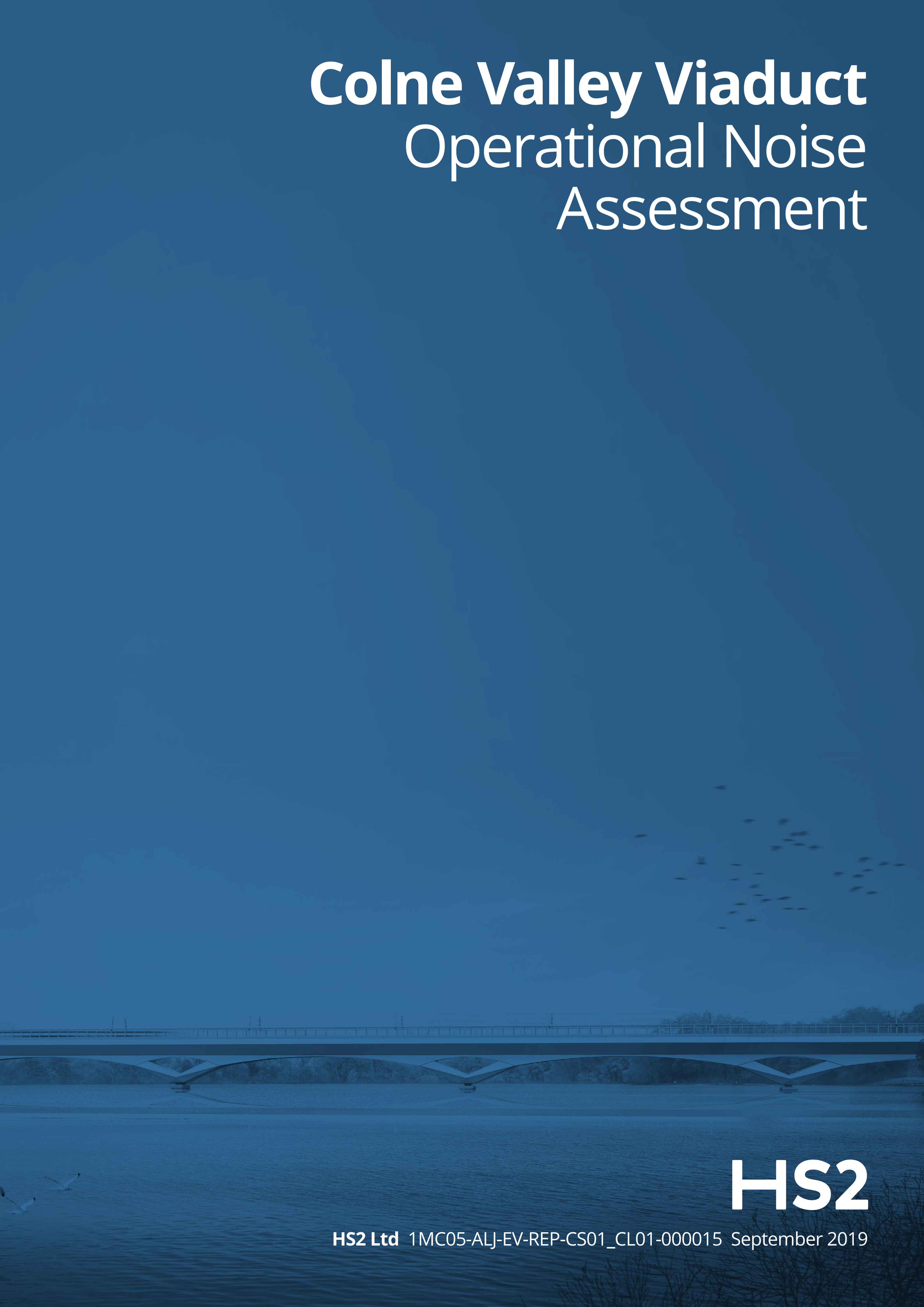
# Colne Valley Viaduct
# Operational Noise Assessment



HS2

**HS2 Ltd** 1MC05-ALJ-EV-REP-CS01_CL01-000015 September 2019

# Colne Valley Viaduct and Incidental Earthworks & Fencing

# Colne Valley Viaduct Schedule 17 Railway Operational Noise Assessment

## Align JV Consent Ref: ALJ-TP-083

**Document no: 1MC05-ALJ-EV-REP-CS01_CL01-000015**

| Revision | Author | Reviewed by | Approved by | Date approved | Reason for revision |
|---|---|---|---|---|---|
| C01 | Nigel Triner / Caroline Vickers | Jon Neale | Daniel Altier | 30-Jul-2019 | Initial Issue |
| C02 | Nigel Triner / Caroline Vickers | Jon Neale | Daniel Altier | 20-Sep-2019 | Client Comments Incorporated |

Security classification: OFFICIAL

**Handling Instructions:**

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# 1 Introduction

## 1.1 Purpose

1.1.1 This document sets out the operational information, predicted noise effects and proposed indicative noise mitigation for the Colne Valley viaduct (CVV) section of HS2 in support of the application for these Schedule 17 requests for approval for the permanent works under Schedule 17 of the HS2 Act.

# 2 Policy, requirements and standards

## 2.1 Planning Forum Notes

2.1.1 The purpose of these notes, developed through the HS2 Phase One Planning Forum, is to provide further details of the design and associated information to be provided to local authorities when considering Schedule 17 requests for approval.

### Planning Forum Note 10 (PFN10): Indicative Mitigation

2.1.2 This document sets out the form of the indicative mitigation information that will be provided. For noise (paragraph 8) it states:

*For works which have a mitigating effect in relation to the operational noise from the railway or new road a report will be provided demonstrating as far as is reasonably practicable how the works are expected to perform in mitigating the noise and vibration impact of the Phase One scheme. The information contained in this report will generally include the following:*

*a) A description of the works;*

*b) Plans showing the location of the works, the surrounding environment and receiver positions;*

*c) Details of the methodology used in predicting noise and vibration levels;*

*d) Assumptions relating to the acoustic performance of rolling stock and track;*

*e) Assumptions relating to the acoustic performance of the work, such as long-term acoustic performance, transmission, sound absorption/reflection, sound diffraction; and* *f) Tables setting out the predicted levels of noise and vibration and tabulated predictions at all individual receivers where the LOAEL [1] is likely to be exceeded.*

### Planning Forum Note 14 (PFN14): Operational Noise from the Railway & Altered Roads

2.1.3 The purpose of this document is to set-out the information that will be provided to demonstrate that noise from the operational railway and altered roads has been reduced 'as far as reasonably practicable' and describes the overarching objectives of Information Paper E20 [1] (refer to Section 3).

2.1.4 PFN14 re-states from PFN 10 the technical information to be provided in Schedule 17 requests for approval, summarised above, and confirms that the 'description of the works', should set out how the works reduce operational noise 'as far as reasonably practicable' (AFARP).

## 2.2 Policy requirements

### Information Paper E20: Control of Airborne Noise from Altered Roads and the Operational Railway

2.2.1 Information Paper E20 outlines the measures that are required to be put in place to control operational airborne noise. It sets out various objectives to minimise operational noise as follows:

- *The nominated undertaker will take all reasonable steps to design and construct altered roads, and to design, construct, operate and maintain the operational railway so that the combined airborne noise from these sources, predicted in all reasonably foreseeable circumstances, does not exceed the lowest observed adverse effect levels.*
- *Where it is not reasonably practicable to achieve this objective, the nominated undertaker will reduce airborne noise from the altered roads and the operational railway as far as is reasonably practicable.*
- *Noise insulation will be offered with the aim that airborne noise from altered roads and the operational railway does not give rise to significant adverse effects on health and quality of life that would otherwise be expected when airborne noise exceeds the significant observed adverse effect levels.*
- *Where possible, the nominated undertaker will also contribute to the improvement of health and quality of life through the control of airborne noise.*
- *Effects on health and quality of life are primarily avoided and minimised through the control of airborne noise at residential dwellings. It is recognised that effects can also*

[1] Lowest Observed Adverse Effect Level - the noise level above which adverse effects on health and quality of life can be detected. Refer to HS2 Information Paper E20 [1].

*occur when people are engaged in noise sensitive activities away from their home. To deliver the Policy aims, reasonable steps will be taken to control airborne noise from altered roads and the operational railway to the levels set out in Appendix B of E20.*

2.2.2 Information Paper E20 states that the following measures to control airborne noise from altered roads and the operational railway will be considered in the following order by the nominated undertaker:

- *reduce noise generation at source;*
- *reduce noise propagation through the design, specification, construction and maintenance of noise fence barriers and/or landscape earthworks; and*
- *reduce the amount of noise entering eligible properties through the offer of noise insulation.*

### Information Paper E21: Control of Ground-borne Noise and Vibration from the Operation of Temporary and Permanent Railways

2.2.3 Information Paper E21 [2] outlines the measures that are required to be put in place to control operational ground-borne noise and vibration. It sets out the requirements of the nominated undertaker in relation to the control of operational ground-borne noise and vibration, as follows:

- *The nominated undertaker will design the temporary and permanent railways such that the level of ground-borne noise and vibration predicted in all reasonably foreseeable circumstances does not exceed the significant observed adverse effect levels (given in Table 1 in Appendix B of IP E21).*
- *The nominated undertaker will take all reasonably practicable steps to construct, operate and maintain the temporary and permanent railways so that the design objective (stated in paragraph 3.1 Appendix B of IP E21) is fulfilled.*
- *In addition, the nominated undertaker will take all reasonable steps to design, construct, operate and maintain the temporary and permanent railways such that, in all reasonably foreseeable circumstances, ground-borne noise and vibration does not exceed the lowest observed adverse effect levels (given in Table 1 in Appendix B of IP E21).*
- *The nominated undertaker will reduce ground-borne noise and vibration from the temporary and permanent railways as far as is reasonably practicable.*
- *In addition to the effects on people inside residential dwellings, it is recognised that impacts can also occur on people and activities in noise sensitive non-residential locations.*
- *The nominated undertaker will design the temporary and permanent railways such that the level of ground-borne noise and vibration predicted in all reasonably foreseeable*

*circumstances does not exceed the impact levels (given in Tables 2 and 3 in Appendix B of IP E21).*

- *The nominated undertaker will take all reasonably practicable steps to construct, operate and maintain the temporary and permanent railways so that this design objective is fulfilled.*

2.2.4 Information Paper E21 also states that the following measures to control ground-borne noise and vibration from the temporary and permanent railways, will be considered in the following order by the nominated undertaker:

- *at design stage, predict, through the use of appropriate modelling, the engineering requirements of the track system that will fulfil the objectives;*
- *design a standard track form with the objective of meeting as many of those engineering requirements identified in the previous bullet as can reasonably be achieved by such a standard track system;*
- *design an enhanced track form for locations where it is predicted that the standard track system will not meet the engineering requirements or to discharge other project commitments and undertakings;*
- *translate the engineering requirements into contract specifications for the track systems; and*
- *procure, install and maintain the track systems to meet the contract specifications established above.*

### Undertakings and Assurances

2.2.5 Route-wide and relevant area specific Undertakings and Assurances (U & As) which form a part of the Environmental Minimum Requirements given by the Secretary of State in relation to operational noise are presented in Table 1. It is noted that in U&As 1177, 1178 and 1179 the terms 'impacts' and 'effects' appear to be used interchangeably.

**Table 1**: Routewide and relevant area specific U & As

| Reference | Detail | Location |
|---|---|---|
| 73 | The nominated undertaker will take all reasonable steps to design and construct altered roads, and to design, construct, operate and maintain the operational railway so that the combined airborne noise from these sources, predicted in all reasonably foreseeable circumstances, does not exceed the lowest observed adverse effect levels set out in Table 1 of Appendix B. [please consult Information Paper E20 [1]. | Route-wide |
| 75 | Where it is not reasonably practicable to achieve this objective, the nominated undertaker will reduce airborne noise from the altered roads and the operational railway as far as is reasonably practicable. | Route-wide |
| 76 | Noise insulation will be offered with the aim that airborne noise from altered roads and the operational railway does not give rise to significant adverse effects on health and quality of life that would otherwise be expected when airborne noise exceeds the | Route-wide |

| Reference | Detail | Location |
|---|---|---|
| | significant observed adverse effect levels set out in Table 1 of Appendix B. Eligibility for noise insulation is explained in Section 5 below.<br><br>5. Provision of noise insulation<br>Noise insulation measures, including ventilation where required, will be offered for qualifying buildings as defined in the Noise Insulation (Railways and Other Guided Transport Systems) Regulations 1996 and the Noise Insulation Regulations 1975 (as amended 1988)3,4,5. Qualification for noise insulation under the Regulations will be identified and noise insulation offered at the time that the Proposed Scheme becomes operational.<br>In addition, following the general time-window of eligibility described in the Noise Insulation Regulations (Railways and Other Guided Transport Systems) 1996, where airborne noise from the use of new or additional railways authorised by the Bill, altered roads authorised by the Bill or the combined airborne noise from both, is predicted outside a permanent dwelling in all reasonably foreseeable circumstances to exceed the significant observed adverse effect levels set out in Table 1 of Appendix B, the nominated undertaker will offer noise insulation.<br>[please consult Information Paper E20]. | |
| 78 | Effects on health and quality of life are primarily avoided and minimised through the control of airborne noise at residential dwellings. It is recognised that effects can also occur when people are engaged in noise sensitive activities away from their home. To deliver the Policy aims, reasonable steps will be taken to control airborne noise from altered roads and the operational railway to the levels set out in Table 2 of Appendix B for noise sensitive non-residential buildings and external amenity spaces | Route-wide |
| 79 | The following measures to control airborne noise from altered roads and the operational railway will be considered by the nominated undertaker:<br>- reduce noise generation at source;<br>- reduce noise propagation through the design, specification, construction and maintenance of noise fence barriers and/or landscape earthworks; and<br>- reduce the amount of noise entering eligible properties through the offer of noise insulation. | Route-wide |
| 81 | In addition, following the general time-window of eligibility described in the Noise Insulation Regulations (Railways and Other Guided Transport Systems) 1996, where airborne noise from the use of new or additional railways authorised by the Bill, altered roads authorised by the Bill or the combined airborne noise from both, is predicted outside a permanent dwelling in all reasonably foreseeable circumstances to exceed the significant observed adverse effect levels set out in Table 1 of Appendix B, the nominated undertaker will offer noise insulation | Route-wide |
| 82 | The nominated undertaker will design the temporary and permanent railways such that the level of ground-borne noise and vibration predicted in all reasonably foreseeable circumstances does not exceed the significant observed adverse effect levels given in Table 2 in Appendix B | Route-wide |
| 1025 | The Secretary of State will require the nominated undertaker, in making predictions of noise and vibration in all reasonably foreseeable circumstances for the purpose of HS2 Information Papers E20, E21 and E22, to include, but not limit such predictions to, the following: the potential for freight operation; planned operational speeds; high speed train noise and vibration characteristics; planned operational rail traffic volumes and compositions; degradation to rolling stock and/or track over the maintenance cycle of the railway; and prediction model uncertainty. | Route-wide |

| Reference | Detail | Location |
|---|---|---|
| 1026 | The Secretary of State will require the nominated undertaker to use noise or vibration prediction models during the design and construction phases of the Proposed Scheme that are validated for the range of circumstances over which they are applied. Validation reports for the prediction models used shall be provided to all Local Authority Environmental Health Departments with a declaration of the numerical values of prediction model uncertainty being applied by the nominated undertaker under paragraph 1 above. | Route-wide |
| 1027 | The Secretary of State will require the nominated undertaker to apply the noise and vibration commitments set out in HS2 Information Papers E20, E21, E22 and E23 to individual noise sensitive receptors. | Route-wide |
| 1028 | The Secretary of State will require the nominated undertaker to share with the Local Authority Environmental Health Departments information that is relevant to understanding the noise and vibration performance of the control measures adopted during the design of the Proposed Scheme for receivers within their administrative area. | Route-wide |
| 1029 | The Secretary of State will require the nominated undertaker to apply the November 2015 release of Government's Transport Analysis Guidance Unit A3 when valuing the effect of noise change and consider this value when assessing the benefit of applying operational airborne noise control measures to the Proposed Scheme. | Route-wide |
| 1030 | The Secretary of State will require the nominated undertaker to monitor peer-reviewed research by independent sources into annoyance and health effects specific to high speed railway noise and vibration and notify all Local Authority Environmental Health Departments on the HS2 Phase One route if a numerical correction to noise and vibration levels from the scheme is applied, to account for the research findings. | Route-wide |
| 714 | The Environmental Statement (ES) [3] reported 48 minor impacts at residential properties at South Harefield. The Secretary of State will require the nominated undertaker to implement a 3m noise barrier on the upside line of Work No. 2/1 from chainage 26+350 to 28+450, or implement noise mitigation measures which deliver equivalent performance in removing 44 of the 48 minor noise effects as reported in the ES. | South Harefield |
| 715 | The ES reported seven moderate impacts and six minor impacts at residential properties close to Savay Farm. The Secretary of State will require the nominated undertaker to implement a 3m noise barrier on the downside line of Work No. 2/1 from chainage 26+730 to 26+960, or implement noise mitigation measures which deliver equivalent performance in removing all 6 of the minor noise effects as reported in the ES. | Savay Farm |
| 716 | The ES reported 18 moderate impacts and 69 minor impacts at residential properties at Wyatt's Covert and Tilehouse Lane. The Secretary of State will require the nominated undertaker to implement a 4m [noise barrier] on the downside line of Work No. 2/1 from chainage 28+500 to 29+850, or implement noise mitigation measures which deliver equivalent performance in removing 16 out of 18 moderate noise effects and 53 out of 69 minor noise effects as reported in the ES. | Wyatt's Covert and Tilehouse Lane |

### Environmental Minimum Requirements

2.2.6 The EMR General Principles require there to be no new significant effects between the predicted detailed design noise effects and those reported in the ES. The relevant ES is comprised of the main ES, November 2013 and the various SES and AP ES, published in 2015.

2.2.7 A potential 'material difference' shall be identified using the following approach:

- *A new significant effect is identified (not reported in the ES); or,*
- *a materially different likely significant effect is identified compared to the significant effect identified in the ES.*

### Appraisal of Mitigation

2.2.8 ALIGN JV is required to consider a list of potential mitigation measures and undertake a proportionate Cost Benefit Analysis (CBA) in accordance and consider all relevant acoustic and non-acoustic costs and benefits including:

- *Monetary benefit of noise reduction compared to cost;*
- *Engineering practicability;*
- *Impacts on other environmental disciplines, including landscape and visual; and*
- *Consultation and stakeholder engagement responses.*

2.2.9 As required by HS2 Ltd, a WebTAG approach is to be followed employing a 1dB WebTAG Noise workbook developed for local HS2 noise mitigation assessments.

2.2.10 It is not considered practicable by ALIGN JV to produce a separate CBA on an asset by asset basis, i.e. to not undertake an economic appraisal for each barrier type along the CVV and Northern Embankment; instead, a local based approach has been used. This report therefore focuses on the assets within the section of route from the South Embankment of the Colne Valley viaduct to the North Embankment, including the continuous length of noise barrier onto the Tilehouse Lane Cutting.

# 3 Descriptions of the works

## 3.1 Overarching strategy

3.1.1 This section of the report describes how the works have been designed to reduce operational noise AFARP. As will be discussed in the following sections, it can be seen that there are a number of non-acoustic factors the barrier design must take into account, which restrains the extent that AFARP can be applied.

3.1.2 The specimen design created a level of expectation in terms of the visual appearance of the proposed CVV and this has been set out in the Design and Access Statement (1MC05-ALJ-TP-REP-CS01_CL01-000005). Extensive consultation across the ALIGN JV viaduct design team has been undertaken to minimise operational noise impacts from the railway, whilst meeting the overall design aspirations. It has been clear from the outset that the noise barriers that are required for the proposed CVV need to be carefully integrated into the overall viaduct design.

## 3.2 Design approach

3.2.1 The design has developed interactively and has considered various viaduct cross sections and noise barrier types. Engineering, aesthetic, environment (including noise), constructability and cost considerations have been important in developing an integrated design. Feedback received from stakeholders has also informed the proposed CVV design, particularly in respect of aesthetic, noise and landscape considerations.

### Project context

3.2.2 As previously discussed, value for money is one of the four criteria required to be demonstrated through AFARP.

3.2.3 The viaduct design is required to meet a number of specific and general requirements. Cost isn't the driver behind the majority of mitigation measures, as these are dictated mainly by non-acoustic issues such as buildability, visual impacts and customer experience.

3.2.4 The viaduct has acoustic constraints which are:

- *Compliance with the EMRs, U&As and IP E20 requirements.*

3.2.5 The viaduct has non-acoustic constraints which include:

- *Barrier height on elevated structure.*
- *Design considerations due to high speed train pass-by pressures.*
- *Ecological considerations regarding bird flight and collisions.*
- *Visual impacts on the surrounding environment.*
- *Quality of customer service and enjoyment, relating to the views from the train.*

3.2.6 The overarching mitigation strategy that has been adopted aims to providing optimised acoustic benefits to the surrounding sensitive receivers, whilst balancing both acoustic and non-acoustic qualitative considerations.

3.2.7 The indicative mitigation design and overarching strategy is the result of extensive cross-discipline collaboration and consideration of the potential constraints. This has included the implementation of innovative approaches to mitigation, allowing more exhaustive and iterative optioneering to occur.

## 3.3 Proposed design

### Viaduct

3.3.1 The Design and Access Statement sets out the considerable aesthetic considerations that have influenced the design. Providing an elegant deck profile that reinforces horizontality, along with the use of different angles and light reflection has been important in reducing the visual mass of the viaduct.

3.3.2 Although the viaduct profile is its most distinctive feature, the width of the viaduct cross section has been reduced as far as possible, along with inclining the noise barriers inwards, which minimises the distance between the diffracting top edge of the barrier and the train body, optimising their acoustic performance.

3.3.3 The design also includes a robust kerb – a low level structure integrated into the viaduct deck, designed to contain the train in case of derailment. This also provides some additional acoustic screening benefit, enhanced through the addition of absorptive material.

### Noise barriers

3.3.4 The deemed Hybrid Bill AP5 scheme, which is referred to by the U&As (set out in Table 1), comprised 3 metre and 4 metre absorptive (visually opaque) parapet barriers at certain locations along with inboard 1.4 metre protection barriers at all locations. Refer to Figure 1 and Figure 2. This provided an increased level of acoustic mitigation compared to the 1.4 metre and 3 metre barriers proposed in the original ES.

3.3.5 All barrier heights in this report are presented as metres above rail (relative) e.g. a 4m hybrid noise barrier would have a top edge height of 4m above the height of lowest rail for the track adjacent to the barrier.

**Figure 1:** Schematic viaduct cross section reproduced from Environmental Statement

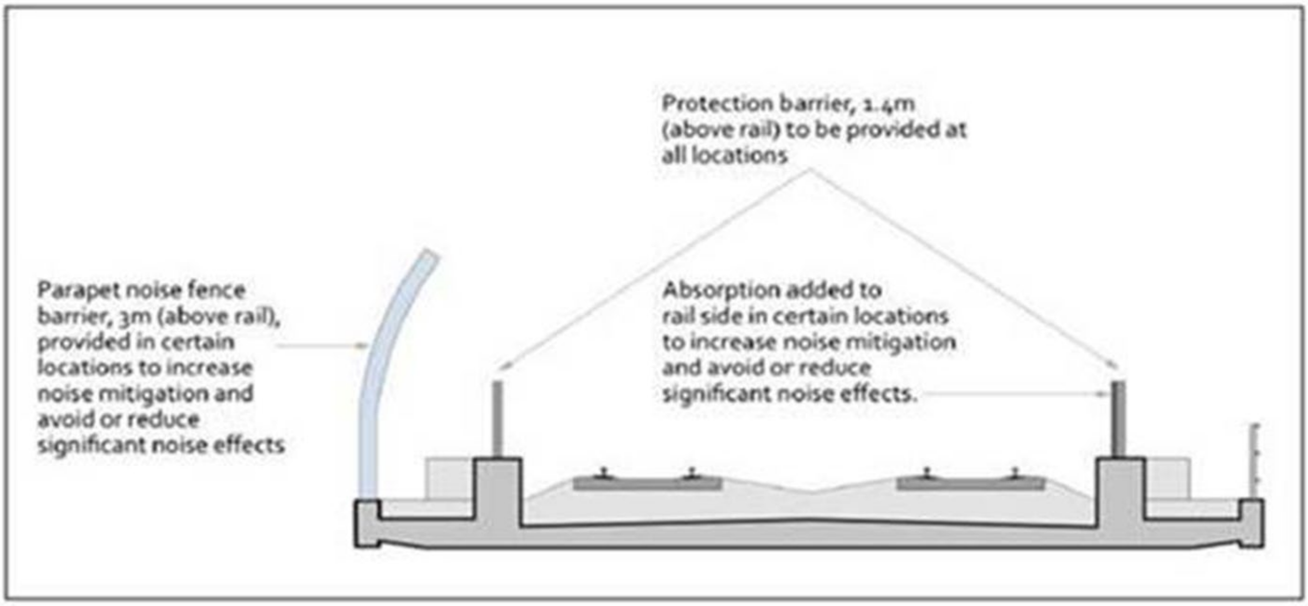
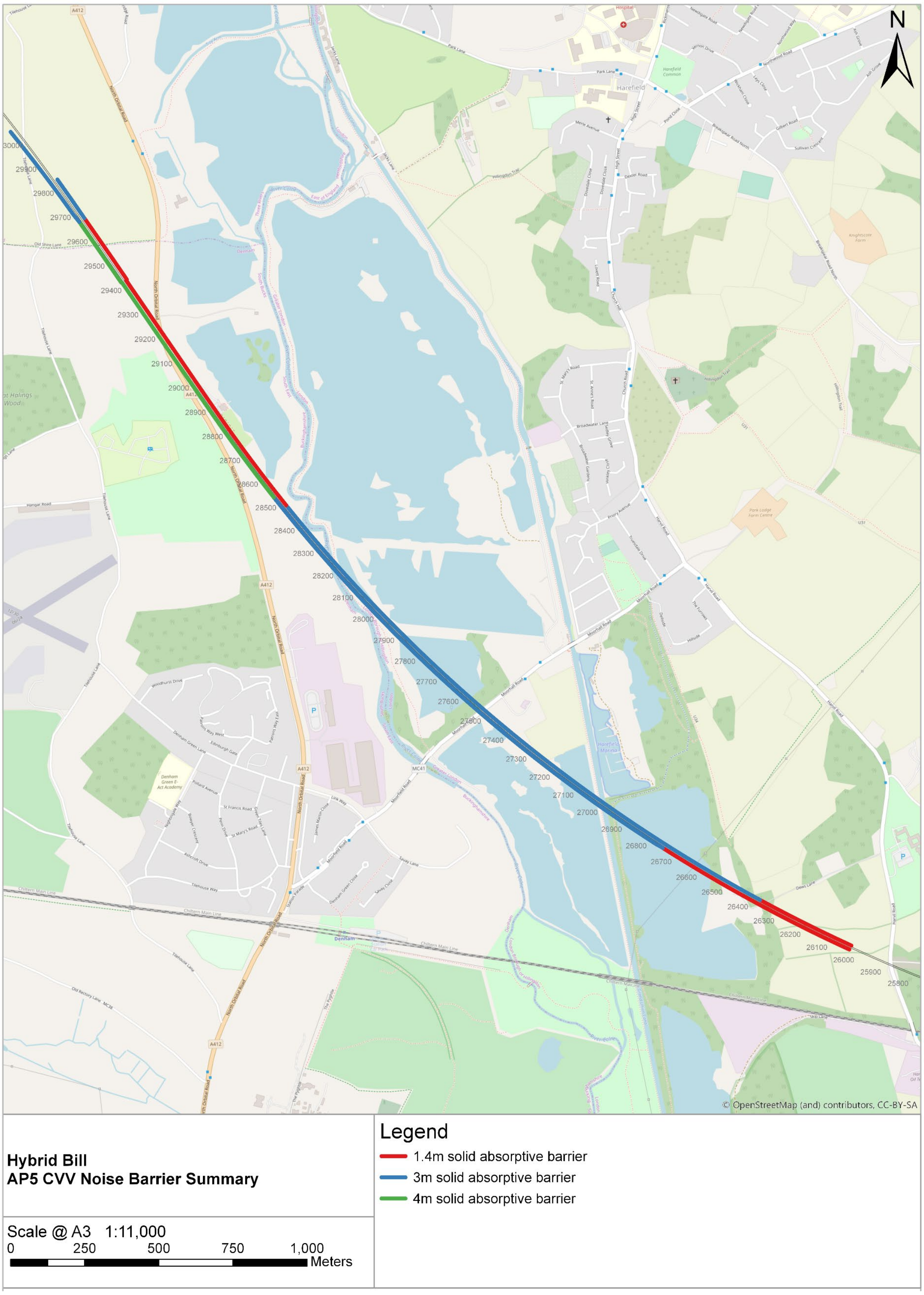


**Figure 2:** Hybrid Bill AP5 CVV Noise Barrier Summary



3.3.6 The noise barrier now proposed in the Schedule 17 requests for approval is a continuous barrier, 4 metres in height on the southern elevation. Except for a proportion of 1.65 metre barrier at the northern end of the viaduct on the northern elevation, the remainder of the northern elevation also consists of a 4 metre barrier. The barriers will be a combination of hybrid barrier (absorptive visually opaque lower element and a reflective transparent upper element), and opaque absorptive barrier with barrier top edge treatments to provide additional levels of acoustic attenuation as necessary. Refer to the 'Design mitigation' section of this chapter for further details.

3.3.7 There is a design aspiration relating to passenger experience which the transparent sections will also facilitate.

3.3.8 The robust kerb (designed for train containment), refer to Figure 3, has been treated as a barrier in the noise model, at a height of 0.7 metres above rail with the inner face assumed to be acoustically absorptive. Whilst lower than the 1.4 metre noise barrier proposed in the hybrid Bill scheme, this structure performs as an effective noise barrier because of its proximity the rail and the absorptive finish.

3.3.9 The 4 metre barriers are inclined inwards by 9° which brings the diffracting edge of the barrier as close as possible to the passing trains, thereby optimising their acoustic efficiency.

3.3.10 As discussed further in Section 3.4, in order to further enhance the performance of the 4 metre barriers, without increasing their physical height, acoustic attachments to the top edge of the barriers are proposed

### Engineering and operational practicability

3.3.11 The dynamic and fatigue structural loadings will be considerable on the barriers due to the close proximity to the passing high speed trains. There is therefore a practical limitation to their height (considered to be 4m) and inclination in order to avoid the addition of excess mass to affix the noise barriers to the viaduct resulting in undesirable architectural elements and maintenance issues (e.g. cleaning transparent sections). There is also a limitation to the proximity of the barrier top edge to the train due to safety requirements.

3.3.12 The height of the robust kerb is limited due to safety requirements for maintenance.

3.3.13 These were considerations during the initial design phases of the proposed CVV.

3.3.14 Galvanised steel has been specified for the cassettes due to their acoustic performance, longevity and visual consistency with other above deck components. The barrier has been designed to be easily inspected, maintained and cleaned from the deck. The cassettes and acrylic panels can be removed from each of the maintenance walkways. The cassettes stack on top of one another so have minimal fixings and can be easily removed and replaced if required.

3.3.15 In order to enhance acoustic performance of the barriers without increasing their height, acoustic top edge treatments are proposed. Aesthetic treatments for the opaque noise barrier have also been considered and applied to the external face of the barriers without compromising their acoustic performance.

3.3.16 Therefore, in terms of engineering and operational practicability the noise barrier design is considered to be AFARP.

### Impacts on other environmental disciplines

3.3.17 Ideally, from a visual aesthetic perspective, the noise barriers would be as low and as transparent as possible, if not eliminated entirely.

3.3.18 Where a 4m hybrid barrier is proposed, the transparent panel is supported between the galvanised steel posts. Any perceived impact from external glare from the transparent panels will be reduced significantly by the inclination of the barriers.

3.3.19 Where a 4m opaque noise barrier is proposed, a galvanized steel sheet is proposed to integrate the noise barrier with the overall viaduct superstructure.

3.3.20 To minimise the likelihood of bird and bat strikes, it would be desirable for the barriers to be as high and solid/opaque as possible, which would potentially provide increased noise benefits, particularly if these were also to be absorptive. However, this also has to be balanced against the visual aesthetic engineering considerations noted above.

3.3.21 ALIGN JV considers that an appropriate balance has been struck between reducing the noise effects of the proposed CVV and the design aesthetic by concealing the lower third of noise barriers, and utilising a galvanized steel sheet to improve the external appearance of the opaque elements of the noise barrier.

3.3.22 Therefore, in terms of impacts on other environmental disciplines the noise barrier design is considered to be AFARP.

### Value for Money

3.3.23 A quantitative comparison has been undertaken of the acoustic benefits of the scheme mitigation of the noise reduction provided compared to the long-life cost of the mitigation in accordance with the commitment to the Local Authority Noise Consortium (LANC).

3.3.24 Galvanised steel has been specified for the barrier cassettes for longevity and designed with minimal fixings to allow efficient inspection, maintenance and cleaning from the deck.

3.3.25 Therefore, in terms of value for money the noise barrier design is considered to be AFARP.

### Stakeholder engagement

3.3.26 The specimen design1F1F2 created a level of expectation in terms of visual appearance and the noise barriers that are now required have been carefully integrated into the overall viaduct design. The Design and Access Statement (Section 5) (1MC05-ALJ-TP-REP-CS01_CL01-000005) sets out the proposed design of the noise barrier and how this has been achieved.

3.3.27 The stakeholder engagement events conducted so far have shown that both the noise from the proposed CVV and the design of the noise barriers to be two issues of greatest priority to communities and the wider public (see section 7 of the Written Statement (1MC05-ALJ-TP-REP-CS01_CL01-000006). Members of the public and the local communities fed back that creating visually unobtrusive barriers was the third ranked priority, below protecting communities (first) and wildlife (second) from train noise. Additionally, local planning authorities and the HS2 Independent Design Panel have fed back that the noise barrier design is crucial to the overall design of the CVV. Initial opaque noise barrier designs suggested in pre-application meetings in early 2019 were stated to be overly dominant and incongruous when compared to the wider substructure of the viaduct.

3.3.28 The stakeholder engagement feedback undertaken has reflected well the design balance between the need to limit the noise effects, whilst provide a good design. Attention has been paid to providing a noise barrier design that respect the visual aesthetic, but also responds to the noise requirements of the ES and in a number of locations, reduces further the noise levels that were reported in the ES.

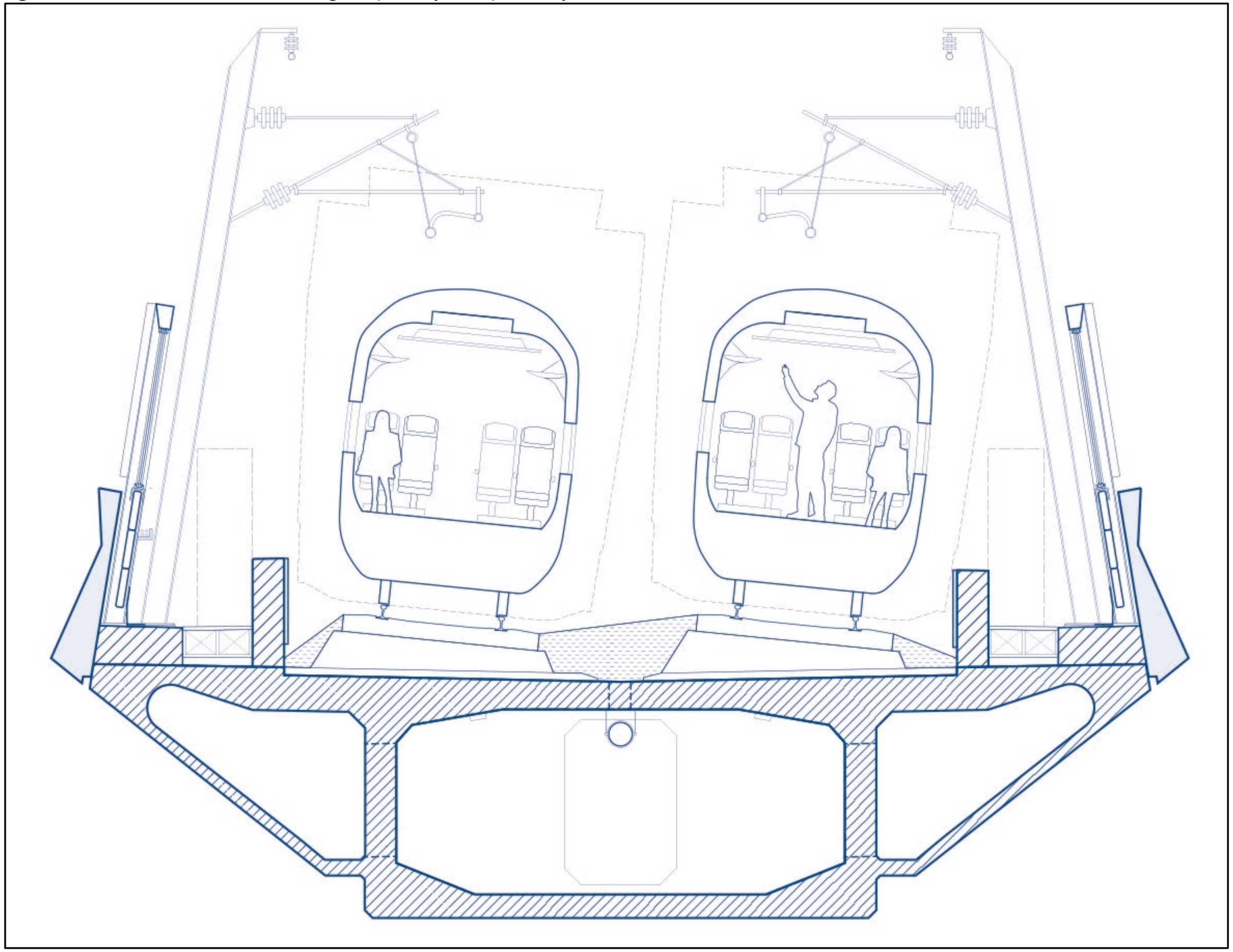
3.3.29 A cross section of the viaduct as now designed is presented in Figure 3.

3.3.30 All of the above factors (Specimen Design, engineering and operational practicability, requirements of other environmental disciplines, value and stakeholder engagement feedback) have influenced the noise barrier design for which approval is being sought. As previously stated, taking in to account all the differing considerations, the noise barrier design is both compliant with the requirements of the assurances set out in Table 1, and the ES. Equally, it provides for noise barriers that appear as light as possible, clearly subsidiary to the main CVV structure and which are fully integrated with the overall

[2] https://knightarchitects.co.uk/wp-content/uploads/CVV-Specimen-Design_210218-1.pdf

design concept. Consequently, the noise barrier design are considered to be AFARP in respect of reducing noise impacts.

**Figure 3:** Viaduct cross section showing 4m partially transparent hybrid barriers



## 3.4 Design mitigation

3.4.1 The submitted design for Schedule 17 requests for approval includes noise barriers as a part of the mitigation strategy for train noise.

3.4.2 The mitigation measures are additional to noise reductions at source. The measures aim to reduce noise propagation by implementing noise barriers and/or landscape earthworks, where required, such that the acoustic requirements are satisfied, as far as reasonably practicable. However, given all the requirements, noise barriers are seen as the key practicable mitigation measure.

3.4.3 In addition to the use of either standard reflective or absorptive noise barrier types, the following additional airborne sound mitigation types have been proposed:

- *Hybrid barrier – a barrier configuration made up of both acoustically absorptive (opaque) and reflective (transparent) elements (approximately 40% absorptive / 60% reflective).*
- *Diffracting edge designs comprising diffracting edge attachments; and absorptive linings on the barrier top edge internal face.*
- *Acoustically absorptive treatments to the robust kerb.*

3.4.4 The need for consideration of these additional mitigation measures has arisen due to a clear design direction to find an acceptable balance between desired noise reduction, visual/landscape concerns and passenger experience.

3.4.5 The noise barrier comprises acoustic cassettes and/ or transparent acrylic panels supported between steel posts. Barrier systems previously tested and certified on high speed rail have been specified to ensure as far as possible the acoustic performance and longevity of the barrier. Galvanised steel has been specified for the cassettes due to their acoustic performance, longevity and visual consistency with above deck components. The barrier has been designed to be easily inspected, maintained and cleaned from the deck. The cassettes and acrylic panels can be removed from each of the maintenance walkways. The cassettes stack on top of one another so have minimal fixings and can be easily removed and replaced if required.

3.4.6 Where a 4m opaque barrier is required, the acoustic cassettes and posts are concealed by a horizontal band of large-format galvanised steel sheets. Sheets are hung along each side via concealed, hook-on fixings, both simplifying the appearance and minimising the number of components requiring future maintenance.

3.4.7 Where a 4m hybrid barrier is proposed, a 2m high by 3m wide transparent panel is supported between the galvanised steel posts.

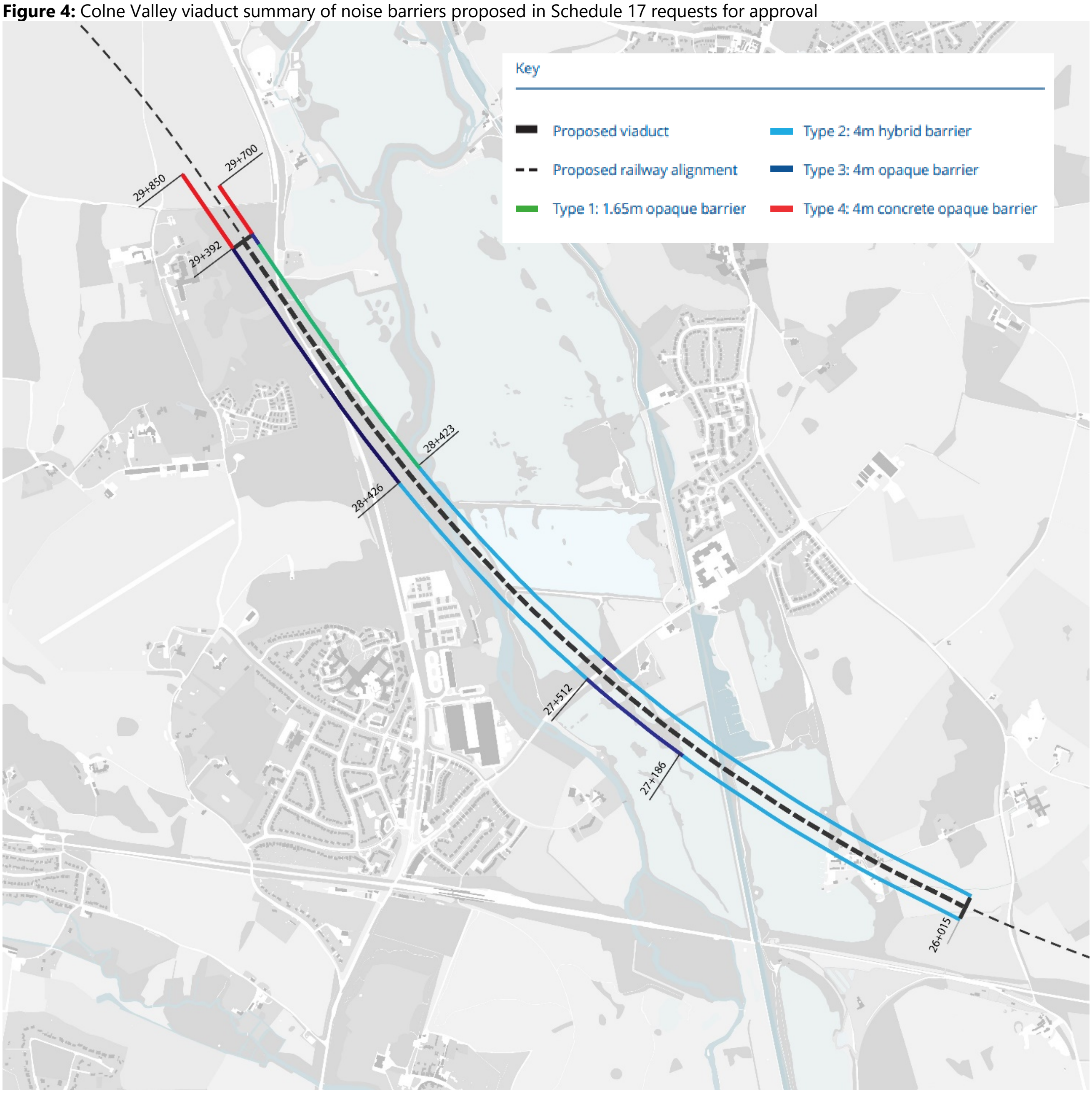
3.4.8 A summary of the mitigation has been included in Table 2 and presented graphically in Figure 4. Please note the top edge treatments specified in the table below occur on the upper and internal faces of the noise barrier.

**Table 2:** Indicative mitigation summary

| Direction | Approximate mitigation extents (Down ML chainage) | | Mitigation measures* |
|---|---|---|---|
| | Start | End | |
| Down Mainline | 26015 | 27186 | Hybrid viaduct barrier (4m) with absorptive top edge (-1dB) |
| | 27186 | 27512 | Solid absorptive viaduct barrier (4m) with resonator top edge (-2.5dB) |
| | 27512 | 28423 | Hybrid viaduct barrier (4m) with absorptive top edge (-1dB) |
| | 28423 | 29392 | Solid absorptive viaduct barrier (4m) with absorptive top edge (-1dB) |
| | 29392 | 29850 | Solid absorptive northern embankment barrier (4m) with absorptive top edge (-1dB) |
| Up Mainline | 26012 | 27472 | Hybrid viaduct barrier (4m) |
| | 27472 | 27512 | Solid absorptive viaduct barrier (4m) with absorptive top edge (-1dB) |
| | 27512 | 28421 | Hybrid viaduct barrier (4m) with absorptive top edge (-1dB) |
| | 28421 | 29393 | Solid absorptive viaduct barrier (1.65m) |
| | 29392 | 29700 | Solid absorptive northern embankment barrier (4m) |

** Figures in brackets refer to additional assumed noise attenuation from top edge attachment (dB)*

**Figure 4:** Colne Valley viaduct summary of noise barriers proposed in Schedule 17 requests for approval




## 3.5 Groundborne Noise and Vibration

3.5.1 Further studies are ongoing, to inform the detailed design and any further specific mitigation requirements.

## 3.6 Structure Radiated Noise

3.6.1 Further studies are ongoing, to inform the detailed design and any further specific mitigation requirements.

# 4 Methodology

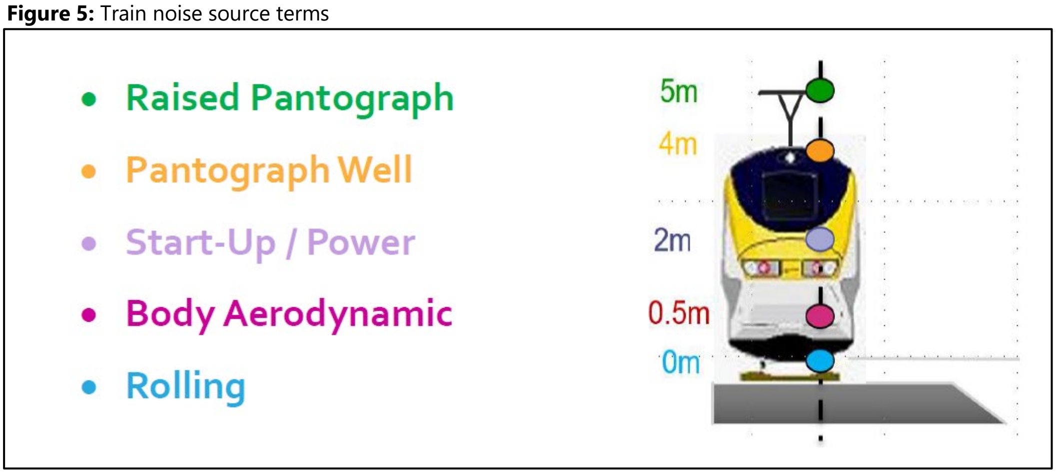
## 4.1 Calculation methodologies and mapping software

### Rail – Airborne noise

4.1.1 Rail noise modelling has been undertaken using the NoiseMap™ [3] software package. This implements the airborne noise calculation methodology (commonly referred to as the Train Noise Prediction Model (TNPM). This validated methodology has been used for the HS2 Environmental Statement and, prior to that, the detailed design of the Channel Tunnel Rail Link (HS1).

4.1.2 The TNPM methodology allows for sources of varying heights to be put onto the same track segments. Figure 4 shows the heights of the 5 sources defined as distances above rail. It should be noted that the Pantograph Well source is not applicable for the proposed trains and that the Start-Up/ Power source is not applicable to any of the ALIGN JV C1 section of the Phase One route (due to other sources becoming dominant at high speeds).

**Figure 5:** Train noise source terms




[3] NoiseMap™ Process for High Speed 2 Airborne Noise Modelling

### Road – Airborne noise

4.1.3 Results from road noise calculations from roads altered by the scheme, as used for the HS2 Phase One Environmental Statement (ES) [4], have been used in this assessment. This is considered to be a reasonable approach. This data will be updated as further information becomes available.

4.1.4 It should be noted that road alterations as a result of the viaduct are minimal, with the exception of the re-alignment of Harvil Road at Copthall Cutting and CVV South Embankment.

### Groundborne Noise and Vibration

4.1.5 Based on the developing design, detailed prediction methodologies are currently being developed for approval by HS2.

### Structure Radiated Noise

4.1.6 Based on the developing design, detailed prediction methodologies are currently being developed for approval by HS2.

## 4.2 Deriving impacts and effects

### Deriving airborne noise impacts

4.2.1 To ensure consistency with the previous work undertaken for the ES, impacts have been derived in accordance with the HS2 Ltd assessment methodology at each assessment location (see Table 3).

**Table 3**: Impact category summary

| Impact category | Description |
|---|---|
| Benefit | Beneficial impact |
| Negligible | Negligible impact below LOAEL |
| Minor | Negligible impact above LOAEL |
| Moderate | Moderate impact above LOAEL |
| Major | Major impact above LOAEL |

### Deriving GBNV noise impacts

4.2.2 To identify GBNV from the operational railway the predicted levels will be assessed against the criteria set out in Appendix B *Ground-borne noise and vibration impact and effect levels from the operational railway* of HS2 Information Paper E21.

### Deriving airborne noise effects

4.2.3 From the HS2 Phase One ES Scope and Methodology report [4], significant effects are determined by taking account the factors listed below.

**Residential receptors:**

- Type of effect being considered
- The number and grouping of receptors subject to impacts
- The magnitude of the impacts and available dose-response information
- The existing sound environment in terms of the absolute level and the character of the existing soundscape
- Any unique features of the Proposed Scheme's sound or impacts in the area being considered (which may require secondary acoustic indicators /criteria)
- The potential combined impacts of sound and vibration
- The duration of impact for temporary sources
- The effectiveness of mitigation through design or other means.

**Non-residential receptors**

- The type of effect being considered;
- The use and sensitivity of the receptor or land use;
- The design of the receptor or land use affected;
- The existing sound environment in the receptor, or on the land use, effected;
- The magnitude of the forecast impact;
- The potential combined impacts of sound and vibration;
- Any unique features of the Proposed Scheme's sound or impacts in the area being considered (which may require secondary acoustic indicators / criteria);
- The frequency and duration over which temporary construction impacts may occur; and
- The effectiveness of mitigation through design or other means.

### Deriving GBNV noise effects

4.2.4 From the HS2 Phase One ES Scope and Methodology report [5], significant effects are determined by taking account the factors listed below.

**Residential receptors**

- *The type of effect being considered;*
- *The magnitude of the impacts and available dose-response information;*
- *The number and grouping of impacts;*

- *The potential combined impacts of airborne sound, ground-borne sound and ground-borne vibration;*
- *Any unique features of the Proposed Scheme's sound or vibration impacts in the area being considered (which may require secondary acoustic indicators/criteria);*
- *The frequency and duration over which temporary construction impacts may occur; and*
- *The effectiveness of mitigation through design or other means.*

**Non-residential receptors**

- *The type of effect being considered;*
- *The magnitude of the impact;*
- *The design of the receptor affected;*
- *The existing ambient sound and vibration levels in the receptor affected;*
- *The use and sensitivity of the receptor;*
- *The potential combined impacts of ground-borne sound and vibration;*
- *Any unique features of the Proposed Scheme's sound or vibration impacts in the area being considered (which may require secondary acoustic indicators/criteria);*
- *The frequency and duration over which temporary construction impacts may occur; and*
- *The effectiveness of mitigation through design or other means.*

## 4.3 Uncertainty – Airborne noise

4.3.1 Details of the tolerances associated with the modelling method are described in the ES [4].

# 5 Assumptions

## 5.1 Summary

5.1.1 The assumptions and key inputs relating to the noise model set up are summarised in Table 4, with further details provided in Section 5.2.

**Table 4:** Key modelling assumptions

| Modelling parameter | Assumption |
|---|---|
| Potential for freight | Not proposed |
| Planned train operational speeds | Speeds vary according to the direction of movement, service, speed range between 280 and 320 kph. |
| Noise source terms | Similar to the levels used for the ES, four sources are considered: rolling, body aero, startup/ power and pantograph. A fifth source, pantograph well is not used, following an instruction from HS2 |

| Modelling parameter | Assumption |
|---|---|
| | advising that this source is not applicable to the proposed high-speed train fleet. |
| Train service plan | As advised by HS2 Ltd, refer to Section 5.2. |
| Degradation to rolling stock and/or track | It is understood that the noise source terms as provided by HS2 have accounted for degradation to rolling stock and/or track in terms of AFRC. |
| Prediction model uncertainty | Awaiting clarification from HS2 Ltd on ARFC. |
| Accounting for hybrid barrier and barrier top edge treatment | Adjustments have been applied to the prediction model to account for a part absorptive, part reflective barrier and barrier top edge attachments. Refer to Appendix B. |

## 5.2 Rail modelling assumptions

5.2.1 In November 2018, an instruction was issued by HS2 Ltd regarding updated train noise source terms and service patterns. These account for unmitigated acoustically reflective slab track plus the HS2 rolling stock.

5.2.2 The HS2 rolling stock and service pattern is made up of two train fleets:

- *Phase 1 and 2a fleet will be made up of Conventional Compatible (CC) trains that can run on both the High Speed and the classic rail network, and*
- *Phase 2b fleet will be made up of Captive (CP) trains that are dedicated to the High Speed network.*

5.2.3 The flows are summarised in Table 5, normalised to 200m long trains.

**Table 5:** Train flow data

| Scheme | Train | Daytime Flow, 16h 07:00 – 23:00 | Night-time Flow, 8h 23:00 – 07:00 |
|---|---|---|---|
| Phase 1 Year 15 Flows | CC (330kph) | 191 | 1 |
| | CC (360kph) | 22 | 12 |
| | CP (330kph) | 222 | 1 |
| | CP (360kph) | 22 | 13 |

5.2.4 The change in total 16-hour daytime flows between those used for the ES and the current expected service pattern, summarised in Table 5, is +3%, i.e. the most recent flows are slightly higher.

5.2.5 Table 6 contains a summary of the latest noise sources provided by HS2 Ltd used in the operational noise modelling; the input source terms have also been included in Appendix A.

**Table 6:** Sound emissions from each train running at 320kph on assumed HS2 infrastructure, expressed in terms of the SEL and $L_{pAFmax}$ 25 m from nearest track and 3.5m above ground

| Source | SEL dB at 25m | | $L_{pAF,max}$ dB at 25m | |
|---|---|---|---|---|
| | Conventional Compatible train | Captive train | Conventional Compatible train | Captive train |
| Rolling | 92 | 92 | 89 | 89 |
| Body Aerodynamic | 92 | 90 | 89 | 87 |
| Start-up / Power | 74 | 74 | 73 | 73 |
| Pantograph Well | N/A | N/A | N/A | N/A |
| Raised Pantograph | 76 | 76 | 78 | 78 |

5.2.6 In accordance with the validated airborne noise prediction methodology (TNPM), an adjustment of +1 dB has been added for sections of the route on viaduct for the purposes of defining the indicative mitigation. For example, predicted noise levels at assessment locations where viaduct sources are dominant will be subject to an adjustment of +1 dB to the calculated total noise level.

5.2.7 As Detailed Design (Technical Design) progresses, the design features of the Colne Valley viaduct (CVV) are being investigated in order to optimise the acoustic performance of the iaduct, meeting HS2 noise policy requirements at the same time as meeting the overall architectural and engineering requirements of the design. To demonstrate the effectiveness of these features, it has been necessary to develop supplementary adjustments to the TNPM. This validated methodology has been used for the HS2 Environmental Statement and, prior to that, the Channel Tunnel Rail Link (HS1). The adjustments have been approved by HS2 Ltd for the purposes of these Schedule 17 requests for approval.

5.2.8 A summary of the indicative source adjustments for the potential generic mitigation design elements is provided in Table 7. Note that for the hybrid barrier, the adjustments have been determined on a case by case basis at each receptor which varies according to the site-specific geometrical relationship between the source, barrier and receptor. As such, singular corrections are not provided in this table. Further details of the adjustments are provided in Appendix B.

**Table 7:** Summary of train noise source adjustments

| Mitigation | Indicative Adjustment for specified noise source1 (dB) | | | Additive Options |
|---|---|---|---|---|
| | Rolling | Body Aero | Pantograph | |
| 1. Hybrid barrier | Hybrid barrier correction[2] | Hybrid barrier correction[2] | Absorptive barrier correction[3] | 2 or 3 |
| 2. Top edge attachment: Diffraction/resonator device | -2.5 | -2.5 | -2.5 | 1 |
| 3. Top edge attachment: Absorptive lining to top edge | -1.0 | -1.0 | 0.0 | 1 |

1Adjustment applies to the equivalent continuous sound pressure level, LpAeq,T and the maximum sound pressure level, LpAFmax

2Apply geometry specific, and trackside absorption arrangement specific, Hybrid correction on a case by case basis

3Absorptive barrier model specified for this source due to the absence of a reflective train body, and hence unlikely conditions for any reverberant sound field build-up.

# 6 Results

## 6.1 Modelling results – Airborne noise

### Baseline

6.1.1 Baseline noise levels for each assessment location, as previously used in the ES, have been included in the Appendix C. Full details of the baseline study have been reported in the ES Appendix (SV-002-007) [6].

6.1.2 As discussed and agreed with HS2 Ltd, baseline data has not been updated as part of this assessment.

### Rail

6.1.3 Rail noise levels have been exported from NoiseMap™ as $L_{pAeq,\ 1h}$ and $L_{pAmax}$ indices and have been modified as necessary for the hybrid barrier and top edge attachment adjustments, to produce $L_{pAeq,\ 16h}$ for daytime, $L_{pAeq,\ 8h}$ for night time and $L_{pAmax}$ indices to inform the impact assessment.

### Road

6.1.4 Road noise levels have been calculated as $L_{pAeq,\ 16h}$ for daytime and $L_{pAeq,\ 8h}$ for night time at each assessment location and are presented in Appendix D.

## 6.2 Modelling results - GBNV

6.2.1 The ES reported groundborne noise and vibration levels at two assessment locations: Denham Way (ID 389096) and the Hillingdon Outdoor Activities Centre (HOAC - ID 711001). No groundborne noise and vibration impacts from the operational railway were identified.

6.2.2 As required by HS2 Information Paper E21, groundborne noise and vibration will be predicted and assessed, as detailed design develops, in terms of dB $L_{pASMax}$, $VDV_{day}$ m/s$^{1.75}$ and $VDV_{night}$ m/s$^{1.75}$.

## 6.3 Assessment of compliance

### Compliance with the U&As

6.3.1 To comply with the EMRs, acoustic mitigation providing a certain level of performance is required to ensure that no new significant effects are created with respect to the ES predictions, taking into account the reduced number of impacts/effects specified in U&As 1177, 1178 and 1179.

6.3.2 As previously discussed, the ES road traffic noise predictions and the measured ES baseline noise levels have not been updated as part of this assessment. Therefore, the key influence over increased noise effects, relative to AP5, is the operational rail noise. Therefore, to avoid any new significant effects, and to comply with the Environmental Minimum Requirements, the impact of the operational rail noise has been the focus for mitigation design.

6.3.3 During the iterative design development, a hybrid barrier scheme (without top edge treatments) was modelled and assessed for compliance with the U&As. This design did not provide sufficient acoustic attenuation to meet the requirements of the location specific U&As and the barrier design was subsequently modified.

6.3.4 The submitted design utilises a combination of 4m hybrid (i.e. partially absorptive) and 4m opaque fully absorptive barrier designs along with top edge treatments. This design is predicted to reduce the specified numbers of impacts/effects to those required by all three location specific U&As.

**Table 8:** Full hybrid and submitted results comparison

| ID | Location | Minimum Requirements for U&A Compliance | | | Full hybrid design impacts | | | Submitted design impacts | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Minor | Mod-erate | Major | Minor | Mod-erate | Major | Minor | Mod-erate | Major |
| U&A_1177 | South Harefield | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| U&A_1178 | Savay Farm | 0 | 7 | 0 | 0 | 13 | 0 | 0 | 7 | 0 |
| U&A_1179 | Wyatt's Covert and Tilehouse Lane | 16 | 2 | 0 | 70 | 5 | 0 | 16 | 2 | 0 |

**Table 9:** Noise Barrier compliance summary: U&As

| Reference | Summary Requirements | ALIGN Barrier Scheme | Compliant? |
|---|---|---|---|
| U&A_1177 (714) | ES reported 48 minor impacts at residential properties at South Harefield. Mitigation measures required to remove 44 of the 48 minor noise effects as reported in the ES. | The impacts at all receptors at South Harefield have been reduced to 'Negligible' with the ALIGN JV design. | Yes |
| U&A_1178 (715) | The ES reported seven moderate impacts and six minor impacts at residential properties close to Savay Farm. Mitigation measures required to remove all 6 of the minor noise effects as reported in the ES. | The 6 minor impacts have been reduced to 'Negligible' with the ALIGN JV design. The 7 moderate impacts remain. | Yes |
| U&A_1179 (716) | The ES reported 18 moderate impacts and 69 minor impacts at residential properties at Wyatt's Covert and Tilehouse Lane. Mitigation measures required to remove 16 out of 18 moderate noise effects and 53 out of 69 minor noise effects as reported in the ES. | The 18 moderate impacts have been reduced to 2 with the ALIGN JV design. The 69 minor impacts have been reduced to 16. | Yes |

### Compliance with the Environmental Minimum Requirements

6.3.5 With respect to airborne noise, it is considered that no 'new significant effects' will be introduced by the proposed CVV subject to these Schedule 17 requests for approval as the impact categories at all noise assessment locations are predicted to be no worse than the associated impact category presented in the ES. A summary of the calculated airborne noise impacts has been presented graphically in Figure 6.

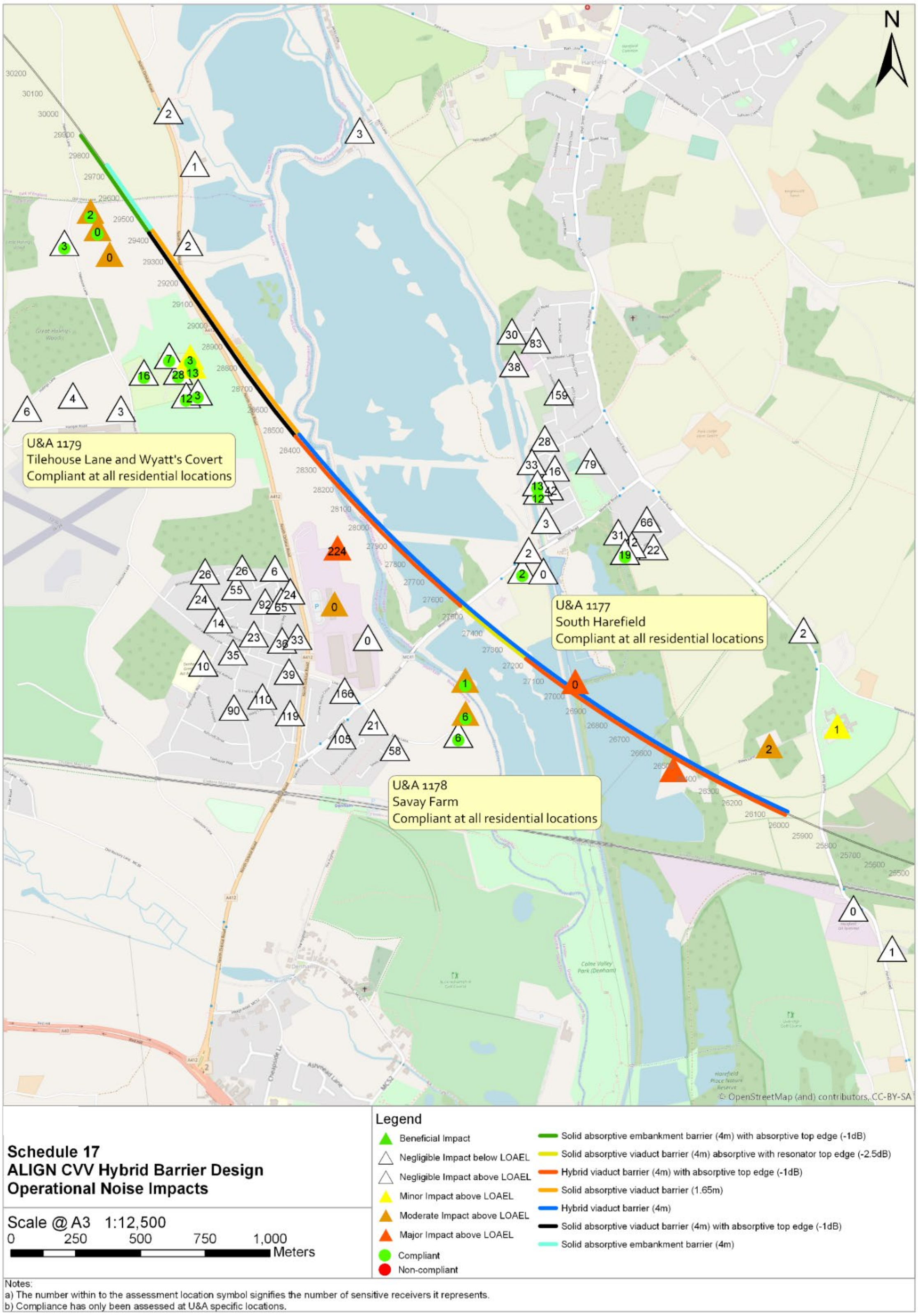



**Figure 6:** ALIGN JV Proposed CVV Design impact assessment

6.3.6 Full impact assessment results for receptors where the LOAEL is predicted to be exceeded is provided in Appendix D. The following additional receptors have been assessed which were not previously considered in the ES:

- *Moorhall Cottage, Moorhall Road, Harefield, Uxbridge, UB9 6PE.*
- *The Denham Film Studios, Denham Media Park, North Orbital Road, Denham, UB9 5HQ.*

6.3.7 A summary of assessment results for the additional receptors is provided in Table 10.

**Table 10:** Summary of additional receptor assessment results

| Area represented | Impacts represented | Baseline noise level, dB | | Predicted overall 'Do Something' noise level, dB | | Change in noise level, dB | | Impact Category |
|---|---|---|---|---|---|---|---|---|
| | | Day $L_{Aeq,16h}$ | Night $L_{Aeq,16h}$ | Day $L_{Aeq,16h}$ | Night $L_{Aeq,16h}$ | Day $L_{Aeq,16h}$ | Night $L_{Aeq,16h}$ | |
| DENHAM FILM STUDIOS, DENHAM | 224 | 46 | 39 | 56 | 47 | 11 | 8 | Major |
| MOORHALL COTTAGE, HAREFIELD | 1 | 58 | 53 | 59 | 54 | 1 | 0 | Negligible |

6.3.8 The Denham Film Studio residential development has been constructed since the ES was undertaken and hence was not considered as a committed development at the time of the HS2 ES. Table 10 shows that 224 new sensitive receptors are predicted to have a 'Major' noise impact. However, as planning permission was granted on the basis that the scheme was designed to consider the future acoustic environment, appropriate mitigation should have been implemented.

6.3.9 Further analysis has been undertaken to identify whether any 'new significant effects' or 'material changes' are predicted to be introduced by the proposed CVV design at the Denham Film Studios development. Noise calculations were retrospectively undertaken to produce a modified ES design model that included the Denham Film Studio residential development.

6.3.10 The results of the further analysis showed that it is highly likely that if the Denham Film Studio residential development had been included in the ES, the calculated impact category would also have been 'Major'. Therefore, it is considered that no 'new significant effects' or 'material changes' will be introduced by the proposed CVV design.

6.3.11 The Moorhall Cottage receptor has been assessed and the impact category has been calculated to be 'Negligible'. It is considered that the proposed CVV design is not predicted to introduce any 'new significant effects' or 'material changes' at Moorhall Cottage.

## 6.4 Assessment of Airborne Train Noise Levels

6.4.1 In addition to the assessment of impacts and effects considered in Section 6.2, required to demonstrate U&A compliance, this section provides an appraisal of train noise levels, as requested during stakeholder consultation. To provide context, a comparison is provided with the ES predicted levels. The AP5 predicted noise levels are not available.

### Airborne train noise levels at selected receptors - $L_{Amax}$

6.4.2 Table 11 contains a summary of $L_{Amax}$ train noise levels at a selection of sensitive receivers, including those requested during consultation with LB Hillingdon, along the proposed alignment, for both the ES and now proposed CVV design. Noise levels are also presented in Figure 7. The reported values represent the most affected floor for the associated receiver and are provided for information only.

6.4.3 The results in Table 11 show that all reported receptors are predicted to have lower $L_{Amax}$ train noise levels when considering the proposed CVV design results, compared with those reported in the ES.

6.4.4 The reduction in predicted $L_{Amax}$ levels ranges from 2 dB to 8 dB, with the average reduction being 6 dB. These reductions are a combined result of the proposed CVV design mitigation measures and the changes to the rolling stock source terms. In particular, the improvements can be attributed to the removal of the TSI trains which formed part of the originally proposed rolling stock fleet.

**Table 11:** Summary of $L_{Amax}$ train noise levels at selected receivers

| Address | OSGB Coordinates | | Predicted HS2 train noise, dB $L_{Amax}$ | |
|---|---|---|---|---|
| | X | Y | ES | Schedule 17 |
| PEERLESS DRIVE, HAREFIELD | 504970 | 188915 | 63 | 58 |
| HARVIL ROAD, HAREFIELD | 505862 | 187932 | 76 | 74 |
| TILEHOUSE LANE, DENHAM | 503270 | 189930 | 75 | 67 |
| HILLSIDE, HAREFIELD | 505306 | 188682 | 63 | 57 |
| MOORHALL ROAD, HAREFIELD | 504909 | 188610 | 70 | 64 |
| BROADWATER GARDENS, HAREFIELD | 505049 | 189299 | 57 | 52 |
| NORTH ORBITAL ROAD, DENHAM | 503637 | 189398 | 74 | 66 |
| SAVAY LANE, DENHAM | 504689 | 188057 | 67 | 62 |
| TILEHOUSE LANE, DENHAM | 503242 | 189996 | 73 | 67 |
| NORTH ORBITAL ROAD, DENHAM | 503627 | 189434 | 75 | 67 |

| | | | | |
|---|---|---|---|---|
| MOORHALL ROAD, HAREFIELD | 504689 | 188186 | 69 | 64 |
| MOORHALL COTTAGE, HAREFIELD* | 505007 | 188685 | 65 | 61 |
| HOAC, DEWS LANE, HAREFIELD | 505491 | 187840 | 81 | 74 |
| *Not reported in the ES. Closest representative receiver results used to provide an indicative level (ID_402669). | | | | |

### Airborne scheme total noise levels at selected receptors - $L_{Aeq}$

6.4.5 Table 12 contains a summary of scheme total $L_{Aeq}$ noise levels at a selection of receptors along the proposed alignment, including those requested during consultation with LB Hillingdon, for both the ES and Schedule 17 scheme designs. Noise levels are also presented in Figure 7. The reported values represent the most affected floor for the associated receiver. The 16 hour daytime and 8 hour night-time periods are between 07:00-23:00 and 23:00-07:00 respectively.

6.4.6 Scheme total noise takes account of HS2 train noise, ambient noise and any changes in traffic noise from new or altered roads as a result of HS2.

6.4.7 The results in Table 12 show that all reported receptors are predicted to have equal or lower $L_{Aeq}$ noise levels when considering the Schedule 17 design results, compared with those reported in the ES.

6.4.8 The reduction in predicted $L_{Aeq}$ levels is generally between 1 and 2 dB, with some levels remaining unchanged during the night time period. The reductions are a combined result of the proposed Schedule 17 mitigation measures and the changes to the rolling stock source terms.

**Table 12**: Summary of scheme total $L_{Aeq}$ noise levels at selected receivers

| Address | OSGB Coordinates | | Predicted scheme total noise level, dB | | | |
|---|---|---|---|---|---|---|
| | | | ES | | Schedule 17 | |
| | X | Y | $L_{Aeq,16h}$ | $L_{Aeq,8h}$ | $L_{Aeq,16h}$ | $L_{Aeq,8h}$ |
| PEERLESS DRIVE, HAREFIELD | 504970 | 188915 | 53 | 45 | 52 | 45 |
| HARVIL ROAD, HAREFIELD | 505862 | 187932 | 61 | 52 | 59 | 51 |
| TILEHOUSE LANE, DENHAM | 503270 | 189930 | 58 | 49 | 57 | 49 |
| HILLSIDE, HAREFIELD | 505306 | 188682 | 53 | 46 | 51 | 45 |
| MOORHALL ROAD, HAREFIELD | 504909 | 188610 | 59 | 53 | 58 | 52 |
| BROADWATER GARDENS, HAREFIELD | 505049 | 189299 | 53 | 51 | 52 | 51 |
| NORTH ORBITAL ROAD, DENHAM | 503637 | 189398 | 60 | 52 | 58 | 50 |
| SAVAY LANE, DENHAM | 504689 | 188057 | 52 | 44 | 51 | 43 |
| TILEHOUSE LANE, DENHAM | 503242 | 189996 | 58 | 50 | 57 | 49 |
| NORTH ORBITAL ROAD, DENHAM | 503627 | 189434 | 60 | 52 | 58 | 50 |
| MOORHALL ROAD, HAREFIELD | 504689 | 188186 | 54 | 45 | 52 | 44 |
| MOORHALL COTTAGE, HAREFIELD | 505007 | 188685 | 57 | 52 | 59 | 54 |
| HOAC, DEWS LANE, HAREFIELD | 505491 | 187840 | 66 | 57 | 61 | 53 |
| *Not reported in the ES. Closest representative receiver results used to provide an indicative level (ID_402669). | | | | | | |

6.4.9 It can be seen that daytime predicted noise levels at HOAC are 5 dB lower than predicted for the ES.

### Airborne noise levels along the Proposed Recreational Route

6.4.10 As part of the landscape design, a recreational route has been proposed to enhance the local environment and improve connectivity within the Colne Valley Regional Park.

6.4.11 Table 13 contains a summary of train $L_{Aeq}$ and train $L_{Amax}$ noise levels at selected of locations along the 'Recreational Route', for the proposed CVV design. These predicted levels are train noise only (due to lack of baseline data), which due to the close proximity to the route are likely to be reasonably representative of total noise levels. The reported values represent noise levels at a height of 1.5m above ground. Noise levels are also presented in Figure 8.

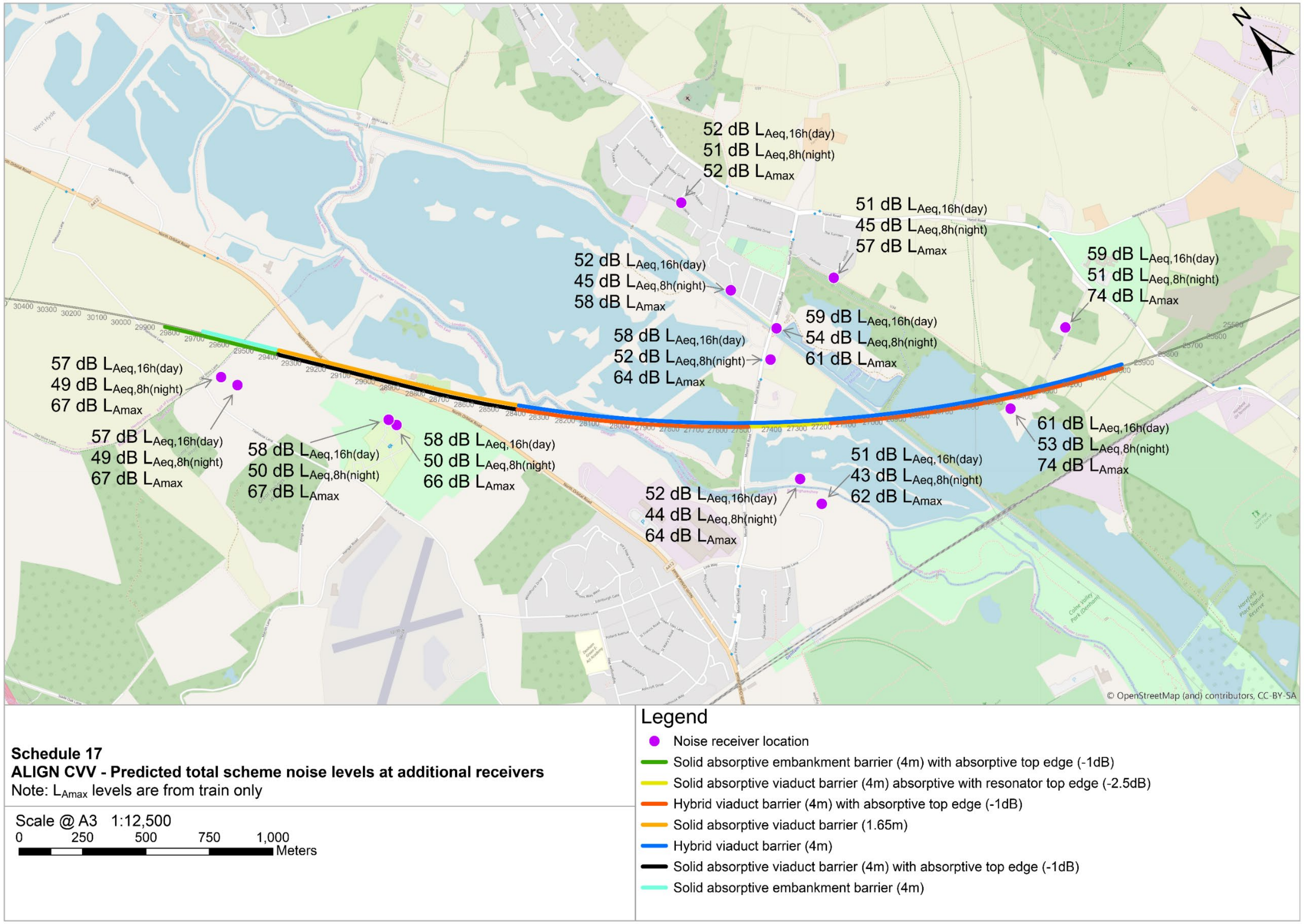



**Figure 7:** Predicted total scheme noise levels at additional receivers

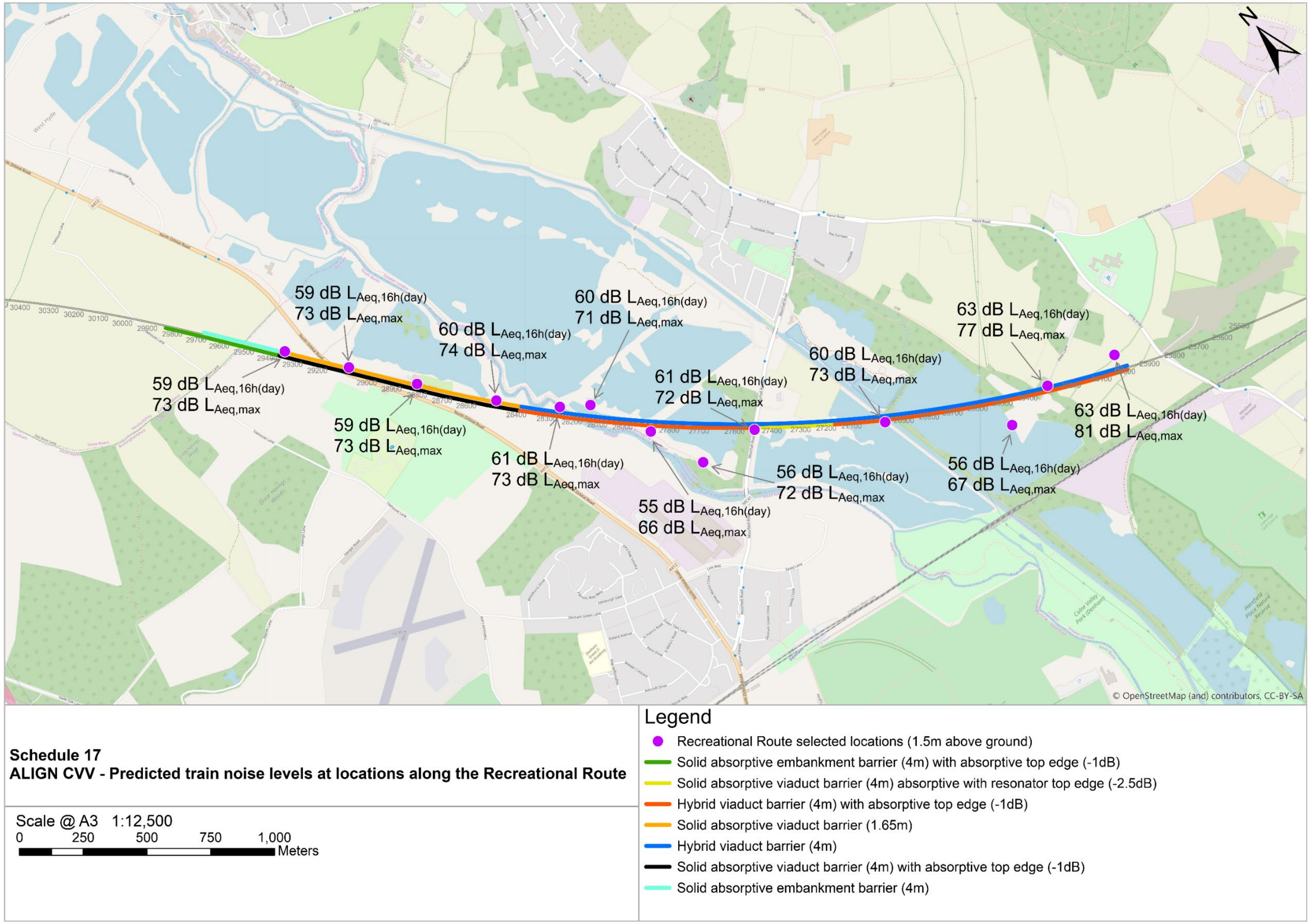



**Figure 8:** Predicted train noise levels at locations along the Recreational Route

**Table 13:** Predicted train noise levels along the Proposed Recreational Route

| ID | OSGB Coordinates | | Predicted Train Noise Level | |
|---|---|---|---|---|
| | X | Y | $L_{Aeq,16h}$ | $L_{Amax}$ |
| Recreational Route 1 | 503496 | 189911 | 59 | 73 |
| Recreational Route 2 | 503643 | 189697 | 59 | 73 |
| Recreational Route 3 | 503801 | 189473 | 59 | 73 |
| Recreational Route 4 | 503990 | 189218 | 60 | 74 |
| Recreational Route 5 | 504161 | 189034 | 61 | 73 |
| Recreational Route 6 | 504255 | 188960 | 60 | 71 |
| Recreational Route 7 | 504365 | 188726 | 61 | 72 |
| Recreational Route 8 | 504439 | 188500 | 55 | 66 |
| Recreational Route 9 | 504674 | 188461 | 56 | 72 |
| Recreational Route 10 | 505077 | 188143 | 60 | 73 |
| Recreational Route 11 | 505442 | 187804 | 56 | 67 |
| Recreational Route 12 | 505647 | 187826 | 63 | 77 |
| Recreational Route 13 | 505923 | 187742 | 63 | 81 |

6.4.12 The noise levels in Table 13 are reasonably consistent along the Recreational Route, with the $L_{Aeq}$ levels ranging from 55 – 63 dB and the $L_{Amax}$ levels ranging from 66 – 77 dB. The variation in noise levels is primarily associated with distance to the viaduct. These levels only consider the train as a source and other environmental noise sources may also affect the acoustic climate and total noise levels along the Recreational Route.

6.4.13 Noise levels at locations typically underneath the viaduct, or at ground level in proximity to the viaduct are predicted to have LAeq levels ranging from 55 – 63 dB and the LAmax levels ranging from 66 – 77 dB. There are no specific design guidance noise levels for public rights of way and/or footpaths. Given the location of the new footpaths will be in the location of a new transport corridor, and that users of the footpath will be transient rather than static, it is considered that these noise levels will be acceptable to most users seeking to use these routes.

6.4.14 As a comparison, the $L_{Aeq,16h}$ levels on the Old Shire Lane bridleway (CSP/44/1), at the junction with Rickmansworth 004 bridleway, over 400m from the M25, are approximately 58 dB.

# 7 Conclusions

7.1.1 Extensive consultation across the ALIGN JV viaduct design team has been undertaken to minimise operational noise from the railway, whilst meeting the overall design aspirations for the viaduct, for example, the incorporation of transparent panels into the barriers. The specimen design created a level of expectation in terms of visual appearance and the noise barriers that are required, need to be carefully integrated into the overall viaduct design.

7.1.2 In order to demonstrate compliance in terms of AFARP, the following criteria have been considered:

- *Monetary benefit of noise reduction compared to cost;*
- *Engineering practicability;*
- *Impacts on other environmental disciplines, including landscape and visual; and*
- *Consultation and stakeholder engagement responses.*

7.1.3 This report identifies the assessment locations predicted to exceed LOAEL (as set out in Table 1 of Appendix B of Information Paper E20) and describes how these levels have been reduced as far as reasonably practicable (AFARP), through mitigation design.

7.1.4 The viaduct design features to minimise airborne noise include:

- *viaduct cross section width has been reduced as far as possible;*
- *barriers inclined inwards 9°;*
- *robust kerb, incorporating acoustic absorption;*
- *continuous barrier, 4m in height on both elevations, except for a section of 1.65m barrier at the northern end of the viaduct on the northern elevation;*
- *the barriers will be a combination of hybrid (absorptive visually opaque lower element and a reflective transparent upper element), and opaque absorptive barrier; and*
- *barrier top edge treatments will provide additional levels of acoustic attenuation.*

7.1.5 It is considered that the mitigation design, in the context of the wider aspirations for the viaduct, complies with HS2 Ltd.'s Environmental Minimum Requirements, which are governed by the Government's Policy on Noise and described in IP E20 and IP E21; the viaduct design reduces noise AFARP and complies with the relevant U&As.

# 8 Reference Documents

| # | Document Title | Reference |
|---|---|---|
| [1] | HS2 Phase One Information Paper E20: Control of Airborne Noise from Altered Roads and the operational railway | IP E20 |
| [2] | HS2 Phase One Information Paper E21: Control of Ground-borne Noise and Vibration from the Operation of Temporary and Permanent Railways | IP E21 |
| [3] | HS2 Environmental Statement – Technical Appendices, CFA7 Colne Valley Baseline (SV-002-007) sound, noise and vibration | SV-002-007 |
| [4] | HS2 Environmental Statement - Volume 5: sound, noise and vibration CFA 07 - Appendix SV - 001 - 000: Annex D2: Operational Assessment - Airborne sound | SV - 001 - 000 Annex D2 |
| [5] | HS2 Environmental Statement Volume 5 Scope and methodology report CT-001-000/1, November 2013 | CT-001-000/1 |
| [6] | HS2 Environmental Statement – Technical Appendices, CFA7 Colne Valley Baseline (SV-002-007) sound, noise and vibration. | SV-002-007 |

# Appendix A

## Source values for HS2 trains expressed in terms of SEL and $L_{pAF,max}$

| Source | SEL dB | | $L_{pAF,max}$ dB | |
|---|---|---|---|---|
| | Conventional Compatible train | Captive train | Conventional Compatible train | Captive train |
| Rolling | 42.1 | 42.1 | 13.6 | 13.6 |
| Body Aerodynamic | -57.9 | -59.9 | -86.5 | -88.5 |
| Start-up / Power | 98.7 | 98.7 | 73.0 | 73.0 |
| Pantograph Well | N/A | N/A | N/A | N/A |
| Raised Pantograph | -74.3 | -74.3 | -97.3 | -97.3 |

# Appendix B

# HS2 Train Noise Prediction Model Refinements: Summary of Preliminary Proposals

# Contents



**List of tables**

# 1 Executive Summary

1.1.1 As part of the Hybrid Bill process, a commitment was given that noise barriers of specific height (or implement noise mitigation measures which deliver equivalent performance) would be provided to mitigate the effects of trains crossing the Colne Valley viaduct (CVV) on properties in the South Harefield, Savay Farm and Wyatt's Covert and Tilehouse Lane areas, as set out in U&As 1177, 1178 and 1179. These three U&A commitments are summarised below.

**Table 1**: Summarised Specific U&A requirements for CVV

| ID | Summarised Undertakings & Assurances Text | Location |
|---|---|---|
| U&A_1177 (714) | The Environmental Statement (ES) reported 48 minor impacts at residential properties at South Harefield. The Secretary of State will require the nominated undertaker to implement a 3m noise barrier on the upside line of Work No. 2/1 from chainage 26+350 to 28+450, or implement noise mitigation measures which deliver equivalent performance in removing 44 of the 48 minor noise effects as reported in the ES. | South Harefield |
| U&A_1178 (715) | The ES reported seven moderate impacts and six minor impacts at residential properties close to Savay Farm. The Secretary of State will require the nominated undertaker to implement a 3m noise barrier on the downside line of Work No. 2/1 from chainage 26+730 to 26+960, or implement noise mitigation measures which deliver equivalent performance in removing all 6 of the minor noise effects as reported in the ES. | Savay Farm |
| U&A_1179 (716) | The ES reported 18 moderate impacts and 69 minor impacts at residential properties at Wyatt's Covert and Tilehouse Lane. The Secretary of State will require the nominated undertaker to implement a 4m [noise barrier] on the downside line of Work No. 2/1 from chainage 28+500 to 29+850, or implement noise mitigation measures which deliver equivalent performance in removing 16 out of 18 moderate noise effects and 53 out of 69 minor noise effects as reported in the ES. | Wyatt's Covert and Tilehouse Lane |

1.1.2 Any noise barrier provision to the viaduct must fulfil these commitments and is subject to confirmation through noise modelling.

1.1.3 Potential design features of the Colne Valley viaduct (CVV) are being investigated to maximise the acoustic performance of the viaduct, meeting HS2 noise policy requirements whilst optimising the overall architectural and engineering aspirations of the design.

1.1.4 To demonstrate the effectiveness of these features, it is necessary to develop supplementary adjustments to the airborne noise calculation methodology (commonly referred to as the Train Noise Prediction Model (TNPM)). This validated methodology has been used for the HS2 Environmental Statement and, prior to that, the Channel Tunnel Rail Link (HS1). A brief TNPM technical background is provided in Appendix B(i).

1.1.5 The purpose of this study is to present an initial approximation, with justifications, of the TNPM adjustments that are being applied to quantify the acoustic benefits of the potential design features and indicative mitigation for the CVV. The adjustments are in the process of being approved by HS2 Ltd.

1.1.6 The continued use of TNPM ensures calculations are fundamentally consistent with the validated calculation methodology but allows certain design features that are outside the functionality of the calculation methodology to be accounted for in the predicted noise levels.

1.1.7 In addition to the provisions already included in TNPM for wholly reflective and absorptive noise barriers, the following further airborne sound mitigation options have been identified. It may be necessary to incorporate these options in isolation or in combination:

- Hybrid barrier (a barrier configuration consisting of both acoustically absorptive and reflective elements).
  Barrier top edge attachments compromising diffracting edge attachments and absorptive linings.
- Acoustically absorptive treatments to the vertical surfaces adjacent to the trackbed area, for example the inner faces of the robust kerb.

1.1.8 It should be noted that the above mitigation options are based on ALIGN JV's scope as Main Works Civils Contractor MWCC. The area in and around the track forms part of the Rail Systems contract and thus the potential further performance benefits and engineering practicability considerations of absorptive treatments in the track design are not considered here.

1.1.9 Further to the need to deliver a design which demonstrates the requirement to reduce airborne noise as far as reasonably practicable (AFARP[1]), consideration of a hybrid barrier option has arisen due to a design aspiration to achieve an acceptable balance between desired noise reduction, visual/landscape requirements and passenger experience. This requires the developing of a noise barrier design incorporating part transparent and part acoustically absorptive (opaque) sections. It should be noted that, with the introduction of such transparent elements, this will inevitably introduce acoustically reflective properties on the trackside of the noise barriers.

1.1.10 The report provides a brief review of the proposed methodologies to adjust the predicted noise levels from the TNPM, along with technical justifications.

1.1.11 A summary of the indicative source adjustments for the potential generic mitigation design elements is provided below. Note that for the hybrid barrier, the adjustments will

[1] AFARP – 'as far as is reasonably practicable', refer to HS2 Information Paper E20 Control of airborne noise from altered roads and the operational railway.

be determined on a case by case basis and so it is not feasible to provide singular corrections within this table.

**Table 2:** TNPM adjustment summary

| Mitigation | Indicative Adjustment for specified noise source[1] (dB) | | | Additive Options |
|---|---|---|---|---|
| | Rolling | Body Aero | Pantograph | |
| 1. Hybrid barrier | Hybrid barrier correction[2] | Hybrid barrier correction[2] | Absorptive barrier correction[3] | 2 or 3 |
| 2. Top edge attachment: Diffraction/resonator device | -2.5 | -2.5 | -2.5 | 1 |
| 3. Top edge attachment: Absorptive lining to top edge | -1.0 | -1.0 | 0.0 | 1 |

[1]Adjustment applies to the equivalent continuous sound pressure level, $L_{pAeq,T}$ and the maximum sound pressure level, $L_{pAFmax}$
[2]Apply geometry specific, and trackside absorption arrangement specific, Hybrid correction on a case by case basis
[3]Absorptive barrier model specified for this source due to the absence of a reflective train body, and hence unlikely conditions for any reverberant sound field build-up.

1.1.12 For all of these adjustments there is a degree of uncertainty inherent when applied to the prediction methodology. However, where judgements on the derivation of the adjustments have required consideration of a range of reported performances in the literature, the proposed adjustment value has in every case erred on the side of caution. For example, there are various magnitudes of performance reported for the many different forms of top edge attachments and which can be dependent upon the geometrical relationship between the source, barrier and receiver at a specific location. In the absence of research information that enables a geometrically related generic algorithm to be developed for such an adjustment, it has been necessary to select a reasonable worst case (lower end of the reported performance range) to enable the adjustment to be safely applied in all CVV cases and for all relevant source types and locations. Following this approach, the adjustment values are considered sufficiently robust and appropriate for the purposes of advancing the design and for seeking Schedule 17 (Para 3) plans and specifications approval for mitigation in the CVV area.

1.1.13 It should be noted that there is a requirement that validated prediction models are to be used for the design phase of the Proposed Scheme and so the adjustment method proposed will be validated at scheme design stage including the application of numerical values of prediction model uncertainty.

1.1.14 The options for mitigation described in this note relate to potentially beneficial acoustical performance, and constitute a shortlist of potential measures that are to be considered further during the forthcoming modelling and design optimisation exercises. The measures either in isolation or combination are still subject to the necessary investigations on engineering practicability and other cost benefit considerations which are requirements of the project's airborne noise commitments. Such studies will be undertaken as the design optimisation progresses in order to provide both acoustical and non-acoustical justifications for the final mitigation scheme.

1.1.15 In order to provide a suitable level of certainty to the noise predictions reported for the final proposed scheme, a more detailed noise modelling study will be conducted which will incorporate ray-tracing and/or numerical modelling methods to validate the TNPM adjustments applied during the design development stages. This will provide further assurance that the outcomes resulting from the adoption of the proposed adjustments, described in this note, are robust and have further justified the cautious approach employed in the adjustment derivation process.

# 2 Introduction

## 2.1 Background

2.1.1 In order to model scenarios beyond the capability of the calculation methodology included in the Train Noise Prediction Model (TNPM), corrections or adjustments to the output Noisemap noise levels have been discussed in outline with other Main Works Civils Contractors (MWCCs) and HS2 Ltd. This ensures calculations are fundamentally based on the validated TNPM methodology but allows acoustic features that are outside the functionality of the calculation methodology to be considered in both the optioneering and detailed design development of an asset.

## 2.2 Objectives

2.2.1 This report sets out proposals for the use of adjustments to the TNPM for the purposes of advancing the design of indictive airborne sound mitigation measures for the Colne Valley viaduct (CVV). The emerging viaduct design will incorporate certain innovative approaches for the reduction of airborne sound.

2.2.2 To provide support for these approaches and to guide the next phases of the design, it is necessary to ensure that the proposed adjustments are justifiable and that they can be confidently used to determine compliance with HS2's various airborne sound commitments.

2.2.3 Therefore, this paper also provides the background information that has been considered in deriving the proposed TNPM adjustments.

# 3 Potential Mitigation Measure Options

3.1.1 In addition to the use of either standard reflective or absorptive noise barriers, which are already catered for within TNPM, the following additional airborne sound mitigation options have been identified from an initial sift of options. It may be necessary to incorporate these options in isolation or in combination:

- Hybrid barrier – a barrier configuration made up of both acoustically absorptive and reflective elements.
- Application of acoustic absorption treatments on the trackside vertical surfaces of the robust kerb.
- Barrier top edge attachments comprising diffracting edge attachments; and absorptive linings.

3.1.2 The need for consideration of a hybrid barrier option has arisen due to a clear design direction to find an acceptable balance between desired noise reduction, architectural aspirations, visual/landscape concerns and passenger experience.

3.1.3 The current design considers that to achieve this balance it will be necessary to provide a proportion of the extensive lineside noise barrier mitigation on the viaduct in the form of transparent panels. There is currently no technically verified possibility of achieving this requirement without the transparent elements introducing acoustically reflective properties on the inside of the noise barriers. Therefore, it has been necessary to investigate further the potential effect that such elements may introduce to the achievable noise barrier attenuation and how TNPM can be adjusted to take any such effects into account.

# 4 Proposed TNPM Adjustments

## 4.1 Application of TNPM to HS2

4.1.1 The historical application of the TNPM calculation methodology on the HS2 project is based upon the straight use of the published barrier algorithms[2] for each of the separate sources associated with the HS2 trains. A brief TNPM technical background is provided in Appendix B(i).

4.1.2 No adjustment is included for any barrier performance differences that might arise from consideration of the sources individually. Thus, for an absorptive barrier, even the raised pantograph arm source, 5m above railhead would still be attenuated to a level that assumes the presence of an absorptive inner face to any adjacent barrier. This report does not seek to alter that agreed approach, other than to apply the appropriate adjustments for the additional mitigation options on a selective basis to those sources where such adjustments can be technically justified and to err on the side of caution in any such selective decision-making.

4.1.3 The HS2 prediction methodology directs that the start-up / stationary noise source for trains travelling above 250km/h should be ignored. This source has therefore been excluded from further consideration. The noise sources, along with heights above railhead, considered in this exercise are:

- Rolling noise source at 0.0m
- Body aerodynamic noise source at 0.5m
- Raised pantograph noise source at 5.0m

[2] Ashdown Environmental Limited. British Railways Board Rail Link Project. Validation of the Methodology for Calculation of High Speed Train Noise. Final Report. October 1991.

4.1.4 When applying the above source to TNPM, the horizontal noise source position used for HS2 assessments assumes separate centreline (between the two rails of the track) sources for the up and down lines respectively.

4.1.5 The application of the TNPM calculation methodology in NoiseMap also includes an algorithm to take into account the combined attenuation from more than one barrier ('multiple barriers') along any propagation path. As such, both the robust kerb and the higher noise barriers on the deck edge can combine to generate a marginally higher overall attenuation than the attenuations from the individual barriers modelled in isolation. This approach is to be continued for HS2 design purposes.

## 4.2 Review of Evidence for Proposed TNPM Adjustments

4.2.1 The following subsections address the three generic mitigation options set out in Section 3.1.

### Hybrid barrier

4.2.2 The adjustment derived for the use of a hybrid barrier is based upon the following observations and assumptions:

- That an equivalent barrier attenuation curve for a hybrid barrier would reasonably be expected to sit somewhere between the TNPM reflective and absorptive barrier attenuation curves;
- That the position of the curve would reasonably be expected to relate to the specific civil design features and dimensional arrangements of any acoustic absorption placed on the trackside of the barrier;
- That the relative contribution of direct and reverberant sound fields diffracted around a barrier edge and received at any receptor sitting behind a noise barrier are inherently taken into account in the empirically derived TNPM barrier attenuation algorithms and cannot be readily disaggregated for detailed consideration accordingly;
- For large path difference situations (c.1.5m and above) and with all other parameters remaining equal, the TNPM algorithms indicate that the introduction of a full absorptive lining to the trackside of a reflective noise barrier would improve the attenuation by c.5 dB. This indicates that, in the absence of an absorptive lining, the contribution from the reverberant sound field is greater than from the direct diffracted component due to the higher density of contributing image sources (and consequently lower path differences for them) that arise due to the presence of the train body;
- As the path difference decreases with increasing source height (or decreasing barrier height) the attenuation afforded by absorption reduces to around c. 1.5 dB. This indicates that in the absence of an absorptive lining, the contribution from the reverberant sound in these situations is less than from the direct diffracted sound field due to a reduced density of contributing images sources;

- Absorption applied to the trackside of vertical surfaces will have a more pronounced effect in controlling the build-up of the reverberant sound field if placed close to the source. This is supported by advice provided in HMSO's Calculation of Railway Noise[3] (CRN) which implies that the effect of the reverberant field increases for a reflective barrier with decreasing distance between the barrier and the source (CRN Chart 6c);
- Considerable differences in the performance of hybrid noise barriers might exist between trains operating on near-side and far-side tracks respectively, and that the potential implications of this need to be further understood and tested when attempting to identify a single barrier attenuation algorithm for a hybrid barrier that can be applied to the centreline source of the nearside and far-side tracks;
- That the hybrid barrier algorithm needs to be adaptable for rapid re-assessment of a limited but known set of possible design iterations still to be investigated;
- TNPM applies the reflective and absorptive barrier attenuation algorithms to both $L_{pAeq,T}$ and $L_{pAFmax}$ calculations; and
- CRN suggests that absorptive panelling needs to extend to at least 1m above the source heights under investigation (CRN Chart 6c), although this requirement was removed in the addendum to CRN[4]. The principle is, however, that there must be an appreciable dimension to the noise barrier for it to be able to cause obstruction (and hence reflection) to a sound path from a particular source. A minimum dimension can be used as a primary design guide for the arrangement of trackside absorption for hybrid barriers.

4.2.3 An adjustment to account for the potential acoustical effects of assessing hybrid (i.e. part reflective and part absorptive) wayside noise barriers along sections of the HS2 trace that pass through the Colne Valley has been derived based on a simplified sound path ray tracing technique. The technique has been developed solely to identify a reasonable assumption for the attenuation performance of a hybrid barrier arrangement within the confines of the established reflective and absorptive barrier attenuation curves already defined and validated within the TNPM calculation methodology.

4.2.4 The method considers the proportion of absorption present on the trackside of the barrier and also its proximity to the relevant source under investigation. The approach ensures that the performance of the absorptive vertical surface element is no higher than the validated TNPM models allow for, but at the same time introduces a weighting of importance to each sound path by virtue of accounting for the distance to each of the surfaces, and the proportion of those sound paths that are modified by absorption.

### Diffracting Edge Options

4.2.5 A group of techniques are available which are intended to alter the way that the sound field diffracts around the top edge of a noise barrier. These techniques are intended

[3] Calculation of Railway Noise, 1995. HMSO.
[4] HMSO Calculation of Railway Noise, 1995 (Addendum).

primarily for situations where the receptor lies deep within the shadow zone of a noise barrier, and where the received sound field is principally comprised of the diffracted component of sound.

4.2.6 Whilst the group of techniques are associated with the addition of diffusive elements to the top of the barrier, there are notable sub-sets to these techniques. These include:

- the introduction of multiple diffracting edges using shaped attachments;
- the addition of absorptive treatments to the diffracting edges or between the diffracting edges; and
- the use of tuned Helmholtz resonator devices either in combination with the above or as a proprietary standalone product.

4.2.7 The additional acoustic performance from noise barriers incorporating different diffraction profiles, treatments and/or additional devices compared with the standard barrier top edge design have been derived theoretically for road traffic applications where sources are in general always below the height of the barrier diffracting edge.

4.2.8 Appendix B(ii) provides further information and explanation on a number of research publications including those reported by the Transport Research Laboratory (TRL) and papers by various parties including Kitagawa, Belingard, Horvat and product manufacturer information from Fonocon, In light of TRL experiences (e.g. 2.4 dB reduction due to multiple diffracting edges for same height barrier) it is proposed to include a cautious -2.5 dB adjustment to apply for a generic attachment device to all high speed rail sources. This is likely to err on the side of caution in the shadow zone (Kitagawa reported scaled measured benefits of -6 dB for lower sources and -3 dB for pantograph, and Belingard reported total reductions in high speed rail noise of -3.5 dB). As well as the 5 to 7 dB benefit reported for the Fonocon Sound-Resonator device. other devices investigated in the TRL report suggest that interference attachments could provide between 1.9 (tuned interference channel device) and 3.7 dB (cavity excitation device) reduction according to test results. No information has been identified relating to the use of these devices in high speed railway environments.

4.2.9 Information provided in the TRL review of noise barriers suggests that sound absorbing material applied to the diffraction edge of noise barrier designs could improve road traffic noise mitigation by about a further 1 dB (0.6 dB for flat T shape attachment, and 0.8 dB for a rounded absorptive cap). Belingard also refers to Japan Railway East research undertaken to optimise an ‘L’ shaped barrier by including a large plate on top. With the same top covered with absorbent material, 1 dB more performance is obtained.

4.2.10 On the basis that this is likely to be the case for a conventional reflective barrier where the diffracting edge has been designed to incorporate sound absorption with the aim of modifying the diffraction performance of the barrier, a 1 dB improvement to the attenuation is an appropriate adjustment, in the absence of any other more detailed evidence available for the specific design of the emerging barrier detailing. The addition of absorption to a barrier top would not be additive to the reduction assumed for a barrier top device / attachment.

# 5 Assumptions and Limitations

5.1.1 The work reported here presents an initial approximation of the TNPM adjustments that are needed in order to quantify, with justification, the acoustic benefits of certain specific design elements of the Colne Valley viaduct and for determining indicative mitigation for Schedule 17 (Para 3) plans and specifications approval.

5.1.2 Beyond the indicative mitigation definition stages, the adjustments may require modification using more sophisticated techniques as a more robust assurance and refinement exercise.

# Appendix B(i)

## TNPM Technical Background

1. A fully validated airborne sound calculation methodology was developed for the HS1 project and is used to calculate both $L_{pAeq,T}$ and $L_{pAFmax}$ noise levels from high speed and conventional trainsets. The HS2 project requires that a calculation methodology compliant with the HS2 Technical Standards is used for the purposes of ensuring compliance with the Project's airborne sound commitments including the EMRs and other applicable U&As. The HS1 calculation methodology has been incorporated into a proprietary noise modelling software package known as Noisemap allowing its application on the HS2 project. The proposal to apply adjustments is therefore predicated on being able to apply such adjustments outside of the software package as a post processing mechanism. It has not been considered practicable to request changes to the software package itself.
2. The original calculation methodology that was developed for HS1 assumed that the notional noise source line for the railway is positioned horizontally at midpoint between the up and down lines, and at a vertical height of 0.5m above the railhead. The model has been applied for use on HS2 differently to better represent the vertically distributed sources of noise on trains capable of running at speeds in excess of 300km/h. The model applied for HS2 also requires, however, that train movements on both the up and down lines are defined as separate sources. This is a material consideration when attempting to establish adjustments that can be applied that take into account the expected deterioration in noise barrier performance that might arise as a result of reverberant sound build-up between the inside faces of noise barriers and the sides of the passing trains. In practice, the barrier attenuation effects and any deterioration in performance due to a reverberant sound field would be different for trains passing close to the barrier (on the nearside track) compared to those passing further away (on the far-side track).
3. The TNPM includes separate algorithms for the calculation of barrier attenuation from reflective and absorptive noise barriers. The extent of attenuation afforded by either type of barrier is dependent upon the geometrical relationship between the source, barrier and receptor and in particular is directly related to the propagation 'path difference'. This is defined as the additional distance that sound travels over the top of a barrier compared to the direct distance it would take in the absence of the barrier. The Path Difference is at its maximum (and hence noise reducing properties at their maximum) when the barrier is either placed close to the source or close to the receptor.
4. Figure A1 below presents graphically the barrier attenuation plots by Path Difference.

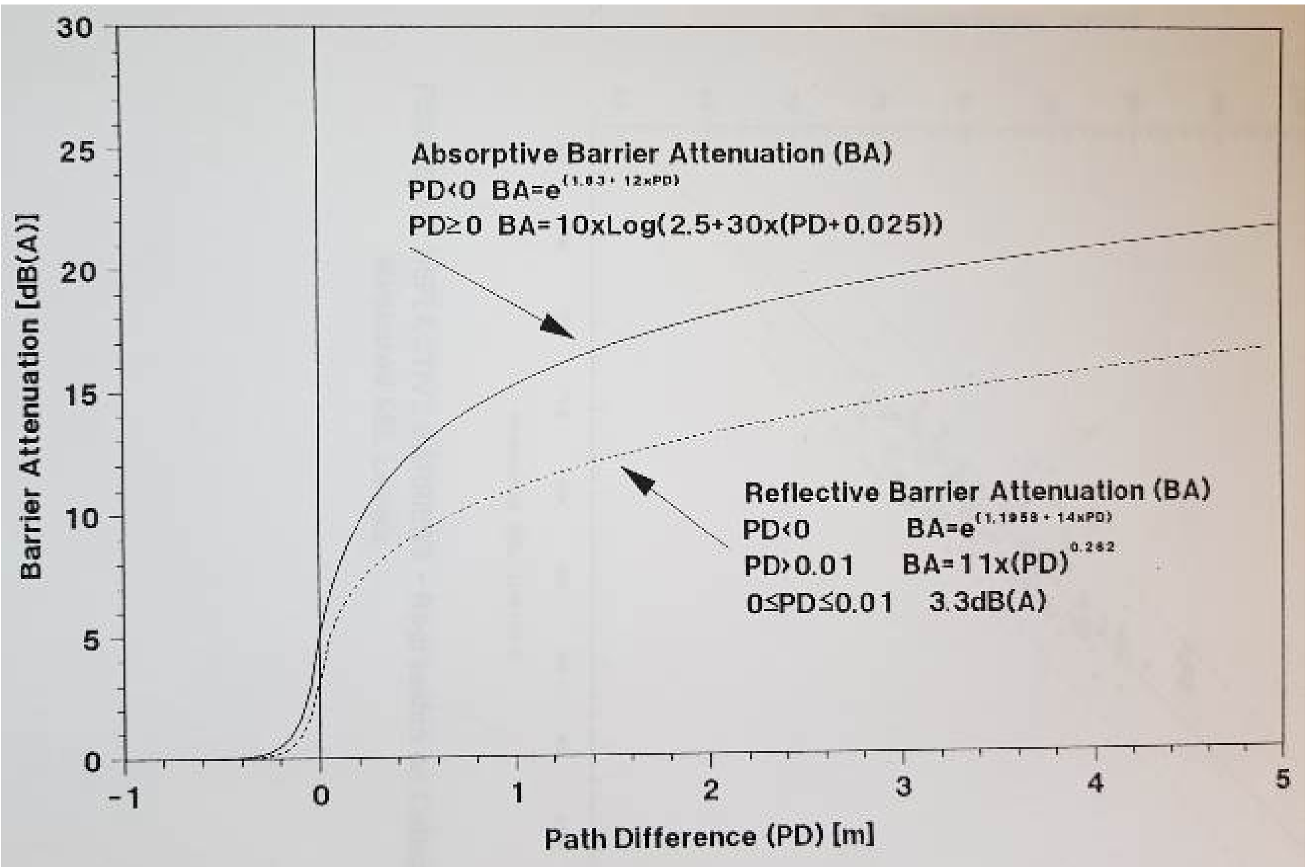



**Figure A1:** graphical representation of TNPM barrier attenuation algorithms

# Appendix B(ii)

## Barrier Top Edge Attachments

1. Studies into the additional acoustic performance from noise barriers incorporating different diffraction profiles, treatments and/or additional devices compared with the standard barrier top edge design may only be applicable to railway rolling and body aerodynamic noise sources but not to the more elevated pantograph sources. There are spectral differences between road and rail noise sources, as well as major differences in the level of reverberant sound fields that can be present for railway rolling stock that is not as pronounced in highway noise. These differences may confound attempts to apply the results from road traffic noise studies to railway noise directly.

2. A review of the acoustic performance of noise barriers incorporating different diffraction profiles has been carried out by TRL[5] and indicate a T shaped diffracting edge provides an additional 1.4 dB(A) compared with a traditional vertical barrier of similar height and a multiple diffracting edge barrier provides about an additional 2.4 dB(A). For highway noise, further additions to the multiple diffracting edge design (including absorption, widening the separation between fins and deepening the fins) had little additional effect.

3. Several studies are available for conventional and high-speed railways. Horvat *et al*[6] conducted field studies on three types of noise barrier configuration: a reference wood cement barrier (absorptive barrier) with a height of 2.14m above rail; an additional 0.5m of a highly absorptive vertical panel with a height of 2.64m above rail; and the replacement of that panel with a T shaped highly absorptive device. Inspection of the photographs contained in the paper suggest that the field studies were in fact based upon a Y shaped device with an open trough rather than a flat-topped T shape. For the purposes of this study the difference in performance of the latter configurations is of interest. The first case has a lower barrier height and is therefore not directly comparable.

4. The paper concludes that replacing the vertical absorptive top with the absorptive T-top device yields an additional increase in barrier attenuation of up to 2.5 dB.

5. However, it should be noted that the field studies used loudspeakers set close to the ground and on the track using synthesised pink noise signals. Whilst the post-processing applied a railway noise spectrum, it is noted that there was no attempt to replicate the physical and acoustical effects of the train body in those studies and hence the benefits reported (from a nominal source

[5] Watts G R and Morgan P A (2005). Noise barrier review (PPR046). Crowthorne: Transport Research Laboratory
[6] Horvat et al (2016). The influence of top finishing of the influence of the top finishing of the noise barrier on its acoustic performance - Field examination. EuroRegio June 2016

position close to the track level) might not be evident in a situation where the train body introduces a reverberant sound field between the train and the barrier.

6. The results of the Horvat study are provided in the form of relative benefits at a number of microphone heights and distances form the track. There are some encouraging trends in the data but also a number of anomalies exist which might suggest that either meteorological effects and/or reduced acoustic power in some frequency bands from the loudspeaker may have been introduced. It is concluded that there should be caution in relying solely on this information for the purposes of this study.

7. Kitagawa *et al*[7] conducted scale model tests on 34 different types of barrier configurations (see Figure B1) to conclude that the 'Y' shaped barrier top performed the best.

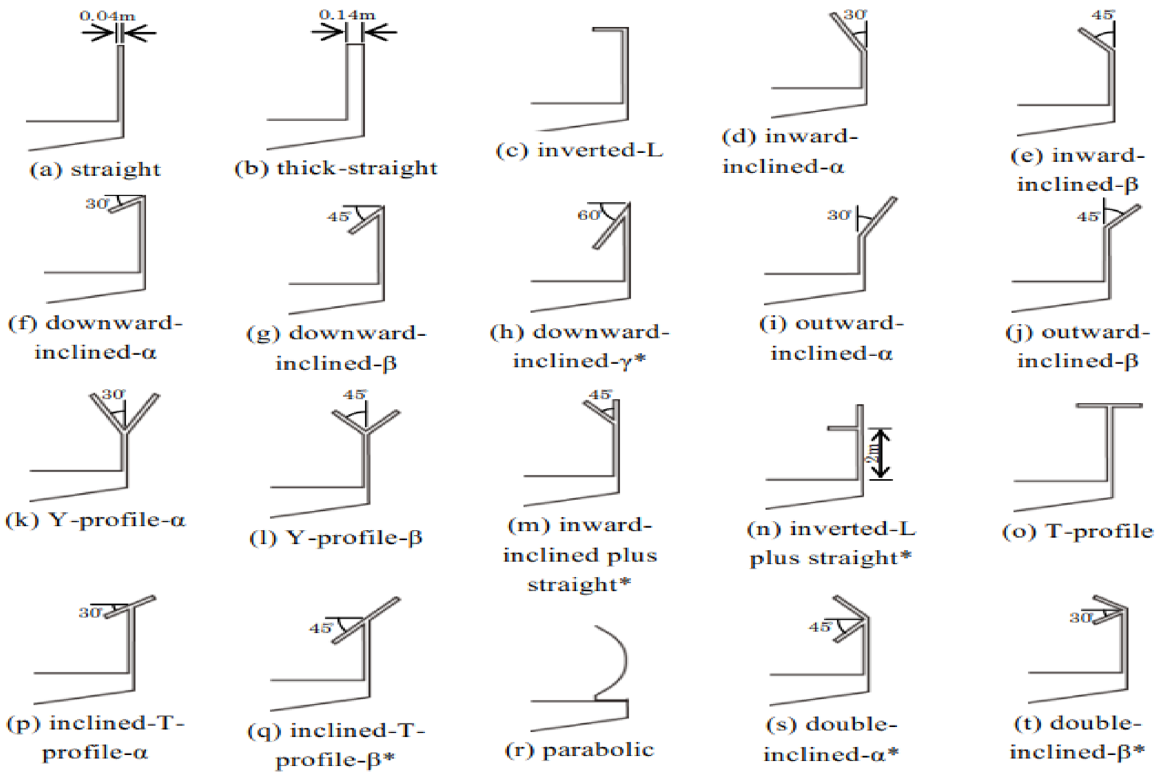



**Figure B1:** Barrier configurations scale tested by Kitagawa

8. For a viaduct example, and when compared to a straight barrier, the 'Y' shaped top portion was shown to provide 6 dB or more in deep shadow zone situations for the sources of noise lower

[7] T. Kitagawa et al (2013). Study on effective sound barriers for high speed trains. Session 12: Interior noise, sound barrier. Proceedings of the 11th International Workshop on Railway Noise, September 2013

down on the train body, and around 3 dB for pantograph noise in the shadow zone. This was explained to be due to the inward inclined part of the device not only increasing the path difference for lower sources of noise but also better controlling reflections for those sources, and the outward inclined part of the device widening the shadow zone (by increasing the path difference) for the pantograph.

9. A 30m long section of 2m high test barrier (see Case 1 in Figure B2) was installed along a Shinkansen railway line on an 8m high viaduct. Variations tested also included the installation of the Y shaped device (see Case 2 in Figure B2), installation of absorption on the trackside of the barrier (vertical portion and inclined portion) (see Case 3 in Figure B2) and the inclusion of vertically located acoustic tubes (Helmholtz resonators) (see Case 4 in Figure B2) ranging from 0.1 to 1.0m in length.

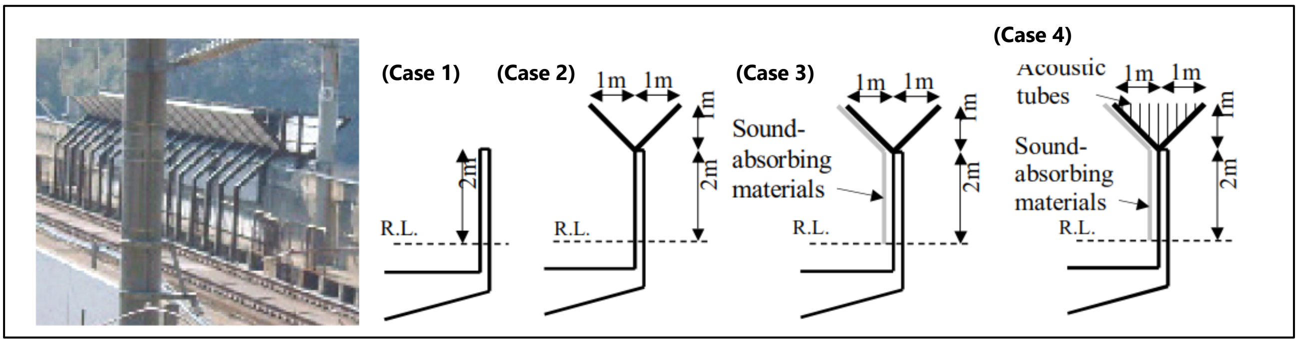



**Figure B2:** Field test configurations by Kitagawa

10. For trains running at 275km/h, the results showed that all variants of the Y shaped barrier provided the same performance to pantograph noise, providing 5 dB more attenuation than the reference vertical 2m high barrier (see Case 1 in Figure 3). This supports the scale model finding that the widened shadow zone caused by outward inclined panel is the primary mechanism for controlling pantograph noise.

11. For the lower sources of noise which the paper indicates may have been contaminated by contriutions of bridge noise, the study showed that the inclusion of the Y shaped device improved the attenuation by 3.5 dB compared to the reference Case 1 (N.B. 1m lower in total height). Only 0.5 dB further benefit was shown with the inclusion of the absorption linings on the trackside, and a further 0.5 dB benefit with the acoustic tubes.

12. According to Belingard[8], a collaborative study referred to as Euroecran[9] (European progamme for elaboration of competitive railways noise barriers) was carried out to design more efficient barriers, validate numerical models and test some of the improved barriers at full scale.

13. The Erocrean study appears to support the Kitagawa findings in that the use of Helmholtz resoators is not an efficient method of improving performance. Belingard undertook field tests on the TGV network in France on a range of barrier shapes and treatments with trains running at up to 380km/h. Again the study did not attempt to rationalise the results according to the changes in positions on the diffracting edges but did provide useful conclusions on the effects of introducing additional diffracting edges using a inclined attachments to the top of the barrier, allowing the effects of a single inward 45 degree cantilevered top section, and a full 'Y' shaped top section (an inward 45 degree cantilevered panel in combination with an outward inclined cantilevered panel) to be investigated. Various absorptive treatments were also investigated in combination with the devices. Notable conclusions from this study are:

    1. Absorptive treatments provided to a standard vertical reflective barrier increases the noise barrier efficiency by 4 to 5 dB, which is consistent with the TNPM calculation methodology;

    2. At running speeds of 375 km/h, a single inward inclined top panel (with absorption on the non-trackside face of the top panel) provided a 1.5 dB reduction compared to the equivalent reflective vertical barrier of the same height;

    3. At running speeds of 320 and 375 km/h, the introduction of an absorptive Y shaped device on the top portion of a barrier (with absorption on the non-trackside faces of the top panels) provides between 3.5 and 4 dB reduction respectively compared to the equivalent reflective vertical noise barrier of the same height;

    4. The inclusion of absorption to the trackside parts of the Y shaped attachment (and not the vertical element) showed no benefit compared to the equivalent attachment without the absorption. This is consistent with the Kitagawa findings which showed only a limited 0.5 dB additional benefit when the entire trackside face was treated with absorption.

14. The conclusion in 3 above is likely to be attributed to the increased path differences (for both lower sources and pantograph sources) associated with the Y shaped option compared to the single inward cantilevered panel.

15. It should be noted that the dimensions described in the Belingard paper suggest that the total heights of the barriers tested in this study were a total of 2.1m above railhead, with the top 1.0m

[8] P. Belingard et al (2012). Experimental Study of Noise Barriers for High-Speed Trains. Noise and Vibration Mitigation for Rail Transportation Systems. Notes on Numerical Fluid Mechanics and Multidisciplinary Design, vol 118. Tokyo
[9] Collaborative project. "Euroecran". Final report. 1998

(c.50% of the total height) being used for the top panel / device variants. Similar dimensions are reported in the Kitagawa paper. These are relatively substantial impingements on both the inward and outward horizontal footprint of the barrier. The magnitude of these dimensions may preclude their practicable application in the case of CVV. They are nevertheless included below as adjustments for the purposes of the looking at all available options in the technical studies.

16. Both Belingard and Kitagawa report measured improvements of at least 3.5 dB for noise barriers with a Y shaped device installed on the top portion of the barrier instead of a fully vertical noise barrier adjacent to high speed trains. However, Kitagawa's reduction was compared only with a lower (by c.1m) vertical barrier. The lower magnitudes of benefit reported by Horvat are less reliable as the study only considered direct sound paths from loudspeakers. Whilst showing some promising data trends, this method is considered to have omitted significant mechanisms associated with railway noise generation including vibration decay rates along the track (and hence rail and trackbed radiation contributions), and the effects of the train body (both in terms of aerodynamic effects, and those associated with the reverberant sound field between the train and the barrier).

17. A proprietary attachment device known as Fonocon Sound-Resonator manufactured by Forster Metalbau (see Figure B3) is reported to be able to provide additional insertion losses of between around 5 and 7 dB at varying distances from the barrier when compared to the attenuation from a vertical noise barrier of the same height, and when accounting for the dimension of the device itself. The field study considered a 3m high noise barrier, with a single loudspeaker source 3.8m from the barrier. The microphone was positioned at a height of 1.5m above ground and distances ranging from 10m to 300m from the barrier.

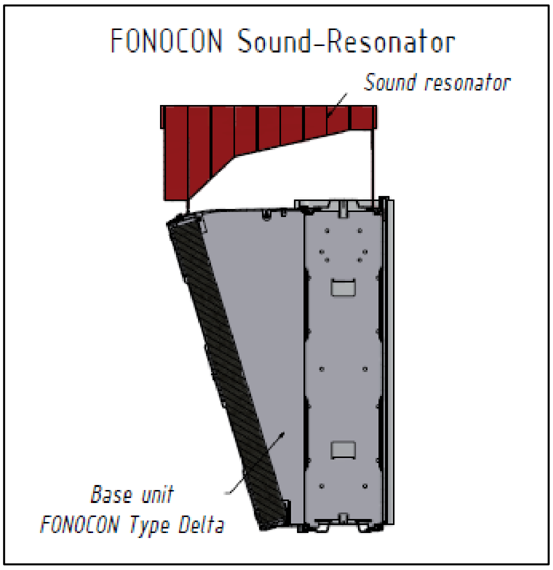



**Figure B3:** Schematic of Fonocon Sound-Resonator

18. There is insufficient information available to understand any robust path difference relationship for the resonator device as the field measurements were restricted to a relatively narrow range of path differences. In addition, as the field studies were conducted using a single point source loudspeaker the results may not be representative of those expected in a railway environment.

19. Without information on how the beneficial effects of such a device change when the receptor is deep within the shadow zone (as is the case for the CVV) or for specific railway environments it has not been deemed practicable to derive and apply an adjustment for the purpose of the CVV design that is based upon anything other than a conservative linear value at this time.

# Appendix C

## Baseline noise measurement data from ES Baseline Report [6]

| ID | Area represented | Baseline measured noise level, dB | | |
|---|---|---|---|---|
| | | Day $L_{Aeq,16h}$ | Night $L_{Aeq,8h}$ | Average $L_{Amax}$ |
| 401424 | HARVIL ROAD, HAREFIELD | 55 | 50 | 58 |
| 391428 | NORTH ORBITAL ROAD, DENHAM | 46 | 39 | 67 |
| 384374 | TILEHOUSE LANE, DENHAM | 50 | 44 | 50 |
| 401764 | HARVIL ROAD, HAREFIELD | 51 | 47 | 53 |
| 402608 | HARVIL ROAD, HAREFIELD | 72 | 68 | 81 |
| 700368 | TILEHOUSE LANE, DENHAM | 51 | 45 | 50 |
| 402669 | MOORHALL ROAD, HAREFIELD | 57 | 52 | 56 |
| 389222 | UNNAMED ROAD, DENHAM | 55 | 48 | 59 |
| 385086 | UNNAMED ROAD, DENHAM | 55 | 48 | 59 |
| 396888 | OLD UXBRIDGE ROAD, WEST HYDE | 54 | 47 | 56 |
| 391607 | MOORHALL ROAD, HAREFIELD | 56 | 52 | 70 |
| 408975 | HARVIL ROAD, HAREFIELD | 61 | 53 | 63 |
| 391211 | MOORFIELD ROAD, DENHAM | 53 | 46 | 59 |
| 408811 | HARVIL ROAD, ICKENHAM | 61 | 53 | 63 |
| 383893 | UNNAMED ROAD, DENHAM | 55 | 48 | 59 |
| 384372 | NORTH ORBITAL ROAD, DENHAM | 55 | 48 | 59 |
| 709521 | HAREFIELD MARINA MOORINGS | 46 | 39 | 48 |
| 391326 | SAVAY LANE, DENHAM | 46 | 39 | 48 |
| 711001 | HILLINGDON OUTDOOR ACTIVITIES CENTRE | 51 | 47 | 53 |
| 389429 | TILEHOUSE LANE, DENHAM | 51 | 45 | 50 |
| 700371 | NORTH ORBITAL ROAD, DENHAM | 55 | 48 | 59 |
| 700370 | UNNAMED ROAD, DENHAM | 65 | 58 | 61 |
| 700372 | UNNAMED ROAD, DENHAM | 55 | 48 | 59 |
| 700375 | MOORHALL ROAD, HAREFIELD | 46 | 39 | 48 |
| 700374 | MOORHALL ROAD, HAREFIELD | 58 | 53 | 70 |
| 711000 | HORSE & BARGE VISITOR MOORINGS | 55 | 50 | 56 |
| 396945 | OLD UXBRIDGE ROAD, WEST HYDE | 54 | 47 | 56 |
| 389194 | TILEHOUSE LANE, DENHAM | 51 | 45 | 50 |
| 391453 | DENHAM FILM STUDIOS, DENHAM | 46 | 39 | 67 |

# Appendix D

## Summary of assessment results at receptors predicted to be above LOAEL

| ID | Area represented | Impacts represented | Baseline Day | Baseline Night | Baseline average $L_{Amax}$ | HS2 Train Day | HS2 Train Night | HS2 Train $L_{Amax}$ | DM Traffic Model Day | DM Traffic Model Night | DS Traffic Model Day | DS Traffic Model Night | HS2 Total $L_{Aeq}$ Day | HS2 Total $L_{Aeq}$ Night | Residual Noise Day | Residual Noise Night | DS Day | DS Night | Change Day | Change Night | Impact Category |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 401424 | HARVIL ROAD, HAREFIELD | 1 | 55 | 50 | 58 | 55 | 45 | 73 | 55 | 46 | 55 | 45 | 58 | 48 | 0 | 49 | 58 | 51 | 3 | 1 | 102 |
| 391428 | NORTH ORBITAL ROAD, DENHAM | 0 | 46 | 39 | 67 | 51 | 42 | 62 | 35 | 26 | 34 | 25 | 51 | 42 | 46 | 39 | 52 | 44 | 6 | 4 | 103 |
| 384374 | TILEHOUSE LANE, DENHAM | 3 | 50 | 44 | 50 | 49 | 40 | 59 | 36 | 27 | 36 | 27 | 49 | 40 | 50 | 44 | 53 | 45 | 3 | 2 | 99 |
| 401764 | DEWS LANE, HAREFIELD | 2 | 51 | 47 | 53 | 58 | 49 | 74 | 52 | 42 | 51 | 42 | 59 | 50 | 0 | 46 | 59 | 51 | 7 | 4 | 103 |
| 402608 | HARVIL ROAD, HAREFIELD | 2 | 72 | 68 | 81 | 48 | 39 | 64 | 45 | 36 | 41 | 32 | 49 | 40 | 72 | 68 | 72 | 68 | 0 | 0 | 99 |
| 700368 | TILEHOUSE LANE, DENHAM | 0 | 51 | 45 | 50 | 56 | 46 | 67 | 35 | 26 | 31 | 23 | 56 | 46 | 51 | 45 | 57 | 49 | 6 | 4 | 103 |
| 402669 | MOORHALL ROAD, HAREFIELD | 3 | 57 | 52 | 56 | 49 | 40 | 59 | 29 | 21 | 29 | 21 | 49 | 40 | 57 | 52 | 57 | 52 | 1 | 0 | 99 |
| 389222 | UNNAMED ROAD, DENHAM | 28 | 55 | 48 | 59 | 52 | 43 | 63 | 29 | 21 | 28 | 20 | 52 | 43 | 55 | 48 | 57 | 49 | 2 | 1 | 99 |
| 385086 | UNNAMED ROAD, DENHAM | 12 | 55 | 48 | 59 | 51 | 42 | 62 | 29 | 21 | 29 | 21 | 51 | 42 | 55 | 48 | 56 | 49 | 2 | 1 | 99 |
| 396888 | OLD UXBRIDGE ROAD, WEST HYDE | 1 | 54 | 47 | 56 | 53 | 44 | 65 | 31 | 22 | 30 | 22 | 53 | 44 | 54 | 47 | 57 | 49 | 2 | 2 | 99 |
| 391607 | MOORHALL ROAD, HAREFIELD | 2 | 56 | 52 | 70 | 53 | 44 | 64 | 36 | 28 | 35 | 27 | 53 | 44 | 56 | 52 | 58 | 52 | 2 | 1 | 99 |
| 408975 | HARVIL ROAD, HAREFIELD | 0 | 61 | 53 | 63 | 55 | 45 | 70 | 65 | 55 | 57 | 47 | 59 | 49 | 0 | 0 | 59 | 49 | -2 | -3 | 99 |
| 391211 | MOORFIELD ROAD, DENHAM | 0 | 53 | 46 | 59 | 50 | 41 | 62 | 35 | 26 | 34 | 25 | 50 | 41 | 53 | 46 | 55 | 47 | 2 | 1 | 99 |
| 408811 | HARVIL ROAD, ICKENHAM | 1 | 61 | 53 | 63 | 55 | 46 | 67 | 56 | 46 | 56 | 46 | 58 | 49 | 59 | 52 | 62 | 54 | 1 | 1 | 99 |
| 383893 | UNNAMED ROAD, DENHAM | 7 | 55 | 48 | 59 | 53 | 43 | 64 | 30 | 21 | 30 | 22 | 53 | 43 | 55 | 48 | 57 | 50 | 2 | 1 | 99 |
| 384372 | NORTH ORBITAL ROAD, DENHAM | 13 | 55 | 48 | 59 | 55 | 46 | 66 | 30 | 22 | 29 | 21 | 55 | 46 | 55 | 48 | 58 | 50 | 3 | 2 | 102 |
| 709521 | HAREFIELD MARINA MOORINGS | 0 | 46 | 39 | 48 | 62 | 53 | 75 | 38 | 29 | 38 | 29 | 62 | 53 | 45 | 39 | 62 | 53 | 16 | 13 | 104 |
| 391326 | SAVAY LANE, DENHAM | 6 | 46 | 39 | 48 | 49 | 40 | 62 | 37 | 28 | 36 | 27 | 50 | 40 | 45 | 39 | 51 | 43 | 5 | 3 | 103 |
| 711001 | HILLINGDON OUTDOOR ACTIVITIES C | 0 | 51 | 47 | 53 | 61 | 51 | 74 | 42 | 33 | 41 | 33 | 61 | 51 | 51 | 47 | 61 | 53 | 10 | 5 | 104 |
| 389429 | TILEHOUSE LANE, DENHAM | 2 | 51 | 45 | 50 | 56 | 47 | 67 | 40 | 31 | 41 | 32 | 56 | 47 | 51 | 45 | 57 | 49 | 6 | 4 | 103 |
| 700371 | NORTH ORBITAL ROAD, DENHAM | 3 | 55 | 48 | 59 | 56 | 46 | 67 | 30 | 21 | 29 | 21 | 56 | 46 | 55 | 48 | 58 | 50 | 3 | 2 | 102 |
| 700370 | UNNAMED ROAD, DENHAM | 2 | 65 | 58 | 61 | 61 | 51 | 72 | 28 | 20 | 27 | 19 | 61 | 51 | 64 | 57 | 66 | 58 | 2 | 1 | 99 |
| 700372 | UNNAMED ROAD, DENHAM | 3 | 55 | 48 | 59 | 53 | 44 | 64 | 29 | 21 | 28 | 20 | 53 | 44 | 55 | 48 | 57 | 50 | 2 | 1 | 99 |
| 700375 | MOORHALL ROAD, HAREFIELD | 1 | 46 | 39 | 48 | 51 | 42 | 64 | 36 | 28 | 36 | 27 | 51 | 42 | 45 | 39 | 52 | 44 | 6 | 4 | 103 |
| 700374 | MOORHALL ROAD, HAREFIELD | 2 | 58 | 53 | 70 | 51 | 42 | 62 | 35 | 26 | 34 | 26 | 52 | 42 | 58 | 53 | 59 | 54 | 1 | 0 | 99 |
| 711000 | HORSE & BARGE MOORINGS | 0 | 55 | 50 | 56 | 52 | 43 | 62 | 36 | 27 | 35 | 27 | 52 | 43 | 55 | 50 | 57 | 51 | 2 | 1 | 99 |
| 396945 | OLD UXBRIDGE ROAD, WEST HYDE | 2 | 54 | 47 | 56 | 51 | 42 | 65 | 32 | 24 | 31 | 23 | 52 | 42 | 54 | 47 | 56 | 48 | 2 | 1 | 99 |
| 389194 | TILEHOUSE LANE, DENHAM | 0 | 51 | 45 | 50 | 55 | 46 | 66 | 32 | 24 | 29 | 21 | 55 | 46 | 51 | 45 | 57 | 48 | 5 | 3 | 103 |
| 391453 | DENHAM FILM STUDIOS, DENHAM | 224 | 46 | 39 | 67 | 56 | 47 | 68 | 32 | 23 | 33 | 24 | 56 | 47 | 46 | 39 | 56 | 47 | 11 | 8 | 104 |
| - | MOREHALL COTTAGE, HAREFIELD | 1 | 58 | 53 | 70 | 50 | 41 | 61 | 35 | 26 | 34 | 26 | 51 | 41 | 58 | 53 | 59 | 54 | 1 | 0 | 99 |

Impact Category 98 = Negligible / 99 = Negligible / 102 = Minor / 103 = Moderate / 104 = Major

Description of summary table fields.

| Field | Description |
|---|---|
| ID | Assessment location ID |
| Area represented | Assessment location address |
| Impacts represented | Number of sensitive receptors the assessment location represents |
| Baseline Day | Measured baseline noise level dB $L_{Aeq,16h}$ (ES) |
| Baseline Night | Measured baseline noise level dB $L_{Aeq,8h}$ (ES) |
| Baseline average $L_{Amax}$ | Average measured $L_{Amax}$ from ES |
| HS2 Train Day | Predicted dB $L_{Aeq,16h}$ noise level from HS2 trains |
| HS2 Train Night | Predicted dB $L_{Aeq,8h}$ noise level from HS2 trains |
| HS2 Train $L_{Amax}$ | Predicted dB $L_{Amax}$ noise level from HS2 trains |
| DM Traffic Model Day | Modelled road traffic noise levels from new or affected roads (ES) dB $L_{Aeq,16h}$ |
| DM Traffic Model Night | Modelled road traffic noise levels from new or affected roads (ES) dB $L_{Aeq,8h}$ |
| DS Traffic Model Day | Modelled road traffic noise levels from new or affected roads (ES) dB $L_{Aeq,16h}$ |
| DS Traffic Model Night | Modelled road traffic noise levels from new or affected roads (ES) dB $L_{Aeq,8h}$ |
| HS2 Total $L_{Aeq}$ Day | The total $L_{Aeq}$ noise levels generated by the HS2 scheme for daytime (07:00 -23:00) |
| HS2 Total $L_{Aeq}$ Night | The total $L_{Aeq}$ noise levels generated by the HS2 scheme for night-time (23:00 – 07:00) |
| Residual Noise Day | Baseline Day -- DM Traffic Model Day |
| Residual Noise Night | Baseline Night -- DM Traffic Model Night |
| DS Day | The overall Do Something $L_{Aeq}$ noise levels for daytime (07:00 -23:00) |
| DS Night | The overall Do Something $L_{Aeq}$ noise levels for night-time (23:00 – 07:00) |
| Change Day | DS Day - Baseline Day |
| Change Night | DS Night - Baseline Night |
| Impact Category | 98 = Negligible / 99 = Negligible / 102 = Minor / 103 = Moderate / 104 = Major |