Wanda

Wanda Sydney Tower B

Acoustic Report

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Appendices

1 Introduction

Arup have been commissioned by Wanda to provide advice on acoustics for the Wanda Sydney project. This report reviews the design of the Tower B project which is primarily a hotel. Potential vibration impacts from the proposed railway below are also assessed. Separate reports deal with entertainment noise impact and noise associated with the construction of the hotel and the demolition of the existing buildings on site.

2 Existing Environment

2.1 Site Description

The Tower B of Wanda Sydney development is located at Circular Quay, Sydney, as shown in Figure 1 below. It is bounded by Alfred Street, Pitt Street and Rugby Place.

The development is generally surrounded by office/commercial buildings and hotel buildings besides the Cahill Expressway, Sydney Train line and ferry quays on the north.

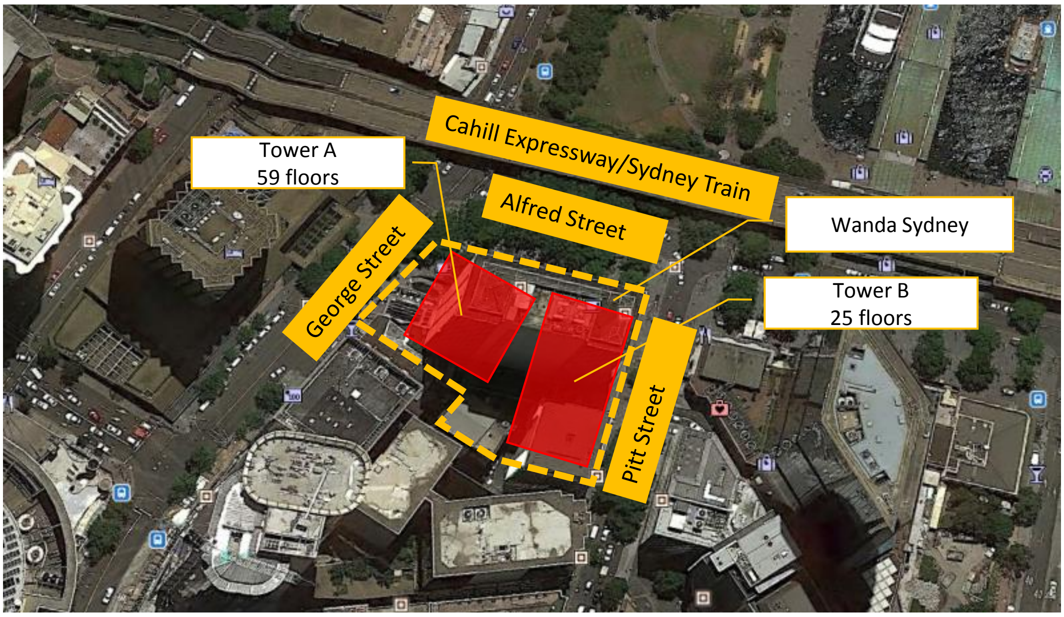

Figure 1 Location of Wanda Sydney

2.2 Existing Noise Environment

The Circular Quay area is characterised as a busy urban area, a transport hub for cars, trains, buses, ferries and cuisine ship, and a focal point for community celebrations (e.g. new year and Vivid Sydney). The existing noise environment is thus complex and dynamic.

The major noise impact to the Tower B comes from road traffic of the Cahill Expressway on the north, due to the high traffic volume and pass-by speed. The

Northern façade will be the most affected portion of Tower B. Unfortunately, guestrooms towards north include a large area of glass to allow enjoyment of the best view of the harbour and Circular Quay area.

Towards the south into the city space, the noise environment changes to 'urban hum' with lower noise levels.

Noise levels on the higher floors are greater than the lower floors since the angle of view to the Cahill Expressway, and therefore exposure to road traffic noise becomes greater and the externally located mechanical equipment noise impact from surrounding buildings increases as floor increases. After a certain height, the noise levels drop again due to distance attenuation.

Noise measurements have been conducted on site. Figure 2 illustrates the locations of measurements.

Figure 2 Long-term noise monitoring and short-term noise measurement locations

2.2.1 Attended Noise Monitoring

Attended short term noise measurements were conducted on 2 June and 18 June 2016 at various locations (identified in Figure 2) to confirm and supplement the long term noise logging. Noise levels from the Cahill Expressway were also measured on 11 July 2016 at ground level. Where possible, attended measurements were conducted simultaneously with unattended noise logging to enable comparison of results between attended measurements and long term noise logging.

Results of the attended noise surveys are summarised in Table 1.

Table 1: Attended noise monitoring results

Location	Time	Measured Sound Pressure Levels, dB $L_{A90,\ 15mins}$
Gold Fields House facing George Street (Location 1)	Typical Weekday 2 June, 2016 10.30-13.15	61
FairFax Building (Location 2)		62
Gold Fields House @ L26 facing West		66
Gold Fields House @ L26 facing South		67
Rugby Club		64
Cahill Expressway (measured at the pavement of Cahill Expressway)	Typical Weekday 11 July, 2016 13.30 – 14.00	69 – 70
Gold Fields House facing George Street (Location 1)	Saturday 18 June, 2016 12.00	61

2.2.2 Rating Background Level (RBL)

The Rating Background Level (RBL), which are stated in the *DA Acoustic Assessment Report* dated 15/6/2015 by Acoustic Logic, has been approved by the City of Sydney Council. These recommendations were derived from the noise survey conducted at that time and are considered still valid. As such, it is appropriate to adopt this approved RBL for the purpose of this report. The RBLs are summarised in Table 2 below.

Table 2 Approved RBLs

Floor	Time	RBL, dB$L_{A90,peroid}$
Level 1	Day	64
	Evening	64
	Night	61
Level 26	Day	65
	Evening	65
	Night	64

3 Acoustic Criteria

3.1 Noise to Atmosphere

All Sydney Council and NSW EPA requirements (INP) for external noise shall be complied with. The Project Specific environmental noise limiting criteria applicable at the property boundary to external receivers derived from the NSW Industrial Noise Policy procedures shall be complied with and are as follows. The standard time periods are defined as per the NSW INP.

Table 3 below summarises environmental noise criteria set in the *DA Acoustic Assessment Report* dated 15/6/2015 by Acoustic Logic. As the acoustic environment in the area has not changed, it is appropriate to adopt this approved noise criteria for the purpose of this assessment.

Table 3 Project Specific Noise Criteria for Noise Emission

Receiver	**Time Period**	**Intrusiveness Criterion** ($L_{Aeq, 15min}$)	**Amenity Criterion** ($L_{Aeq, period}$)	**Project-Specific Noise Criterion** ($L_{Aeq, period}$)
Residential	Day (7am – 6pm)	69 dB	60 dB	60 dB
	Evening (6pm – 10pm)	69 dB	50 dB	50 dB
	Night (10pm – 7am)	66 dB	45 dB	45 dB
Commercial	Day (7am – 6pm)	-	59 dB	59 dB
	Evening (6pm – 10pm)	-	59 dB	59 dB

In addition to the Council noise requirements, noise emissions shall be controlled to preserve amenity on the site, particularly on the rooftop and outdoor terraces. The criterion for this is as follows:

- 55 dBL_{Aeq} at outdoor occupied areas (e.g. Bar Terrace) or at 1 m from louvre/air openings of normally operating plant

3.2 Internal noise and Vibration

3.2.1 Building Services Noise Target

Table 4 below summarises the building services noise targets. This is based on the Wanda Biaozhun (WB – Wanda Standard) document, Australian Standard AS2017:2000 and Arup’s previous experience of premium hotels.

The proposed building services noise targets below are generally in line with the Wanda Standard. Based on our understanding of the expected acoustic environment for the premium hotel, we have adjusted some targets to provide a premium quality acoustic environment as well as to avoid unnecessary cost.

Table 4 Building Services Noise Limits

Space	A-weighted Sound Pressure Level or Noise Rating		Arup's Recommendation and Adopted Criterion	
	Wanda Standard	**AS2107**	**Target Noise Levels**	**Corresponding Noise Rating**
FOH				
Guestroom (Bay, JR Suite, Suite, Premier and Presidential)	Day: 35 dB(A) Night: 25 dB(A) or NR32 [1]	35-40 dB(A) (hotels and motels near major roads)	35 dB(A) (Any Time)	NR30
Grand Ballroom	40 dB(A) (Multi-purpose Hall) Or NR35 (Multi-purpose Hall)	35-45 dB(A) (conference areas with sound reinforcement)	40 dB(A)	NR35
Bridal Room	-	-	40 dB(A)	NR35
Meeting Room (Meeting and VIP Meeting)	40 dB(A) or NR35	35-40 dB(A) (conference areas up to 50 persons without sound reinforcement)	40 dB(A)	NR35
VIP Lounge	NR35	35-40 dB(A) (bars and lounges)	40 dB(A)	NR35
Activity Room/Gym/Yoga	NR38	-	45 dB(A)	NR40
Salon	NR38	-	45 dB(A)	NR40
SPA	NR38	-	40 dB(A)	NR35
Dining (All day dining, Chinese Restaurant)/Café/Bar	50 dB(A) or NR38	40-45 dB(A)	50 dB(A)	NR45
Private Dining	NR38	40-45 dB(A)	45 dB(A)	NR40

[1] The internal noise limit of 35 dB(A) for Daytime and 25 dB(A) for Night time is specified in WB Volume 1 Section 10.1.1. The building services noise limit of NR32 is specified in WB Volume 3 Section 1.1. There is a discrepancy between these two noise limits in guestrooms.
35 dB(A) is considered to be a reasonable noise limit for guestrooms (both daytime and night time) in the premium hotel, which meets the high standard expectation of guests in terms of acoustics. It is not necessary and not practicable to achieve 25 dB(A) with air conditioning operating at night time, especially in a hotel with fan coil units. At night time, building services noise level of 35 dB(A) provides a quiet and comfortable space for sleeping, and as a masking sound, it also gives benefits for sound privacy and sound insulation.

Space	**A-weighted Sound Pressure Level or Noise Rating**		**Arup's Recommendation and Adopted Criterion**	
	Wanda Standard	**AS2107**	**Target Noise Levels**	**Corresponding Noise Rating**
Retail	NR38	45-50 dB(A)	50 dB(A)[2]	NR45
Sales	-	40-45 dB(A) (Speciality shops: where detailed discussion is necessary in transactions)	45 dB(A)	NR40
Karaoke/VIP Room (Bar)	-	-	45 dB(A)[3]	NR40
Pantry	-	-	50 dB(A)	NR45
Guest Floor Corridor/Pre-Function/Lobby/Reception	NR38	45-50 dB(A)	40 dB(A)	NR35
Corridor on non-guest floor	NR40	45-50 dB(A)	45 dB(A)	NR40
Lift Lobby	NR38	45-55 dB(A)	45 dB(A)	NR40
Change Room/Toilets	NR40	45-55 dB(A)	45 dB(A)	NR40
Pool (if indoor)	NR38	-	45 dB(A)	NR40
BOH				
Kitchen	-	45-55 dB(A)	55 dB(A) with up to 60dB(A) directly below extract hoods	NR50
Executive Office	45 dB(A)	40-45 dB(A) (General Office Area)	45 dB(A)	NR40
Offices	45 dB(A)	40-45 dB(A) (General Office Area)	45 dB(A)	NR40
Reservation/Operator	-	40-45 dB(A) (Call Centre)	45 dB(A)	NR40
Cloak	-	-	50 dB(A)	NR45

[2] The occupational noise in the retail spaces is expected to be high; thus it is usually not necessary to specify a low building services noise limit. In addition, it is possible to include measures to reduce the building services noise by the retail tenant if needed.

[3] For the general purpose and usage of Karaoke, the sound level from sound reinforcement system is usually much higher than the building services noise. The building services noise level of 45 dB(A) will generally maintain the suitable acoustic environment for speech when not singing. As such, it is appropriate to adopt 45 dB(A) as the limit for the building services noise.

Space	A-weighted Sound Pressure Level or Noise Rating		Arup's Recommendation and Adopted Criterion	
	Wanda Standard	AS2107	Target Noise Levels	Corresponding Noise Rating
Storage/Linen/Cool Room/Bev. Store	-	-	50 dB(A)	NR45
Butchery	NR45	-	50 dB(A)	NR45
AV Control Room	-	,.	40 dB(A)	NR35
Switch Room	-	-	50 dB(A)	NR45
Plant Room	-	-	-	-
Hotel Bin Store	NR45	-	50 dB(A)	NR45

3.2.2 Lift Noise and Vibration

Noise limits specified below should apply to all noise arising from operation of the lift and escalator installations including direct sound transmission, breakout noise and re-radiation of structure borne noise.

- Door opening/closing noise when measured at 1.5 m from the floor and 1m from the door face shall not exceed 55 dB(A).
- Lift noise, when measured at 1.5 m from the floor and 1m from the door face with the door closed, shall not exceed 50 dB(A) at any time during the lift cycle.

Vibration from lift operation should be limited to the criteria in the DEC Assessing Vibration recommended vibration limits for maintaining human comfort in residences and offices. Refer to Table 5 given in Vibration section below.

3.2.3 Vibration Criteria

Vibration levels caused by activities on the site (including plant) shall not exceed the levels specified in the DEC Assessing Vibration guideline at any place of different occupancy at and around the site.

The DEC Assessing Vibration recommended vibration limits for maintaining human comfort in residences and offices (commercial) are shown in Table below.

Table 5 Vibration Criteria for Tower B

Location/ Space	Assessment Period [4]	Maximum z-axis weighted rms vibration acceleration (m/s^2)		Vibration Dose Value ($m/s^{1.75}$)
		Continuous	Impulsive	
Residences	Daytime	0.020	0.60	0.40
	Night-time	0.014	0.20	0.26
Offices/ Retail etc. (Commercial)	Day- or night-time	0.040	1.28	0.80

3.3 Structureborne Noise

Based on the NSW Rail Infrastructure Noise Guideline (RING), the groundborne noise limits in the guestrooms are summarised below.

Table 6 Structureborne Noise Limits

Sensitive Land Use	Time of day	Internal Noise Trigger Levels, dB(A)
Residential	Day (7.00am – 10.00pm)	40 $dBL_{Amax,slow}$
	Night (10.00pm – 7.00am)	35 $dBL_{Amax,slow}$

There are no formal limits in RING for commercial spaces/properties. However projects usually adopt a limit of between 45-50 $dBL_{Amax,slow}$.

3.4 Façade Requirements

The façade sound insulation requirements are designed that the intrusive noise (measured in dBL_{Aeq}) is no more than the target building services noise level, as defined in Table 4 above.

3.5 Internal Sound Insulation Criteria

The internal sound insulation criteria are proposed to provide adequate acoustic separation between adjacent spaces, especially between guestrooms and other guestrooms or noisy areas. Sufficient sound insulation performance along with an appropriate background noise levels will be the key to provide a private and comfortable staying experience to guests.

The internal sound insulation criteria for guestrooms are determined based on the Wanda standard, latest Australian National Construction Code (NCC 2016) and Arup's previous experience of premium hotels. Note that the NCC requirements are mandatory and therefore are the minimum that can apply.

Since the NCC and AS2107 do not have sound separation requirements for non-residential premises, the sound insulation criteria for non-guestroom spaces (e.g. Grand Ballroom, SPA and Lounges) are proposed based on their functional usages, their sensitivity to noise and speech privacy and their adjacencies.

[4] Daytime is 7.00am to 10.00pm and night-time is 10.00pm to 7.00am

Table 7 below gives a summary of internal sound insulation criteria for key spaces. These sound insulation criteria are applied to both horizontal and vertical adjacencies. Adequate design of sound flanking paths will maintain the sound insulation requirements specified in Table 7.

Table 7 Internal Sound Insulation Criteria for Key Spaces

Space	Weighted Sound Reduction Index		Arup's Recommendation
	Wanda Standard	**NCC 2016**	
Guestroom to Guestroom	R_w 50	R_w+C_{tr} 50	R_w+C_{tr} 50
Bathroom to habitable space in other guestroom [to be avoided by planning where practicable]	R_w 50	R_w+C_{tr} 50 with discontinuous construction	R_w+C_{tr} 50 with discontinuous construction
Guestroom to Guest Floor Corridor	R_w 40 (with door)	R_w 50	R_w 50 with a R_w 35 Door
Guestroom to Other FOH Functional Spaces (e.g. Restaurant, Office, etc.)	-	R_w+C_{tr} 50	R_w+C_{tr} 50
Guestroom to Plant Room	-	R_w+C_{tr} 50 with discontinuous construction [5]	Minimum R_w (C_{tr}) 55(-5) with discontinuous construction [5]
Plant Room to BOH regular occupied spaces	-	-	R_w 55

3.6 Impact Noise Isolation Criteria

An important part of guestroom sound insulation is to ensure that impact noiseon the floor (e.g. high heels, dropping items, etc.) are sufficiently mitigated for rooms on the level directly below.

Preliminary impact sound insulation criteria are given for the construction of floors and ceilings and their ability to reduce impact sound transmission from one space to another.

[5] Discontinuous construction is only required for walls (i.e. floor/ceiling construction does not require a discontinuous construction.) Note that the floor/ceiling construction should achieve the impact noise isolation criteria.

Table 8 Impact Noise isolation Criteria

Space Above: / **Space Below:**	**Guestrooms, restaurant, public corridor, lobby or stairway, $L'_{nT,w} + C_i$** [6]	**Plant room, $L'_{nT,w} + C_i$**
Guestrooms	55 [7]	55
Commercial (office or retail)	62	n/a

4 Noise emission from project

4.1 Noise from Plant

4.1.1 Noise Break-out from General Plant

Break-out of noise from plant rooms via exhaust and intake/discharge louvres should be controlled to meet environmental noise limits outlined in Section 3.1 and to meet internal noise limits in Section 3.2.1. The specific noise control requirements should be determined as design progresses, but the following mitigation measures/strategy are proposed at this stage:

- Select the plant as quiet as practicable, and/or
- Discharge/intake louvres and flues shall be located to minimise noise nuisance problems and designed to include appropriate noise control, and/or
- Discharge/intake path of the plant shall be provided noise attenuators, internal lined duct and/or acoustic louvres
- Provide acoustic enclosure where suitable

4.1.2 Diesel Standby Emergency Generators

It is understood that the generator is currently proposed to be located on the Ground Mezzanine-MEP Level.

The limiting criteria for generators and smoke exhaust testing are based on the NSW INP “Daytime” RBL and the additional allowance in the INP due to the limited duration.

The limiting criterion, measured at the worst affected site boundary, for noise from testing of equipment such as emergency generators and smoke exhaust fans is summarised by the following formula:

- $L_{Aeq,15min} \leq RBL_{(Daytime)}$ + 5 dB(A) + 5dB(A) = 64 dB(A)+10 dB(A) = **74 dB(A)**

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[6] $L'_{nT,w}$ – weighted standardised impact sound pressure level (field measurement). C_i - spectrum adaptation term. Note that in contrast to an airborne sound insulation rating (such as R_w or $D_{nT,w}$), a lower $L'_{nT,w}$ rating is a better performing construction (i.e. reduced impact noise).

[7] This is a requirement from the Sydney DCP 2012. The standard requirement in the NCC is 65 $L'_{nT,w} + C_i$

Generator testing should be carried out under reduced test loads where possible. Lower sound levels are typically produced when operating under reduced loads because of variable speed fans.

It must be noted that the above criterion is proposed for consideration of external receivers only and does not take into consideration the noise impact on the development itself.

During the emergency generator operating, the following criteria for the spaces within the development should not be exceeded:

- 60 dB(A) in BOH spaces
- 75 dB(A) in the outdoor occupiable space

The following potential mitigation measures are allowed at this stage.

- Select the generator as quiet as practicable, and/or
- Provide acoustic attenuator to air paths and exhaust to reduce noise emissions, and/or
- Provide acoustic enclosure to the generator set, and/or
- Provide absorptive finishes on the plant room walls to reduce the noise build-up inside the plant room and noise emission.

4.1.3 Chillers

Chillers are located on the Ground Mezzanine-MEP Level. Chillers will be provided with appropriate levels of noise and vibration control to ensure that the internal and external noise criteria are achieved. A detailed assessment of this is ongoing as plant selections are being developed.

4.1.4 Cooling Tower Noise Assessment

There are three (3) cooling towers in a partially enclosed space (open on top) on Level 24. The adjacent noise sensitive receiver is the VIP/KTV room on Level 24. In addition, there is a private party BBQ open terrace to the north of the cooling tower. The closest residential receiver will be the apartment in Tower A of the Wanda Sydney Development.

Based on the preliminary plant spectrum data supplied by the Arup Mechanical team, noise levels to the worst affected receivers (BBQ area in Tower B and Apartments in Tower A) have been predicted. The noise break-in through the slab to VIP/KTV has also been predicted. Calculations have taken into account distance loss and shielding from any intervening building structures or screens.

This prediction assumes all three cooling towers are operating at the same time at full capacity.

Based on these predictions, in order to meet the most stringent night time noise criteria as specified in Section 3.1, the following potential mitigation measures are allowed at this stage.

- Select the cooling tower as quiet as practicable, and/or
- Provide discharge attenuator or internally lined transfer duct to reduce noise emissions
- Provide a solid noise barrier with the minimum height to reach the top of cooling towers
- Provide absorptive finishes on the plant room walls

4.2 Entertainment Noise Break-out

A separate assessment report for entertainment noise has been prepared by Arup Acoustics. Please refer to "*Acoustic Assessment for Entertainment Noise of Wanda Sydney Tower B*" for details.

5 Proposed Acoustic Design Recommendations for the Project

5.1 Façade sound insulation

5.1.1 Glass Construction

An acoustic assessment for façade sound insulation requirements has been conducted based on the noise levels measured at various locations near the site and the latest architectural drawings.

Table 9 provides the façade sound insulation requirements and recommended glass build-ups for key spaces at this stage of the design. Figure 3 illustrates the façade requirements and recommended build-up for a typical guest floor such that the intrusive noise (measured in dBL_{Aeq}) is no more than the target building services noise level as defined in Table 3.

As mentioned in Section 2.2, suites and functional spaces facing north will be the most noise affected spaces due to noise from the Cahill Expressway. The façade sound insulation assessment indicated that greater sound insulation performance is required on the northern façade, hence thicker glass options are recommended.

The north-eastern and north-western façades are exposed lower levels of traffic noise from the Cahill Expressway due to the limited angle of view and beneficial barrier effect of Tower A/nearby building. However, the suites with façades facing both north and east/west will be exposed to greater cumulative noise levels. As such, it is recommended to adopt the same glass as the northern façade for these instances (as marked in red in Figure 3) to reduce the cumulative façade intrusive noise level.

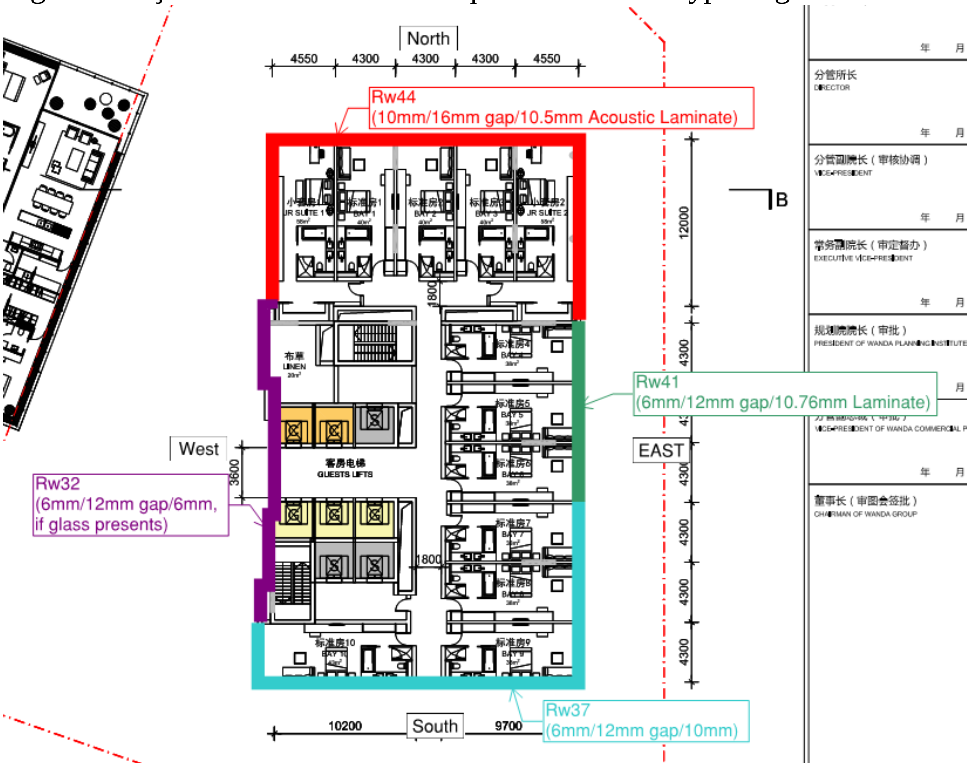
Please note that façade sound insulation requirements and recommended glass build-ups may need to be reviewed and updated as design progresses.

Table 9 Façade Sound Insulation Requirements and Recommended Glass Build-up

Spaces	East	South East /South/ South West	West	North/North West/North East
GF-L2 General Spaces	R_w 32 6mm/12mm gap/6mm			
VIP Meeting Rooms/Meeting Room/Boardroom/Executive Office	R_w 37 6mm/12mm gap/10mm		R_w 37 6mm/12mm gap/10mm	
Ballroom	-	-	-	R_w 41 6mm/12mm gap/10.76lam
Guestrooms (Bay, Suite, Premier and Presidential) [8]	R_w 41 6mm/12mm gap/10.76lam (Bay 4,5 and 6 on typical guest floor)	R_w 37 6mm/12mm gap/10mm	-	R_w 44 10mm/16mm gap/10.5mm acoustic laminate
Corridor/Guest Lift lobby	R_w 32 6mm/12mm gap/6mm			
Chinese Restaurant	R_w 32 6mm/12mm gap/6mm			
Karaoke	R_w 32 6mm/12mm gap/6mm			

[8] Refer to **Error! Reference source not found.** for the location of different sound insulation requirements on a typical guest floor.

Figure 3 Façade sound insulation requirements for a typical guest floor



5.1.2 Façade-Partition/Façade-Slab Junctions

The façade-partition/façade-slab junctions will be designed to maintain the sound insulation performance specified in Table 7.

Acoustic treatment details will be developed when the façade junction designs becomes available as design progresses.

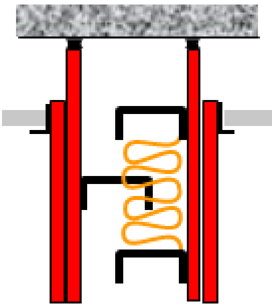
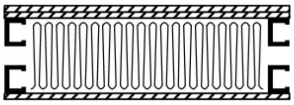
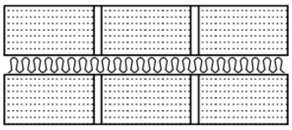
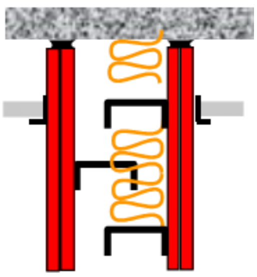
5.2 Internal sound insulation

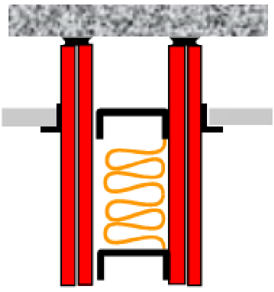
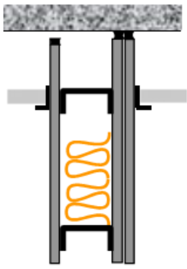
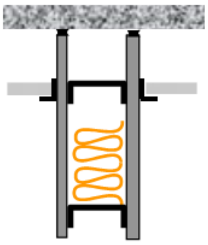
5.2.1 Wall Constructions

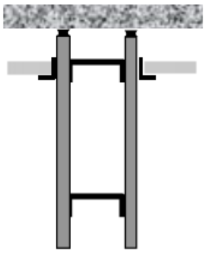
Table 10 below provides typical construction details of wall to achieve the sound insulation performance requirements specified in Section 3.5. Both Lightweight and Masonry options are given for each sound insulation rating.

The wall construction details may need further review and develop to suit specific situations as design and coordination progresses.

Table 10 Typical acoustic wall constructions

Sound Insulation Performance	**Wall Build-up**	
R_w+C_{tr} 50		<u>Lightweight</u> - 2 × 16 mm high density plasterboard (≥ 13 kg/m² per sheet) - ≥ 150 mm cavity with staggered stud (separate stud if plumbing runs through wall cavity) - 50 mm fibreglass (33 kg/m^3) in cavity (or equivalent) - 2 × 16 mm high density plasterboard (≥ 13 kg/m² per sheet)
		<u>Masonry</u> • 150mm concrete OR • 190 mm core-filled concrete block
R_w+C_{tr} 50 discontinuous construction		<u>Lightweight</u> - 1 × 13 mm high density plasterboard (≥ 10.5 kg/m² per sheet) - 2 × 64mm double stud with minimum 80mm gap between studs - 200 mm fibreglass (14 kg/m^3) in cavity (or equivalent) - 2 × 13 mm high density plasterboard (≥ 10.5 kg/m² per sheet)
		<u>Masonry</u> - 1 × 110mm clay brick masonry - ≥ 50mm cavity with 50mm thick fibreglass (11kg/m^3) - 1 × 110mm clay brick masonry
R_w 55		<u>Lightweight</u> - 2 × 13 mm high density plasterboard (≥ 10.5 kg/m² per sheet) - 2 × 64 mm staggered stud - 50 mm fibreglass (33 kg/m^3) in cavity (or equivalent) - 2 × 13 mm high density plasterboard (≥ 10.5 kg/m² per sheet)
		<u>Masonry</u> • 190 mm core-filled dense block (minimum surface mass 380 kg/m^2) or • 160mm concrete (minimum density 2400 kg/m^3) or

		• 140mm core-filled blockwork (minimum blockwork surface mass 252 kg/m^2) + 25mm furring channel and absorptive quilt + 13mm plasterboard to one side
R_w 50	 	<u>Lightweight</u> - 2 × 13 mm high density plasterboard (≥ 10.5 kg/m² per sheet) - 64 mm stud - 50 mm fibreglass (33 kg/m^3) in cavity (or equivalent) - 2 × 13 mm high density plasterboard (≥ 10.5 kg/m² per sheet) <u>Masonry</u> • 140 mm core-filled dense block (minimum surface mass 250 kg/m^2) or • 190 mm hollow block (minimum surface mass 270 kg/m^2)
R_w 45	 	<u>Lightweight</u> - 1 × 13 mm plasterboard - 64 mm stud - 50 mm fibreglass (33 kg/m^3) in cavity (or equivalent) - 2 × 13 mm plasterboard <u>Masonry</u> • 90 mm core-filled dense block (minimum surface mass 150 kg/m^2) or • 140 mm hollow block (minimum surface mass 160 kg/m^2)
R_w 40	 	<u>Lightweight</u> - 1 × 13 mm plasterboard - 64 mm stud - 50 mm fibreglass (33 kg/m^3) in cavity (or equivalent) - 1 × 13 mm plasterboard <u>Masonry</u> • 100 mm hollow block (minimum surface mass 115 kg/m^2)

R_w 35		Lightweight - 1 × 13 mm plasterboard - 64 mm stud - 1 × 13 mm plasterboard

5.2.2 Doors and Seals

Doors will limit the overall sound insulation of a partition since they are generally of much lighter construction than the partition and they are difficult to effectively seal. While high performance doors can be provided, it should be understood that they are likely to be heavy, more difficult to operate and relatively expensive.

Depending on the arrangement of the door, and the relationship of the room to other adjacent spaces, a door with a sound insulation performance considerably less than the partition itself will be appropriate.

Table 11 Typical acoustic door requirements, build-up and sealing arrangements

Partition Sound Insulation Rating	**Typical Corresponding Door Insulation**	**Typical Door Construction and Sealing Arrangement**
R_w 40	R_w 25	- Solid core (minimum 40 mm) or specialist acoustic glazed door, well fitted to effective frame - Vision panel (if required) to comprise of 10.6 mm laminated glass
R_w 45	R_w 30	- Solid core (minimum 45 mm) or specialist acoustic glazed door, well fitted to effective frame - Compression seals to head, jambs, meeting stiles and threshold (can be drop seal) - Vision panel (if required) to comprise of 10.6 mm laminated glass
R_w 50	R_w 35	- Specialist acoustically-rated door construction provided with a full set of seals and full frame. Door provided with an acoustic test certificate.
R_w 55	R_w 40	- Proprietary steel composite core acoustic door set, 45-55 mm with high performance frame, potential double rebate, perimeter and drop-down threshold seals, no vision panels, no keyholes Or - Specialist acoustically-rated door construction with an acoustic test certificate

Partition Sound Insulation Rating	Typical Corresponding Door Insulation	Typical Door Construction and Sealing Arrangement
R_w+C_{tr} 50 (i.e. Interconnecting Door between units)	R_w 45	- Back-to-back doors construction with each door rated minimum R_w 35 - Provided with a full set of seals and full frame. Or - Specialist acoustically-rated door construction provided with a full set of seals and full frame. Door provided with an acoustic test certificate.

Additionally, the door ironmongery should provide effective compression of the door seals. Sealing mechanisms should allow for the accommodation of building tolerances and of floor level variations.

Note that even with full perimeter and drop-down threshold seals, it is not possible to achieve above R_w 30 for a pair of 35 - 40 mm solid core timber doors (i.e. double doors).

5.2.2.1 Sound Lock Configurations

To reduce cost and improve reliability, 'sound lock' door configurations utilising lower performance doors can be used to replace single high performance acoustic doors. A large separation between the two doors is recommended (e.g. 1 m).

Additionally, 'sound locks' are recommended in the following instances:

- It is recommended to adopt the lobby door system for KTV on Level 24 to reduce the noise transfer between Bar and KTV.
- Where double doors are required for access reasons then 'sound lock' door configurations will be required. This is because of an inability to effectively seal the central vertical meeting stiles.
- If a plant room door opens into an occupied space (e.g. Bar, office area) then 'sound lock' configurations are recommended. This is to maintain an acoustic performance commensurate with the partitions and to minimise noise disruption to occupants while the door is opening/closing.

5.2.3 Impact Noise/Footfall Noise Mitigation

Generally, to control impact noise from footfall, we recommend that carpeted floor coverings are provided in guestrooms and guest floor circulation areas.

For critical spaces or spaces involving impact noise activities (such as the Bar), Table 12 below summarises our preliminary recommendations on impact noise mitigation. These mitigation measures will meet the impact noise criteria specified in Table 8.

This need to be reviewed and updated as design progresses.

Table 12: Impact noise mitigation measures

Impact Noise Source Room	Receiver Room/Space Below	Recommended Mitigation Measures in the Source Room
Guestroom	Guestroom	Carpet
Gym on L2	Grand Ballroom on L3	Floating Floor
Grand Ballroom on L3	Swimming Pool on L2	Resilient floor
Kitchen on L4	Meeting Room	Resilient floor
Kitchen on L4	Grand Ballroom	Resilient floor
All Day Dining/Speciality Restaurant on L4	Grand Ballroom/Meeting rooms	Carpet
Kitchen on L23	Presidential Suite	Resilient floor
Private Dining on L23	Presidential Suite	Carpet
Bar on L24	Restaurant	Carpet
VIP/KTV on L24	Restaurant	Floating floor
Cooling Tower on L25	Bar/VIP/KTV	Vibration isolation measures to cooling towers

5.3 Building Services Noise Control

5.3.1 FCU Noise Control in the Guestrooms

At this stage, the selection and noise data of the FCU are not available. As a general guidance, the FCU system within the guestroom will be designed to meet the requirements specified in Table 4. To achieve the targets, FCU units will be selected to be as quiet as possible. Acoustic mitigation measures (e.g. internal acoustic lining for duct, attenuator, etc.) will be included, if required.

5.3.2 Vibration Isolation

The recommendations in ASHRAE Applications Handbook, Chapter 48, Table 47, should be included in the design of vibration isolation. In general this will include:

Fans/AHUs:	Steel rails or concrete inertia base and spring vibration isolators.
Pumps:	Concrete inertia base and spring vibration isolators or equivalent pump mounting and vibration method that meets ASHRAE Applications C48 table 47 requirements (deflections, base types for given equip type). Additionally, all manufacturer's requirements & recommendations shall be met, including relevant Australian Standards.
Boilers:	Steel rails and spring vibration isolators.

Pipes, ducts, and conduit:	Connections to equipment should be made via flexible connections. Pipes, ducts, and conduit attached to vibration isolated equipment should also be vibration isolated.
Pipes:	On domestic water, waste water, and rain water piping use resilient lining between pipe and pipe hanger/mount.

Drain pipes should not short circuit the vibration isolated equipment and pipes.

5.3.3 Vertical Transportation Noise and Vibration Control

The following should be included in the design to achieve the requirements specified in Section 3.2.2:

- Solid concrete/masonry walls, floor, ceilings around the lift machine rooms.
- Vibration isolation of the lift gear.
- Use of manufacturer's polyurethane roller guides on the cab guide system to reduce cab movement noise.
- Guide-rails should be smoothly jointed, and rail alignment tolerances should be tight.

5.4 Noise from Proposed New Rail Facilities

5.4.1 Vibration Data

The following information has been provided by Sydney Trains (formerly RailCorp):

"All structures must be designed, constructed and maintained so as to avoid any damage or other interference which may occur as a result of noise and vibration from railway operations, on the assumption (without admitting that this is or will be the case) that source vibration levels from trains as a result of attenuation provided by the track structure may be as follow.'

Table 13: L_{max} fast response vibration velocity level (dB re 1E-6mm/s)

	1/3rd octave band centre frequency (Hz)																
	5	6.3	8	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200
Vibration velocity level	97	97	95	95	97	98	92	86	83	84	90	89	80	80	72	73	74

It is not stated how these reference vibration levels were determined by RailCorp, or whether they are intended to be representative of vibration levels from a mitigated or unmitigated trackform. Arup have compared this data with data obtained for other projects and measurements by Arup and data published for recent underground railway projects. While the very low frequency reference vibration levels appear to be somewhat high, the reference vibration levels quoted are considered reasonable for a system with a degree of vibration mitigation (eg resilient track fixings). It is worth noting that the Sydney One development is not the only noise-sensitive building in proximity to the railway and it is likely that a degree of vibration mitigation would be required to protect these buildings as well as the Sydney One development.

In practice, it would be extremely costly to reduce vibration at the receiver (eg by including vibration isolation bearings at the base of the building structure) and virtually impossible to isolate existing buildings from vibration, other than applying vibration isolation at the source (ie. using a resilient trackform).

5.4.2 Vibration Impacts

Groundborne and structureborne vibration from rail movements potentially results in two different issues. Rail movements can be perceived as *perceptible vibration* (usually as feelable movements in a floor either when standing, seated or lying in bed). Vibration can also be heard as low-frequency noise (rumble) where room surfaces effectively become loudspeakers and radiate sound (called structureborne or re-radiated noise). In most cases, the latter is the most onerous requirement (ie, vibration is heard before it is felt), unless the building in question houses vibration-sensitive equipment.

Separate criteria are given below for structureborne noise (vibration that is ultimately heard) and perceptible vibration (vibration that is felt rather than heard).

5.4.2.1 Structureborne Noise

US and UK guidelines, together with experience from international railway projects show the following approximate relationship between groundborne noise levels and community response.

Table 14: Illustrative descriptions of the effects arising from groundborne noise for new rail systems, assuming that airborne rail noise is not significant.

Groundborne Noise Level dBL_{Amax}, slow	**Description of Effect**
35-39	The passage of trains may be audible during quieter periods of the day such as evening and late morning. Level of annoyance likely to be low with few complaints
40-44	The passage of trains is likely to be audible regardless of the time of day. Level likely to give rise to some annoyance during quieter periods of the day. There may be some complaints.
45-49	Noise from the passage of trains will tend to be predominant and give rise to annoyance regardless of the time of day. It is likely that there will be some complaints.
>50	During the passage of trains groundborne noise will probably be dominant above noise from other sources. Considerable annoyance likely throughout the day and night. There may be some sleep disturbance.

In Australia, the NSW Rail Infrastructure Corporation (RIC) introduced groundborne noise limits in 2003. More recently, this was formalised in the NSW Rail Infrastructure Noise Guideline (RING) to be;

Table 15: Groundborne noise trigger levels for heavy or light rail projects, ref: NSW RING.

Sensitive Land Use	Time of day	Internal noise trigger levels dB(A)
Residential	Day (7am–10pm)	40 $dBL_{Amax,slow}$
	Night (10pm–7am)	35 $dBL_{Amax,slow}$
Schools, educational institutions, places of worship	When in use	40–45 $dBL_{Amax,slow}$

These noise limits apply *inside* the property.

There are no formal limits in the RING for commercial properties. However projects usually adopt a limit of between 45–50 $dBL_{Amax,slow}$. It is therefore recommended that a limit of 35 $dBL_{Amax,slow}$ is adopted for railway groundborne noise affecting for residential dwellings for this project.

5.4.2.2 Perceptible Vibration

A different approach is taken to assessing 'feelable' vibration. The Australian guidance for acceptable groundborne and structure-borne vibration is quite confusing, particularly following some recent changes.

The relevant guideline vibration velocity limits from AS2670.2[9] and Annex C of ISO10137[10] are shown in Table 16 below.

The *multiplying factors* are applied to the base curve (which is close to the threshold of perception) to relax the criteria for different types of use. The *intermittent or impulsive* criteria would only apply to short term events such as blasting and not relevant to vibration from railway movements.

Table 16: Guideline vibration velocity limits, after AS2670.2

Place	Time	Multiplying Factors (Curve No.)	
		Continuous Vibration	Intermittent or Impulsive
Residential	Day	2	60
	Night	1.4	20

Typically, curve 1.4 is taken to be the threshold of perception and would be the appropriate criteria to assess vibration in residential units at night.

Reference is sometimes made to BS6472-1:2008 when assessing perceptible vibration. This allows calculation of a complex parameter, the Vibration Dose

[9] AS 2670-1983. Vibration and shock - Guide to the evaluation of human exposure to whole body vibration

[10] ISO 10137:2007. Bases for design of structures - Serviceability of buildings and walkways against vibrations

Value (VDV). The calculation of the VDV has to take account of vibration level *and duration* (ie number of events in a given period). Arup's experience is that maximum vibration level is more appropriate for assessing rail vibration, particularly when the timetable for rail movements is not available. It is unlikely that an assessment against VDV criteria would indicate any concerns if the maximum vibration level is below the threshold of perception.

5.4.3 Expected Internal Noise and Vibration

5.4.3.1 Methodology and Assumptions

The assessment has made reference to the data referred to above. The following corrections were then made:

Distance from railhead: A correction is made to derive the vibration level at the footings of the Sydney One development. It has been assumed that the tunnel would be through rock (a worst case assumption). As the footings are expected to be close to the rail tunnel, approximately 3 m from the tunnel, this distance-loss correction is small.

Effect of track support: assumed to be zero for the base case (any track isolation provisions have been factored into the data provided in section 5.4.1 above).

Effect of speed: assumed to be zero for the base case (ie the calculations are based on a speed of 50kph – we have not corrected for possibly higher speeds)

Foundation coupling loss: the reduction of vibration resulting at the connection between the footings and the surrounding ground – based on published data for typical piled foundations.

Slab amplification: factor to account for the *increase* in vibration level in floors as you move away from the supporting columns – based on empirical measurement data for concrete floors.

Decay of Vibration within building: An allowance for the decay of vibration with height. This is relatively low (around 1 dB per floor)

Room acoustics: the resulting noise level in the affected spaces will depend on the room acoustics of the room (how 'dead' the room feels). This will of course vary depending on the internal fitout / furnishings chosen by the eventual tenant. The room acoustic conditions have been assumed to be typical of residential property, based on the guidance in AS 2107.

5.4.4 Results

The results of the calculations are shown below:

5.4.4.1 Noise Levels

On the basis of the data provided, the analysis shows that noise levels will be around 25–30 dB $L_{Amax, fast}$. This compares with a target noise level of 35dB$L_{Amax, slow}$ for night-time and is therefore considered acceptable. As a reference, a calculation has been made using public-domain information on the vibration expected from the proposed Melbourne Metro. These calculations, using data for track with 'standard' vibration mitigation, show noise levels slightly higher than calculated with the Sydney data, but that are below the 35dBL_{Amax} target.

However it is worth noting that the vibration data given are heavily caveated (with no guarantee that the vibration levels mentioned will be achieved). In practice, there will be some variation in vibration between train sets and vibration levels are also dependant on maintenance protocols (particularly the surface roughness of the wheels and rails).

5.4.4.2 Vibration Levels

Calculations show that overall vibration levels are likely to be below curve 1.4 noted and therefore also within acceptable limits. The Figure 4 below shows the predicted vibration levels relative to those in the tunnel wall.

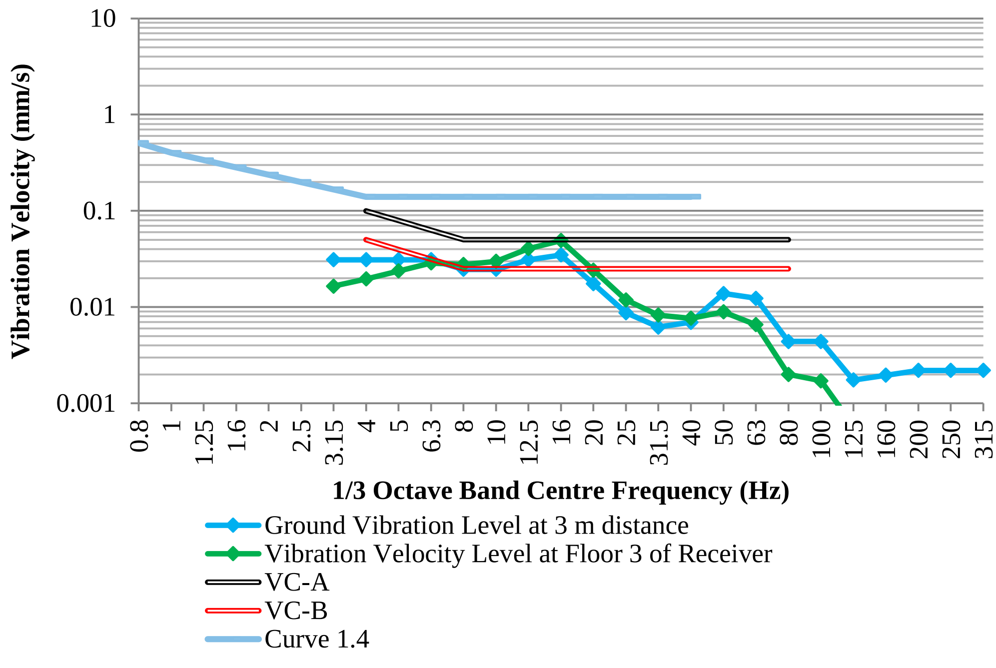


Figure 4 Predicted vibration levels relative to those in the tunnel wall

5.4.5 Conclusion

Using the data provided by Sydney Trains, it is concluded that vibration and groundborne noise at the Sydney One project is likely to be within acceptable limits.

6 Conclusion

On the basis of the information above, it is concluded that the proposed development can operate successfully within the City of Sydney and the NSW state guidelines, without noise from events or fixed equipment disturbing noise sensitive receivers in the vicinity.

The project will be constructed to a high standard with excellent acoustic amenity for guests.

Appendix A

Acoustic Terminology

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressure levels, which would be unwieldy if presented on a linear scale. Therefore a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.

dB(A)

dB(A) denotes a single-number sound pressure level that includes a frequency weighting ("A-weighting") to reflect the subjective loudness of the sound level.

The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, and so the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A).

Some typical dB(A) levels are shown below.

Sound Pressure Level dB(A)	Example
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

L_1

The L_1 statistical level is often used to represent the maximum level of a sound level that varies with time.

Mathematically, the L_1 level is the sound level exceeded for 1% of the measurement duration. As an example, 87 dB $L_{A1,15min}$ is a sound level of 87 dB(A) or higher for 1% of the 15 minute measurement period.

L_{10}

The L_{10} statistical level is often used as the “average maximum” level of a sound level that varies with time.

Mathematically, the L_{10} level is the sound level exceeded for 10% of the measurement duration. L_{10} is often used for road traffic noise assessment. As an example, 63 dB $L_{A10,18hr}$ is a sound level of 63 dB(A) or higher for 10% of the 18 hour measurement period.

L_{90}

The L_{90} statistical level is often used as the “average minimum” or “background” level of a sound level that varies with time.

Mathematically, L_{90} is the sound level exceeded for 90% of the measurement duration. As an example, 45 dB $L_{A90,15min}$ is a sound level of 45 dB(A) or higher for 90% of the 15 minute measurement period.

L_{eq}

The ‘equivalent continuous sound level’, L_{eq}, is used to describe the level of a time-varying sound or vibration measurement.

L_{eq} is often used as the “average” level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period of time (i.e. the constant sound level that contains the same sound energy as the measured level). When the dB(A) weighting is applied, the level is denoted dB $L_{Aeq.}$ Often the measurement duration is quoted, thus $L_{Aeq,15\ min}$ represents the dB(A) weighted energy-average level of a 15 minute measurement.