 Two objections that reference vibration have been received. These were submitted on behalf of University of Cambridge and the Medical Research Council in relation to their buildings on the Cambridge Biomedical Campus. Both parties have subsequently had a Statement of Case submitted on their behalf.

7.1.1.2 The following sub-sections summarise the objections and points raised within the Statement of Case. These are then addressed in the following section in turn.

7.1.1.3 In addition to these objections, Cambridge City Council and South Cambridgeshire District Council have also referenced vibration within their statement of cases. These are considered in the following sub sections.

7.2 University of Cambridge Objection and Statement of Case

7.2.1 The University of Cambridge Objection letter (dated 30th July 2021) sets out a number of grounds of objection. Ground 1 relates to Noise and Vibration Impacts and the key points raised are:

1. The AMB is a highly sensitive facility which operates 24 hours a day, 365 days per year and disruption to the vibration environment identified could render the building unusable for scientific research;
2. The vibration criteria set out in the environmental statement are appropriate, but the findings of the ES are that there would be significant impact to the sensitive work being undertaken. There is a concern that it has not been proven to be possible to construct the development without adversely impacting the AMB;
3. A potential concern over impact during the operational phase is also raised; and
4. There are no specific protective measures in the TWAO to protect the University to the satisfaction of the University of Cambridge.

7.2.2 A statement of case was submitted by Mills and Reeve on behalf of University of Cambridge (dated 14th September 2021). This document and its appendices provide a more detailed background to the importance of the AMB to the University and how elevated vibration levels could impact on research being undertaken.

7.2.3 The statement of case sets out the University of Cambridge's specific concerns relating to the construction phase and the operational phase. Additional information is requested in relation to the assessment that has been undertaken to allow the University to assess the potential impacts further.

7.3 Medical Research Council Objection and Statement of Case

7.3.1 The Medical Research Council letter of Objection dated 30th July 2021 sets out the background to the LMB and the criticality of a low vibration environment to the building. The objection is focussed on the impact of construction vibration and how this could severely impact the research being carried out if it exceeds very low levels.

7.3.2 The MRC submitted a statement of case dated 15th September 2021 which provides some further information on the key points of objection. For vibration this mainly refers to the construction phase vibration impact. However, it is also noted that they disagree with the conclusion that there would not be a significant effect in the operational phase as shown in the ES Chapter.

7.3.3 These points are considered in the following section.

7.4 Cambridge City Council Statement of Case

7.4.1 The Cambridge City Council statement of case paragraphs 75 to 77 cover operational and construction phase impacts.

7.4.2 Paragraphs 75 and 76 are related to mitigation for the MRC LMB needing to be determined in the detailed design phase. They set out that a planning condition and a legal agreement between Network Rail and the MRC LMB may be required. This matter is covered in more detail in the MRC LMB section.

7.4.3 Paragraph 77 relates to the construction vibration assessment which concludes the approach is satisfactory and that Best Practicable Means will be implemented and controlled as part of the Code of Construction Practice Part B. There is no further discussion required in relation to this item.

7.5 South Cambridgeshire District Council Statement of Case

7.5.1 The SCDC statement of case paragraph 24 includes the findings of the ES that there is a potential significant adverse impact on residents near to Shepreth Branch Junction. They also acknowledge the planned mitigation steps planned and how these will be secured through the Code of Construction Practice Part B.

7.5.2 They have set out that "It is important to have good and early engagement with the Council and residents on both the mitigation measures and the consultation strategy to minimise the disruption to local residents and impact on mental health."

7.5.3 This early engagement is planned to be implemented to ensure the mitigation is agreed and implemented.

8. RESPONSE TO MRC/UOC OBJECTIONS/STATEMENT OF CASES

8.1.1 This section sets out the responses to the objections and specific points within the statements of case submitted by University of Cambridge and MRC.

8.2 Response to University of Cambridge Statement of Case

8.2.1 Responses to each point in the UoC statement of case is included in Technical Note 5 in Appendix B.

8.2.2 In relation to operational phase vibration the technical note provides an assessment of the vibration levels predicted from freight trains passing over the switches and crossings and demonstrates that these are not predicted to cause significant adverse effects.

8.2.3 The technical note also addresses the other operational phase queries and provides technical justification for each point.

8.2.4 In relation to construction phase vibration the technical note presents additional information on the assessments undertaken and more detail on the background for the AMB. The specific technical queries raised in the UoC Statement of Case are also addressed.

8.2.5 The detail of the refined analysis presented in the technical note and the conclusions from it are included in Section 6.3.2

8.2.6 Subsequent engagement with UoC

8.2.6.1 As set out in 4.2.2 there has been ongoing dialogue with UoC with the aim of reaching agreement.

8.2.6.2 Technical notes 8 and 9 (Appendices C and D) were issued to provide further information following additional queries from UoC. Technical Note 8 provided further information relating to the ground parameters used in the assessment.

8.2.6.3 Technical Note 9 provided details of the assessment of the vibration impact of minor track changes near to the AMB following this being queried by UoC. This showed that there would be no significant adverse effects.

8.2.6.4 As of 6th January 2022, evidence has been provided to UoC to demonstrate that there should be no significant adverse effects from the operational phase proposals.

8.2.6.5 All the requested details of the construction phase are not available at the time of writing and providing the level of detail requested by UoC has not been possible. The construction phase assessments undertaken have shown that no significant adverse effect is predicted except for the closest track works. For construction activity in that area the predictions using available published data show there is a risk of VC-A exceedance on upper floors and a potential marginal exceedance of VC-C.

8.2.6.6 During the period of further engagement with UoC the adjacent building plot for Astrazeneca has commenced construction. The location is shown in Figure 6 and is slightly further than the closest track works for CSIE.

8.2.6.7 UoC have been asked about the construction vibration mitigation that has been implemented and whether any vibration monitoring is ongoing within AMB which could give useful data for the CSIE assessment. Similar construction activity to that proposed for CSIE has been occurring and UoC were asked whether the VC-A and VC-C levels are being achieved and if not whether that has had any adverse effect. No response to this question has been received.

8.2.6.8 Also noted on Figure 6 is the future UoC building plot adjacent to the AMB which is closer than the CSIE track works.

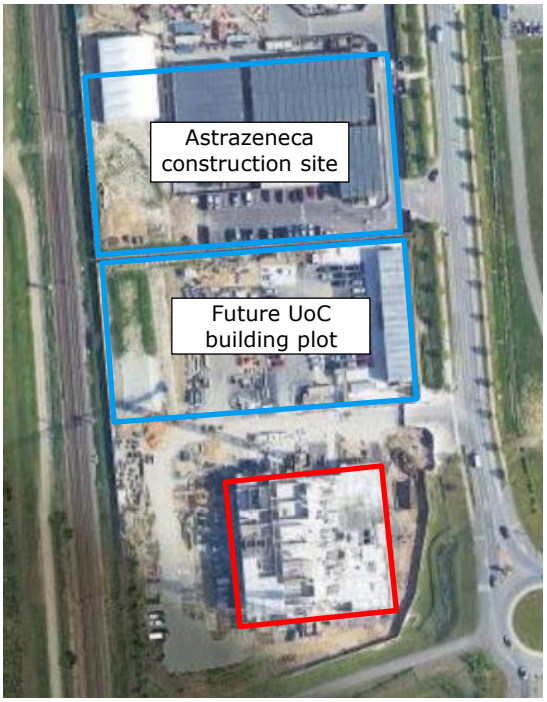

Figure 6 – AMB in relation to the current Astrazeneca construction site

8.2.6.9 As of 6th January 2022, it has not been possible to reach agreement with UoC on the construction phase mitigation that would satisfy them that there would be no overall significant adverse impact if vibration levels higher than their original criteria were to occur.

8.2.6.10 On this basis, to secure agreement, Network Rail have issued proposed Heads of Terms to UoC which give a commitment to providing a detailed construction methodology and assessment in advance of construction, monitoring vibration levels within the AMB and controlling vibration levels during construction to below the VC-A and VC-C criteria in the relevant areas except where agreed otherwise. A formal response from UoC was received on 23rd December 2021 with revised wording of the proposed Heads of Terms which is currently being reviewed before responding as of 6th January 2022.

8.3 Response to MRC Statement of Case

8.3.1 Vibration sensitivity and importance of LMB

8.3.1.1 The importance and sensitivity of the LMB is recognised and was taken into account for the purposes of the ES assessment:

- The vibration criteria used in the assessment were based on the agreed levels established in the stakeholder engagement;
- The vibration criteria are very onerous and commensurate with the level of sensitivity and many times lower than levels which would be perceptible to humans; and
- The Significance matrix of the ES (Table 6-10) and bespoke ES assessment process for the scientific facilities on CBC mean that a significant adverse effect results even when only a Minor increase in vibration occurs. This effectively means that any increase in vibration levels above the established criterion would result in a significant adverse impact.

8.3.1.2 The approach in the ES results in the vibration sensitivity of the building being very well addressed and in line with that set out in the MRC objection and statement of case.

8.3.2 Construction Phase Assessment and Mitigation

8.3.2.1 A potential significant effect during some construction activities for the most sensitive scientific equipment has been predicted. MRC have objected on the basis that any significant effect during construction would be detrimental to their operation.

8.3.2.2 Mitigation is set out within the ES which includes:

1. Avoidance of impact and vibratory piling methods;
2. Well-constructed and maintained haul road;
3. Low vibration construction techniques;
4. Enhanced consultation and engagement; and
5. Vibration monitoring with real-time feedback

8.3.2.3 In the detailed design stages and with a contractor appointed for the scheme more detailed assessments and specific mitigation will be set out and included with the COCP Part B. The specific aspects of the COCP Part B that relate to the MRC LMB will be agreed with them in advance of the formal submission of the document.

8.3.2.4 The LMB has been adjacent to a major construction project for a number of years. The construction of the Astrazeneca R&D building included a significant basement construction, tunnelling works and major building works. At its closest it is less than 100m from the microscopy area of the LMB which is closer than any of the CSIE Project works.

Figure 7 – Aerial image of LMB and Astrazeneca R&C building showing the proximity to the most sensitive area of the LMB building

8.3.2.5 At the Stakeholder meeting with the MRC in September 2021 feedback on the impact of the AZ construction works was given by MRC. This was:

- Generally, there was no significant impact;
- During piling works for the R&D building basement one microscope experienced disturbance which was problematic. This did not occur during other works;
- No specific mitigation measures were implemented to reduce the potential impact.

8.3.2.6 The direct construction activities associated with CSIE would be far less significant than for the AZ building works for the following reasons:

- being at a further distance away;
- smaller construction machinery and less intrusive techniques being proposed;
- the period of relevant construction activity being considerably shorter.

8.3.2.7 From the stakeholder engagement meeting, it appears that if the proposed mitigation measures are implemented, the main concern for the MRC LMB in relation to construction vibration impact is the risk of an indirect effect. The indirect effect of concern is that their vehicular deliveries may be prevented from passing to the west of the building and instead would need to pass to the east and immediately adjacent to their most vibration sensitive areas of the building. Figure 8 shows a markup of the LMB building to highlight the relevant areas.

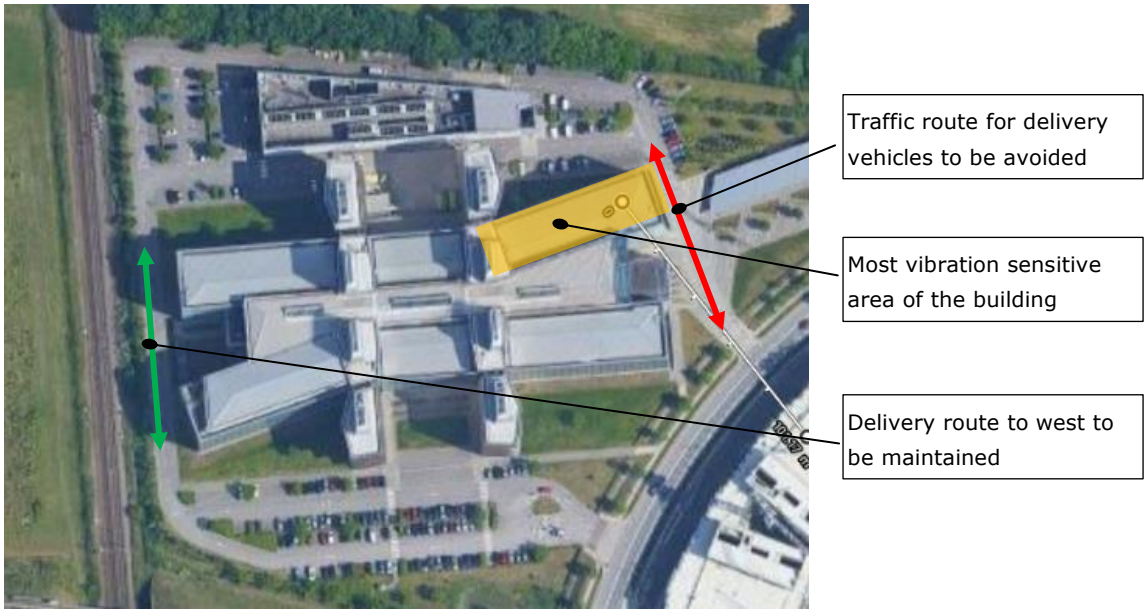

Figure 8 – MRC LMB markup showing delivery routes and adjacency to the most sensitive equipment

8.3.2.8 Network Rail have confirmed that access to the west of the building would be maintained for the LMB to use and that they would not need to change their vehicular routes. A traffic management plan would be in place to control this and this will be included in the legal agreement between Network Rail and MRC LMB.

8.3.2.9 The following additional mitigation steps are being planned to further reduce the construction vibration impacts and would be included in the legal agreement between Network Rail and MRC LMB:

- The construction haul road through the LMB site would not be constructed as alternative construction routes to the west have been identified. For a small number of activities for which the need to access from the eastern side of the railway is unavoidable, agreement to use the existing LMB roads is planned; and
- Major construction traffic would use the haul road to the west of the railway line and, specifically, earthworks traffic would use that route.

8.3.2.10 This further mitigation has been accounted for in a refined construction phase vibration assessment which has been documented in Technical Note 10 (see Appendix G) and issued to MRC. This concludes that there is no significant adverse effect predicted from construction.

8.3.2.11 Draft Heads of Terms have been proposed by Network Rail which give a commitment to controlling construction vibration to ensure no significant adverse effects occur. It is understood that, subject to further detail being added, MRC are satisfied with the proposed approach.

8.3.2.12 The assessment undertaken, the relevant example from the AZ construction and the additional clarifications and mitigation proposed since the TWAO submission result in the conclusion that construction works can be carried out without a significant adverse effect on the MRC LMB building.

8.3.3 Operational Phase Assessment and Mitigation

8.3.3.1 The operational phase assessment in the ES predicted a significant adverse effect for the most sensitive items of equipment in the north east of the LMB building. It was also set out in the ES (section 6.5.9) that a legal agreement would be entered into between Network Rail and MRC to secure mitigation to avoid any significant adverse impact on the MRC LMB.

8.3.3.2 The draft Heads of Terms of the legal agreement has been issued by Network Rail to MRC and includes provisions to protect the MRC LMB by securing that the critical aspects of the track layout that have been assessed in Technical Note 7 (Appendix E) Section 5.1 are implemented (large radius S&C and location). This was assessed to be sufficient mitigation to avoid significant adverse effects. This conclusion has also been validated through the additional vibration surveys undertaken since the ES and presented to MRC LMB in November 2021 (included as Appendix F).

8.3.3.3 Following the issue of the technical notes and engagement with MRC no further queries have been received on vibration and it is understood they are satisfied with the evidence provided. The legal agreement between MRC and Network Rail will formalise this position and should allow the MRC objection to be withdrawn.

9. CONCLUSIONS

9.1.1 This proof of evidence has set out an overview of the CSIE Project and the key aspects of the scheme relating to vibration as well as the legislative and policy background.

9.1.2 The findings of the ES are summarised which concluded that three receptors have the potential to be significantly adversely impacted by the development. These are:

- Residential receptors near to Shepreth Branch Junction during some construction activity;
- The AMB for some activity during the construction phase; and
- The MRC LMB in the construction and operational phases.

9.1.3 A more detailed background to the assessment approach for each of the receptors above is set out in the document and summarised below along with the author's opinion on the proposed mitigations.

9.2 Residential Receptors near to Shepreth Branch Junction

9.2.1 Potential significant adverse impact is predicted for one residence when earthworks activities are taking place within 30m which will be for short duration. Vibratory piling works should not be undertaken within 125m of residences unless it can be demonstrated by the contractor that the vibration levels are below the onset of significant adverse impact or it is essential for the purposes of completing construction activity within a railway possession.

9.2.2 A more detailed assessment of the likely vibration levels and the detailed mitigation is secured through the production and approval by the local authority of the Code of Construction Practice Part B. This approach is appropriate in the author's opinion.

9.3 University of Cambridge Anne McLaren Building

9.3.1 No significant adverse impact is predicted for the operational phase. In addition to the findings of the ES, additional analysis has been carried out in response to the University's letter of objection and statement of case to demonstrate that this is the case for freight trains as well as passenger trains.

9.3.2 A significant adverse impact on the sensitive scientific activities was predicted in the ES for some construction activities that could not be avoided close to the AMB building. This was following the application of best practicable measures as mitigation including avoiding the use of vibratory piling. The author considers this approach is appropriate for scientific facilities of this level of sensitivity where exceedances of an onerous criterion can typically be accepted provided advance warning is in place and the duration of exceedance is kept short.

9.3.3 However, it is recognised that the response from the University sets out the criticality of achieving the VC-A criterion at all times. A review of the evidence on the potential impact of elevated vibration levels on animals provided by UoC has been presented along with a proposal to allow some exceedances of the VC-A criteria up to the level set out in a paper provided by UoC in their statement of case.

9.3.4 The author considers that minor exceedances of VC-A are not likely to be detrimental to the animals and research being undertaken based on empirical experience of construction near to similar facilities. However, the author is not aware of evidence that scientifically demonstrates this albeit the papers presented by UoC present higher levels of vibration as being acceptable.

9.3.5 In the absence of published evidence, UoC are not willing to accept any exceedances of their criteria. It has not been possible to agree the technical approach to achieving this in the construction phase at this point due to the early stage of the construction planning; the necessary level of detail is not currently available. As such Network Rail have proposed draft Heads of Terms for a legal agreement with UoC which commits that construction activity would not exceed the VC-A and VC-C levels within the relevant areas of the AMB except when agreed otherwise.

9.3.6 Revisions to the proposed Heads of Terms have been received from UoC on 23rd December 2021 and, ss of 6th January 2022, these are being reviewed by the Network Rail team prior to responding to UoC.

9.4 Medical Research Council Laboratory of Molecular Biology

9.4.1 A potential for significant adverse impact was predicted for the construction and operational phases within the ES. Operational phase mitigation was not possible to confirm at that early stage of design and instead a commitment was made to MRC that mitigation would be assessed and implemented in the detailed design phase to avoid any significant adverse effects.

9.4.2 Following the TWAO submission further detailed analysis and design has allowed the proposed mitigation to be set out and analysed. Technical notes have been produced and issued to the MRC which show that the proposed large radius switch and crossing geometry and the location of the points is sufficient to avoid significant adverse effects. The predictions have been further validated by an additional vibration survey carried out to the north of the LMB where the track layout and adjacent open land could test the assumptions made.

9.4.3 The potential construction phase impacts have been discussed with MRC LMB at further stakeholder engagement sessions. Lessons learned from the Astrazeneca building construction have been considered and the key aspects for the LMB addressed; notably the concern about having to re-route delivery vehicles near to the most sensitive part of the building. This has been avoided by clarifying the shared use of the haul road to the west of the LMB site.

9.4.4 The additional mitigation and feedback from the AZ works have been included in a refined construction phase vibration analysis which has shown that significant adverse effects can be avoided through the proposed mitigation. This has been issued to MRC and it is understood MRC are satisfied with the evidence presented.

9.4.5 Network Rail have proposed draft Heads of Terms to MRC that secure that the critical operational phase mitigations will be implemented and that construction phase vibration levels will be monitored and controlled to avoid significant adverse effects. In the author's opinion the assessment and secured mitigation is appropriate.

10. DECLARATIONS

I hereby declare as follows:

- This Proof of Evidence includes all facts which I regard as being relevant to the opinions that I have expressed and that the inquiry's attention has been drawn to any matter which would affect the validity of that opinion;
- I believe the facts I have stated in this Proof of Evidence are true and that the opinions expressed are correct; and
- I understand my duty to the inquiry is to help it with matters within my expertise and I have complied with that duty.