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Masterplan Noise and Vibration Assessment

1 - 11 Neil Street, Merrylands

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Masterplan Noise and Vibration Assessment

1 - 11 Neil Street, Merrylands

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1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by Landmark Group Australia Pty Ltd to prepare a noise and vibration assessment of a Masterplan submission for a proposed residential apartment development on land located at 1 -11 Neil Street, Merrylands. The acoustical assessment is required to accompany the Development Application for the project to Holroyd Council.

The project site is located adjacent to Neil Street and the Inner West/Cumberland Rail Line and is therefore potentially affected by noise from road traffic and noise and vibration from rail.

This report presents the results of acoustical measurements conducted to quantify the exposure of the site to road and rail traffic noise and to determine the levels of ground vibration due to rail movements. Based upon the results from noise and vibration monitoring, the levels of transportation noise (and vibration) have been predicted at and around the location of future residential apartment buildings and assessed against regulatory guidelines for residential amenity. The proposed Masterplan concept has been compared with Holroyd Council's DCP scheme to evaluate the suitability of the site layout on the basis of acoustics.

In addition to the assessment of residential acoustical amenity, environmental goals for operational noise emissions from the development (such as mechanical plant and equipment) have been determined and environmental criteria for construction noise and vibration have also been included.

2 PROJECT DESCRIPTION

2.1 Site Location

The location of the proposed residential development site is shown in **Figure 1**. The project area is bounded by the Inner West/Cumberland Rail Line along the eastern boundary, and Neil Street along the southern boundary. Merrylands Station lies approximately 200 m to the southwest. Land immediately to the north of the site has been redeveloped with residential apartments. To the northwest of the site, the adjacent land is public space. The property immediately to the west is light industrial and properties on the southern side of Neil Street are generally light industrial. The general area to the southwest is commercial/light industrial. Land on the southern side of Neil Street is also proposed for residential development.

Figure 1 Project Location

Aerial image courtesy of NearMap

2.2 Proposed Development

The project Masterplan proposes six residential apartment buildings to be developed on the previous industrial site. The preliminary proposed scheme involves two (nominally) eight-storey apartments buildings located adjacent to the eastern boundary. These buildings (Buildings 4 and 6) effectively screen the site from the rail corridor. Building 4 returns around the southern end of the site and in conjunction with Building 2, screens the interior of the site from Neil Street. The remaining four apartment buildings will be lower in height, nominally five-storey and will be oriented so that the interior space of the site can be landscaped to provide a series of flowing courtyards with a more open central landscaped area fronting the proposed access roadway through the site. The proposed preliminary building layout and landscape concept is shown in **Figure 2**.

Figure 2 Proposed Masterplan Scheme and Landscape Concept

Drawing by Marchese Partners International Pty Ltd courtesy of Landmark Group

3 ASSESSMENT REQUIREMENTS AND PROCEDURE

The NSW Department of Planning and Infrastructure document *Development near Rail Corridors and Busy Roads – Interim Guideline* (hereafter referred to as the DP&I Guideline) is generally referred to for guidance in relation to the extent of assessment required for noise and vibration sensitive developments located in the vicinity of existing rail lines or major roads.

To enable appropriate acoustical amenity to be achieved for residential development near rail corridors where passenger and freight services operate at speeds less than 80 km/h, a full noise assessment is recommended where residential development is proposed within 25 m of the nearest operational track.

Vibration assessments are required for residential buildings on “hard” ground (such as sandstone) located less than 25 m from the nearest operational track.

Where a residential apartment building is proposed within 200 m of a roadway carrying in excess of 20,000 vehicles per day (the RMS’ most recently reported annual average daily traffic flow on Neil Street is 22,867 vehicles) an acoustical assessment is required to determine the acoustical treatment requirements to ensure the regulatory criteria for airborne noise within apartments will be achieved.

In accordance with the DP&I Guideline recommendations, the following investigations have been carried out at the proposed development site:

- Measurements of noise and vibration levels due to passenger and freight services on the adjacent rail line.
- Measurements of noise levels due to road traffic on Neil Street.
- Measurements of the ambient noise environment.

Based upon the site-specific noise and vibration monitoring, the suitability of the proposed Masterplan arrangement, in terms of acoustical amenity, has been assessed and in-principle recommendations to enable the relevant regulatory criteria to be achieved have been determined.

4 AMBIENT NOISE AND VIBRATION LEVELS

4.1 Ambient Noise Monitoring

In order to establish the existing levels of rail and road traffic noise experienced at the project site, attended and unattended measurements were conducted at locations representative of the potentially most noise-exposed facades of the proposed future buildings.

The unattended environmental noise monitoring survey was conducted at two (2) locations between Wednesday 26 March and Tuesday 1 April 2014.

The instrumentation used for the survey consisted of two (2) Acoustic Research Laboratories (ARL) Environmental Noise Loggers Type EL-316 (Logger 1 serial number 16-207-021 and Logger 2 serial number 16-207-041) both fitted with a microphone windshield. Calibration of the loggers was checked prior to and following measurements. Drift in calibration did not exceed ±0.5 dBA. All equipment carried appropriate and current NATA (or manufacturer) calibration certificates.

The selected monitoring locations, which are shown in **Figure 1**, were:

- **Location 1 Rail Corridor** (**Eastern Boundary):** The logger was located approximately 15 m from the nearside rail line (the up line) to measure the levels of rail noise that are likely to be experienced at the proposed eastern facade of Building 4 and 6.
- **Location 2 Neil Street (Southern Boundary):** The logger was located approximately 15 m from the edge of the nearside carriageway to measure the levels of road traffic noise that are likely to be experienced at the proposed southern facade of Buildings 2 and 4.

Attended measurements of the noise levels during train passby events were also carried out at Location 1. Instrumentation used for these measurements consisted of a Brüel and Kjær Type 2260 Modular Precision Sound Level Analyser. All equipment carried appropriate and current NATA calibration certificates. Calibration of the sound level meter was checked before and after the measurements, with the drift in calibration found to be within acceptable limits.

4.2 Noise Monitoring Results

The results of the unattended noise logging, have been processed in accordance with the NSW SEPP (Infrastructure) 2007, NSW *Road Noise Policy* (DECCW 2011), Rail Infrastructure Corporation (RIC) and State Rail Authority's (SRA) *"Consideration of Rail Noise and Vibration in the Planning Process - Interim Guidelines for Councils"* time periods to determine the daytime and night-time levels of rail and road noise.

The data has also been processed according to the NSW *Industrial Noise Policy* (INP 2000) time periods to determine the Rating Background Levels (RBL) and existing ambient L_{Aeq} noise levels at the site. The processed noise monitoring results are presented in **Table 1**, **Table 2** and **Table 3.**

Table 1 Rail Noise Levels – Location 1

Logging Location	$L_{Aeq(15\ hour)}$ 7:00 am – 10:00 pm External Noise Level	$L_{Aeq(9\ hour)}$ 10:00 pm – 7:00 am External Noise Level
15 m from up line	59 dBA	57 dBA

Table 2 Road Traffic Noise Levels - Location 2

Logging Location	$L_{Aeq(15\ hour)}$ 7:00 am – 10:00 pm External Noise Level	$L_{Aeq(9\ hour)}$ 10:00 pm – 7:00 am External Noise Level
Neil Street	62 dBA	57 dBA

Table 3 Ambient Noise Levels – NSW INP Time Periods

Location	Measurement Descriptor	Measured Noise Level - dBA re 20 µPa		
		Daytime 7:00 am – 6:00 pm	Evening 6:00 pm – 10:00 pm	Night-time 10:00 pm – 7:00 am
Logger 1 (East)	L_{Aeq}[1]	58	61	57
	RBL (Background)[2]	49	50	40
Logger 2 (South)	L_{Aeq}[1]	62	63	57
	RBL (Background)[2]	50	48	37

Note 1: The L_{Aeq} is essentially the average sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time-varying sound.

Note 2: The RBL noise level is representative of the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

The averaged results of attended noise measurements recorded during a total of 20 trains passbys (including two freight trains) on 1 April 2014 are summarised in **Table 4**. The average speed of the measured trains was 56 km/h. The results of the attended noise measurements are in **Table 4**.

Table 4 Attended Train Passby Noise Measurement Results

Measurement Location	Average L_{AE} Noise Level	Average L_{Amax} Noise Level	Highest L_{Amax} Noise Level
15 m from rail corridor	79 dBA	74 dBA	84 dBA

4.3 Vibration Monitoring Results

Attended measurements of ground vibration levels during 20 rail passby events (including two freight trains) were conducted using a Brüel and Kjær Type 2260 Modular Precision Sound Level Analyser. All equipment carried appropriate and current NATA calibration certificates. Calibration of the meter was checked before and after the measurements, with the drift in calibration found to be within acceptable limits.

The results of the attended vibration measurements in the frequency bands from 5 Hz to 80 Hz are presented in **Table 5**. The rms vibration velocity was measured in 1 second intervals in third octave frequency bands.

Table 5 Attended Train Passby Vibration Measurement Results 20 m from Centre of Nearside Track (dB re 10^{-9} ms^{-1})

Train Type	Average Maximum Passby Vibration Level	95^{th} Percentile Maximum Passby Vibration Level
Passenger Train	95 dB[1]	93 dB[1]
Freight Train	91 dB	89 dB

Note 1: Presented levels are 1 second rms vibration velocity levels. The maximum passby vibration levels refer to the maximum 1 second rms vibration velocity during a passby.

5 ASSESSMENT CRITERIA

5.1 Noise Intrusion – Acoustical Amenity

5.1.1 Holroyd Development Control Plan 2013

Holroyd Development Control Plan 2013 Part B, Residential Controls contains guidance in relation to acoustical amenity within residential developments adjacent to rail corridors or busy roads. General guidance in terms of planning arrangements is included and the following design limits for internal noise levels are documented in Clause C11:

- Recreation Areas 40 dBA
- Sleeping Areas 35 dBA
- Other Habitable Rooms 40 dBA

The recommended internal design noise levels are in accordance with AS/NZS 2107:2000 *Acoustics: Recommended design sound levels and reverberation times for building interiors* and are also consistent with the requirements of SEPP (Infrastructure) 2007.

5.1.2 SEPP (Infrastructure) 2007/Department of Planning and Infrastructure

SEPP (Infrastructure) 2007 was introduced to assist the delivery of necessary infrastructure by improving regulatory certainty and efficiency. The Infrastructure SEPP has specific planning provisions and development controls for various types of infrastructure and for development adjacent to infrastructure. SEPP (Infrastructure) 2007 has superseded many of the previous policies and guidelines relating to the control of rail and road traffic noise intrusion including Railcorp's *Interim Guidelines for Applicants*.

In accordance with the SEPP, Table 3.1 of the DP&I Guideline provides noise criteria for residential buildings. These criteria are summarised in **Table 6**.

Table 6 DP&I Interim Guideline Noise Criteria

Residential Buildings		
Type of occupancy	**Noise Level dBA**	**Applicable time period**
Sleeping areas (bedroom)	35	Night 10 pm to 7 am
Other habitable rooms (excl. garages, kitchens, bathrooms & hallways)	40	At any time

Note 1: Airborne noise is calculated as $L_{Aeq(15hour)}$ daytime and $L_{Aeq(9hour)}$ night-time

The following guidance is also provided in the DP&I Guideline:

> *"These criteria apply to all forms of residential buildings as well as aged care and nursing home facilities. For some residential buildings, the applicants may wish to apply more stringent design goals in response to market demand for a higher quality living environment.*
>
> *The night-time "sleeping areas" criterion is 5 dB(A) more stringent than the "living areas" criteria to promote passive acoustic design principles. For example, designing the building such that sleeping areas are less exposed to road or rail noise than living areas may result in less onerous requirements for glazing, wall construction and acoustic seals. If internal noise levels with windows or doors open exceed the criteria by more than 10 dB(A), the design of the ventilation for these rooms should be such that occupants can leave windows closed, if they so desire, and also to meet the ventilation requirements of the Building Code of Australia."*

The noise criteria shown in **Table 6** apply to a 'windows closed condition'. Standard window glazing of a building will typically attenuate noise ingress by 20 dBA with windows closed and 10 dBA with windows open (allowing for natural ventilation). Accordingly, the external noise threshold above which an apartment would generally require mechanical/alternative ventilation is an $L_{Aeq(9hour)}$ of 55 dBA for bedrooms and $L_{Aeq(15hour)}$ of 60 dB(A) for other areas.

5.1.3 AS/NZS 2107:2000

Australian/New Zealand Standard **AS/NZS 2107:2000** - *"Acoustics - Recommended design sound levels and reverberation times for building interiors"* is primarily concerned with establishing internal noise levels for relatively steady noise sources, such as airconditioning plant and continuous road traffic noise. The internal noise levels required by SEPP (Infrastructure) 2007 to be achieved within dwellings are comparable with the recommendations of Australian Standards relevant to acceptable noise levels within buildings.

Table 7 provides a summary of recommended internal noise levels for residential premises near "major roads" as given in AS/NZS 2107:2000. The guideline lower and upper range of the noise levels are described as "satisfactory" and "maximum" respectively.

Table 7 AS/NZS 2107:2000 Recommended Internal Design Sound Levels

Type of Occupancy/Activity	Recommended Design Sound Level L_{Aeq} dBA re 20 µPa	
	Satisfactory	Maximum
Houses and apartments near major roads		
Living areas	35	45
Sleeping areas	30	40
Work areas	35	45

5.2 Acoustical Amenity – Sound Insulation

The proposed new residential apartments will be required to comply with the provisions relating to *Sound Transmission and Insulation* under Part F5 of the National Construction Code Series Building Code of Australia (NCC 2014). **Table 8** details the minimum acoustic performance requirements documented in the NCC.

Table 8 NCC 2014 Sound Insulation Requirements

Construction	2014 NCC	
	Laboratory Rating	**Verification**
Walls between sole occupancy units	$R_w + C_{tr}$ not < 50	$D_{nT,w} + C_{tr}$ not < 45
Walls between a bathroom, sanitary compartment, laundry or kitchen in one sole occupancy unit and a habitable room (other than a kitchen) in an adjoining unit	$R_w + C_{tr}$ not < 50 and **Must have a minimum 20 mm cavity between two separate leaves**[1]	$D_{nT,w} + C_{tr}$ not < 45 "Expert Judgment" Comparison to the "Deemed to satisfy" Provisions
Walls between sole occupancy units and a plant room or lift shaft	R_w not < 50 and **Must have a minimum 20 mm cavity between two separate leaves**[1]	$D_{nT,w}$ not < 45
Walls between sole occupancy units and a stairway, public corridor, public lobby or the like, or parts of a different classification	R_w not < 50	$D_{nT,w}$ not < 45
Door assemblies located in a wall between a sole-occupancy unit and a stairway, public corridor, public lobby or the like	R_w not < 30 [2]	$D_{nT,w}$ not < 25
Floors between sole-occupancy units or between a sole-occupancy unit and a plant room, lift shaft, stairway, public corridor, public lobby or the like, or parts of a different classification	$R_w + C_{tr}$ not < 50 $L_{n,w} + C_I$ not > 62	$D_{nT,w} + C_{tr}$ not < 45 $L'_{nT,w} + C_I$ not > 62
Soil, waste, water supply and stormwater pipes and ductwork to habitable rooms	$R_w + C_{tr}$ not < 40	n/a
Soil, waste, water supply and stormwater pipes and ductwork to kitchens and other rooms	$R_w + C_{tr}$ not < 25	n/a
Intra-tenancy Walls	There is no statutory requirement for airborne isolation via intra-tenancy walls.	

Note 1: A wall must be of "discontinuous construction" if it separates a bathroom, sanitary compartment, laundry or kitchen in one sole occupancy unit from a habitable room (including a kitchen if open plan design is used for kitchen/living/dining) in an adjoining unit and a sole occupancy unit from a plant room or lift shaft. Clause F5.3(c) defines "discontinuous construction" as a wall having a minimum 20 mm cavity between two separate leaves with no mechanical linkage except at the periphery.

Note 2: Clause FP5.3(b) in the 2014 NCC states that the required insulation of a floor or wall must not be compromised by a door assembly.

5.3 Operational Noise Emissions

Noise criteria relating to operational noise emissions from the development to surrounding potentially sensitive receivers are contained in the INP. The Policy is applicable to noise emission from mechanical and other sources of continuous noise-generation at the subject site and has the following broad objectives:

- Controlling **intrusive** noise impacts (to residences only)
- Maintaining noise level **amenity** for residential and other land uses over the medium to long-term.

Where an intrusive and an amenity criterion are established for a receiver, the more stringent (lower) of the two criteria applies.

Intrusiveness Criterion

For assessing intrusiveness, the background noise level of the area needs to be established. The intrusiveness criterion essentially requires the equivalent continuous noise level (L_{Aeq}) of a noise source to not exceed the measured RBL by more than 5 dBA, over any 15 minute period.

Amenity Criterion

The amenity assessment is based on noise criteria specific to land use and corresponding sensitivity to noise. The cumulative effect of noise from industrial sources needs to be considered in assessing the impact. The criteria relate only to continuous industrial noise sources and do not apply to road, rail or community noise. If the existing (measured) industrial-type noise level approaches the criterion value, then the Policy sets maximum noise emission levels from new sources with the objective of ensuring that the cumulative levels do not significantly exceed the criterion.

Holroyd Development Control Plan 2013

Holroyd Development Control Plan 2013 Part B, Residential Controls contains guidance in relation to operational noise emissions from mechanical equipment items typically associated with residential development, such as airconditioners and swimming pool pumps. Clause C15 requires operational noise emissions from these sources to not exceed the L_{A90} background noise levels by more than 5 dBA and to not be audible within a habitable room of a neighbouring dwelling. Emissions are also required to comply with the Protection of the Environment Operations Act 1997 and regulations.

Project Specific Noise Levels

The INP classifies the noise environment of the subject area as “Urban”. An “Urban” noise environment is an area that:

- Is dominated by “urban hum” or industrial source noise.
- Has through traffic with characteristically heavy and continuous traffic flows during peak periods.
- Is near commercial districts or industrial districts.
- Has any combination of the above.

Having defined the area type, the data obtained from ambient noise monitoring, analysed in accordance with INP procedures (refer to **Table 3**), has been used to generate project specific noise criteria for the assessment of continuous operational noise emissions from the development. The lowest of the levels measured at each of the two locations have been adopted for the purposes of establishing the design limits.

In accordance with INP guidelines, the project specific noise levels for residential receivers to the north of the site and within the subject development itself are the lower of the amenity or intrusive criteria as shown in bold in **Table 9**. In this case the area surrounding the site is controlled by transportation noise and not industrial noise sources so the amenity criterion becomes equal to the Recommended Amenity Criteria for Residences in an Urban Area (ANL or Acceptable Noise Level).

Table 9 NSW INP Criteria for Continuous Operational Noise Emissions to Nearby Residences

Time of Day	ANL[1] (period) dBA	Measured RBL[2] $L_{A90(15minute)}$ dBA	Measured $L_{Aeq(15minute)}$ dBA	Criteria for New Sources[3]	
				Intrusive $L_{Aeq(15minute)}$	Amenity $L_{Aeq(Period)}$
Day	60	49	58	**54**[4]	60
Evening	50	48	61	53	**50**
Night	45	37	57	**42**	45

Note 1: ANL Acceptable Noise Level for an urban area.
Note 2: RBL Rating Background Level.
Note 3: Assuming existing noise levels unlikely to decrease.
Note 4: Project Specific Criteria are shown in bold.

5.4 Vibration

The NSW Environment Protection Authority guideline *Assessing Vibration: a technical guideline (hereafter referred to as 'The Vibration Guideline')* identifies three types of vibration: continuous, impulsive, and intermittent and the assessment criteria applicable to each. Train passbys are classified as intermittent vibration events and the criteria is specified in terms of Vibration Dose Values (VDVs). However, because the criteria for continuous vibration are more stringent than that for intermittent vibration, the continuous vibration criteria can be used as a screening procedure to determine whether the calculation of vibration dose values is necessary. The criteria for continuous vibration are specified in terms of vibration velocity (dB re 10^{-9} ms^{-1}).

The recommended maximum levels for exposure to continuous vibration in residences are 106 dB during the daytime and 103 dB during the night-time. The recommended maximum levels applicable to intermittent vibration are 112 dB during the daytime and 109 dB during the night-time. The Vibration Guideline indicates that the night time criterion for continuous vibration (103 dB) represents the threshold of perception for most people.

5.5 Construction Noise and Vibration

When dealing with noise from construction works, the NSW Environment Protection Authority (EPA) recognises that higher levels of noise are likely to be tolerated by people in view of the relatively short duration of the works. As a result, the EPA has published the "*Interim Construction Noise Guideline*" (ICNG 2009) for the management of construction works noise.

The ICNG recommends the following approaches to mitigating adverse noise impacts from construction sites.

Hours of Construction

The ICNG recommend confining permissible work times as outlined in **Table 10**.

Table 10 Preferred Hours of Construction

Day	Preferred Construction Hours
Monday to Friday	7:00 am to 6:00 pm
Saturdays	8:00 am to 1:00 pm
Sundays or Public Holidays	No construction

Construction Noise Assessment Method

The ICNG recognises that people are usually annoyed more by noise from longer-term works than by the same type of works occurring for only a few days. For this reason the Guideline identifies two methods of assessing noise from construction:

- The quantitative assessment method which applies to long-term duration work.
- The qualitative assessment method which applies to short-term duration work.

Quantitative Assessment Method

The ICNG recommends that the $L_{Aeq(15minute)}$ noise levels arising from a construction project, measured within the curtilage of an occupied noise-sensitive premises (ie at boundary or within 30 m of the residence, whichever is the lesser), should not exceed the levels indicated in **Table 11**. These noise management levels are generally consistent with community reaction to construction noise.

Table 11 Recommended General Noise Management Levels for Construction Works

Period of Noise Exposure	$L_{Aeq(15minute)}$ Construction Noise Management Level
Recommended Standard Hours	Noise affected[1] RBL + 10 dBA
	Highly Noise affected[2] 75 dBA
Outside Recommended Standard Hours	Noise affected[1] RBL + 5 dBA

Note 1: The noise affected level represents the point above which there may be some community reaction to noise.
Note 2: The highly noise affected level represents the point above which there may be strong community reaction to noise.

Scope for Exceedances

Where predicted or measured levels exceed the Noise Management Levels the ICNG recommends that the proponent apply all "feasible and reasonable" work practices in order to minimise noise.

Where $L_{Aeq(15minute)}$ construction noise levels are predicted to be "highly noise affected" (ie above 75 dBA) the relevant authority (consent, determining or regulatory) may require respite periods to be observed. This may include restricting the hours that the very noisy activities can occur, taking into account:

- Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences).
- If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

The implementation of an effective community consultation and liaison programme is emphasised as being a critical tool in successfully handling adverse noise impacts from construction works.

The ICNG provides comprehensive guidance for work practices which aim to achieve *"desired environmental outcomes - there are no prescribed noise controls for construction works."*

Qualitative Assessment Method

The qualitative method for assessing construction noise is a simplified way to identify the cause of potential noise impacts. It avoids the need to perform complex predictions by using a checklist approach to assessing and managing noise. Short-term means that the works are not likely to affect an individual or sensitive land use for more than three weeks in total.

The following checklist for work practice can be used:

- Community notification.
- Operate plant in a quiet and efficient manner.
- Involve workers in minimising noise.
- Handle complaints.

The quantitative assessment method is considered the appropriate method for the works as the construction works are likely to operate for more than 3 weeks.

5.5.1 Construction Vibration Criteria

Vibration targets vary primarily according to whether the particular activities of interest are continuous in nature or intermittent, and whether they occur during the day or night-time. 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, ie human disturbance.
- Those in which the integrity of the building or the structure itself may be prejudiced.
- Those where the building contents may be affected.

Criteria which are relevant to the response of building occupants to vibration are more stringent than those relevant to building damage. This is because people are able to "feel" vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building.

This ability of people to sense vibration at relatively low magnitudes has created a widespread and strong public misconception which can cause considerable overestimation of the risk of damage associated with vibration in buildings. This is particularly the case when the source of that vibration is outside the building, visible and audible, but generally not within the occupant's control.

Many people, for example, believe that even barely perceptible levels of building vibration from say, traffic, excavation or construction works can damage dwellings, or may affect delicate objects or other items of personal value within their homes. This largely subjective response is particularly the case when these low levels of vibration are accompanied by high noise levels, or if there are other adverse connotations or effects associated with the source of the vibration. These might include alarm, loss of privacy or perceived loss of property value, fear, inconvenience, odour, etc.

On the other hand, sources of much higher levels of vibration (eg domestic appliances, people walking on floors, slamming of doors, etc) are readily accepted due to their day-to-day familiarity or because they are "within the control" of the occupant.

It is primarily these day-to-day effects which cause the gradual, long-term fatigue-induced deterioration of most structures - considered to be normal ageing. Provided that the levels of vibration-induced structural stress from an additional source are well below those of "normal" stress-inducing events, then the additional source of vibration is unlikely to accelerate the normal ageing process.

General

Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels which are well below those causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2-1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in **Table 12**.

Table 12 Peak Vibration Levels and Human Perception of Motion

Approximate Vibration Level		Degree of Perception
Peak Vibration Level	RMS Vibration Level	
0.10 mm/s	0.07 mm/s	Not felt
0.15 mm/s	0.1 mm/s	Threshold of perception
0.35 mm/s	0.25 mm/s	Barely noticeable
1 mm/s	0.7 mm/s	Noticeable
2 mm/s	1.4 mm/s	Easily noticeable
6 mm/s	4.2 mm/s	Strongly noticeable
14 mm/s	10 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having a frequency content in the range of 8 Hz to 80 Hz. The RMS vibration levels assume a crest factor of 1.4 for sinusoidal vibration.

Table 12 suggests that people will just be able to feel floor vibration at levels of about 0.1 mm/s (RMS) and that the motion becomes "noticeable" at a level of approximately 0.7 mm/s (RMS).

The EPA's *Assessing Vibration: a technical guideline* notes that *"vibration in buildings can be caused by many different external sources, including industrial, construction and transportation activities. The vibration may be continuous (with magnitudes varying or remaining constant with time), impulsive (such as in shocks) or intermittent (with the magnitude of each event being either constant or varying with time)."*

Construction activities typically generate building vibrations that are intermittent or impulsive in nature, however vibration levels may sometimes be constant from sources such as generators or ventilation fans.

Examples of intermittent vibration events include the vibration generated by rockbreakers, vibratory rollers, drilling/piling and excavators. Examples of impulsive vibration events include the vibration generated by demolition activities, blasting or the dropping of heavy equipment.

Where vibration is intermittent or impulsive in character, the EPA vibration guideline (and other similar guidelines) recognises that higher vibration levels are tolerable to building occupants than for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous vibration sources.

The following sections describe the applicable continuous and intermittent vibration goals for construction activities.

Human Comfort Goals for Continuous and Impulsive Vibration

The NSW *Assessing Vibration: a technical guideline* is applicable for this proposal and is based on the guidelines contained in British Standard BS 6472-1992 *Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)*. The guideline refers only to human comfort considerations and nominates preferred and maximum vibration goals for critical areas, residences and other sensitive receivers.

The criteria in the guideline are non-mandatory, "*they are goals that should be sought to be achieved through the application of all feasible and reasonable mitigation measures. Where all feasible and reasonable measures have been applied and vibration values are still beyond the maximum value, the operator would need to negotiate directly with the affected community*".

Construction vibration can be continuous, intermittent or impulsive and the NSW vibration guideline provides different goals for each category. The continuous vibration goals are most stringent and higher vibration levels are acceptable for intermittent and impulsive vibration on the basis of the shorter exposure times. Examples of typical vibration sources are provided in **Table 13**.

Table 13 Examples of Vibration (NSW Vibration Guideline)

Continuous Vibration	Impulsive Vibration	Intermittent Vibration
Machinery, steady road traffic, continuous construction activity.	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading. Blasting is assessed using ANZECC (1990).	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer this would be assessed against impulsive vibration criteria.

The applicable human comfort vibration goals for continuous, intermittent and impulsive vibration sources are provided in **Table 14**, **Table 15** and **Table 16** respectively. In all cases, the vibration goals are expressed in terms of the RMS vibration velocity level in mm/s, measured in the most sensitive direction (z-axis).

The EPA vibration guideline notes the following in relation to the preferred and maximum vibration levels:

> *"There is a low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values. Activities should be designed to meet the preferred values where an area is not already exposed to vibration. Where all feasible and reasonable measures have been applied, values up to the maximum value may be used if they can be justified. For values beyond the maximum value, the operator should negotiate directly with the affected community. Situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances and infrequent events of short term duration. An example is a construction or excavation project.*

In circumstances where work is short term, feasible and reasonable mitigation measures have been applied, and the project has a demonstrated high level of social worth and broad community benefits, then higher vibration values (above the maximum) may apply. In such cases, best management practices should be used to reduce values as far as practicable, and a comprehensive community consultation programme should be instituted."

Table 14 Preferred and Maximum Vibration Levels for Continuous Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.14	0.28
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: Daytime is 7:00 am to 10:00 pm and Night-time is 10:00 pm to 7:00 am.

Table 15 Preferred and Maximum Vibration Levels for Intermittent Vibration (Vibration Dose Values)

Building Type	Preferred Vibration Dose Value ($m/s^{1.75}$)	Maximum Vibration Dose Value ($m/s^{1.75}$)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.10	0.20
Residential Daytime	0.20	0.40
Residential Night-time	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80
Workshops	0.80	1.60

Note: For the definition of the Vibration Dose Value refer to the discussion in the following section. Daytime is 7:00 am to 10:00 pm and night-time is 10:00 pm to 7:00 am.

Table 16 Preferred and Maximum Vibration Levels for Impulsive Vibration

Building Type	Preferred Vibration Level RMS Velocity (mm/s)	Maximum Vibration Level RMS Velocity (mm/s)
Critical Working Areas (eg hospital operating theatres, precision laboratories)	0.1	0.2
Residential Daytime	6.0	12.0
Residential Night-time	2.0	4.0
Offices, schools, educational institutions and places of worship	13.0	26.0
Workshops	13.0	26.0

Note: Daytime is 7:00 am to 10:00 pm and night-time is 10:00 pm to 7:00 am.

Vibration Criteria - Surface Structures

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.

British Standard 7385: Part 2 - 1993 Guidelines

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.

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 17** and graphically in **Figure 3**.

Table 17 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

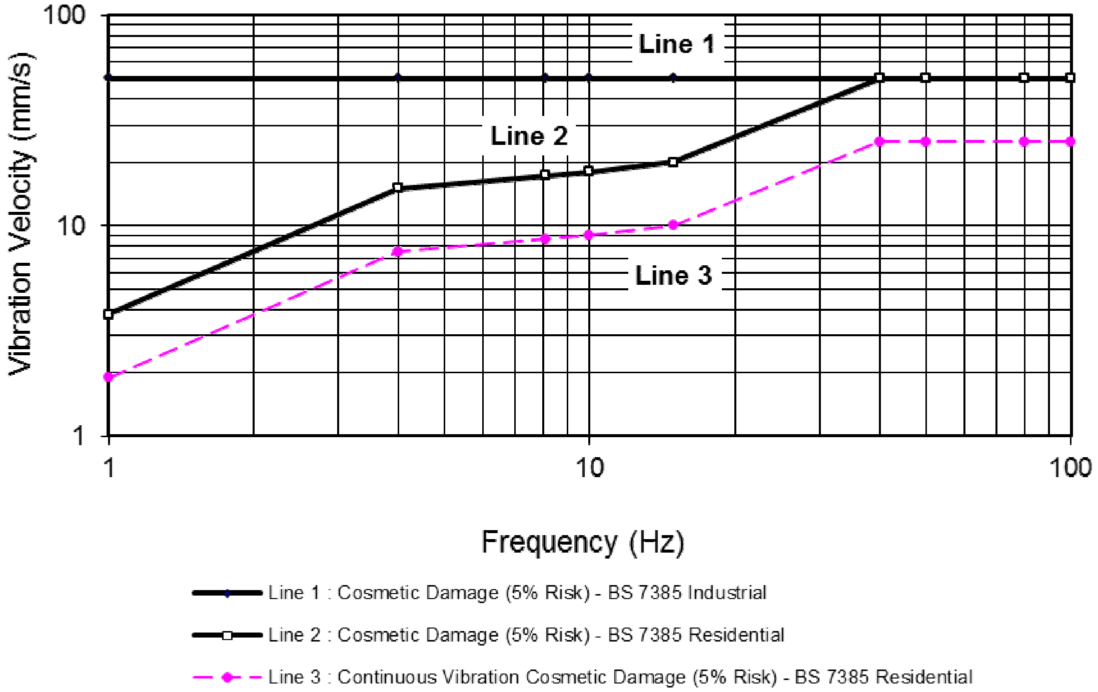
Line	Type of Building	Peak Component Particle Velocity on Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	15 Hz and Above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial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

The Standard states that the guide values in **Table 17** 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 17** may need to be reduced by up to 50%.

Note: Rockbreaking/hammering 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%.

Figure 3 Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for building types corresponding to “Line 2” are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

The Standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 17**, 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 17** should not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS 2187 specifies that vibration measured should be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) should be compared with the guidance curves presented in **Figure 3**.

It is noteworthy that extra to the guide values nominated in **Table 17**, 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.”*

6 NOISE AND VIBRATION ASSESSMENT

6.1 Noise

6.1.1 Noise Intrusion

Future residential apartments will be exposed to noise from rail traffic, chiefly on the eastern facade facing onto the rail corridor. The southern facades (facing Neil Street) are exposed to road traffic noise and progressively reducing levels of rail noise.

A review of the results of measurements carried out at the site to determine the levels of rail and road traffic noise received at the proposed location of the nearest future residential apartment building facades is summarised as follows:

Buildings 4 & 6 Eastern Facade – Rail Noise Levels

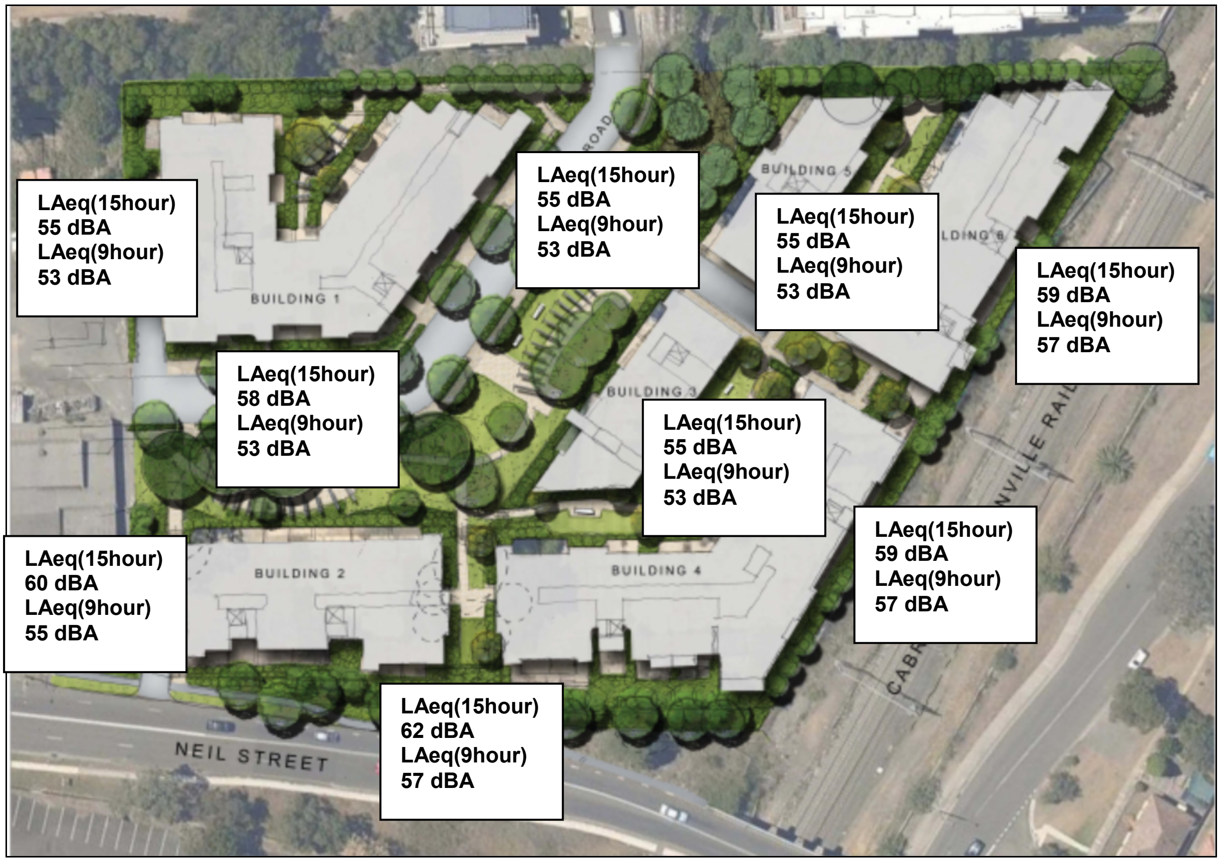
- Daytime (7:00 am - 10:00 pm) $L_{Aeq(15hr)}$ 59 dBA
- Night-time (10:00 pm - 7:00 am) $L_{Aeq(9hr)}$ 57 dBA

Buildings 2 & 4 Southern Facade – Road Traffic Noise Levels

- Daytime (7:00 am - 10:00 pm) $L_{Aeq(15hr)}$ 62 dBA
- Night-time (10:00 pm - 7:00 am) $L_{Aeq(9hr)}$ 57 dBA

The expected daytime and night-time noise levels impinging upon the facades of the future apartment buildings, predicted based upon the survey results are shown in **Figure 4**.

Figure 4 Predicted Daytime and Night-time Noise Levels at Future Residential Apartments



Drawing by Marchese Partners International Pty Ltd courtesy of Landmark Group

Standard window glazing of a building will typically attenuate external noise ingress by 20 dBA with windows closed and 10 dBA with windows open (allowing for natural ventilation). The expected range of internal noise levels for standard facade glazing is presented in **Table 18** for the windows open and windows closed scenarios, and the predicted levels of environmental noise impinging on the future facades of apartments.

Table 18 Predicted Internal Road Traffic Noise Levels (dBA) - Standard Glazing

Building/Facade	Space	Descriptor	Internal Noise Level		Criterion	
			Windows Open	Windows Closed	Windows Open	Windows Closed
1 South Facade	Living	LAeq(15hr)	48	38	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
1 West Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
1 East Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
2 North Facade	Living	LAeq(15hr)	48	38	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
2 South Facade	**Living**	LAeq(15hr)	**52**	**42**	50	40
	Bedrooms	LAeq(9hr)	**47**	**37**	45	35
2 West Facade	Living	LAeq(15hr)	50	40	50	40
	Bedrooms	LAeq(9hr)	45	35	45	35
3 East Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
3 West Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
4 North Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
4 East Facade	Living	LAeq(15hr)	49	39	50	40
	Bedrooms	LAeq(9hr)	**47**	**37**	45	35
4 South Facade	**Living**	LAeq(15hr)	**52**	**42**	50	40
	Bedrooms	LAeq(9hr)	**47**	**37**	45	35
5 East Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
5 West Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35
6 East Facade	Living	LAeq(15hr)	49	39	50	40
	Bedrooms	LAeq(9hr)	**47**	**37**	45	35
6 West Facade	Living	LAeq(15hr)	45	35	50	40
	Bedrooms	LAeq(9hr)	43	33	45	35

The predicted internal noise levels indicate that, with the exception of bedrooms on the eastern facade of Buildings 4 & 6 (facing the rail corridor) and living (habitable rooms) and bedrooms located on the southern facade of Buildings 2 & 4 (facing Neil Street) as indicated in **bold** in **Table 18**, the recommended internal noise criteria will be achieved across the proposed residential development with windows open and closed.

Upgraded glazing will be required for the rooms as nominated in **bold** in **Table 18** in order to achieve acceptable internal noise levels with the windows closed. In-principle, windows and doors with a laboratory-tested minimum acoustical performance of **R_w 28** will provide the required additional attenuation of external noise levels. This acoustical performance can typically be achieved with 6.38 mm laminated glazing in well-sealed frames of heavy-duty construction. Full perimeter acoustical seals will be required, felt weather seals are inappropriate.

In addition, where windows and doors are required to be closed to meet internal noise levels as nominated in **bold** in **Table 18**, alternative means of achieving the requirement for "comfort ventilation" will need to be considered to enable openings in the external facade to remain fully closed during noisy periods. The ventilation requirements of the BCA should be satisfied and design input should be sought from an appropriately qualified mechanical consultant. It is likely that an alternative means of comfort ventilation will need to be provided for all habitable spaces in the development.

Sleep Disturbance and Night-time Rail Movements

Consideration should be given to the potential for sleep disturbance as a result of high noise level rail events occurring during the night-time. Based upon documented research into sleep disturbance, it can be concluded that maximum noise levels within bedrooms below 50 dBA – 55 dBA are unlikely to cause awakening. Also, one or two events per night with maximum internal noise levels of 65 dBA – 70 dBA are not likely to affect health and well-being significantly (EPA 2011).

During the survey, maximum noise events of between 85 dBA – 90 dBA occurred up to two times on three of the seven nights of monitoring. With the inclusion of the recommended upgraded glazing and provision of mechanical ventilation to enable windows/doors to be closed for bedrooms located on the eastern facade of Buildings 4 and 6, the occurrence of maximum internal noise level events of between 65 dBA – 70 dBA is not generally expected to occur more than twice per night. On this basis, acoustical amenity in terms of sleep disturbance appears to be satisfactory.

6.2 External Acoustical Amenity

There are no criteria specifically relating to outdoor acoustical amenity for residential receivers. The INP recommends L_{Aeq} levels of between 50 dBA and 60 dBA for recreation areas although this criteria relates to noise from industrial sources and is not intended to apply to transportation noise sources. However, in the absence of specifically applicable criteria, these levels are considered an acceptable basis upon which to assess outdoor acoustical amenity.

Based upon the measured levels of noise exposure at the site, the predicted daytime $L_{Aeq(15hour)}$ levels around the interior landscaped common usage open-space areas are between 55 dBA and 58 dBA. This is achieved principally by means of the proposed building layout adopted in the Masterplan in which the buildings located adjacent to the rail corridor and road effectively shield the interior of the residential development site.

When compared with the INP recommended levels, outdoor acoustical amenity appears to be acceptable.

6.3 Operational Noise Emissions

Precise mechanical plant selection is unknown at this stage, as plant selection will take place during the detailed design phase of the project.

It is anticipated that the development will be serviced by typical mechanical ventilation/airconditioning equipment involving individual low-noise split systems. Basement carparking will likely be served by an exhaust system, with the fans possibly housed in basement plantrooms. The plant is expected to operate during daytime hours only (that is, not beyond 10:00 pm).

It is likely that the criteria set out in **Section 5.3** will be met through the use of conventional noise control methods (eg selection of equipment on the basis of quiet operation and, where necessary, providing full enclosures, localised barriers, silencers and lined ductwork).

The mechanical plant associated with the development must be reviewed by an appropriately qualified acoustic consultant at the construction certificate and tender stage when preliminary, and final plant selections have been made.

All mechanical plant and equipment with the potential to operate continuously would need to be selected, positioned, and, if necessary, treated, to ensure compliance with the limiting noise criterion of **42 dBA** during the night-time period and with the daytime/evening **50 dBA** criterion (for operations until 10:00 pm) for nearby residential receivers to satisfy Holroyd Council requirements.

6.4 Ground-borne Noise and Vibration

Measured vibration levels during passenger train passbys at a distance of approximately 15 m from the near track (the up line) are presented in **Section 4**. The expected vibration levels at the base of a future apartment building adjacent to the eastern boundary (typically Building 6 and Building 4 – eastern wing) are presented in **Table 19**.

Table 19 Maximum Vibration Levels at approximately 15 m from Centre of Near Track

Train Type	95th Percentile Maximum Vibration Level[1] (dB re 10^{-9} ms^{-1})	Continuous Vibration Criteria (dB re 10^{-9} ms^{-1})
Passenger Train	93	103
Freight Train	89	103

Note 1: '95th percentile maximum vibration level' is the vibration level that is expected to be exceeded during 5% of train passbys. It refers to the maximum 1 second rms vibration velocity during a train passby.

Assessment of vibration has been carried out in accordance with the EPA Vibration Guideline. The measured vibration levels were found to be below the recommended maximum levels for exposure to continuous vibration in residences (106 dB during the daytime and 103 dB during the night) and are well below the recommended maximum levels for intermittent vibration (112 dB during the daytime and 109 dB during the night-time). According to the Vibration Guideline, the night time criterion for continuous vibration (103 dB) is the threshold of perception for most people. Since rail vibration is intermittent rather than continuous, the human comfort vibration criteria will be achieved within all apartments constructed adjacent to the rail corridor without the need for any specific mitigation measures.

The criteria for human exposure to vibration are well below the limiting criteria for building damage. As such, compliance with human exposure vibration criteria infers compliance with building damage-related vibration criteria.

6.5 Ground-borne Noise Assessment

Ground-borne noise in buildings adjacent to railway lines is most common in railway tunnel situations where there is an absence of airborne noise to mask the ground-borne noise emissions. Ground-borne noise results from the transmission of ground-borne vibration rather than the direct transmission of noise through the air. The vibration is generated by wheel/rail interaction and is transmitted from the trackbed, via the ground and into the building structure.

The vibration entering the building then causes the walls and floors to faintly vibrate and hence to radiate noise (commonly termed "ground–borne noise" or "regenerated noise").

If of sufficient magnitude to be audible, this noise has a low frequency rumbling character, which increases and decreases in level as a train approaches and departs the site. This type of noise can be experienced in many buildings constructed in close proximity to urban underground rail systems.

The measured ground vibration levels have been used to estimate maximum internal ground-borne noise levels inside an apartment building located approximately 15 m from the nearest operational track. It is noted that prediction of internal noise levels, based on external vibration levels, is highly dependent on a number of assumptions including coupling losses between the ground and the building, vibration transmission between different floors of the building and possible amplification effects due to resonances of the structure. For this reason, the estimated internal levels can only be regarded as indicative.

Table 20 Estimated Internal Ground-borne Noise Levels 95th Percentile $L_{Amax(slow)}$

External Vibration (dB re 1nm/s)	Estimated Internal Ground-borne Noise at Ground Level (dBA)	Estimated Internal Ground-borne Noise at First Floor Level (dBA)	Criteria for Internal Ground-borne Noise Levels (dBA)
93	33	30	35

Ground-borne noise levels are estimated to be below the design criteria for internal noise. Furthermore, for developments near surface tracks the effect of ground-borne noise tends to be less of an issue due to the masking of the ground-borne component by the direct transmission of airborne noise.

7 CONCLUSION

An assessment has been conducted of the potential noise and vibration impacts upon the Masterplan scheme proposed for a residential apartment development at 1 – 11 Neil Street, Merrylands.

A survey of the exposure of the site to noise from rail and road traffic, and the levels of vibration generated by rail movements was carried out. Based upon the results of noise and vibration monitoring, noise levels at the future apartment building facades were predicted along with levels of ground vibration and regenerated noise.

Noise levels within living spaces and bedrooms of future residential apartments have been estimated and compared with regulatory requirements for internal acoustical amenity. Acceptable noise levels will generally be achieved across the development. Bedrooms located adjacent to the eastern boundary, overlooking the rail line, will require upgraded glazing to achieve the required internal noise levels. In addition, a system of comfort ventilation is recommended to enable any window or door openings in these rooms to be closed during noisy periods. Living spaces and bedrooms located adjacent to the southern boundary, overlooking Neil Street, will also require upgraded glazing in order to achieve acceptable internal noise levels. Provision of a comfort ventilation system will be necessary to enable window and door openings on the noise-affected facade to remain closed when required.

The potential for sleep disturbance due to high-level rail noise events occurring during the night-time was examined. Based upon the results of continuous noise monitoring, the likelihood of significant adverse effects to health and well-being appear unlikely with the inclusion of the in-principle recommendations for noise control treatments.

Vibration levels and regenerated noise were found to be within acceptable limits.

Building construction is required to be in accordance with the NCC Part F5 in relation to sound insulation between sole occupancy units. The requirements of the NCC have been documented within this report.

Outdoor acoustical amenity has been reviewed and given the shielding of the site achieved through the building layout proposed under the Masterplan scheme, outdoor noise levels will be within acceptable limits.

Although the proposed Masterplan scheme adopted for the residential development is not in accordance with the option outlined under Holroyd Council DCP 2013, the building arrangement minimises the number of potentially-noise impacted spaces and is acoustically preferable.

Mechanical design is not sufficiently developed at this stage to enable a comprehensive assessment of noise emissions associated with the operation of mechanical plant and equipment. Design limits have been included for the future assessment purposes.

Similarly, there is no construction scheduling available at this Masterplan stage of the development. Guidelines for the assessment of construction noise and vibration and recommendations for measures to minimise potential impacts have been included.

In conclusion, based upon review of the Masterplan scheme, the proposed residential development achieves the relevant criteria for noise and vibration assessment and can be supported on the basis of acoustics.