08 Noise and Vibration

08 Noise and Vibration

Introduction

8.1 This chapter of the ES describes the assessment of likely significant noise and vibration impacts associated with the construction phase and upon completion and occupation of the proposed development. In particular, this chapter has considered the potential impacts on representative receptors, in terms of:

- Predicted noise and vibration levels from construction activities;
- Noise from building services plant that are part of the completed Proposed Development; and
- Any increases to road traffic attributed to the Proposed Development.

8.2 The chapter also provides an assessment of the suitability of the application site for the proposed uses, in terms of existing noise and vibration, and the acceptability of the internal noise environment.

8.3 This chapter has been produced by URS Infrastructure & Environment UK Ltd (URS).

Noise and Vibration Terminology

8.4 For the purposes of this ES chapter, the following terminology and abbreviations are used:

- dB – The unit of noise measurement that expresses the loudness in terms of decibels (dB);
- Hz – Hertz: the unit of measurement of frequency or pitch;
- LA1, LA5, LA10, LA50, LA90, LA99 – A-weighted sound pressure level exceeded for 1, 5, 10, 50, 90 or 99% of the measured time;
- LAeq – Equivalent continuous A-weighted sound pressure level over a given period of time;
- LAmax – The maximum A-weighted sound pressure level over a given period of time;
- LAmin – The minimum A-weighted sound pressure level over a given period of time; and
- VDV ($m/s^{1.75}$) – Vibration Dose Values in metres per second$^{1.75}$. An integrated value determined from the time varying vibration levels over a 16-hour day and 8-hour night-time period.

Planning and Policy Context

National Planning Guidance

National Planning Policy Framework

8.5 The National Planning Policy Framework (NPPF) (Ref. 8-1) was introduced by the Department of Communities and Local Government in March 2012. The document sets out the Government's planning policies for England and how they are expected to be applied. As a result of the NPPF, Planning Policy Guidance 24 (PPG24) has been withdrawn.

8.6 The NPPF provides for the production of distinctive local and neighbourhood plans by Councils, in consultation with local people, which should be developed to reflect the needs and priorities of their communities.

8.7 Applications for planning permission must be determined in accordance with the development plan (which includes any Local plan or neighbourhood plans which have been adopted for the area), unless material considerations indicate otherwise. The NPPF must be taken into account in the preparation of local and neighbourhood plans, and is a material consideration in the determination of planning applications.

8.8 The NPPF states "*The planning system should contribute to and enhance the natural and local environment by preventing both new and existing development from contributing to or being put at unacceptable risk from, or being being adversely affected by unacceptable levels of noise pollution*".

8.9 The NPPF states that planning policies and decisions should aim to:

- *"Avoid noise from giving rise to significant adverse impacts on health and quality of life as a result of new development;*
- *Mitigate and reduce to a minimum other adverse impacts on quality of life arising from noise from new development, including through the use of conditions;*
- *Recognise that development will often create some noise and existing businesses wanting to develop in continuance of their business should not have unreasonable restrictions put on them because of changes in nearby land uses since they were established; and*
- *Identify and protect areas of tranquillity which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason."*

Noise Policy Statement for England

8.10 The Noise Policy Statement for England (NPSE) (Ref. 8-2) seeks to clarify the underlying principles and aims in existing policy documents, legislation and guidance that relate to noise. The statement applies to all forms of noise, including environmental noise, neighbour noise and neighbourhood noise.

8.11 The statement sets out the long term vision of the government's noise policy, which is to "*promote good health and a good quality of life through the effective management of noise within the context of policy on sustainable development*".

8.12 The guidance aims to:

- *Avoid significant adverse impacts on health and quality of life;*
- *Mitigate and minimise adverse impacts on health and quality of life; and*
- *Where possible, contribute to the improvement of health and quality of life.*

8.13 The statement adopts established concepts from toxicology that are currently being applied to noise impacts. The concept details noise levels, at which the impacts of an exposure may be classified into a specific category. The classification categories detailed within NPSE are as follows:

- *No Observed Effect Level (NOEL) - the level below which no effect can be detected. Below this level no detectable effect on health and quality of life due to noise can be established;*
- *Lowest Observable Adverse Effect Level (LOAEL) - the level above which adverse effects on health and quality of life can be detected; and*
- *Significant Observed Adverse Effect Level (SOAEL) - the level above which significant adverse effects on health and quality of life occur.*

8.14 It is recognised that SOAEL does not have a single objective noise-based level that is applicable to all sources of noise in all situations and therefore the SOAEL is likely to be different for different sources, receptors and at different times of the day.

8.15 The first aim of the statement is to avoid significant adverse impacts on health and quality of life. The second aim is to mitigate and minimise adverse impacts on health and quality of life. The third aim is to contribute to the improvement of health and quality of life where possible. All three aims should be considered in the context of the Governments policy on sustainable development and does not mean that adverse impacts cannot occur.

8.16 Defra has let a research contract to identify the SOAEL and LOAEL for a limited range of noise sources. . However, no guidance from this research has been issued at the time of writing.

08 Noise and Vibration

Regional Planning Policy

The London Plan – Spatial Development Strategy for Greater London

8.17 With specific reference to noise issues as part of the planning process, Policy 7.15: 'Reducing Noise and Enhancing Soundscapes' of the London Plan 2011 (Ref 8-3) states:

"Planning Decisions:

B) Development proposals should seek to reduce noise by:

a) Minimising the existing and potential adverse impacts of noise on, from, within, or in the vicinity of, development proposals

b) Separating new noise sensitive development from major noise sources wherever practicable through the use of distance, screening, or internal layout in preference to sole reliance on sound insulation

c) Promoting new technologies and improved practices to reduce noise at source."

'Sounder City' The Mayor's Ambient Noise Strategy

8.18 The London Ambient Noise Strategy (Ref. 8-4) aims to minimise the adverse impacts of noise on people living, working in and visiting London by using the best available practices and technologies within a sustainable development framework.

8.19 The Strategy aims to work towards more compact city development, while minimising noise. It requires careful consideration of the adverse impact of noise on, from, within or in proximity to proposed developments.

The Mayor's Supplementary Planning Guidance: Sustainable Design and Construction

8.20 The London Plan Supplementary Planning Guidance (Ref 8-5) provides additional information to support the implementation of the Mayor's London Plan. The guidance sets essential standards which apply to all major developments in London and a second tier of preferred standards. With respect to noise the guidance states;

- *"Essential Standard: Demonstrate that adverse impacts of noise have been minimised, using measures at source or between source and receptor including choice and location of plant or method, layout, screening and sound absorption, in preference to sound insulation at the receptor, wherever practicable, and*
- *Preferred Standard: For residential development achieve BS 8233:1999 (Table 5) 'good' standards for external to internal noise and improve on Building Regulations (2003) Part E for internal sound transmission standards by 5dB".*

Local Planning Policy

London Borough of Camden (LBC) Local Development Framework (LDF) Core Strategy

8.21 It should be noted that the LBC LDF was published prior to the NPPF and consequently does not fully accord with the policies of this more recent document.

8.22 The LDF Core Strategy (Ref 8-6) refers to Camden Development Policy 28 (DP28) (Ref 8-7) for the impact of noise and vibration:

"DP28 on Noise and Vibration contributes towards achieving the approach in Core Strategy policies CS5 - Managing the impact of growth and development, CS7 – Promoting Camden's centres and shops and CS9 - Achieving a successful Central London, as well as its main 'parent' policy CS14 - Promoting high quality places and conserving our heritage."

8.23 Camden Development Policy 28 states the following regarding noise and vibration for noise and vibration sensitive developments:

"The Council will seek to ensure that noise and vibration is controlled and managed and will not grant planning permission for:

a) Development likely to generate noise pollution; or

b) Development sensitive to noise in locations with noise pollution, unless appropriate attenuation measures are provided.

Development that exceeds Camden's Noise and Vibration Thresholds will not be permitted.

The Council will only grant permission for plant or machinery if it can be operated without causing harm to amenity and does not exceed our noise thresholds.

The Council will seek to minimise the impact on local amenity from the demolition and construction phases of development. Where these phases are likely to cause harm, conditions and planning obligations may be used to minimise the impact."

8.24 Where noise sensitive developments are proposed in environments with noise pollution, LBC requires attenuation measurements to achieve suitable internal noise levels for residential premises to ensure LBC's requirements for noise sensitive developments are met.

8.25 LBC also states that a PPG24: Planning and Noise type assessment is to be carried out when noise generating and noise sensitive developments are proposed. Noise limits derived from those contained within PPG24 are provided in LBC Development Policy 28 to assess the suitability of a site for residential development. It should be noted that PPG24 was withdrawn in 2012.

8.26 DP28 provides noise levels for residential sites adjoining roads at which planning permission will not be granted. These are provided in Table 8-1. It should noted these noise levels are based on those presented in the withdrawn PPG24.

Table 8-1 LBC DP28, Noise levels at which planning permission will not be granted

Noise description and location of measurement	Period	Time	Sites adjoining roads
Noise at 1 metre external to a sensitive facade	Day	07:00 – 19:00	72 dB $L_{Aeq,\ 12hr}$
Noise at 1 metre external to a sensitive facade	Evening	19:00 – 23:00	72 dB $L_{Aeq,\ 4hr}$
Noise at 1 metre external to a sensitive facade	Night	23:00 – 07:00	66 dB $L_{Aeq,\ 8hr}$

8.27 DP28 also provides noise levels on residential sites adjoining roads at and above which attenuation measures will be required. These noise levels are provided in Table 8-2.

Table 8-2 LBC DP28, Noise levels above which attenuation will be required

Noise description and location of measurement	Period	Time	Sites adjoining roads
Noise at 1 metre external to a sensitive facade	Day	07:00 – 19:00	62 dB $L_{Aeq, 12hr}$
Noise at 1 metre external to a sensitive facade	Evening	19:00 – 23:00	57 dB $L_{Aeq, 4hr}$
Noise at 1 metre external to a sensitive facade	Night	23:00 – 07:00	52 dB $L_{Aeq, 1hr}$
Individual noise events several times an hour	Night	23:00 – 07:00	>82 dB L_{Amax} (S time weighting)

8.28 DP28 also provides vibration levels on residential sites adjoining railways and roads at which planning permission will not be granted. These vibration levels are provided in Table 8-3.

Table 8-3 LBC DP28, Vibration levels at which planning permission will not be granted

Vibration description and location of measurement	Period	Time	Vibration Levels
Vibration inside dwellings	Day and evening	07:00 – 23:00	0.2 to 0.4 VDV $ms^{-1.75}$
Vibration inside dwellings	Night	23:00 – 07:00	0.13 VDV $ms^{-1.75}$

8.29 LBC Development Policy 28 states:

"Where dwellings may be affected by ground-borne regenerated noise internally from, for example, railways or underground trains within tunnels, noise levels within the rooms should not be greater than 35dB(A)max."

8.30 DP28 also provides noise levels from plant and machinery at which planning permission will not be granted. These noise levels are provided in Table 8-4.

Table 8-4 LBC DP28, Noise levels from plant and machinery at which planning permission will not be granted

Noise description and location of measurement	Period	Time	Noise Level
Noise at 1 metre external to a sensitive facade	Day, evening and night	00:00 – 24:00	5dB(A) < L_{A90}
Noise that has a distinguishable discrete continuous note (whine, hiss, screech, hum) at 1 metre external to a sensitive facade	Day, evening and night	00:00 – 24:00	10dB(A) < L_{A90}
Noise that has distinct impulses (bangs, clicks, clatters, thumps) at 1 metre external to a sensitive facade	Day, evening and night	00:00 – 24:00	10dB(A) < L_{A90}
Noise at 1 metre external to sensitive façade where L_{A90}>60dB	Day, evening and night	00:00 – 24:00	55dB(A) L_{Aeq}

Guide for Contractors Working In Camden

8.31 The Guide for Contractors Working in Camden (Ref. 8-8) refers to noise and vibration from construction. The purpose of the guide regarding noise and vibration, is to make sure that disturbances due to those arising from demolition and construction work on all building sites within the Borough, including the public highway, are kept to an acceptable minimum level.

8.32 The guidance does not provide noise limits but refers to Best Practicable Means (BPM) to reduce the noise created. Permitted hours of operation for works which produce noise are provided.

8.33 The permitted hours for noisy works (i.e. works that are audible at the construction site boundary) are:

- Monday to Friday – 08:00 to 18:00;
- Saturday – 08:00 to 13:00; and
- Sunday – noisy working not permitted.

British Standards

British Standard 7445: Description and Measurement of Environmental Noise

8.34 BS 7445-2 'Description and Measurement of Environmental Noise, Part 2: Guide to the Acquisition of Data Pertinent to Land Use' (Ref. 8-9) defines the parameters, procedures and instrumentation required for noise measurement and analysis.

British Standard 8233: Sound Insulation and Noise Reduction for Buildings - Code of Practice

8.35 BS 8233 'Sound Insulation and Noise Reduction for Buildings - Code of Practice' (Ref. 8-10) provides criteria for the assessment of internal noise levels for various uses including dwellings and commercial properties.

British Standard 6472: Guide to Evaluation of Human Exposure to Vibration in Buildings'

8.36 BS 6472-1 'Guide to Evaluation of Human Exposure to Vibration in Buildings, Part 1: Vibration Sources Other Than Blasting' (Ref. 8-11) presents recommended frequency weighted vibration spectra (for

continuous vibration) and vibration dose values (VDV) for intermittent vibration above which adverse comment is likely to occur in residential properties.

British Standard 5228: Noise and Vibration Control on Construction and Open Sites

8.37 BS 5228 'Noise and Vibration Control on Construction and Open Sites' (Ref. 8-12) provides an industry accepted guide for noise and vibration control and includes sound power level and sound pressure level data for individual plant as well as a calculation method for noise from construction activities.

British Standard 7385: Evaluation and Measurement for Vibration in Buildings

8.38 BS 7385 'Evaluation and Measurement for Vibration in Buildings' (Ref. 8-13) presents guide values or limits for transient vibration, above which there is a likelihood of cosmetic damage.

British Standard 4142: Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas

8.39 BS 4142 'Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas' (Ref. 8-14) can be used for assessing the impact of noise from mechanical services plant. The method compares the difference between the 'rating level' of the new noise, with the lowest 'background level' at the receptor position.

Other Standards and Guidance

Control of Pollution Act 1974

8.40 The Control of Pollution Act 1974 (CoPA) (Ref. 8-15) requires that 'Best Practicable Means' (as defined in Section 72 of CoPA) are adopted to control construction noise on any given site. CoPA makes reference to BS 5228 as best practicable means.

Calculation of Road Traffic Noise

8.41 Department of Transport/Welsh Office Memorandum 'Calculation of Road Traffic Noise' (CRTN) (Ref. 8-16) describes procedures for traffic noise calculation, and is suitable for environmental assessments of schemes where road traffic noise may have an impact.

Design Manual for Roads and Bridges

8.42 The Highways Agency 'Design Manual for Road and Bridges Volume 11 Section 3 Part 7 - 'Traffic Noise and Vibration' (DMRB) (Ref. 8-17) provides guidance on the appropriate level of assessment to be used when assessing the noise and vibration impacts arising from all road projects, including new construction, improvements and maintenance and any development which may result in changes in traffic flows.

Crossrail Guidance

8.43 It should be noted the Crossrail guidance relates to Crossrail works and not to the Over Site Develeopment.

Information Paper D9

8.44 Crossrail Information Paper D9 (IPD9) (Ref. 8-18) provides guidance on the mitigation scheme for the provision of off-site mitigation for significant construction noise impacts. It gives details of the criteria that apply to construction noise and the levels at which noise insulation or temporary rehousing will be provided to mitigate significant construction noise levels, arising from Crossrail works.

Information Paper D10

8.45 Crossrail Information Paper D10 (IPD10) (Ref. 8-19) provides details of the measures that will be put in place to control groundborne noise and vibration that are expected to occur due to the operation of Crossrail. IPD10 includes details of the groundborne noise and vibration criteria that apply to different noise sensitive buildings and the mitigation measures that could be incorporated into the design of the Crossrail infrastcture to mitigate ground borne noise and vibration levels to within the required criteria.

Information Paper D25

8.46 Crossrail Information Paper D25 (IPD25) (Ref. 8-20) covers the assessment of noise from fixed installations. IPD25 explains the measures that will be put in place to control the emission of noise from Crossrail sites that affect dwellings The document outlines the criteria that apply to the assessments and the processes that will apply in the design of Crossrail to ensure that all installations comply with these requirements.

Assessment Methodology and Significance Criteria

8.47 This section presents the methodology used to assess each type of noise and vibration impact, in terms of the application of the standards and guidance used (as detailed above), the types of data and analyses carried out, and the derivation of the presented significance or compliance criteria used in the assessments.

8.48 As described in ***Chapter 2: EIA Methodology***, for the purpose of consistency and in accordance with the principles of section 14 of the Crossrail Act, the assessment methodologies and significance criteria presented in this section are in line with the methodology and criteria used in the Crossrail Environmental Statement (Ref. 8-21).

8.49 Where assessments particular to the Proposed Development are required that were not originally scoped within the Crossrail ES, additional methodology and significance criteria have been provided.

Description of Impact Categories

8.50 These criteria apply a common EIA approach of classifying impacts according to whether they are **non-significant impacts (NSig)**, **significant impacts (Sig)** or **significant impacts of particular importance (PSig)**, and are considered to be **adverse** or **beneficial**. Impacts may also be classified as **negligible** where appropriate.

8.51 The following terminology has been used in the ES to define residual impacts:

- Adverse – detrimental or negative impacts to an environmental resource or receptor;
- Negligible – imperceptible impacts to an environmental resource or receptor; or
- Beneficial – advantageous or positive impact to an environmental resource or receptor.

Ambient Noise and Vibration Affecting Future Occupants of the Proposed Development

Internal Ambient Noise within the Proposed Development

8.52 The noise-sensitive uses within the Proposed Development are dwellings.

8.53 BS 8233 provides recommendations for suitable internal noise levels for reasonable resting/sleeping conditions in dwellings. These recommended levels are detailed in Table 5 of BS 8233 and are summarised in Table 8-5. These levels relate to the noise with windows closed.

Table 8- 5 BS 8233 Recommended Internal Ambient Noise Levels

Criterion	Typical Situations	Design Range dB L_{Aeq}	
		Good	Reasonable
Reasonable resting/sleeping conditions	Living rooms	30	40
	Bedrooms[a]	30	35
[a] For a reasonable standard in bedrooms at night, individual noise events (measured with F time-weighting) should not normally exceed 45dB L_{Amax}			

8.54 For the Proposed Development it is proposed to design to the 'good' criterion for both bedrooms and living rooms as far as possible This is the level as specified as the 'Preferred Standard' in the London Plan

Supplementary Planning Guidance and also as required by LBC as was agreed during consultation with a LBC environmental health officer. This is the criterion to achieve with windows closed. The building design will include appropriate attenuated background ventilation.

8.55 BS 8233 also advises "*in gardens and balconies etc. it is desirable that the steady noise level does not exceed 50dB LAeq,T and 55dB LAeq,T should be regarded as the upper limit*". During consultation with LBC, it was indicated that if the 50dB LAeq, 16h noise level cannot be achieved and the costs of achieveing this noise level are too onerous then the EHO would consider 55dB LAeq, 16h as an alternative criterion. No criterion for outdoor spaces is included in LBCs LDF.

Groundborne Noise from Underground and Railway Activities

8.56 The impact of groundborne noise levels arising from underground and railway activities within residences is assessed against the LBC criterion of 35dB LAmax,slow. Provided this criterion can be achieved, the application site is considered to be suitable for the Proposed Development.

Vibration from Underground and Railway Activities

8.57 The impact of vibration arising from underground and railway activities within residences is assessed against the LBC criterion presented in Table 8-3. Provided this criterion can be achieved, the application site is considered to be suitable for the Proposed Development.

Noise and Vibration from Construction Activities

Construction Noise

8.58 BS 5228 provides practical information on noise and vibration reduction measures, and promotes a 'best practice means' approach. The calculation method provided in BS 5228 is based on the number and types of equipment operating, their associated sound power levels, and the distance to receptors, together with the impacts of any screening.

8.59 For noise from surface construction activity, levels predicted to occur at sensitive receptors (residential and community) have been considered to be significant (**Sig**) if the total noise (pre-existing ambient plus airborne construction noise) exceeds the pre-existing ambient noise by 5 dB or more. The above is subject to lower cut-off values of 65, 55 and 45 dB LAeq from construction noise alone, for the daytime, evening and night-time periods, respectively. Where the background noise levels exceed the lower cut-off values, a smaller change may be considered significant.

Construction Vibration

8.60 Vibration from construction can cause disturbance to humans, including concern over building damage and actual building damage ranging from cosmetic (minor cracking) to full structural impacts (major cracking and movement); although the latter is very rare and generally requires the occurrence of other influences, such as differential settlement, for significant damage to occur. The impacts of vibration from construction have been assessed for impacts on both people and buildings.

8.61 The Crossrail ES assessed the impacts of construction vibration on building occupants using the guidance and criteria given within BS 6472:1992 and BS 5228-4:1992. Since the production of the Crossrail ES, both of these Standards have been superseded. Therefore, the assessment of construction vibration deviates from that contained within the Crossrail ES due to the introduction of updated national guidance related to the subject.

8.62 Table 8-8 provides Peak Particle Velocity (PPV) levels and their potential impact on humans. This provides a simple method of determining annoyance alongside evaluation of cosmetic damage associated with vibration. The impact is considered significant (**Sig**) if the predicted levels are at or above 1.0 mm/s.

Table 8- 8 Guidance on Human Impacts of Peak Particle Velocity (PPV) Levels

Peak Particle Velocity Level	Impact
0.14 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 mm/s	Vibration might be just perceptible in residential environments.
1.0 mm/s	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.
10 mm/s	Vibration is likely to be intolerable for any more than a very brief exposure to this level.

8.63 The potential for a significant (**Sig**) impact upon structures has been deemed to occur if the limits defined in Table 8-9 are predicted to be exceeded. Where they are predicted to be exceeded, individual receptors are screened and assessed for sensitivity, both to their structure and content, to determine if an impact is likely.

Table 8- 9 Construction Vibration – Threshold of Significant Impacts on Structures – Peak Particle Velocity (PPV) (mm/s) at Building Foundation

Category of Building	Threshold of Potential Cosmetic Damage
Standard buildings	5 mm/s
Listed or potentially vulnerable buildings	3 mm/s

Construction Traffic Noise

8.64 Construction traffic noise is assessed by considering the short-term increase in traffic flows during works, following the principles of CRTN and DMRB.

8.65 The criteria for the assessment of traffic noise changes arising from construction works are taken from Table 3.1 of DMRB (criteria for short term changes) and are provided in Table 8-10.

Table 8- 10 Road Traffic Noise Assessment Criteria (Short Term Changes)

Noise Change Band	Magnitude of Impact	Impact Significance
0 dB(A)	No change	**NSig**
0.1 – 0.9 dB(A)	Negligible	**NSig**
1 - 2.9 dB(A)	Minor	**NSig**
3 – 4.9 dB(A)	Moderate	**Sig**
5dB(A) or more	Major	**PSig**

8.66 This method is consistent with the criterion given in the Crossrail ES, which states that a significant change in road traffic has occurred if road traffic noise level change by more than +/- 3 dB.

Operational Noise from the Proposed Development

Operational Traffic Noise

8.67 The criteria for the assessment of road traffic noise changes arising from long term traffic changes resulting from the Proposed Development are taken from Table 3.2 of DMRB (criteria for long term changes) and are provided in Table 8-11.

Table 8- 11 Road Traffic Noise Assessment Criteria (Long Term Changes)

Noise Change Band	Magnitude of Impact	Impact Significance
0 dB (A)	No change	**NSig**
0.1 – 2.9 dB(A)	Negligible	**NSig**
3 – 4.9 dB(A)	Minor	**NSig**
5 – 9.9 dB(A)	Moderate	**Sig**
10 dB(A) or more	Major	**PSig**

8.68 This method is consistent with the crierion given in the Crossrail ES, which states that a significant change in road traffic has occurred if road traffic noise level change by more than +/- 3 dB.

Noise from Building Services Plant

8.69 BS 4142 provides guidance on the likely community response to new fixed noise sources (e.g. building services) affecting sensitive residential receptors.

8.70 The method is based upon a comparison between the rating level of the noise from the specific source being considered and the background noise level (measured as an LA90), in the absence of the specific source. The noise level from the specific source is increased by 5 dB if the source has any distinctive characteristics (tones or impulses such as whines, hums or bangs), or if it is irregular enough to attract attention and becomes known as the rating level.

8.71 As mentioned above, BS 4142 states that if the rating level of the noise exceeds the background noise by around 10 dB or more, complaints are "likely". An increase of 5 dB is deemed to be of "marginal significance" whilst a difference of minus 10 dB or more indicates that "complaints are unlikely". These descriptions are summarised in Table 8-12 below:

Table 8- 12 BS 4142 Significance Criteria

BS 4142 Assessment Level dB (Rating level relative to background level)	BS 4142 Semantic Criteria (as described in BS 4142)	Impact Significance
< -10	"If the rating level is more than 10 dB below the measured background level then this is a positive indication that complaints are unlikely"	**NSig**
-10 to +5	No BS description but the more negative the difference, the less the likelihood of complaints	**NSig**
+5	"A difference of around +5 dB is of marginal significance" - as BS description	**Sig**
+5 to +10	No BS description but the more positive the difference, the greater the likelihood of complaints	**Sig**
> +10	"A difference of around 10 dB or more indicates that complaints are likely"	**PSig**

8.72 Mechanical and electrical services for the Proposed Development will be designed and constructed to ensure that, at residential receptors the difference between the rating level of the plant in normal operation and the existing LA90 background noise level is not more than -5 dB, and -10 dB where acoustic features apply, assessed in accordance with BS 4142.

8.73 The above proposed criteria are in accordance with LBC DP28 as outlined in paragraph 8.29. Provided the above criterion of -5dB, and -10 dB where acoustic features apply, is achieved, noise due to building services plant will be **NSig**.

Sensitive Receptors

8.74 Potential sensitive receptors in proximity to the application site have been identified, and are used as representative receptors for the assessment of the overall impacts associated with noise and vibration levels from the construction and operational phases of the Proposed Development. The sensitive receptors identified are as follows.

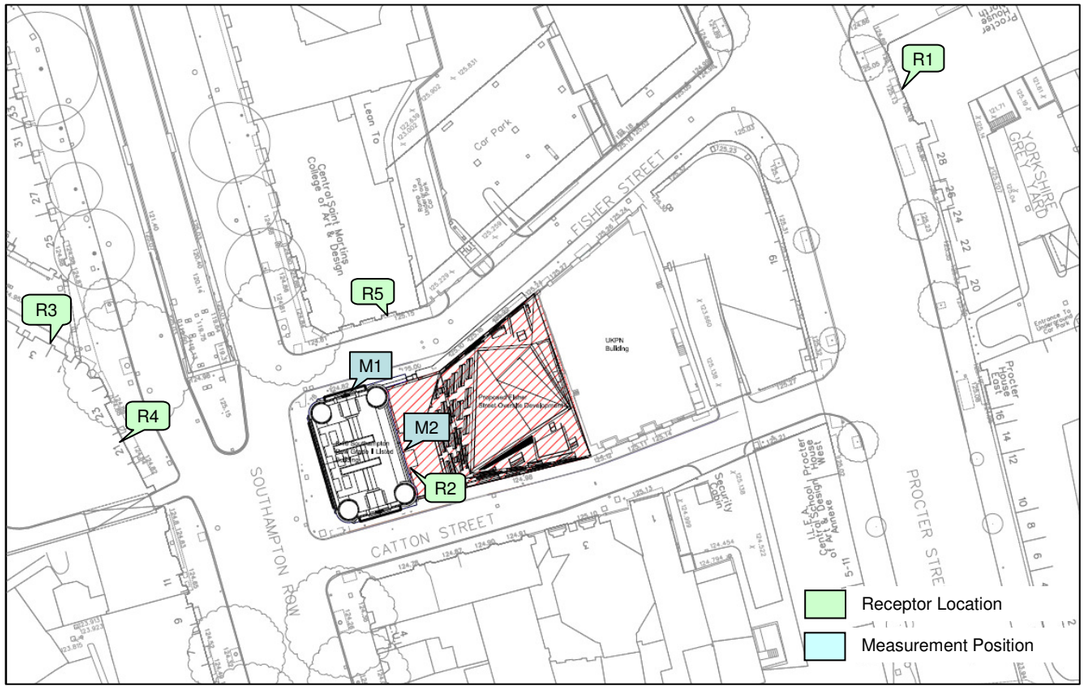
- Benin House, to the east of the application site;
- 8 – 10 Southampton Row;
- Sicilian House to the west of the application site;
- 21 Southampton Row, to the west of the application site; and
- St Martins College, to the north of the application site.

8.75 Figure 8-1 presents the application site boundary, monitoring position and locations of potential sensitive receptors. Table 8-13 describes the noise monitoring locations and noise sensitive receptors.

Table 8- 13 Map Key

Key	Description	Location
M1	Noise monitoring position	8 – 10 Southampton Row - North façade
M2	Noise monitoring position	8 – 10 Southampton Row – East façade
R1	Sensitive receptor (residential)	Benin House
R2	Sensitive receptor (residential)	8 – 10 Southampton Row
R3	Sensitive receptor (residential)	Sicilian House
R4	Sensitive receptor (residential)	21 Southampton Row
R5	Sensitive receptor (College)	St Martins College

Figure 8-1 Application Site Map - Application Site Boundary, Receptors, and Measurement Positions



Baseline Conditions and Suitability of Site

Baseline Survey

8.76 The dominant noise across the application site during baseline meaurements was road traffic. It is anticipated that this will remain the case once the Crossrail Fisher Street intervention shaft has been completed. As such, the same baseline can be adopted for both construction and operational impacts.

8.77 A noise survey in the area was originally undertaken by Jacobs between 12th and 23rd May 2011 at the north and east facades of 8 – 10 Southampton Row. These locations are considered representative of the closest noise sensitive receptors and are considered appropriate to define existing background and ambient noise levels. The locations were agreed with LBC.

8.78 Full details of the noise survey are contained in Fisher Street Shaft D25 – Background Noise Report (Ref 8-22).

Survey Results

8.79 The baseline noise results for the surrounding environment for the assessment within this ES have been taken from the Fisher Street Shaft D25 – Background Noise Report and are shown in Table 8-14.

Table 8- 14 Noise Survey Results

Measurement Location	Average Free-Field Ambient Level dB L_{Aeq}			Lowest Background Noise Level dB L_{A90}[1]	
	Daytime 07:00 – 19:00	Evening 19:00 – 23:00	Night-Time 23:00 – 07:00	Daytime 07:00 – 23:00	Night-Time 23:00 – 07:00
M1	70	69	66	58	54
M2[2]	63	62	59	53	49

1. Lowest averaged hourly background noise level
2. Position representative of noise sensitive receptor

8.80 Measurement position M1 is considered most representative of noise levels at the Proposed Development. Measurement position M2 is considered to represent noise levels at the nearest noise sensitive receptor.

8.81 The measured LAeq noise levels at position M1 for the daytime and evening periods, are below those advised by LBC where planning permission would not be granted (ref Table 8-1). The night time noise level at position M1 is relatively high. However, it should be noted that the M1 measurement position was approximately 12 metres from the dominant noise source (traffic on Southampton Row) and the Proposed Development is approximately 28 metres from the dominant noise source. Noise levels at the façade of the Proposed Development would therefore be around 4dBA lower assuming line source propagation.

8.82 The M1 measurement position was at 4th floor level with the microphone located approximately 1 metre from the building façade. PPG24 states noise levels should be measured at 1.2 to 1.5 metres above ground in free-field conditions. A correction of +3dBA is usually taken to account for noise reflections at 1 metre from a building façade. However, noise levels at ground level are likely to be higher than at 4th floor level. Taking a conservative estimate, it is considered noise at the 4th floor could be 2dBA lower than at ground level.

8.83 As such, considering the measurement position M1 in relation to the assessment location for the Proposed Development, overall noise levels at the Proposed Development would be 5dBA lower. The predicted free-field noise levels are therefore as presented in Table 8-15.

Table 8- 15 Predicted Free-field Noise Levels at Proposed Development

Average Free-Field Ambient Level dB L_{Aeq}		
Daytime 07:00 – 19:00	Evening 19:00 – 23:00	Night-Time 23:00 – 07:00
65	64	61

8.84 The predicted noise levels are below those advised by LBC where planning permission would not be granted.

8.85 The predicted noise levels at the Proposed Development are above those where mitigation measures would be required.

08 Noise and Vibration

Suitability of the Application Site for Proposed Uses

Ambient Noise

8.86 External ambient noise levels of 65 dB LAeq during the daytime have been predicted for the Proposed Development. Since the criteria given within BS 8233 are the same for day and night time when working towards good internal noise levels, it follows that if the façade design is acceptable to control daytime noise intrusion, night time noise levels will also be suitably controlled.

8.87 In order to achieve the 'good' internal ambient noise criteria for livingrooms given in BS 8233, the worst case affected facades would be required to achieve a sound reduction performance of at least 35dB Rw + Ctr. This level of sound attenuation can be achieved using 6/6-20/10.8 laminated double glazing in conjunction with a passive attenuated in-wall ventilator.

8.88 It is therefore demonstrated that a façade construction solution exists which would mitigate the highest noise levels at the application site. For other facades at a greater distance from or acoustically screened from Southampton Row noise levels will be lower and alternative glazing and ventilation schemes are likely to be acceptable.

8.89 It is therefore considered that the "good" criterion given in BS 8233 can be achieved and the impact would be **NSig**.

8.90 External noise levels at the Proposed Development are predicted to be 65dB LAeq. Balconies will be provided with solid ballustrades which would provide some acoustic screening but noise on balconies and terraces is expected to be greater than the level recommended in BS 8233 and by LBC. Further work would be needed during detailed design to address this issue.

8.91 It is considered that the benefits of providing external amenity space at the development with higher than recommended noise levels should be balanced against providing no access to external amenity space.

Groundborne Noise and Vibration

8.92 The application site is close to the alignment of the existing London Underground Piccadilly Line. However, the proximity of Crossrail to the Proposed Development is likely to result in the Crossrail running tunnels being the closest source of groundborne noise and vibration upon completion of the Proposed Development. The potential for vibration and groundborne noise due to the operation of Crossrail has been considered as part of the Crossrail ES. Information Paper D10 (Ref 8-19) explains the measures that will be put in place to control the impacts of groundborne noise and vibration that might otherwise arise from the operation of the railway in the Crossrail tunnels. It may be assumed that a high level of mitigation will be included in the tunnels.

8.93 From Table 1 of Information Paper D10, for residential properties the adopted criterion for groundborne noise is 40dB LAmax,s.

8.94 The findings of the Crossrail ES demonstrated the above criteria was unlikley to be breached at any location during the operation of Crossrail.

8.95 Information Paper D10 also states the following:

"In recognition of the local authorities' preference for groundborne noise levels within residential dwellings which are no greater than 35dB LAmax,s during the operation of Crossrail, the nominated undertaker will provide the information identified in paragraph 4.2 to the relevant local authority where any residential property is predicted through modelling as being likely to experience noise levels exceeding 35dB LAmax,s

Further as paragraph 1.5 of the Environmental Minimum Requirements explains, the nominated undertaker will use reasonable endeavours to adopt mitigation measures that will further reduce any adverse environmental impacts caused by Crossrail, insofar as these mitigation measures do not add unreasonable costs to the project or unreasonable delays to the construction programme. This requirement will be applied to any residential property in which the level of groundborne noise arising from the operation of the Crossrail passenger service near the centre of any noise-sensitive room is predicted to equal or exceed 35dB LAmax,s".

8.96 The tunnels will incorporate designs to minimise the transmission of vibration.

8.97 For residential properties, the adopted criterion for vibration is presented in Table 2 in Information Paper D10. This is reproduced as Table 8-16.

Table 8- 16 Crossrail Construction and Operational Vibration Criteria

In the Absence of Appreciable Existing Levels of Vibration		Appreciable Existing Levels of Vibration [1] [2]
VDV $ms^{-1.75}$ Daytime (07:00 – 23:00)	VDV $ms^{-1.75}$ Night time (23:00 – 07:00)	% Increase in VDV
0.31	0.18	40

Notes:

1. Highest impact category used, daytime or night time

2. There is an appreciable existing level of vibration where daytime and night time vibration dose values (VDVs) exceed 0.22$ms^{-1.75}$ and 0.13$ms^{-1.75}$ respectively.

8.98 Information Paper D10 also states the following:

"During the detailed design stage referred to in paragraph 2.9, the nominated undertaker will also be required to design the permanent track system, in accordance with the guidance in British Standard 6472:1992 "Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)", so that operational vibration arising from it at buildings identified in Table 1, expressed as vibration dose value (VDV), is predicted in all reasonably foreseeable circumstances not to exceed the levels presented in Table 2.

The potential impact of Crossrail trains running through tunnels during construction and operation of the railway has been assessed and the findings reported in the Environmental Statement. The running of both the construction and permanent railways is not forecast to cause vibration impacts which will be felt by those occupying the buildings above.

Vibration from the passage of the tunnel boring machines may be perceptible. However, this will be a transient effect lasting only a few days at any one location and will not cause damage to buildings".

8.99 The mitigation measures available to reduce potential groundborne noise and vibration and which will be incorporated into the design as necessary include:

- standard trackform design to use continuously welded rail;
- the rails in tunnels will be supported on resilient track support systems, and track installation will be carried out using modern technology to achieve very much more accurately laid and smoother track than exists in traditional tube tunnels; and
- floating slab track or similar technology.

08 Noise and Vibration

8.100 Initial assessments undertaken by Crossrail suggest that the groundborne and structure borne noise levels that can be expected within the Proposed Development are expected to be no more than 15dB $L_{Amax,s}$. This assessment assumes an enhanced low vibration trackform in the tunnels in the vicinity of Fisher Street intervention shaft.

8.101 It is therefore considered that the impact of groundborne noise and vibration in the Proposed Development would be **NSig**.

8.102 Overall, it is considered that through the use of appropriate design measures (to be determined during detailed design phases), groundborne noise and vibration affecting future occupants of the Proposed Development will be controlled and the impact would be **NSig**. As such the application site is deemed to be suitable for the Proposed Development.

Potential Impacts and Mitigation Measures

8.103 This section discusses impacts to representative receptors associated with noise and vibration arising from the Proposed Development during the construction and operational phases.

8.104 Where significant adverse impacts are predicted to occur, outline mitigation measures have been identified in order to demonstrate the feasibility of reducing the magnitude of these impacts to an acceptable level.

Construction Noise and Vibration

Construction Works Noise

8.105 The duration of the construction works for the Proposed Development is currently envisaged to be approximately 30 months. Only limited demolition and no groundworks will be required as part of the Proposed Development.

8.106 Whilst specific details relating to the construction programme have not been finalised, the main activities are anticipated to be as follows;

- Enabling works and site setup;
- Limited Demolition;
- Main structure construction;
- Fit-out; and
- Public realm and external works.

8.107 Details of typical construction equipment and machinery are not available at this time. However, it is understood the main building structure will be formed using re-inforced concrete founded on loading points within the Crossrail intervention shaft, ground beams on pile foundations to the east of the intervention shaft and the basement structure on the west side of the intervention shaft.

8.108 There is insufficient room on-site for concrete mixing facilities and therefore concrete will be delivered ready mixed.

8.109 Based on the proposed construction process, Table 8-17 presents the type, estimated number and sound level of the construction equipment assumed during the main building structure construction. The typical sound level for each item of equipment has been taken from BS 5228.

Table 8-17 Construction Equipment during Main Structure Construction

Plant	Noise dB L_{Aeq} at 10 metres	Qty	dB L_{Aeq}
Mobile/Tower Cranes	70	1	70
Air Compressors	65	1	65
Scaffold/Hydraulic access platforms	68	1	68
Ready mixed concrete lorry	80	1	80
Concrete mixer truck (discharging) & concrete pump (Pumping)	75	1	75
Poker Vibrator	78	2	81
Flat bed articulated vehicle	74	1	74
Total Noise at 10 metres			85

8.110 Based on the numbers and types of equipment detailed in Table 8-15, calculations have been undertaken to determine the resultant noise levels at the nearest noise sensitive receptors identified in Table 8-13. The calculations have considered the distance to the nearest noise sensitive receptor from the centre of the application site. In addition it is assumed each item of plant would only be operational for 50% of the time.

8.111 Table 8-18 presents the calculated noise levels and the impact significance based on the measured existing noise level.

Table 8-18 Construction Noise Impact Assessment

Receptor	Calculated Noise Level (dBA)	Existing Noise Level (dBA)	Significance
R1	67	63[1]	**NSig**
R2	80	63[1]	**Sig adverse**
R3	71	70[2]	**NSig**
R4	72	70[2]	**NSig**
R5	78	70[2]	**Sig adverse**

1 Existing noise level based on monitoring position M2

2 Existing noise level based on monitoring position M1

8.112 It may therefore be noted that construction noise is predicted to have a **NSig** impact during construction of the main structure at R1, R3 and R4. At R2 and R5 an **Sig adverse** impact is predicted.

8.113 During the fit-out and subsequent phases, the majority of noisy works will take place within the building which will provide acoustic screening to sensitive receptors. As such construction noise will be lower.

08 Noise and Vibration

8.114 Mitigation measures will help to reduce the scale of the impacts on the environment. Noise and vibration will be managed to reduce impacts, and mitigation measures will be documented in a suitable Demolition and Construction Method Statement (DCMS). Mitigation measures which would be typically included are provided in the LBC Guide for Contractors Working in Camden and are as follows:

- BPM will be employed to reduce negative impacts and increase beneficial impacts on the environment by controlling noise, vibration or other nuisance which may cause offence to the local community or environment.
- Wherever possible, the construction site will be totally surrounded by fencing or hoarding to reduce the amount of noise that escapes from the site. All site gates will be controlled so that they are open long enough to allow vehicles to pass through but no loud noise can escape to the surrounding areas.
- Wherever possible, fixed items of construction machinery will be electrically powered rather than powered by diesel or petrol. Where this is not practical, suitable measures such as acoustic enclosures will be employed. A three-phase electricity supply will be installed on site as soon as possible, and power for lighting at night will be provided by a proper electrical supply or battery, not a generator.
- Machines that are not used very often will be shut down when they are not in use or throttled down to a minimum. Equipment that needs to run continuously and which produces a lot of noise, will be kept it in a suitable acoustic enclosure.
- Vehicles and machinery will be fitted with effective exhaust silencers, be maintained in good and efficient working order, and be used in a way that reduces noise as much as possible. The relevant European Community Directive and United Kingdom Statutory Instruments will be followed.
- Any compressors will be 'sound-reduced' models that are fitted with properly lined and sealed acoustic covers kept closed whenever the machine is in use. Also, pneumatic percussive tools will be fitted with the most effective muffler or silencer available.
- Equipment which breaks concrete by pressure will be employed as far as is reasonably practical.
- Hydraulic or electrical powered rotary drills and bursters will be employed where practical to remove hard materials.
- Noisy machinery and equipment will be kept as far away as practical from residential or other noise-sensitive properties. Barriers; for example, soil banks, stock piles of materials, site portacabins or proprietary acoustic barriers will be employed where practical.
- Care will be taken when loading or unloading vehicles, dismantling scaffolding or moving materials to reduce the noise.
- All material and machinery that is delivered to the construction site, and any waste or other material that is to be removed, will take place within the permitted hours.
- The arrival of delivery vehicles will be properly co-ordinated at the construction site to prevent parking in local streets while awaiting access to the site. Vehicles will not arrive before 08:00. In-cab communication will be considered to prevent unacceptable queuing on streets outside the site.
- Plans will be drawn up to make sure that lengthy work can be completed within the permitted hours.
- All employees, subcontractors and people employed on the construction site will be instructed to not cause unnecessary noise from their activities; for example, 'revving' vehicle engines, music from radios and shouting.
- All subcontractors and other people employed in connection with the work will be made aware of and, where practical, keep to these guidelines.

8.115 The appointed contractor will be a member of the 'Considerate Constructors Scheme' which is an initiative designed to encourage best practice beyond statutory requirements.

Construction Works Vibration

8.116 BS 5228 indicates that construction activities (particularly piling) generally only generate vibration impacts when they are located less than 20 metres from sensitive locations. The impact depends on the type of piling, ground conditions, and receptor distance.

8.117 The Proposed Development will not involve any piling. All piling will be undertaken as part of the construction of the Crossrail intervention shaft and head house.

8.118 It is understood there are no construction activities as part of the Proposed Develeopment which are likely to generate vibration impacts. As such constructiuon vibration is considered to be **NSig**.

Construction Traffic Noise

8.119 The total number of HGVs accessing the construction site is not known at this stage. During the construction of another larger over site development at One Oxford Street, the peak number of HGVs was predicted to be 10 per day. Therefore, for the Proposed Development a lower number are anticipated.

8.120 It is assumed the access route for delivery and construction vehicles would be similar to that for the construction of the Crossrail intervention shaft and head house. As such access would be from the Euston Road via Woburn Place and Southampton Row. HGVs would exit Fisher Street on to Proctor Street, High Holborn, Gray's Inn Road, Clerkenwell Road and continue to the Old Street Roundabout.

8.121 Considering the high volume of traffic on the existing road network, construction traffic noise on these road will be likely to result in a **NSig** impact.

8.122 The typical LAeq noise level due to an HGV passby is 76dB at 10 metres. A worst case assessment has been considered where 4 HGVs access the construction site per hour and travel along Fisher Street. Each HGV takes approximately 30 seconds to pass. The calculated LAeq, 1hr is 61dB.

8.123 Typical daytime LAeq noise levels measured on Fisher Street and screened from Southampton Row are 63dB. The resultant LAeq noise level on Fisher Street would therefore be 65dB which represents a 2dB(A) increase. With reference to Table 8-10, this represents an **NSig** impact.

Operational Phase

Operational Traffic Noise

8.124 There will be no car parking on the application site. Waste collection vehicles and any other servicing vehicle numbers will be low. Considering the high volume of traffic on the existing road network, operational traffic noise for the Proposed Development will result in a **NSig** impact.

Noise from Building Services Plant

8.125 Building services plant will be designed and installed to meet the noise limits specified in Table 8-19. The lowest average background noise levels are taken from the Fisher Street Shaft D25 Background Noise Report (Ref. 8-22). The levels specified assume the plant noise will be non-tonal. Where plant is tonal or irregular enough to attract attention, the noise levels will be 5dB(A) lower than those set out in Table 8-19.

Table 8-19 Building Services Recommended Operational Noise Limits (Non-Tonal)

Location	Daytime 07:00 – 23:00		Night-Time 23:00 – 07:00	
	Lowest Average Background Level dB L_{A90}	Operational Noise Limit dB L_{Aeq}	Lowest Average Background Level dB L_{A90}	Operational Noise Limit dB L_{Aeq}
R1	57	52	53	48
R2	52	47	48	43
R3	57	52	53	48
R4	57	52	53	48
R5	52	47	48	43

8.126 Precise details of the plant to be installed are not yet available but it is currently anticipated all plant items would be located within a plantroom at ground floor level, including a transformer substation. The plantroom will therefore control noise break out. Any ventilation openings will be suitably attenuated to meet the specified noise levels. This will be considered during the detailed design.

8.127 An emergency generator will be located at ground floor level in the bicycle store/courtyard. This will be contained in an acoustic enclosure to meet the requirments of LBC.

8.128 It is therefore considered noise due to building services plant and equipment at the Proposed Development will be **NSig**.

Residual Impacts and Conclusions

Suitability of the Application Site for Proposed Uses

8.129 It is considered that through the use of appropriate design measures (to be determined during detailed design phases), ambient noise and vibration affecting future occupants of the Proposed Development can be controlled such that the application site is suitable for the proposed uses.

Construction Noise and Vibration Impacts

8.130 Adherence to a DCMS, and the use of Best Practicable Means will reduce the duration of and magnitude of noise and vibration impacts on sensitive receptors.

8.131 Construction works noise is predicted to have a **Sig adverse** impact at receptors R2 and R5 and an **NSig** impact at receptors R1, R3 and R4 during construction of the main structure which is anticipated to represent the noisiest works.

8.132 There will be no piling or other works likely to generate vibration and there will be an **NSig** impact at all receptors.

8.133 Construction traffic noise is predicted to have an **NSig** impact at all receptors.

Completed Operational Noise and Vibration Impacts

8.134 Building service plant will be designed and installed to have a rating level no greater than 5 dB(A) (or 10dB(A) for tonal plant) below the background noise level. Therefore **NSig** impacts are expected at all receptors.

8.135 There are no operational vibration sources associated with the operational Proposed Development.

8.136 Operational traffic noise is predicted to have an **NSig** impact at all receptors.

Summary of Residual Impacts

8.137 Table 8-20 presents a summary of the residual impacts.

Table 8-20 Summary of Residual Impacts

Description	Nature of Impact / Mitigation	Geographic Scale	Significance
Ambient Noise and Vibration Environment and Suitability of the Application Site for Proposed Uses			
Ambient Noise	Recommendations are made for suitable sound insulation. It is considered that the levels of sound attenuation required for suitable internal noise levels are viable. Noise levels on balconies and terraces to be investigated further at detailed design.	Local	**N/A**
Groundborne Noise and Vibration	Mitigation measures will be included in the design and construction of Crossrail to achieve the specified criteria in IPD10.	Local	**N/A**
Construction Impacts			
Construction Noise	Mitigation measures advised to employ “best practicable means” to control noise.	Local	**NSig to Sig Adverse**
Construction Vibration	No vibration generating construction methods are anticipated	Local	**NSig**
Construction Traffic Noise	No significant increase in road traffic noise due to construction traffic.	Local	**NSig**
Operational Impacts			
Noise from Building Services Plant	Plant noise may affect noise sensitive receptors. Suitable noise limits are defined to control noise within acceptable criteria.	Local	**NSig**
Operational Traffic Noise	No significant increase in road traffic noise due to operational traffic.	Local	**NSig**

References

Ref. 8-1 Department for Communities and Local Government (DCLG) (2012); National Planning Policy Framework.

Ref. 8-2 Department for Environment, Food and Rural Affairs (2010); Noise Policy Statement for England (NPSE).

Ref. 8-3 Greater London Authority (2011); The London Plan – Spatial Development Strategy for Greater London.

Ref. 8-4 Greater London Authority (GLA) (2004); ‘Sounder City: The Mayor’s London Ambient Noise Strategy’.

Ref. 8-5 Greater London Authority (2006); The London Plan Supplementary Planning Guidance – Sustainable Design and Construction

Ref. 8-6 London Borough of Camden (2010) Local Development Core Strategy.

Ref. 8-7 London Borough of Camden (2010) Development Policy 28.

Ref. 8-8 London Borough of Camden (2008) Guide for contractors working in Camden

Ref. 8-9 British Standards Institute (1991); BS 7445 - Description and Measurement of Environmental Noise. Part 2: Guide to the Acquisition of Data Pertinent to Land Use, BSi, London.

Ref. 8-10 British Standards Institute (1999); BS 8233 - Code of Practice for Sound Insulation and Noise Reduction for Buildings, BSi, London.

Ref. 8-11 British Standards Institute (2008); BS 6472 - Guide to Evaluation of Human Exposure to Vibration in Buildings, BSi, London.

Ref. 8-12 British Standards Institute (2009); BS 5228 - Noise and Vibration Control on Construction and Open Sites, BSi, London.

Ref. 8-13 British Standards Institute (1990); BS 7385 - Evaluation and Measurement for Vibration in Buildings, BSi, London.

Ref. 8-14 British Standards Institute (1997); BS 4142 - Method for Rating Industrial Noise Affecting Mixed Residential and Industrial Areas, BSi, London.

Ref. 8-15 Control of Pollution Act (1974); HMSO, London.

Ref. 8-16 Department of Transport/Welsh Office (1998); Calculation of Road Traffic Noise.

Ref. 8-17 Highways Agency (2011); Design Manual for Road and Bridges Volume 11 Section 3 Part 7-Traffic Noise and Vibration.

Ref. 8-18 Crossrail (2008); Crossrail Information Paper D9 – Noise and Vibration Mitigation Scheme.

Ref. 8-19 Crossrail (2008); Crossrail Information Paper D10 – Groundborne Noise and Vibration.

Ref. 8-20 Crossrail (2008); Crossrail Information Paper D25 – Noise from Fixed Installations.

Ref. 8-21 ERM/Crossrail Ltd (2005); Crossrail Environmental Statement Volume 5.

Ref. 8-22 Jacobs/Crossrail (2012); Fisher Street Shaft D25 – Background Noise Report.