

CONSTRUCTION NOISE AND VIBRATION STRATEGY

APPENDIX E



Integrated
Management
System

Sydney Metro City & Southwest Construction Noise and Vibration Strategy

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Sydney Metro Integrated Management System (IMS)

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1. FOREWORD

The Department of Environment, Climate Change and Water NSW (now the Environmental Protection Authority EPA) issued the Interim Construction Noise Guideline (ICNG) in July 2009.

The main objectives of the ICNG are stated in Section 1.3, a portion of which is presented below:

“The main objectives of the Guideline are to:

- promote a clear understanding of ways to identify and minimise noise from construction works*
- focus on applying all ‘feasible’ and ‘reasonable’ work practices to minimise construction noise impacts*
- encourage construction to be undertaken only during the recommended standard hours unless approval is given for works that cannot be undertaken during these hours*
- streamline the assessment and approval stages and reduce time spent dealing with complaints at the project implementation stage*
- provide flexibility in selecting site-specific feasible and reasonable work practices in order to minimise noise impacts.”*

The ICNG guideline (in Section 7.3) also encourages organisations involved with construction, maintenance or upgrading works (such as Sydney Metro) to develop their own best-practice techniques for managing construction noise.

In line with this recommendation the purpose of this ‘Construction Noise and Vibration Strategy’ is to document how Sydney Metro proposes to manage construction noise and vibration for the Sydney Metro and SouthWest project including any potential extensions.

2. PURPOSE AND SCOPE

2.1. Background

People are usually more tolerant to noise and vibration during the construction phase of proposals than during normal operation. This response results from recognition that the construction emissions are of a temporary nature – especially if the most noise-intensive construction impacts occur during the less sensitive daytime period. For these reasons, acceptable noise and vibration levels are normally higher during construction than during operations.

Construction often requires the use of heavy machinery which can generate high noise and vibration levels at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts would be minimised by using feasible and reasonable management techniques.

At any particular location, the potential impacts can vary greatly depending on factors such as the relative proximity of sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration levels, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

The construction noise and vibration emissions associated with a large infrastructure project such as Sydney Metro will cause disturbance to adjacent communities. This is of particular relevance in urban areas, such as in the Sydney CBD, where many sensitive receivers (not just residential) are present.

Due to the nature of this large infrastructure project a significant number of activities will be required outside normal construction hours as work during daytime periods would be highly disruptive to road traffic for commuters. In addition, noise and vibration impacts for this project are generally expected to have a duration of several years. It is therefore important that reasonable and feasible mitigation measures (as defined in the ICNG) are identified and implemented to ensure that construction noise and vibration impacts are reduced to a minimum.

2.2. Strategy Objectives

Generally the strategy is intended to provide a single interface for the large number of policies, guidelines, standards and regulations that apply to a large infrastructure project such as Sydney Metro. Where possible the strategy consolidates these information sources eg vibration criteria from numerous sources are collated into one section of this strategy for ease of reference. Further, the strategy aims to provide interpretation of the reference documents which are specific to the Metro project. Where the reference documents are found to have insufficient detail the strategy provides additional assessment criteria and methodologies.

The specific objectives of this Construction Noise and Vibration Strategy are as follows:

- Applying the strategy during the different construction phases of the project
- Environmental Protection Licence (EPL) conditions
- Construction noise and vibration guidelines to apply to the project (additional guidance to complement the ICNG)
- Construction noise and vibration assessment methodology
- Standard noise and vibration mitigation measures for the project
- Additional noise and vibration mitigation measures for the project
- Out of hours (OOH) Work
- Monitoring, auditing and reporting
- Construction noise and vibration documentation requirements

2.3. Distribution and Use

This document may be used in the development of, or referred to in:

- Environmental impact assessment documents
- Design and construction environmental management documents
- Contract documents
- Approvals and licences (subject to the agreement of the relevant regulatory authority)

2.4. Strategy Review

The strategy will be reviewed, as a minimum, annually to ensure that it meets the needs of the community, Sydney Metro and the contractors engaged on Sydney Metro projects. This document does not take precedence over approval or licence conditions and will be reviewed as required in response to the release of relevant approvals, licences, guidelines, standards and policies dealing with construction noise and vibration.

3. APPLYING THE STRATEGY

The planning procedure for all infrastructure projects requires that a detailed Environmental Assessment of the construction phases of the proposal be completed. As construction contractors are not typically appointed until much later in a project's timeline, the exact construction methodology they will use for a particular project may not be known during the environmental assessment stage.

It is expected that conservative assumptions would be incorporated at early stages of the project approval process and these must not unduly restrict innovation (eg construction methods or mitigation) at later design stages. This reflects the refinement of construction methodologies with subsequent stages of the project.

This document therefore defines the strategies by which construction noise and vibration impacts are to be minimised on Sydney Metro projects throughout the construction of a project by recognising the changing assessment requirements for each construction phase.

Table 1 outlines the level of detail expected from the assessment process (refer to Section 7) at the following stages of the project:

- Environmental Impact Statement / Environmental Assessment
- In delivery / pre-construction impact statements

Table 1: Summary of Assessment Detail Required During the Various Stages of the Project

Assessment Input	Environmental Impact Statement / Environmental Assessment	In Delivery / Pre-construction Impact Statements
Construction Scenarios / Equipment List	Construction scenarios defined by project team, based on potential construction methodologies known at the time	Construction scenarios defined by construction team. These are expected to include finalised equipment lists, itemising the realistic worst-case plant proposed to be used at any one time, and in any one location
Modelled works location	Works location by scenario (or group of scenarios) ie different locations for different works	Works location by works scenario ie specific locations for each works
Background noise monitoring	Background noise monitoring required to determine RBL at locations representative of worst-affected receiver areas adjacent to the works areas	Supplementary noise monitoring required to determine RBL at locations representative of worst-affected receiver areas adjacent to the works areas where noise survey data is not current (ie more than 5 years old)
Study Area	The study area must, as a minimum, include receivers subjected to predicted $L_{Aeq}(15\text{minute}) \geq RBL + 5\text{dB}$ for the applicable time period. Vibration level predictions up to 100 m	Predict noise and vibration levels to the sensitive receivers within the area surrounding the works, to include all receivers where the $L_{Aeq}(15\text{minute}) \geq RBL + 5\text{dB}$ and the vibration screening criteria are exceeded during the applicable time periods.

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Assessment Input	Environmental Impact Statement / Environmental Assessment	In Delivery / Pre-construction Impact Statements
Reporting	n/a	Predictions would be undertaken for the proposed time period of the works
Assessment of mitigation	Demonstration that assessment of this stage includes reasonable and feasible mitigation measures	Based on these predictions the Construction Noise Management Plan (CNMP) shall identify all reasonable and feasible mitigation measures to minimise noise and vibration from construction. Sections 7 and 8 identify the standard and additional mitigation measures to be included where applicable in the CNMP. Eg. Detailed vibration assessments to include dilapidation surveys, continuous vibration monitoring and accurate vibration transfer measurements (site law measurements) for all buildings with the potential to exceed the screening criteria for vibration.
Documentation	n/a	Implementation of the EPL conditions, or as modified by subsequent CNVIS (eg for OOHV)

4. ENVIRONMENTAL PROTECTION LICENCES (EPL)

Environmental Protection Licences are a fundamental noise control requirement for large infrastructure projects. These licences often provide detailed construction noise and vibration criteria and management measures that are tailored to the specifics of individual projects. To use this strategy effectively the time-line of assessments, approvals and licences would be understood and the necessary interaction of this strategy, the CNIS reports it generates and the EPL issued for the project.

4.1. Time-line of Assessments, Approvals and the EPL

The general time-line for this process with respect to noise and vibration from construction activities is outlined below:

1. Project concept. Preliminary high-level CNIS and CNMP reports.
2. Department of Planning Issues the Conditions of Approval for the project.
3. Environmental Impact Statement (EIS). Preliminary but more detailed CNIS and CNMP reports based on a complete concept design.
4. Project Approval from the Department of Planning.
5. Contactor Tender and Award.
6. Contractor Detailed Design. Mature CNIS and CNMP reports based on the detailed design.
7. Contractor application for Environmental Protection License for the project.
8. Licence award by the Environmental Protection Agency EPL.
9. Construction commences.
10. Ongoing of review of construction methodology and project noise and vibration issues.
11. Re-assess CNIS and CNMP based on new inputs (if necessary).
12. Consistency Assessment
13. Contractor application for amendments to the EPL.
14. Approval of the amendments to the EPL.

As can be seen from the above time-line this Strategy is used through the planning, approval and construction stages. Steps 10 through to 14 can be repeated to review and add to the EPL conditions, if necessary, during the construction stage.

5. NOISE AND VIBRATION GUIDELINES

5.1. Construction Noise Metrics

The three primary noise metrics used to describe construction noise emissions in the modelling and assessments are:

- LA1(1minute) The typical 'maximum noise level for an event', used in the assessment of potential sleep disturbance during night-time periods. Alternatively, assessment may be conducted using the LA_{max} or maximum noise level
- LA_{eq}(15minute) The 'energy average noise level' evaluated over a 15-minute period. This parameter is used to assess the potential construction noise impacts.

LA90 The 'background noise level' in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively. The LAeq(15minute) construction noise management levels are based on the LA90 background noise levels.

The subscript 'A' indicates that the noise levels are filtered to match normal hearing characteristics (A weighted).

5.2. Construction Hours

Where possible, works will be completed during the standard day time construction hours of Monday to Friday 7.00 am to 6.00 pm and Saturdays 8.00 am to 1.00 pm. However, the nature of the project means evening and night work are required throughout the construction program. Many of the construction scenarios for this project will require 24/7 operation. These scenarios include:

- Excavation of station shafts
- Excavation of the station caverns
- Operation of the tunnel boring machines
- Spoil removal and transport from site

Out of Hours Works (OOHWs) are to be included in the assessment for all proposed works at all locations in order to inform the scheduling of construction activity and management of noise during the detailed design phase. It is anticipated that the finalised requirements for OOHWs would be determined at a later design stage. It is understood that any OOHWs would be subject to a separate approval on a case-by-case basis and would likely require approval under the project's Environmental Protection Licence (EPL).

5.3. Construction Noise Management Levels (NML)

Construction Noise Management Levels (NML) for all Sydney Metro projects will be determined in accordance with the procedures nominated in the DECCW's "Interim Construction Noise Guideline" dated July 2009 (ICNG, 2009). The following information is intended to supplement the ICNG with respect to the unique requirements of the Metro project.

5.3.1. Residences and Other Sensitive Land Uses

Table 2 sets out the noise management levels and how they are to be applied. This approach intends to provide respite for residents exposed to excessive construction noise outside the recommended standard hours whilst allowing construction during the recommended standard hours without undue constraints.

Table 2 the rating background level (RBL) is used when determining the management level. The RBL is the overall single-figure background noise level measured in each relevant assessment period (as defined in the EPA "Industrial Noise Policy" dated January 2000).

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Table 2: Noise at Residences Using Quantitative¹

Time of Day	Management Level LAeq(15minute) ²	How to Apply
Recommended standard hours: Monday to Friday 7.00 am to 6.00 pm Saturday 8.00 am to 1.00 pm	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured LAeq(15minute) is greater than the noise affected level, the proponent would apply all feasible and reasonable work practices to minimise noise. The proponent would also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
No work on Sundays or public holidays	Highly noise affected 75 dB	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the proponent would consider very carefully if there is any other feasible and reasonable way to reduce noise to below this level. If no quieter work method is feasible and reasonable, and the works proceed, the proponent would communicate with the impacted residents by clearly explaining the duration and noise level of the works, and by describing any respite periods that will be provided.
Outside recommended standard hours	Noise affected RBL + 5 dB	A strong justification would typically be required for works outside the recommended standard hours. The proponent would apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5 dBA above the noise affected level, the proponent would negotiate with the community. For guidance on negotiating agreements see Section 7.2.2 of the ICNG.

Note 1: Adopted from the ICNG.

Note 2: Noise levels apply at the property boundary that is most exposed to construction noise. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence.

Table 3 presents management levels for noise at other sensitive land uses based on the principle that the characteristic activities for each of these land uses would not be unduly disturbed. The noise management levels apply only to when the property is being used, for example classrooms during school hours. Internal noise levels are to be assessed at the centre of the occupied room. External noise levels are to be assessed at the most-affected point within 50 m of the area boundary.

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Table 3: Noise at Other Sensitive Land Uses Using Quantitative Assessment¹

Land Use	Management Level, LAeq(15minute) (Applies When Land Use is being Utilised)
Classrooms at schools and other educational institutions	Internal noise level 45 dB
Hospital wards and operating theatres	Internal noise level 45 dB
Places of worship	Internal noise level 45 dB
Active recreation areas (such as parks and sports grounds or playgrounds)	External noise level 65 dB
Passive recreation areas (such as outdoor grounds used for teaching, outdoor cafes or restaurants)	External noise level 60 dB

Note 1: Adopted from the ICNG.

Other noise-sensitive businesses require separate specific noise goals and it is suggested in the ICNG that the internal construction noise levels at these premises are to be referenced to the 'maximum' internal levels presented in AS 2107. Recommended 'maximum' internal noise levels from AS 2107 are reproduced in **Table 4** for other sensitive receiver types.

However, the ICNG and AS 2107 do not provide specific criteria for childcare centres. Childcare centres generally have internal play areas and sleep areas. The Association of Australian Acoustical Consultants (AAAC) Technical Guideline on Child Care Centre Noise Assessments provides criteria for these land uses. Based on this guideline an LAeq (1hour) of 55 dBA for external play areas and LAeq (1hour) of 40 dBA for indoor play areas and sleeping areas would be adopted.

Table 4 AS 2107 Recommended Maximum Internal Noise Levels

Land Use	Time Period	AS 2107 Classification	Recommended "Maximum" Internal LAeq (dBA)
Hotel	Daytime & Evening	Bars and Lounges	50
	Night-time	Sleeping Areas: - Hotels near major roads	40
Café	When in use	Coffee bar	50
Bar/Restaurant	When in use	Bars and Lounges / Restaurant	50
Library	When in use	Reading Areas	45
Recording Studio	When in use	Music Recording Studios	25
Theatre / Auditorium	When in use	Drama Theatres	30

5.3.2. Commercial and Industrial Premises

Due to the broad range of sensitivities that commercial or industrial land can have to noise from construction, the process of defining management levels is separated into three categories. The external noise levels would be assessed at the most-affected occupied point of the premises:

- Industrial premises (external): 75 dB LAeq(15minute)
- Offices, retail outlets (external): 70 dB LAeq(15minute)
- Other businesses that may be very sensitive to noise, where the noise level is project specific as discussed below

Examples of other noise-sensitive businesses are theatres, studios and child care centres. The proponent would undertake a special investigation to determine suitable noise levels on a project-by-project basis; the recommended internal noise levels presented in Table 1 of AS 2107 “Acoustics - Recommended design sound levels and reverberation times for building interiors” (Standards Australia 2000) may assist in determining relevant noise levels; however, an acoustical consultant would be engaged in order to determine corresponding external noise levels based on the published internal noise levels. The proponent would assess construction noise levels for the project, and consult with occupants of commercial and industrial premises prior to lodging an application where required. During construction, the proponent would regularly update the occupants of the commercial and industrial premises regarding noise levels and hours of work.

5.4. Ground-Borne Vibration

The effects of vibration in buildings can be divided into three main categories; those in which the occupants or users of the building are inconvenienced or possibly disturbed, those where the building contents may be affected and those in which the integrity of the building or the structure itself may be prejudiced.

5.4.1. Human Comfort Vibration

The DECCW’s “Assessing Vibration: a technical guideline” dated February 2006 (DEC, 2006) recommends the use of BS 6472-1992 for the purpose of assessing vibration in relation to human comfort.

British Standard 6472-1992 “Guide to evaluation of human exposure to vibration in building” nominates guideline values for various categories of disturbance, the most stringent of which are the levels of building vibration associated with a “low probability of adverse comment” from occupants.

BS 6472-1992 provides guideline values for continuous, transient and intermittent events that are based on a Vibration Dose Value (VDV), rather than a continuous vibration level. The vibration dose value is dependant upon the level and duration of the short term vibration event, as well as the number of events occurring during the daytime or night-time period.

The vibration dose values recommended in BS 6472-1992 for which various levels of adverse comment from occupants may be expected are presented in **Table 5**.

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Table 5: Vibration Dose Value Ranges which Might Result in Various Probabilities of Adverse Comment within Residential Buildings

Place and Time	Low Probability of Adverse Comment (m/s ^{1.75})	Adverse Comment Possible (m/s ^{1.75})	Adverse Comment Probable (m/s ^{1.75})
Residential buildings 16 hr day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings 8 hr night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Note: For offices and workshops, multiplying factors of 2 and 4 respectively would be applied to the above vibration dose value ranges for a 16 hr day.

5.4.2. Structural Damage Vibration

Most commonly specified 'safe' structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

In terms of the most recent relevant vibration damage goals, Australian Standard AS 2187: Part 2-2006 'Explosives - Storage and Use - Part 2: Use of Explosives' recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 'Evaluation and measurement for vibration in buildings Part 2' as they "are applicable to Australian conditions".

The Standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

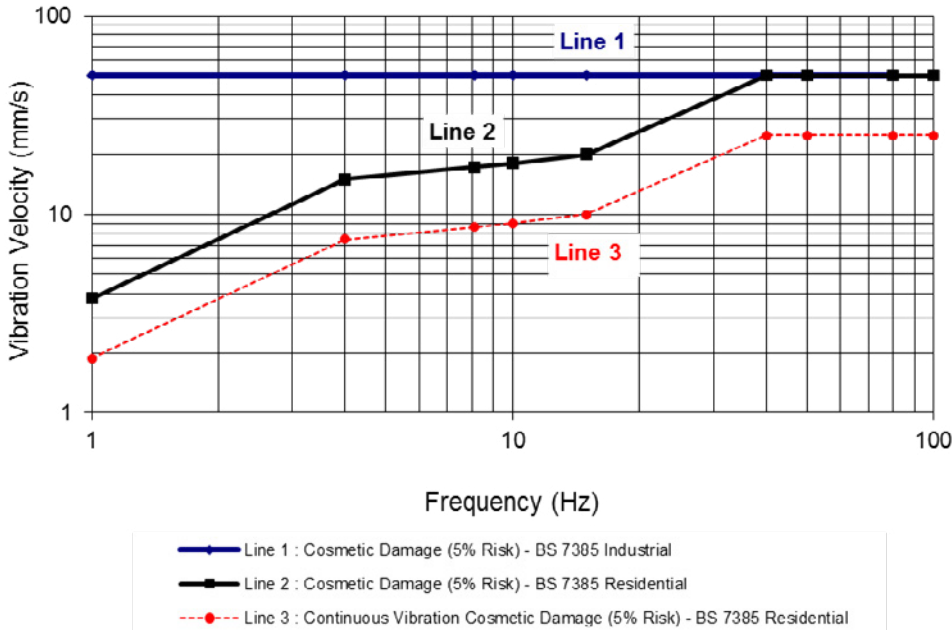
5.4.3. Cosmetic Damage Vibration

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in **Table 6** and graphically in **Figure 1**.

Table 6: Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and Above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Figure 1: Graph of Transient Vibration Guide Values for Cosmetic Damage



The Standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 6**, and major damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the Standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 6** would not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS2187 specifies that vibration measured would be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) would be compared with the guidance curves presented in **Figure 1**.

It is noteworthy that extra to the guide values nominated in **Table 6**, the standard states that:

“Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK.”

Also that:

“A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive.”

5.5. General Vibration Screening Criterion

The Standard states that the guide values in **Table 6** relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration may give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 6** may need to be reduced by up to 50%.

Note: rockbreaking/hammering and sheet piling activities are considered to have the potential to cause dynamic loading in some structures (eg residences) and it may therefore be appropriate to reduce the transient values by 50%.

Therefore for most construction activities involving intermittent vibration sources such as rockbreakers, piling rigs, vibratory rollers, excavators and the like, the predominant vibration energy occurs at frequencies greater than 4 Hz (and usually in the 10 Hz to 100 Hz range). On this basis, a conservative vibration damage screening level per receiver type is given below:

- Reinforced or framed structures: 25.0 mm/s
- Unreinforced or light framed structures: 7.5 mm/s

At locations where the predicted and/or measured vibration levels are greater than shown above (peak component particle velocity), a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be required to determine the applicable safe vibration level.

5.6. Guidelines for Vibration Sensitive and Special Structures

5.6.1. Heritage

Heritage buildings and structures would be assessed as per the screening criteria in **Section 5.5** as they should not be assumed to be more sensitive to vibration unless they are found to be structurally unsound. If a heritage building or structure is found to be structurally unsound (following inspection) a more conservative cosmetic damage criteria of 2.5 mm/s peak component particle velocity (from DIN 4150) would be considered.

5.6.2. Sensitive Scientific and Medical Equipment

Some scientific equipment (eg electron microscopes and microelectronics manufacturing equipment) can require more stringent objectives than those applicable to human comfort.

Where it has been identified that vibration sensitive scientific and/or medical instruments are likely to be in use inside the premises of an identified vibration sensitive receiver, objectives for the satisfactory operation of the instrument would be sourced from manufacturer's data. Where manufacturer's data is not available, generic vibration criterion (VC) curves as published by the Society of Photo-Optical Instrumentation Engineers (Colin G. Gordon - 28 September 1999) may be adopted as vibration goals. These generic VC curves are presented below in **Table 7** and **Figure 2**.

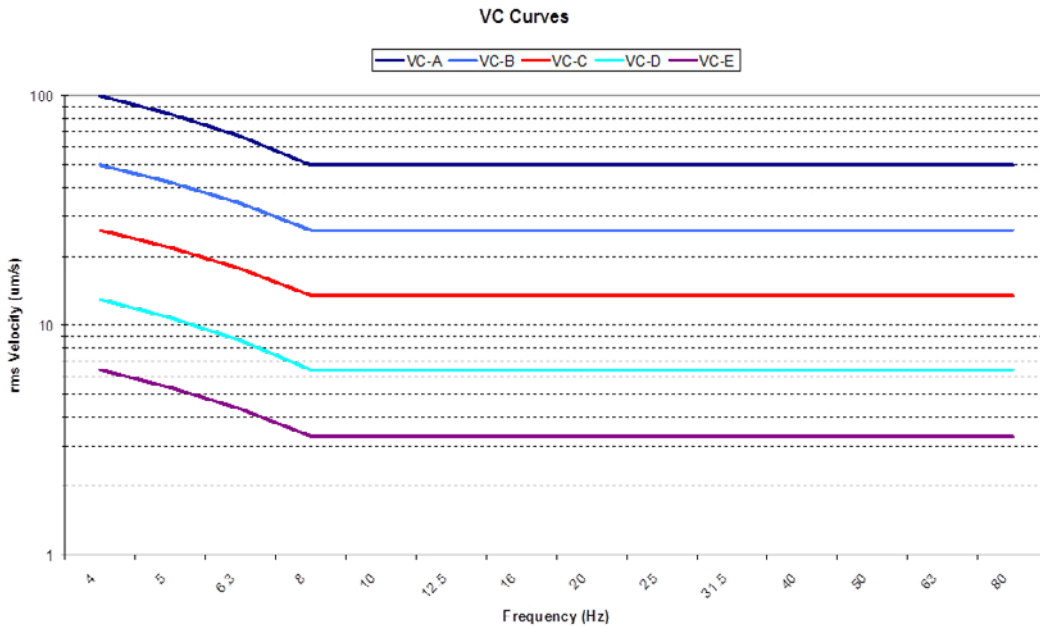
Table 7: Application and Interpretation of the Generic Vibration Criterion (VC) Curves
(as shown in Figure 2)

Criterion Curve	Max Level (µm/sec, rms) ¹	Detail Size (microns) ²	Description of Use
VC-A	50	8	Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.
VC-B	25	3	An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 micron line widths.
VC-C	12.5	1	A good standard for most lithography and inspection equipment to 1 micron detail size.
VC-D	6	0.3	Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability.
VC-E	3	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems requiring extraordinary dynamic stability.

Note 1: As measured in one-third octave bands of frequency over the frequency range 8 to 100 Hz.

Note 2: The detail size refers to the line widths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation requirements of many items depend upon the detail size of the process.

Figure 2: Vibration Criterion (VC) Curves



5.6.3. Other Vibration Sensitive Structures and Utilities

Where structures and utilities are encountered which may be considered to be particularly sensitive to vibration, a vibration goal which is more stringent than structural damage goals presented in Section 5.4 may need to be adopted. Examples of such structures and utilities include:

- Tunnels
- Gas pipelines
- Fibre optic cables

Specific vibration goals would be determined on a case-by-case basis. An acoustic consultant would be engaged by the construction contractor and would liaise with the structure or utility's owner in order to determine acceptable vibration levels.

5.7. Vibration and Overpressure from Blasting

The DECCW's ICNG recommends that vibration and overpressure from blasting be assessed against the levels presented in the Australian and New Zealand Environment Council's (ANZECC) Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration (ANZECC, 1990).

The criteria set by this standard are targeted at operations that occur for long periods of time such as those at mining sites and hence are targeted at protecting human comfort vibration levels. As a result the vibration levels are conservative and can introduce unnecessary constraints when applied to construction projects which typically occur for much shorter time periods. Recent NSW infrastructure project approvals have recognised the restrictive nature of these blasting criteria when applied to construction projects and have therefore allowed the following vibration and overpressure limits:

- Vibration (PPV): 25 mm/s
- Overpressure: 125 dBL

These upper limits are deemed acceptable where the proponent has a written agreement with the relevant landowner to exceed the criteria and the Secretary has approved the terms of the written agreement. These upper limits to vibration and overpressure are intended to target the protection of building structures from cosmetic damage rather than human comfort criteria as construction works are considered short-term.

5.8. Ground-Borne (Regenerated) Noise

Ground-borne (regenerated) noise is noise generated by vibration transmitted through the ground into a structure. Ground-borne noise caused, for example by underground works such as tunnelling, can be more noticeable than airborne noise. The following ground-borne noise levels for residences are nominated in the ICNG and indicate when management actions would be implemented. These levels recognise the temporary nature of construction and are only applicable when ground-borne noise levels are higher than airborne noise levels.

The ground-borne noise management levels are given below:

- Day (7.00 am to 6.00pm)
Internal Residential: 45 dB LAeq(15minute)
Internal Commercial: 50 dB LAeq(15minute)

- Evening (6.00 pm to 10.00 pm)
Internal Residential: 40 dB LAeq(15minute)
- Night-time (10.00 pm to 7.00 am)
Internal Residential: 35 dB LAeq(15minute)

The daytime criteria are applicable to both residential and commercial receivers, whereas the evening and night-time criteria are only applicable to residential receivers.

The internal noise levels are to be assessed at the centre of the most-affected habitable room. For a limited number of discrete, ongoing ground-borne noise events, such as drilling or rock-hammering, The LAmax noise descriptor using a slow response on the sound level meter may be better than the LAeq noise descriptor (15 min) in describing the noise impacts. The level of mitigation of ground-borne noise would depend on the extent of impacts and also on the scale and duration of works. Any restriction on the days when construction work is allowed would take into account whether the community:

- Has identified times of day when they are more sensitive to noise (for example Sundays or public holidays).
- Is prepared to accept a longer construction duration in exchange for days of respite.

5.9. Traffic Noise Assessment Goals

When trucks and other vehicles are operating within the boundaries of the various construction sites, road vehicle noise contributions are included in the overall predicted LAeq(15minute) construction site noise emissions. When construction related traffic moves onto the public road network a different noise assessment methodology is appropriate, as vehicle movements would be regarded as 'additional road traffic' rather than as part of the construction site.

The ICNG does not provide specific guidance in relation to acceptable noise levels associated with construction traffic. For assessment purposes, guidance is taken from the RNP.

One of the objectives of the RNP is to apply relevant permissible noise increase criteria to protect sensitive receivers against excessive decreases in amenity as the result of a proposal. In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.

On this basis, construction traffic NMLs set at 2 dB above the existing road traffic noise levels during the daytime and night-time periods are considered appropriate to identify the onset of potential noise impacts. Where the road traffic noise levels are predicted to increase by more than 2 dB as a result of construction traffic, consideration would be given to applying feasible and reasonable noise mitigation measures to reduce the potential noise impacts and preserve acoustic amenity.

In considering feasible and reasonable mitigation measures where the relevant noise increase is greater than 2 dB, consideration would also be given to the actual noise levels associated with construction traffic and whether or not these levels comply with the following road traffic noise criteria in the RNP:

- 60 dB LAeq(15hour) day and 55 dB LAeq(9hour) night for existing freeway/ arterial/ sub-arterial roads.
- 55 dB LAeq(1hour) day and 50 dB LAeq(1hour) night for existing local roads.

5.9.1. Sleep Disturbance and Maximum Noise Events

In addition to the current legislative guidance on potential sleep disturbance outlined in Section 5.10 the RNP refers to Practice Note 3 of the ENMM for specific impacts from road traffic. The ENMM recommends an evaluation of the number and distribution of night-time passby events where the $L_{AFmax} - L_{Aeq(1hour)}$ difference is greater than 15 dB, and the maximum noise level of that event is greater than 65 dB L_{Amax} .

On the basis of the current guidance:

- External sleep disturbance screening criterion of $RBL + 15$ dB
- External sleep disturbance criterion of 65 dB L_{Amax} (assuming open windows).

5.10. Sleep Disturbance and Maximum Noise Level Events

The DECCW's ECRTN and the Road and Traffic Authority's (RTA's) 'Environmental Noise Management Manual' (ENMM) provide guidance as to the likelihood of sleep disturbance resulting from maximum noise level events (mainly associated with heavy vehicle movements). The ECRTN points out the following:

"There are no universally accepted criteria governing the likelihood of sleep disturbance. In other words, at the current level of understanding, it is not possible to establish absolute noise levels that correlate to levels of sleep disturbance (for all or even a majority of people)."

Notwithstanding the ECRTN/ENMM suggests that:

- Maximum internal noise levels below 50 dB to 55 dB L_{Amax} are unlikely to cause awakening reactions.
- One or two events per night, with maximum internal noise levels of 65 dB to 70 dB L_{Amax} , are not likely to affect health and wellbeing significantly.
- At locations where road traffic is continuous rather than intermittent, the $L_{Aeq(9hour)}$ target noise level should sufficiently account for sleep disturbance impacts.
- Where the emergence of L_{Amax} noise levels over the ambient L_{Aeq} noise level is greater than 15 dB, the L_{Aeq} criterion may not sufficiently account for sleep disturbance impacts.

A maximum noise event can be defined as any passby for which the difference in the L_{Amax} and $L_{Aeq(1Hour)}$ noise levels is greater than 15 dB. Furthermore, the ECRTN recommends that the assessment of sleep disturbance should include a consideration of the maximum noise level exceedances occurring during the night-time period and the emergence of these exceedances above the ambient noise level.

6. CONSTRUCTION NOISE & VIBRATION ASSESSMENT METHODOLOGY

6.1. Overview

Program and site constraints require that 24 hour working would most likely be required at all metro construction sites for a significant proportion of the total construction period. In particular, noisy activities such as:

- Excavation of tunnel and station caverns by Tunnel Boring Machines (TBMs) and roadheaders would be required over a 24 hour day, 6 days a week. Note that TBMs typically require routine maintenance of equipment on the 7th day.

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- Bulk excavation of station entry and ventilation shafts by rockbreaker / blasting (or equivalent methodology), raise boring, line drilling and milling head would be required 24 hours a day for 7 days a week.
- Truck movements would be required 24 hours a day for 7 days a week.

6.2. Expected Construction Activities

Table 8 presents the construction activities which are likely to be undertaken during the construction of all Sydney Metro projects, together with typical plant and equipment required to execute each activity.

Table 8: Construction Activities and Typical Plant and Equipment

Activity	Significant Noise and Vibration Generating Plant and Equipment
Demolition	Excavator Dump Trucks Rockbreaker Jackhammer
General Earthworks and site establishment	Excavator Dumps Trucks Delivery Trucks
Spoil Removal	Excavator Dump Trucks
Shaft Excavation	Rockbreakers Penetrating Cone Fracture (PCF) Blasting Jackhammer
Station Cavern Excavation	Roadheaders
Tunnelling	Tunnel Boring Machine (TBM) Roadheaders
Cross passages	Rock breakers Roadheaders
Building/Facility Construction	Standard Construction Techniques Including: - Cranes - Delivery Trucks - Hand Tools/Hand Held Power Tools
Demolition	Excavator Dump Trucks Rockbreaker Jackhammer
General Earthworks and site establishment	Excavator Dumps Trucks Delivery Trucks
Spoil Removal	Excavator Dump Trucks
Shaft Excavation	Rockbreakers Penetrating Cone Fracture (PCF) Blasting Jackhammer

6.3. Noise and Vibration Sensitive Receivers

The sensitivity of occupants to noise and vibration varies according to the nature of the occupancy and the activities performed within the affected premises. For example, recording studios are more sensitive to vibration and ground borne noise than residential premises, which in turn are more sensitive than typical commercial premises.

Specific noise and vibration sensitive receivers relevant to individual construction sites would be identified and addressed in the Environmental Assessment of each Sydney Metro project. Each receiver would be identified as falling into one of the following categories:

- Commercial
- Educational
- Industrial
- Mixed residential/commercial
- Residential
- Residential occupied by shift workers
- Place of Worship
- Medical facilities
- Other sensitive receivers

6.4. General Assessment Procedure

All assessments must be quantitative as per the procedure given in the ICNG. If the assessment is being carried out for the environmental impact assessment documentation (eg EIS) it will be based on a concept design and construction scenarios for the project (usually prepared by a technical advisor and/or planning consultant). If the assessment is being undertaken prior to construction (eg CNIS) it will be based on a more detailed design and actual construction scenario (usually prepared by the design and/or construction contractors).

Constructions Noise Impact Statements (CNIS) are to be developed to assess the potential impact of noise at NSRs as a result of a Sydney Metro project's construction activities prior to the commencement of construction components.

In order to develop accurate and comprehensive CNIS reports for work components associated with the project, specific detail of the construction methodology, including the size and type of equipment is required. Detailed design, construction and engineering solutions are progressively developed and applied throughout the life-span of the project. Consequently, CNIS reports that cover the key construction activities/components are to be developed to reflect the progressive nature of design and construction of the project. There are to be two (2) different types of CNIS report to be developed throughout the project:

- General Construction Activity CNIS for construction scenarios that are consistently the same and progressively move along the project alignment eg tunnelling, retaining walls.
- Location Specific CNIS for construction scenarios that are specific to a location. Where works are required to be undertaken outside of standard construction hours, Out of Hours Work (OOHW) assessments will be included in CNIS or a new CNIS

developed in support of all applicable variations to the project Environment Protection Licence (EPL).

For all CNIS reports the noise impacts are to be assessed based on construction scenarios. A construction scenario relating to noise impact is essentially a construction activity with is made up of the required plant and equipment. A number of construction scenarios will make up any one CNIS report. In undertaking an assessment of the noise impact from a construction scenario(s) including the development of CNIS report, the following steps are to be taken:

- Identify all noise and/or vibration sensitive receivers (NSRs) which may be affected by the project.
- Conduct background noise monitoring at representative NSRs to determine the rating background noise levels (RBLs) in accordance with the procedures presented in the NSW Industrial Noise Policy, where RBLs have not been established in previous project stages.
- Determine the appropriate noise and vibration management levels of each NSR.
- Determine the source noise levels (Sound Power Levels) of each noise generating plant and equipment item required to undertake the construction scenario. Note: Sound Power Levels for each plant and equipment would be less than the maximum allowable levels found in Table 11 and Table 12.
- Clearly indicate which mitigation measures identified in Section 7 have been/are to be incorporated into the noise assessment. Noise mitigation measures to be implemented will vary for reasons such as safety and space constraints, these are to be identified and the calculations adjusted accordingly.
- For Location Specific construction scenarios and where applicable for Generic scenarios, include the effects of noise shielding provided by site offices, residential fences, noise barriers or natural topographic features.
- Where applicable include the effects of noise reflections and ground attenuation.
- On the basis of the duration of each activity (over a typical “worst case” 15-minute period), determine whether any correction between the L_{Amax} and the L_{Aeq} is required.
- Calculate the L_{Aeq} noise or range of levels from construction scenarios at sensitive receiver groups, with the use of noise contour maps where appropriate and/or at 10 m, 25 m, 50 m, 75 m, 100 m and 200 m for more general construction activities.
- Compare these against the goals identified for each NSR and identify predicted exceedances.
- For night-time activities, calculate the $LA_{1(60second)}$ noise levels and compare with the DECCW’s RBL + 15 dB sleep disturbance screening criterion. On the basis of the ambient noise environment during the night-time period, the predicted LA_1 noise levels and the number of expected LA_1 noise events would be assessed. From this assessment determine the likelihood of potential sleep disturbance. Note: the L_{Amax} noise level can be used to estimate the LA_1 noise level.
- On completion of all CNIS reports for the subjective classification of the noise impact is to be evaluated and documented as:
 - Lower Impact
 - Moderate Impact

- High Impact

The classifications are to be determined on a case-by-case basis with consideration of the following points. These are guidelines for classifications only and subjective due to the number of variances within any construction scenario. An objective evaluation is to be applied to all construction scenarios.

- The location of the works in relation to NSRs with consideration of noise attenuation features such as noise barriers including topographical features (earth-mounds), buildings, dividing fences etc (distance of works from sensitive receiver(s)).
- The type and sensitivity of the NSRs:
 - Lower Impact: eg Commercial buildings/ Scattered Residential (low density)
 - Moderate Impact: eg Standard residential (typical density)
 - High Impact: eg Residential home for the elderly/high density unit blocks/persistent complainers/residents deemed to have “construction noise fatigue”.
- The extent of noise exceedance above Noise Management Level.
- The likelihood for potential sleep disturbance RBL + 15 dB.
- The type of and intensity of noise emitted from works (ie tonal or impulsive):
 - Lower Impact: No high noise and/or vibration intensive activities
 - Moderate Impact: Short/intermittent high noise and/or vibration intensive activities
 - High Impact: Prolonged high noise and/or vibration intensive activities.
- The duration of any OOHW required.
- The time frames for any OOHW:
 - Lower Impact: 6.00 pm till 10.00 pm weekdays 1.00 pm till 10.00pm Saturdays
8.00 am till 6.00 pm Sundays or Public Holidays
 - Moderate Impact: 10.00 pm to 7.00 am Weekday Nights 10.00 pm to 8.00 am Saturdays
 - High Impact: 6.00 pm to 7.00 am Sundays and Public Holidays.
- As a result of noise classification and/or the noise level exceedances at sensitive receivers provided by the CNIS reports, appropriate reasonable and feasible noise mitigation is to be adopted and implemented. For sites where works are predicted to significantly exceed noise goals and impact on receivers for a significant period of time, additional reasonable and feasible noise mitigation measures such as those outlined in Section 7 would be considered if practical to reduce the noise levels and impact on sensitive receivers.

6.5. Ground-Borne (Regenerated) Noise

Ground-borne noise as a result of construction activities is usually associated with tunnelling projects where equipment such as tunnel boring machines, road headers, rock hammers and drilling rigs are operated underground. It is therefore anticipated that ground-borne noise may be an issue during the construction of Sydney Metro projects.

If ground-borne noise is anticipated as a result of construction activities, a CNIS report, specifically in relation to the assessment of ground-borne construction noise would be undertaken.

In undertaking a CNIS report for ground-borne construction noise the following steps are to be taken:

- Determine the location of each plant and equipment item in relation to each receiver.
- On the basis of ground-borne noise versus distance prediction algorithms for each plant item, determine the level of ground-borne noise at each building location. For highly sensitive building occupancies, such as recording studios, the assessment may need to incorporate the acoustic properties of the building space and the structural response of the building. This is to be determined by a qualified acoustic consultant, should ground-borne noise be a potential issue.
- Include the effect of all relevant standard mitigation measures as part of the construction scenario.
- Calculate the $L_{Aeq(15\text{minute})}$ noise levels from the proposed construction activities at each receiver and compare these to the ground-borne noise management levels.

6.6. Ground-Borne Vibration

Vibration as a result of construction activities is usually associated with tunnelling projects where equipment such as tunnel boring machines, road headers, rock hammers and drilling rigs are operated underground. It is therefore anticipated that ground-borne vibration may be an issue during the construction of Sydney Metro projects.

If vibration impacts are anticipated as a result of construction activities, a CNIS report, specifically in relation to the assessment of construction vibration would be undertaken.

In undertaking a CNIS report for ground-borne construction vibration the following steps are to be taken:

- Determine the location of each plant and equipment item in relation to each receiver.
- On the basis of ground-borne vibration versus distance prediction algorithms for each plant item, determine the level of ground-borne vibration at each building location. For highly sensitive building occupancies, such as recording studios, the assessment may need to incorporate the vibration properties of the building space and the structural response of the building. This is to be determined by a qualified acoustic consultant, should ground-borne vibration be a potential issue.
- Include the effect of all relevant standard mitigation measures as part of the construction scenario.

Calculate the vibration levels from the proposed construction activities at each receiver and compare these to the ground-borne vibration criteria.

6.7. Vibration and Overpressure from Blasting

Vibration and overpressure as a result of construction activities is usually associated with tunnelling projects where blasting is required. If this construction is implemented then vibration and overpressure may be an issue during the construction of Sydney Metro projects.

If vibration and overpressure impacts are anticipated as a result of construction blasting, a CNIS report, specifically in relation to the assessment of construction blasting would be undertaken.

In undertaking a CNIS report for blasting vibration and overpressure the following steps are to be taken:

- Determine the location of blast charge in relation to each receiver.
- On the basis of vibration / overpressure versus distance prediction algorithms for blasting determine the level of vibration / overpressure at each receiver (building) location.
- Include the effect of all relevant standard mitigation measures as part of the construction scenario.

Calculate the vibration and overpressure levels from the proposed blasting activities at each receiver and compare these to the blasting criteria.

7. STANDARD NOISE AND VIBRATION MITIGATION MEASURES

7.1. Minimum Requirements

This section sets out the standard construction noise and vibration mitigation measures to be implemented on all Sydney Metro projects and delivered via relevant procedures, systems, environmental assessment, construction environmental management and all relevant contract documentation.

For all Sydney Metro construction projects, the standard mitigation measures in **Table 9** shall be applied by default in order to minimise the potential noise and vibration impacts at the surrounding Noise Sensitive Receivers. Additional information in relation to specific mitigation measures, the assessment process and relevant objectives are provided in **Section 8**.

During the preparation of the environmental assessment documentation, a construction noise and vibration assessment would be undertaken. This includes monitoring requirements in order to validate the modelling assumptions and confirm that noise levels from individual plant and equipment items are not excessive. This section provides guidance in relation to standard monitoring and survey requirements that are expected for Sydney Metro construction projects.

7.1.1. Management Strategies during Construction

- Construction hours would be in accordance with the ICNG, project approvals and the EPL, except where otherwise specified in an approved noise management plan.
- When working adjacent to schools, medical facilities and childcare centres, particularly noisy activities would be scheduled outside normal working hours, where feasible and reasonable.
- When working adjacent to churches and places of worship particularly noisy activities would be scheduled outside services, where feasible and reasonable.
- Avoiding the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers will result in reduced noise emissions.

- Where feasible and reasonable, the offset distance between noisy plant items and nearby noise sensitive receivers would be as great as possible.
- Regular compliance checks on the noise emissions of all plant and machinery used for the project would indicate whether noise emissions from plant items were higher than predicted. This also identifies defective silencing equipment on the items of plant.
- Ongoing noise monitoring during construction at sensitive receivers during critical periods (ie times when noise emissions are expected to be at their highest - eg piling and hammering) to identify and assist in managing high risk noise events.
- Where feasible and reasonable heavy vehicle movements would be limited to daytime hours.
- The implementation of procedures to maximise the night-time onsite spoil storage capacity where spoil is produced between the hours of 10.00 pm and 7.00 am.

7.1.2. Site Induction for all Employees, Contractors and Subcontractors

The site induction would include the following as a minimum:

- All relevant project specific and standard noise and vibration mitigation measures
- Relevant licence and approval conditions
- Permissible hours of work
- Any limitations on high noise generating activities
- Location of nearest sensitive receivers
- Construction employee parking areas
- Designated loading/unloading areas and procedures
- Site opening/closing times (including deliveries)
- Environmental incident reporting and management procedures

7.1.3. Source Noise Control Strategies

- Engines and exhausts are typically the dominant noise sources on mobile plant such as cranes, graders, excavators, heavy vehicles, etc. In order to minimise noise emissions, residential grade mufflers would be fitted on all mobile plant utilised on Sydney Metro construction projects.
- The use of damped hammers is recommended such as the 'City' model Rammer hammers. These reduce the 'ringing' of the rockpick, cylinder and excavator arm that is commonly associated with rockbreaking works. Approximately 10 dB attenuation can be achieved compared to undamped hammers of the same size.
- Regular maintenance of all plant and machinery used for the project will assist in minimising noise emissions, including the reporting of the results.
- Acoustic enclosure of plant items, if required, as identified during compliance monitoring.
- Air brake silencers would be correctly installed and fully operational for any heavy vehicle that approaches and uses any Sydney Metro construction site.
- Non-tonal reversing alarms would be used for all permanent mobile plant operating on Sydney Metro construction projects. Whilst the use of non-tonal reversing

alarms is suggested to ensure noise impacts are minimised, it is noted that OH&S requirements must also be fully satisfied.

7.1.4. Noise Barrier Control Strategies

Temporary noise barriers are recommended between the noise sources and nearby potentially affected noise sensitive receivers, wherever feasible. Typically, 5 dB to 15 dB attenuation can be achieved with a well-constructed barrier.

7.1.5. Acoustic Enclosures

Where significant noise impacts are predicted and/or long periods of construction works are planned, acoustic enclosures can be used as an effective mitigation method. Acoustic enclosures act to contain the sources of noise, whilst also providing the benefit of screening the construction site from view. An enclosure with no openings would be expected to provide attenuation the order of 20 dB.

7.1.6. Vibration Control Strategies

Attended vibration measurements are required at the commencement of vibration generating activities to confirm that vibration levels satisfy the criteria for that vibration generating activity. Where there is potential for exceedances of the criteria further vibration site law investigations would be undertaken to determine the site-specific safe working distances for that vibration generating activity. Continuous vibration monitoring with audible and visible alarms would be conducted at the nearest sensitive receivers whenever vibration generating activities need to take place inside the calculated safe-working distances.

7.1.7. Community Consultation

Active community consultation and the maintenance of positive, cooperative relationships with schools, local residents and building owners and occupiers assists in managing impacts from noisier operations and in alleviating concerns and thereby minimising disturbance and complaint. This includes, for example:

- Periodic notification of work activities and progress (eg regular letterbox drops, e-consult)
- Specific notification (letter-box drop) prior to especially noisy activities
- Comprehensive website information
- Project information and construction response telephone line
- Email distribution list

7.2. Summary of the Standard Mitigation Measures

The actions set out in **Table 9** must be implemented on all Sydney Metro construction projects.

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Table 9: Standard Mitigation Measures to Reduce Construction Noise and Vibration

Action required	Applies to	Details
Management Measures		
Implementation of any project specific mitigation measures required	Airborne noise Ground-borne noise and vibration	In addition to the measures set out in this table, any <i>project specific</i> mitigation measures identified in the environmental assessment documentation (eg EA, REF, submissions or representations report) or approval or licence conditions must be implemented.
Implement community consultation measures	Airborne noise Ground-borne noise and vibration	Periodic Notification (monthly letterbox drop) ¹ Website Project information and construction response telephone line Email distribution list Place Managers
Register of Noise Sensitive Receivers	Airborne noise Ground-borne noise and vibration	A register of all noise and vibration sensitive receivers (NSRs) would be kept on site. The register would include the following details for each NSR: <ul style="list-style-type: none"> • Address of receiver • Category of receiver (eg Residential, Commercial etc.) • Contact name and phone number
Site inductions	Airborne noise Ground-borne noise and vibration	All employees, contractors and subcontractors are to receive an environmental induction. The induction must at least include: <ul style="list-style-type: none"> • All relevant project specific and standard noise and vibration mitigation measures • Relevant licence and approval conditions • Permissible hours of work • Any limitations on high noise generating activities • Location of nearest sensitive receivers • Construction employee parking areas • Designated loading/unloading areas and procedures • Site opening/closing times (including deliveries) • Environmental incident procedures
Behavioural practices	Airborne noise	No swearing or unnecessary shouting or loud stereos/radios; on site. No dropping of materials from height; throwing of metal items; and slamming of doors. No excessive revving of plant and vehicle engines Controlled release of compressed air.
Monitoring	Airborne noise Ground-borne noise and vibration	A noise monitoring program is to be carried out for the duration of the works in accordance with the Construction Noise and Vibration Management Plan and any approval and licence conditions.

¹ Detailing all upcoming construction activities at least 14 days prior to commencement of relevant works

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Action required	Applies to	Details
Attended vibration measurements	Ground-borne vibration	Attended vibration measurements are required at the commencement of vibration generating activities to confirm that vibration levels satisfy the criteria for that vibration generating activity. Where there is potential for exceedances of the criteria further vibration site law investigations would be undertaken to determine the site-specific safe working distances for that vibration generating activity. Continuous vibration monitoring with audible and visible alarms would be conducted at the nearest sensitive receivers whenever vibration generating activities need to take place inside the applicable safe-working distances.
Source Controls		
Construction hours and scheduling	Airborne noise Ground-borne noise and vibration	Where feasible and reasonable, construction would be carried out during the standard daytime working hours. Work generating high noise and/or vibration levels would be scheduled during less sensitive time periods.
Construction respite period	Ground-borne noise and vibration Airborne noise	High noise and vibration generating activities ² may only be carried out in continuous blocks, not exceeding 3 hours each, with a minimum respite period of one hour between each block ³ .
Equipment selection	Airborne noise Ground-borne noise and vibration	Use quieter and less vibration emitting construction methods where feasible and reasonable. For example, when piling is required, bored piles rather than impact-driven piles will minimise noise and vibration impacts. Similarly, diaphragm wall construction techniques, in lieu of sheet piling, will have significant noise and vibration benefits.
Maximum noise levels	Airborne-noise	The noise levels of plant and equipment must have operating Sound Power Levels compliant with the criteria in Table 11 .
Rental plant and equipment	Airborne-noise	The noise levels of plant and equipment items are to be considered in rental decisions and in any case cannot be used on site unless compliant with the criteria in Table 11 .
Plan worksites and activities to minimise noise and vibration	Airborne noise Ground-borne vibration	Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site.
Non-tonal reversing alarms	Airborne noise	Non-tonal reversing beepers (or an equivalent mechanism) must be fitted and used on all construction vehicles and mobile plant regularly used on site and for any out of hours work.

² Includes jack and rock hammering, sheet and pile driving, rock breaking and vibratory rolling.

³ "Continuous" includes any period during which there is less than a 60 minutes respite between ceasing and recommencing any of the work.

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Action required	Applies to	Details
Minimise disturbance arising from delivery of goods to construction sites	Airborne noise	<p>Loading and unloading of materials/deliveries is to occur as far as possible from NSRs</p> <p>Select site access points and roads as far as possible away from NSRs</p> <p>Dedicated loading/unloading areas to be shielded if close to NSRs</p> <p>Delivery vehicles to be fitted with straps rather than chains for unloading, wherever feasible and reasonable</p>
Path Controls		
Shield stationary noise sources such as pumps, compressors, fans etc	Airborne noise	<p>Stationary noise sources would be enclosed or shielded whilst ensuring that the occupational health and safety of workers is maintained.</p> <p>Appendix F of AS 2436: 1981 lists materials suitable for shielding.</p>
Shield sensitive receivers from noisy activities	Airborne noise	<p>Use structures to shield residential receivers from noise such as site shed placement; earth bunds; fencing; erection of operational stage noise barriers (where practicable) and consideration of site topography when siting plant.</p>

Table 10: Minimum Requirements for Construction Methods

Method	Minimum Requirements
Excavator	Ensure that the Sound Power Levels given in Table 11 have been met.
Truck	Ensure that the Sound Power Levels given in Table 11 have been met.
Rockbreakers and jackhammers	<p>Ensure that the Sound Power Levels given in Error! Reference source not found. have been met.</p> <p>Noise and vibration monitoring would be conducted at the nearest identified NSR where exceedances of the criteria have been predicted.</p>
PCF	<p>Where it has been predicted that vibration / regenerated noise is likely to be in excess of the nominated goals, specific notification would be given to all NSRs a minimum of 2 weeks prior to a shot being fired.</p> <p>Vibration and overpressure monitoring would be conducted at the nearest identified NSR.</p>
Blasting	<p>Where it has been predicted that vibration / overpressure is likely to be in excess of the nominated goals, specific notification would be given to all NSRs a minimum of 2 weeks prior to a shot being fired.</p> <p>Vibration and overpressure monitoring would be conducted at the nearest identified NSR.</p>
TBM	Noise and vibration monitoring would be conducted at the nearest identified NSR where levels are expected to exceed the relevant noise and vibration goals.
Roadheaders	Noise and vibration monitoring would be conducted at the nearest identified NSR where levels are expected to exceed the relevant noise and vibration goals.

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7.3. Maximum Allowable Plant Sound Power Levels

Plant or equipment operating on Sydney Metro project construction sites shall have an operating sound power level (SWL) which is no higher than the corresponding SWL presented in **Table 11**. The SWLs presented in **Table 11** have been compiled from a selection of field measurements conducted between 2004 and 2008 of plant and equipment operating on large construction projects throughout NSW and are therefore considered to be representative of plant and equipment SWLs which are readily achieved by current plant and equipment normally used in the construction industry.

Plant and equipment with SWLs higher than those presented in **Table 11** would be deemed to be emitting an excessive level of noise and would not be permitted to operate Sydney Metro project construction sites.

Table 11: Maximum Allowable Sound Power Levels for Construction Equipment

Equipment	Maximum Allowable Sound Power Level (dB) LAmax	Maximum Allowable Sound Pressure Level (dB) LAmax at 7 m
Excavator Hammer	118	93
Excavator (approx. 3 tonne)	90	65
Excavator (approx. 6 tonne)	95	70
Excavator (approx. 10 tonne)	100	75
Excavator (approx. 20 tonne)	105	80
Excavator (approx. 30 tonne)	110	85
Excavator (approx. 40 tonne)	115	90
Skidsteer Loaders (approx. 1/2 tonne)	107	82
Skidsteer Loaders (approx. 1 tonne)	110	85
Dozer (tracking) - equiv. CAT D8	118	93
Dozer (tracking) - equiv. CAT D9	120	95
Dozer (tracking) - equiv. CAT D10	121	96
Backhoe/FE Loader	111	86
Dump Truck (approx. 15 tonne)	108	83
Concrete Truck	112	87
Concrete Pump	109	84
Concrete Vibrator	105	80
Bored Piling Rig	110	85
Scraper	110	85
Grader	110	85
Vibratory Roller (approx. 10 tonne)	114	89
Vibratory Pile Driver	121	96
Impact Piling Rig	134	109
Compressor (approx. 600 CFM)	100	75
Compressor (approx. 1500 CFM)	105	80
Concrete Saw	118	93
Jackhammer	113	88

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Equipment	Maximum Allowable Sound Power Level (dB) LAmax	Maximum Allowable Sound Pressure Level (dB) LAmax at 7 m
Generator	104	79
Lighting Tower	80	55
Flood Lights	90	65
Cherry Picker	102	77
Mobile Crane	110	85

Where an item of construction equipment is not listed in **Table 11**, generic sound power levels presented in **Table 12** may be adopted.

Table 12: Generic Equipment or System Sound Power Level Limit¹

Equipment	Maximum Allowable Sound Power Level (dB) LAmax	Maximum Allowable Sound Pressure Level (dB) LAmax at 7 m
Motorised (<25kW)	90	65
Motorised (<50kW)	95	70
Motorised (<100kW)	100	75
Motorised (<200kW)	105	80
Motorised (>200kW)	110	85
All other Auxiliary Equipment or Systems	90	65

Note 1: Sound Power Levels in dBA relative to 10 pW.

7.4. Auditing and Monitoring

All items of plant would have noise audits conducted in accordance with the procedures outlined in **Section 9** of this strategy upon arrival at a Sydney Metro construction site and at 6 month intervals thereafter.

Where it has been identified within this strategy that noise and/or vibration monitoring is required at the nearest sensitive receiver; however, the nearest sensitive receiver has refused monitoring at their property, monitoring would be undertaken at the near point to that receiver within the site boundary or at another suitable location determined by an acoustic consultant.

8. ADDITIONAL NOISE AND VIBRATION MITIGATION MEASURES

8.1. Overview

The implementation of the standard management measures, compliance with maximum sound power levels for plant and equipment, construction hour management and standard community consultation measures in this Strategy should significantly reduce the noise and vibration impacts on nearby sensitive receivers.

Nevertheless, due to the highly variable nature of construction activities and the likelihood of work outside the standard construction hours on Sydney Metro projects, exceedances of the construction noise and vibration management levels are likely to occur.

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Where there is a potential exceedance of the construction noise and vibration management levels a number of additional measures to mitigate such exceedances – primarily aimed at pro-active engagement with affected sensitive receivers – would be explored and have been included in this Strategy. The additional mitigation measures to be applied are outlined in **Table 13**.

Table 13: Additional Management Measures

Measure	Description	Abbreviation
Alternative accommodation	Alternative accommodation options may be provided for residents living in close proximity to construction works that are likely to incur unreasonably high impacts over an extended period of time. Alternative accommodation will be determined on a case-by-case basis.	AA
Monitoring	Where it has been identified that specific construction activities are likely to exceed the relevant noise or vibration goals, noise or vibration monitoring may be conducted at the affected receiver(s) or a nominated representative location (typically the nearest receiver where more than one receiver have been identified). Monitoring can be in the form of either unattended logging or operator attended surveys. The purpose of monitoring is to inform the relevant personnel when the noise or vibration goal has been exceeded so that additional management measures may be implemented.	M
Individual briefings	Individual briefings are used to inform stakeholders about the impacts of high noise activities and mitigation measures that will be implemented. Communications representatives from the contractor would visit identified stakeholders at least 48 hours ahead of potentially disturbing construction activities. Individual briefings provide affected stakeholders with personalised contact and tailored advice, with the opportunity to comment on the project.	IB
Letter box drops	For each Sydney Metro project, a newsletter is produced and distributed to the local community via letterbox drop and the project mailing list. These newsletters provide an overview of current and upcoming works across the project and other topics of interest. The objective is to engage and inform and provide project-specific messages. Advanced warning of potential disruptions (eg traffic changes or noisy works) can assist in reducing the impact on the community. Content and newsletter length is determined on a project-by-project basis. Most projects distribute notifications on a monthly basis. Each newsletter is graphically designed within a branded template.	LB
Project specific respite offer	The purpose of a project specific respite offer is to provide residents subjected to lengthy periods of noise or vibration respite from an ongoing impact.	RO
Phone calls and emails	Phone calls and/or emails detailing relevant information would be made to identified/affected stakeholders within 7 days of proposed work. Phone calls and/or emails provide affected stakeholders with personalised contact and tailored advice, with the opportunity to provide comments on the proposed work and specific needs etc.	PC
Specific notifications	Specific notifications would be letterboxed or hand distributed to identified stakeholders no later than 7 days ahead of construction activities that are likely to exceed the noise objectives. This form of communication is used to support periodic notifications, or to advertise unscheduled works.	SN

8.2. Applying Additional Mitigation Measures

In circumstances where - after application of the standard mitigation measures - the $L_{Aeq(15\text{minute})}$ construction noise and vibration levels are still predicted to exceed the noise or vibration objectives, the relevant Additional Mitigation Measures Matrix (AMMM) (see **Table 14** to **Table 16**) is to be used to determine the additional measures to be implemented. This requirement is supplemental to the basic requirements in the ICNG.

Using the relevant AMMM, the following steps need to be carried out to determine the additional mitigation measures to be implemented:

- Determine the duration (time period) when the work is to be undertaken.
- Determine the level of exceedance.
- From the relevant AMMM table, identify the additional mitigation measures to be implemented (using the abbreviation codes - expanded in **Table 13**).

Table 14: Additional Mitigation Measures Matrix (AMMM) - Airborne Construction Noise

Time Period		Mitigation Measures			
		Predicted $L_{Aeq(15\text{minute})}$ Noise Level Above Background (RBL)			
		0 to 10 dB	10 to 20 dB	20 to 30 dB	> 30 dB
Standard	Mon-Fri (7.00 am - 6.00 pm)	-	-	M, LB,	M, LB
	Sat (8.00 am - 1.00 pm)				
	Sun/Pub Hol (Nil)				
OOHW	Mon-Fri (6.00 pm - 10.00 pm)	-	LB	M, LB	M, IB, LB, PC, RO, SN
	Sat (1.00 pm - 10.00 pm)				
	Sun/Pub Hol (8.00 am - 6.00 pm)				
OOHW	Mon-Fri (10.00 pm - 7.00 am)	-	M, LB,	M, IB, LB, PC, RO, SN	AA, M, IB, LB, PC, RO, SN
	Sat (10.00 pm - 8.00 am)				
	Sun/Pub Hol (6.00 pm - 7.00 am)				

Table 15: AMMM - Ground-borne Construction Noise

Time Period		Mitigation Measures		
		Predicted $L_{Aeq(15\text{minute})}$ Noise Level Exceedance		
		0 to 10 dB	10 to 20 dB	> 20 dB
Standard	Mon-Fri (7.00 am - 6.00 pm)	LB	LB	M, LB, SN,
	Sat (8.00 am - 1.00 pm)			
	Sun/Pub Hol (Nil)			
OOHW	Mon-Fri (6.00 pm - 10.00 pm)	LB	M, LB, SN,	M, IB, LB, PC, RO, SN
	Sat (1.00 pm - 10.00 pm)			
	Sun/Pub Hol (8.00 am - 6.00 pm)			
OOHW	Mon-Fri (10.00 pm - 7.00 am)	M, LB, SN,	AA, M, IB, LB, PC, RO, SN	AA, M, IB, LB, PC, RO, SN
	Sat (10.00 pm - 8.00 am)			
	Sun/Pub Hol (6.00 pm - 7.00 am)			

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Table 16: AMMM - Ground-borne Vibration

Time Period		Mitigation Measures
		Predicted Vibration Levels Exceed Maximum Levels
Standard	Mon-Fri (7.00 am - 6.00 pm)	M, LB, RP
	Sat (8.00 am - 1.00 pm)	
	Sun/Pub Hol (Nil)	
OOHW	Mon-Fri (6.00 pm - 10.00 pm)	M, IB, LB, PC, RO, SN
	Sat (1.00 pm - 10.00 pm)	
	Sun/Pub Hol (8.00 am - 6.00 pm)	
OOHW	Mon-Fri (10.00 pm - 7.00 am)	AA, M, IB, LB, PC, RO, SN
	Sat (10.00 pm - 8.00 am)	
	Sun/Pub Hol (6.00 pm - 7.00 am)	

9. MONITORING, AUDITING AND REPORTING

9.1. Plant Noise Auditing, Compliance Evaluation and Reporting

In order to compare the noise levels of plant and equipment with the values in Section 7, the following guidelines are recommended:

- Measurements of Sound Pressure Level (SPL) at 7 m (with plant or equipment stationary) shall be undertaken using procedures that are consistent with the requirements of Australian Standard AS2012–1990 Acoustics – Measurement of Airborne Noise Emitted by Earthmoving Machinery and Agricultural Tractors – Stationary Test Condition Part 1: Determination of Compliance with Limits for Exterior Noise.
- Measurements of Sound Power Level (SWL) shall be determined using procedures that are consistent with the requirements of International Standard ISO9614-2 1996 Acoustics – Determination of sound power levels of noise sources using sound intensity - Part 2: Measurement by scanning.
- If measuring the SPL at 7 m of moving plant, compliance measurements would be guided by the requirements of Australian Standard AS2012–1977 Method for Measurement of Airborne Noise From Agricultural Tractors and Earthmoving Machinery.

For all measurements, the plant or equipment under test would be measured while operating under typical operating conditions. If this is not practical, it may be appropriate to conduct a stationary test at high idle.

In the case of an exceedance in sound power levels the item of plant would either be replaced, or the advice of an acoustic consultant would be sought to provide suitable mitigation measures, which may include:

- ensuring all bolts are tightened and no parts are loose
- cleaning and/or lubricating moving parts
- replacing old or worn parts

- implementing additional or upgrading existing muffling devices
- building enclosures around items of stationary plant (eg pumps or generators).

A register of measured sound power levels for each item of plant would be kept for reference where future noise audits are conducted. The register would be reviewed annually in conjunction with this strategy and corresponding revisions made to the Sound Power Levels presented in Section 7 to represent contemporary plant noise emission levels.

9.2. Noise Monitoring

Where a CNIS report has been prepared for a Sydney Metro construction site and it has been predicted that noise levels may be in excess of the nominated construction noise goals at a noise sensitive receiver, noise monitoring would be conducted at:

- the affected receiver; or
- if more than one affected receiver has been identified, at the nearest affected receiver; or
- where the nearest affected receiver refuses noise monitoring on their property, at the near point to that receiver within the site boundary.
- If it can be demonstrated that direct measurement of noise from the construction site is impractical, alternative means of determining construction noise levels may be adopted in accordance with Chapter 11 of the NSW Industrial Noise Policy.

All noise monitoring results would be assessed against the nominated noise goals and compiled into a report to be forwarded to the construction contractor and project manager. Reporting would be submitted to the construction contractor and project manager within one week of being undertaken or at weekly intervals for continuous monitoring. All noise monitoring reports would also be made available to the public through a publically accessible website.

9.3. Vibration Monitoring

Where it is anticipated that an item of plant will exceed the cosmetic damage criteria given in Section 5.4.3, vibration monitoring would be required at the nearest affected receiver. Where it is anticipated that an item of plant will exceed the human response / ground borne noise criteria and concerns have been raised regarding vibration, vibration monitoring would also be required at the receiver(s) under question.

All vibration monitoring results would be assessed against the nominated vibration goals and compiled into a report to be forwarded to the construction contractor and project manager. Reporting would be submitted to the construction contractor and project manager within one week of being undertaken or at weekly intervals for continuous monitoring. All vibration monitoring reports would also be made available to the public through the publically accessible website.

9.4. Blast Monitoring

- As specified in the minimum requirements presented in Section 5.7, vibration and overpressure monitoring would be conducted for all PCF and blasting activities which take place on Sydney Metro construction sites.
- Monitoring would be conducted as a minimum at the sensitive receiver(s) likely to receive the maximum vibration and/or overpressure emissions from the blast as identified by an acoustic consultant.

All blast monitoring results would be assessed against the nominated goals and compiled into a report to be forwarded to the construction contractor and project manager. All blast monitoring reports would also be made available to the public through the Sydney Metro website.

As the effect of vibration and overpressure from blasting have the potential to cause structural damage to buildings and services, accurate records of all blasts are required to be maintained. Such records would describe the location of the blast and all the blastholes, the design of the blast in terms of type of explosives, mass of explosives, initiating system used, ground vibration and overpressure measurement data.

Records of every blast would be kept for a minimum of seven years. A longer period of retention of the records may be warranted if a construction project is blasted over an extended or disrupted period.

For any section of tunnel construction where blasting is proposed, a series of initial trials at reduced scale shall be conducted prior to production blasting to determine site-specific blast response characteristics and to define allowable blast sizes to meet the airblast overpressure and ground vibration limits.

9.5. Dilapidation Surveys

If construction activities have the potential to cause damage through vibration to nearby public utilities, structures, buildings and their contents, an Existing Condition Inspection of these items is required to be undertaken in accordance with AS 4349.1 “*Inspection of Buildings*”.

Prior to conducting the Existing Condition Inspections, the property owners will be advised of the inspection scope and methodology and the process for making a property damage claim. At the same time, maintain a register of all properties inspected and of any properties where owners refused the inspection offer.

The findings of all dilapidation surveys conducted for each Sydney Metro construction site would be compiled into a report to be forwarded to the construction contractor and project manager. Follow-up Condition Inspections would be required at the completion of certain major works (eg completion of shaft bulk excavation works).

10. COMPLAINT HANDLING

All complaints handling would be in accordance with the Sydney Metro Construction Complaints Management System.

11. COMMUNITY CONSULTATION AND LIAISON

All community consultation would be in accordance with Sydney Metro Overarching Stakeholder and Community Involvement Plan.

12. DOCUMENTATION REQUIREMENTS

Any acoustic assessment, CNIS or CNVMP undertaken for the Sydney Metro project must document the following as a minimum (where applicable):

- Acoustic Terminology / Glossary
- Overview of the Project / Works
- Secretary’s Environmental Assessment Requirements

- EPL conditions (if applicable)
- Site Plan and Sensitive Receivers
- Ambient Noise Monitoring: methodology, locations, analysis and results
- Construction Noise and Vibration Criteria
 - Construction Airborne Noise Criteria
 - Construction Tunnelling Ground-borne Noise Criteria (if applicable)
 - Construction Ground-borne Noise Criteria
 - Construction Vibration Criteria
- Construction Noise and Vibration Assessment
 - Construction Airborne Noise Methodology / Predictions
 - Construction Tunnelling Ground-borne Noise Methodology / Predictions (if applicable)
 - Construction Ground-borne Noise Methodology / Predictions
 - Construction Vibration Methodology / Predictions
- Summary of Noise and Vibration Impacts
- Summary of all Standard and Additional Mitigation Measures
- References

All noise and vibration predictions are to be presented (as a minimum) as facade noise maps for a distance of at least 300 m in all directions from each work site / project area under assessment.

13. REFERENCES

Related Documents and References
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<ul style="list-style-type: none"> AS 2436, 1981, Guide to Noise Control on Construction, Maintenance and Demolition Sites. Standards Australia.
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