Yuhu Group

Eastwood Retail Development

DA Acoustic Assessment

001

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Job number 248027

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1 Introduction

Arup has been commissioned by Yuhu Group to conduct a DA Acoustic Assessment of the proposed Eastwood Retail Development.

This document identifies key acoustic considerations for the development and establishes relevant acoustic criteria. Acoustic design targets have been derived from relevant local council, state and national standards and guidelines.

A glossary of the acoustic terminology is presented in Appendix A.

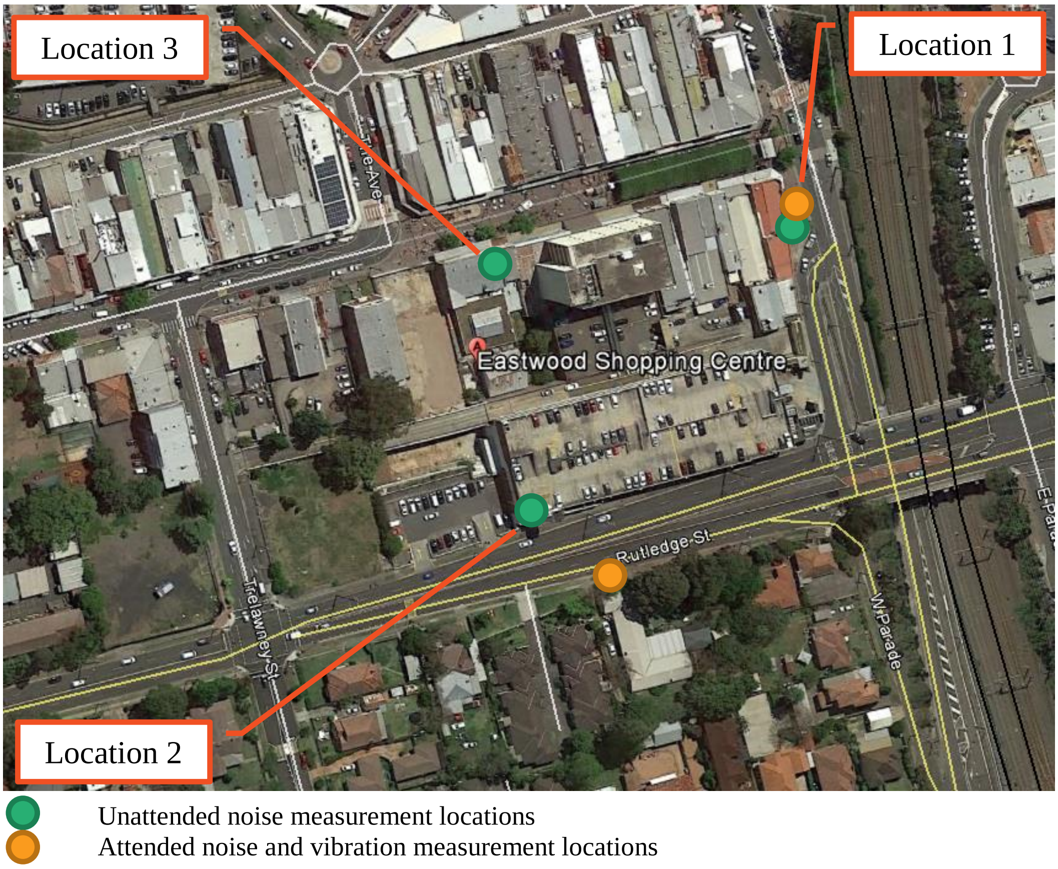
1.1 Development Site

The development site is situated approximately 100 m southwest of Eastwood train station. The site is bound by Rutledge, Trelawney and Rowe Streets and the Northern / Central Coast and Newcastle railway line.

Existing and proposed residential receivers are located across Rutledge Street to the south and Trelawney Street to the south west. Premises to the north and east are predominantly commercial.

Figure 1 shows the location of the development in the context of its surroundings along with noise and vibration monitoring locations.

Figure 1: Development site and surrounding areas

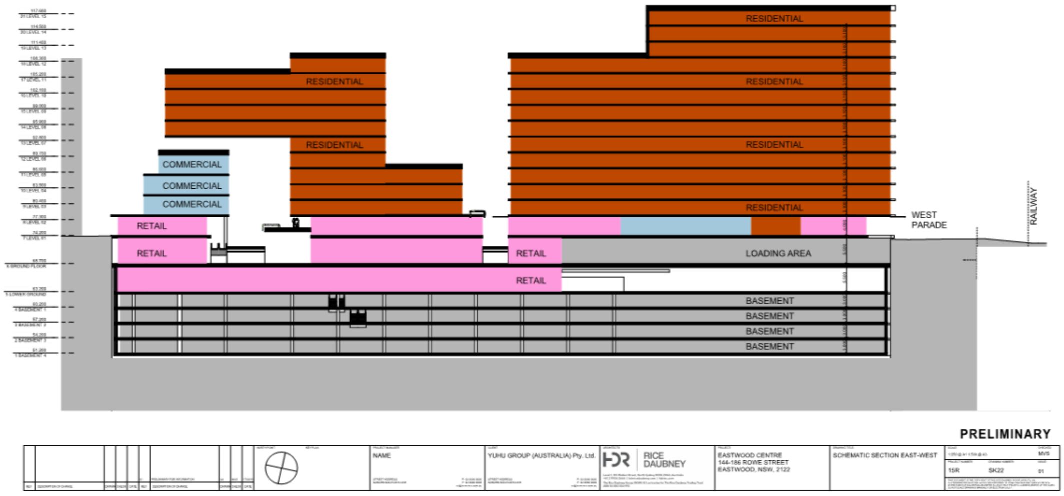


1.2 Development Description

The proposal is to demolish the existing Eastwood Shopping Centre and to erect a multiple storey, multiple tower mixed use retail, commercial and residential development.

Figure 2 shows a preliminary schematic section of the proposed development.

Figure 2: Preliminary Schematic of Development



2 Noise and Vibration Survey

A noise and vibration survey was conducted between Tuesday 1 March and Wednesday 9 March 2016. Both attended and unattended measurements were taken to establish the existing noise environment and gain a preliminary understanding of potential rail vibration impact on the development.

2.1 Equipment

The equipment used to measure the noise levels is described in Table 1. All equipment carried current calibration certificates at the time of the survey. Measurement equipment was checked for calibration before and after each set of measurements, with no significant drift observed.

Table 1: Noise and vibration monitoring equipment

Equipment model	Description of equipment	Serial No.
Brüel & Kjær 2270	Sound level meter	2754328
Brüel & Kjær 4231	Sound level calibrator	2737030
Brüel & Kjær 4294	Vibration level calibrator	2763608
PCB 352C33	ICP Accelerometer	131595
Acoustic Research Labs	Type 1 Sound logger	87807F
Acoustic Research Labs	Type 1 Sound logger	878060
Acoustic Research Labs	Type 1 Sound logger	878061

2.2 Unattended Noise Logging

Three environmental noise loggers were left on site for a period of a week at the locations identified in Figure 1. The locations were selected to provide representative ambient noise levels in the vicinity of the entire Eastwood Shopping Centre development while taking into account access and security considerations.

The noise logger microphones were located approximately 1.2 m above the first floor of the development. The L_{Aeq}, L_{Amax}, L_{A10} and L_{A90} noise indices were measured with a measurement period of 15 minutes and a fast time response.

Measured data has been processed in accordance with relevant EPA guidelines and is presented for each logger location in Table 2 and Table 3. The variation of noise levels over a typical 24 hour period (derived from averaged measured data) is illustrated in Appendix B.

Table 2: Processed unattended noise logger measurement results – Industrial Noise Policy

Logger Location	**Time Period[1]**	**Rating Background Level (RBL) – dBA**	**$L_{Aeq\ (period)}$ - dBA**
1 (Railway)	Day (7am – 6pm)	56	66
	Evening (6pm – 10pm)	54	65
	Night (10pm – 7am)	45	64
2 (Rutledge Street)	Day (7am – 6pm)	57	66
	Evening (6pm – 10pm)	53	65
	Night (10pm – 7am)	46	61
3 (Rowe Street)	Day (7am – 6pm)	56	64
	Evening (6pm – 10pm)	53	60
	Night (10pm – 7am)	48	~~63~~

[1] Time periods as defined in the EPA INP[1]

It is noted that L_{Aeq} measurements taken at the Rowe Street logger location during the night time period are anomalous to the rest of the development site. It is expected that the L_{Aeq} would decrease during the night time period as can be seen with the measured RBL. A review of the data (refer to Figure 6) shows unusually high L_{Amax} and L_{Aeq} noise events local to this logger location. These events are not considered representative of the usual prevailing ambient noise environment and will therefore be omitted from calculation of design solutions. Instead, noise levels measured at the Rutledge Street location will be used as a conservative approach to assessment.

Table 3: Processed unattended noise logger measurement results – Road Noise Policy

Logger Location	**Time Period[1]**	**$L_{Aeq\ (period)}$ - dBA**
1 (Railway)	Day (7am – 10pm)	66
	Night (10pm – 7am)	64
2 (Rutledge Street)	Day (7am – 10pm)	66
	Night (10pm – 7am)	61
3 (Rowe Street)	Day (7am – 10pm)	61
	Night (10pm – 7am)	~~63~~

[1] Time periods as defined in the EPA RNP[2]

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[1] http://www.epa.nsw.gov.au/resources/noise/ind_noise.pdf
[2] http://www.epa.nsw.gov.au/resources/noise/2011236nswroadnoisepolicy.pdf

2.3 Attended Measurements

2.3.1 Noise

Attended noise measurements were taken at each logger location to obtain spectral information. The octave band measured noise spectra are presented in Table 4.

Table 4: Attended measurement spectra – Ambient noise

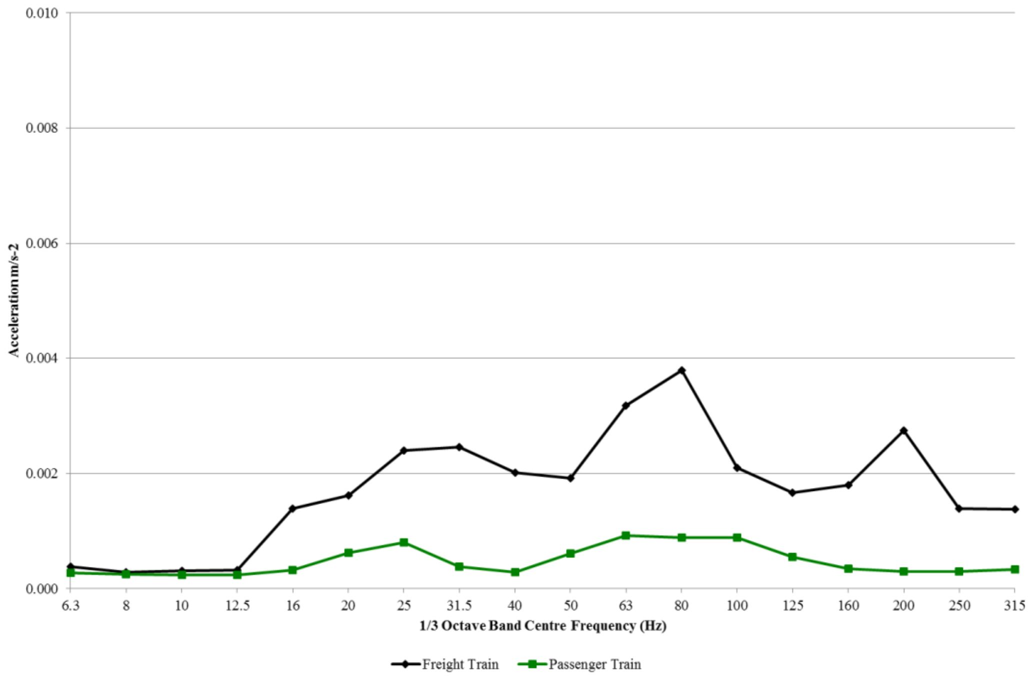
Location	dB(A)	Sound Pressure Level, dB re 20 µPa Octave Band Centre Frequency, Hz							
		63	125	250	500	1k	2k	4k	8k
1	64	75	64	63	61	59	56	49	40
2	65	72	66	63	59	59	58	55	49
3	57	66	60	58	54	52	48	42	34

2.3.2 Vibration

Attended vibration measurements were taken of rail passby events during the day on Tuesday 1 March and Wednesday 9 March. A total of 22 rail passbys were measured (15 passenger and 7 freight). Measurements were conducted at grade and corrected for distance as appropriate to be representative of levels expected at the closest point of the Eastwood Retail Development.

Figure 3 presents the highest measured L_{smax} velocity for passenger and freight train passbys (extrapolated to closest point of the development).

Figure 3: Attended measurement spectra – rail vibration (m/s^2)



3 Criteria

The City of Ryde Council Development Control Plan[3] (DCP 2014) defers to NSW state guidelines and Australian Standards for assessment criteria.

The following guidelines and standards are referenced in the sections that follow:

- NSW Industrial Noise Policy (2000)[4]
- Australian Standard 2107:2000 - Acoustics - Recommended design sound levels and reverberation times for building interiors (2000)[5]
- Development near rail corridors and busy Roads – Interim Guideline (2008)[6]
- National Construction Code (2016)[7]
- Assessing Vibration: A Technical Guideline (2006)[8]

3.1 Noise Emission

The following noise emission criteria have been derived based on the requirements of the Industrial Noise Policy (2000) and are based on measured noise logger data presented in Table 2. These criteria relate to steady state industrial noise emissions (e.g. from plant serving the development) and apply at the boundary of nearest receivers.

Table 5: INP noise emission criteria for new industrial plant

Logger Location	Time Period[1]	Residential Receivers		Commercial Receivers
		Intrusive Criteria dBL$_{Aeq(15min)}$	Amenity Criteria dBL$_{Aeq(Period)}$	
1 (Railway)	Day (7am – 6pm)	61	**56**	57
	Evening (6pm – 10pm)	59	**55**	57
	Night (10pm – 7am)	**50**	54	59
2 (Rutledge Street)	Day (7am – 6pm)	62	**56**	57
	Evening (6pm – 10pm)	58	**55**	57
	Night (10pm – 7am)	51	**51**	63
3 (Rowe Street)	Day (7am – 6pm)	61	**54**	59
	Evening (6pm – 10pm)	58	**50**	63
	Night (10pm – 7am)	53	**53**	61

[3] http://www.ryde.nsw.gov.au/Business-and-Development/Planning-Controls/Development-Control-Plan
[4] http://www.epa.nsw.gov.au/resources/noise/ind_noise.pdf
[5] http://infostore.saiglobal.com/store/details.aspx?ProductID=363589
[6] http://www.rms.nsw.gov.au/documents/projects/guideto-infrastructure-development-near-rail-corridors-busy-roads.pdf
[7] http://www.abcb.gov.au/Resources/Publications/NCC/NCC-2016-Complete-Series
[8] http://www.epa.nsw.gov.au/resources/noise/vibrationguide0643.pdf

The project specific industrial noise emission criteria are taken as the more stringent of Intrusive and Amenity criteria for residential receivers. These are marked as bold in Table 5 and are generally the Amenity criteria with the exception of night-time at Logger Location 1 for which the Intrusive criterion applies.

It is proposed that noise from emergency plant (eg emergency generator sets, smoke fans etc) be limited to 10dB above the criteria listed above for night-time operation. Any testing of the emergency plant would only be undertaken during daytime, ideally on a Saturday morning.

3.2 Internal

The following internal acoustic targets for the development are taken from AS 2107:2000. These relate to steady state noise sources such as:

- Noise from the ventilation system (expected to be present in all areas of the development on every floor)
- Break-in noise from mechanical plant within the development
- Noise from mechanical plant from surrounding buildings breaking in through the façade

Satisfactory and maximum design sound levels are provided by AS 2107. Arup generally recommends targeting the satisfactory design sound levels provided.

Table 6: AS2107 recommended internal noise levels and reverberation times

Type of occupancy/activity	**Recommended design sound level L_{Aeq} dB(A)**		**Recommended reverberation time (T) s**
	Satisfactory	**Maximum**	
RESIDENTIAL			
Houses and apartments near major roads—			-
Living areas	35	45	
Sleeping areas	30	40	
Work areas	35	45	
Apartment common areas (e.g. foyer, lift lobby)	45	55	Low as practicable
RETAIL			
Department stores—			Low as practicable
Main floor	50	55	
Upper floor	45	50	
Enclosed carparks	55	65	-
Show rooms	45	50	Low as practicable
Small retail stores (general)	45	50	Low as practicable

Type of occupancy/activity	Recommended design sound level L_{Aeq} dB(A)		Recommended reverberation time (T) s
	Satisfactory	Maximum	
Speciality shops (where detailed discussion is necessary in transactions)	40	45	Low as practicable
Supermarkets	50	55	Low as practicable
Shopping malls	45	55	Low as practicable
COMMERCIAL			
Board and conference rooms	30	40	0.6 to 0.8
Corridors and lobbies	45	50	0.4 to 0.6
General office areas	40	45	0.4 to 0.6
Private offices	35	40	0.6 to 0.8
Public spaces	40	50	0.5 to 1.0
Reception areas	40	45	Low as practicable
Rest rooms and tea rooms	40	45	0.4 to 0.6
Toilets	50	55	-

3.2.1 Noise Intrusion

In addition to the AS 2107 internal noise level targets stated above, the following noise intrusion criteria are taken from the Interim Guideline (2008)[6]. These targets relate to road and rail traffic noise intrusion into residential areas of the development.

3.2.1.1 Airborne Noise

The internal airborne noise intrusion targets for residential areas of the development are presented in Table 7.

Table 7: Airborne noise intrusion criteria for Residential Dwellings

Type of Occupancy	Applicable Time Period	Noise Level (dBA)
Sleeping Areas	Night 10pm to 7am	35 $dBL_{eq(9hr)}$
Other habitable rooms (excl. garages, kitchens, bathrooms & hallways)	At any time	40 $dBL_{eq(15hr)}$

3.2.1.2 Structureborne Noise

The structureborne noise intrusion targets for residential areas of the development are presented in Table 8. These apply to structureborne noise from external sources such as rail movements.

Table 8: Structureborne noise intrusion criteria for Residential Dwellings

Type of Occupancy	**Applicable Time Period**	**Noise Level (dBA)**
Sleeping Areas	Night 10pm to 7am	35 $dBL_{Amax(slow)}$
Other habitable rooms (excl. garages, kitchens, bathrooms & hallways)	At any time	40 $dBL_{Amax(slow)}$

3.2.2 Sound Insulation

3.2.2.1 Residential

Minimum requirements for inter-tenancy airborne and impact sound insulation for residential areas are detailed in the Australian Building Codes Board *National Construction Code 2016* in Part F5. The NCC 2016 requirements in relation to sound insulation are reproduced in Table 9.

Table 9: NCC 2016 sound insulation requirements

Construction	**NCC 2016**	
	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
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

Construction	**NCC 2016**	
	Laboratory Rating	**Verification**
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 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 NCC 2016 states that the required insulation of a floor or wall must not be compromised by a door assembly.

3.2.2.2 Commercial and Retail

For commercial areas of the development, speech privacy requirements will generally govern the sound insulation requirements. The control of noise transfer between tenancies (eg from background music) is likely to define the requirements between retail tenancies.

The enclosures around plant rooms and the minimum thickness of the slab above and below the plant room levels will need to be designed to meet the internal noise levels outlined in Table 6.

Typical constructions are provided for reference in Section 4.3 for information. These are based on typical requirements in commercial and retail developments. Specific ratings and construction types will need to be developed during detailed design once the nature of the tenancies and intended usages are defined.

3.3 Vibration Criteria

The vibration limits recommended for maintaining human comfort in residential, office and retail areas are shown in Table 10.

For intermittent sources (e.g. trains, heavy vehicles, etc), the Assessing Vibration guideline uses the Vibration Dose Value (VDV) metric to assess human comfort effects of vibration. VDV takes into account both the magnitude of vibration events and the number of instances of the vibration event.

Intermittent events that occur less than 3 times in an assessment period (either day, 7am to 10pm, or night, 10pm to 7am) are counted as "impulsive" sources for the purposes of the Assessing Vibration guideline.

Table 10: Vibration limits in AS 2670.2 for offices and retail areas

Location	**Maximum z-axis weighted rms vibration acceleration (m/s^2)**		**Vibration Dose Value ($m/s^{1.75}$)**
	Continuous	**Impulsive**	**Intermittent**
Residences	0.007	0.1	0.13
Office and retail areas	0.020	0.64	0.40

Vibration from internal and external sources could also generated significant airborne noise. The criteria in Table 8 will apply to this.

4 Assessment and Recommendations

The following sections comprise a preliminary assessment of potential noise and vibration issues associated with the development and are based on the current level of design. All recommendations are to be reviewed and revised accordingly during the detailed design of the project.

4.1 Noise Intrusion

4.1.1 Airborne Noise

The measured spectra in Table 4 have been scaled to relevant time period indices as per the processed logger data in Table 3. These scaled spectra have been used as the basis of airborne noise intrusion calculations to residential areas of the development.

Room sizes and façade glazing configurations are not available at this stage of the project. Calculations have been based on typical residential apartment layouts and glazing components.

Based on preliminary calculations, it is envisaged that residential areas of the development will generally be able to achieve internal noise intrusion criteria summarised in Section 3.2.1.1 via implementation of the following glazing types:

- East Façade: 16mm acoustic laminated glass
- South Facade: 6mm glass / 12mm air gap / 10mm glass
- West / North Facades: 6.4mm laminated glass / 12mm air gap / 10mm glass

These glazing options are provided for information only and will need to be reviewed during detailed design of the project.

The current scheme shows communal spaces for residents on Level 1, Level 2 (including pool), and Level 6. Noise impacts from these areas will depend upon proposed usage and number of residents. It is unlikely that operation of these spaces will dictate glazing selections. Most noise impacts will be able to be addressed via standard management practices to be implemented by the operator of the facility.

4.1.2 Structure Borne Noise

Structure borne noise intrusion has been calculated using the highest measured vibration spectra presented in Figure 3. Room sizes and partition types have been based on typical residential apartment configurations in lieu of detailed information being available at this stage.

Preliminary calculations indicate internal structure borne noise levels at the nearest affected residential apartment in the range 16-20 dBL_{Asmax}. This is within the criteria for structure borne noise intrusion of 35 dBL_{Asmax} given in Section 0, and therefore acceptable.

The above information indicates that no specific structural vibration isolation will be required for the development. This will need to be confirmed during detailed design of the project.

4.2 Vibration

The vibration levels extrapolated from the rail vibration measurements are significantly below the criteria given in Table 10 and not expected to be perceptible as vibration.

There is a potential for vibration and groundborne noise impacts associated with operation of the heavy vehicle turntable proposed at Ground Level. Appropriate specification and installation of this component will be required as the design progresses.

Vibration impacts associated with the proposed pool are not expected to be an issue as the pool is not located above noise sensitive areas. Further analysis may be required as the design progresses.

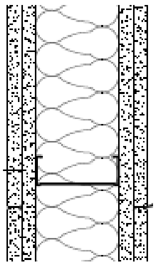
4.3 Internal Sound Insulation

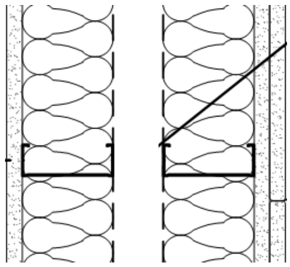
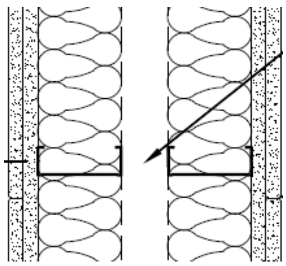
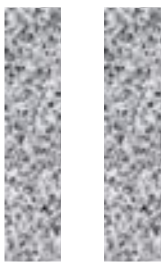
The following typical sound insulating constructions are provided for information to achieve NCC requirements and as a reference of best practice in commercial and retail developments. Specific constructions and configurations will need to be developed during detailed design.

4.3.1 Walls and Partitions

Table 11 provides a range of typical dry wall and masonry constructions for various areas of the development.

Table 11: Typical wall build ups

Wall Build-up			
COMMERCIAL INTER TENANCY WALLS	DRYWALL		2 x 13 mm high-density plasterboard 64 mm stud 2 x 13 mm high-density plasterboard 50 mm absorptive quilt in cavity

Wall Build-up			
	MASONRY		190 mm hollow block (270 kg/m^2) full height OR 140 mm solid blocks (260 kg/m^2) full height
RESIDENTIAL INTER TENANCY WALLS	DRYWALL		1 x 13 mm high-density plasterboard full height 2 x 64 mm separate studs 2 x 13 mm high-density plasterboard full height 2 x 100 mm absorptive quilt in cavity
	MASONRY		150 mm Concrete Panel
PLANT ROOMS	DRYWALL		2 x 16 mm High-Density Plasterboard full height 2 x 64 mm separate studs 2 x 16 mm High-Density Plasterboard full height 100 mm absorptive quilt in cavity
	MASONRY		140 mm Solid Block (260 kg/m^2) full height 50 mm air gap, resilient ties 140 mm Solid Block (260 kg/m^2) full height

4.3.2 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, experience has shown that a door with a sound insulation performance of 10 to 15dB less than the partition itself will be often be appropriate.

Table 12 shows typical sound insulation performances of typical door constructions for reference.

Table 12: Typical door constructions and sound insulation performances

Partition Sound Insulation Rating	Typical Corresponding Door Sound Insulation Rating	Typical Door Construction and Sealing Arrangement
R_w 35	R_w 20	32 - 35 mm solid core door with simple frame seals (e.g. Raven RP94 Si or equivalent), threshold close cut to carpet
R_w 40	R_w 25	35 mm solid core door with frame seals (e.g. Raven RP94 Si or equivalent)
R_w 45	R_w 30	35 - 40 mm solid core door with frame (e.g. Raven RP94 Si or equivalent) and threshold (e.g. Raven RP99 Si or equivalent) seals.
R_w 50	R_w 35	Proprietary door set with full set of seals.
R_w 55	R_w 40	Proprietary acoustic door set, 50-80 mm with double rebated seals

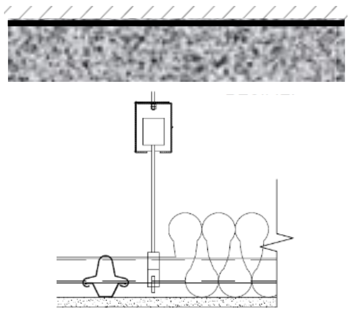
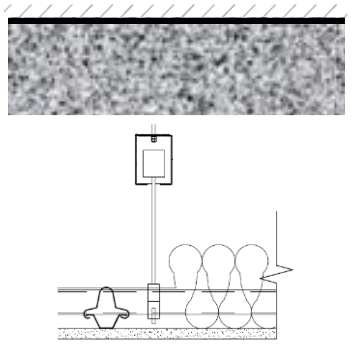
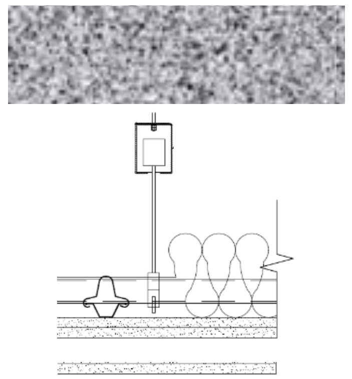
Additionally, the door ironmongery will need to provide effective compression of the door seals. Sealing mechanisms should allow for the accommodation of building tolerances and of floor level variations.

4.3.3 Floors and Ceilings

The recommended airborne sound insulation ratings listed in Section 4.3.1 for partitions will also apply to inter-tenancy floors.

Example constructions based on the current understanding of the development are provided in Table 13 for reference.

Table 13: Typical floor / ceiling constructions

Floor / Ceiling Build up		
COMMERCIAL		Carpet on underlay 140 mm concrete slab >100 mm air gap Suspended sound absorptive ceiling.
RESIDENTIAL		Floor finish with appropriate impact isolation treatment 210 mm concrete slab 150 mm air gap 1 x 13 mm high density plasterboard on resilient hanger. 50 mm absorptive quilt in cavity
PLANTROOMS		210 mm concrete slab 150 mm air gap 2 x 13 mm high density plasterboard on resilient hanger. No penetrations permitted to this ceiling layer. 50 mm absorptive quilt in cavity Additional false ceiling to house lighting and services and allow for penetrations as required.

The junction detail between floors and façade will require specific attention during detailed design. A robust acoustic sealing / fire rated detail is required that maintains the acoustic performance of the floor construction.

The current scheme shows the loading dock located on Ground Floor in the south east corner of the development. The soffit of the loading dock currently overlaps with the slab of residential bedrooms and medical centre on the floor above (Level 1). Preliminary calculations indicate that noise transfer through the slab will be within acceptable limits. These calculations make various assumptions on loading dock activities at this early stage of development. Noise and vibration impacts from this space to sensitive areas above will need to be analysed in further detail as the design progresses.

4.4 Mechanical Plant Noise Emission

The noise emission of mechanical plant associated with the development will be controlled so that the operation of such plant does not adversely impact nearby residential properties and other dwellings within the same development.

At this stage of the project the location and selection of mechanical plant has not been finalised. Therefore appropriate assessment will need to be conducted at the early design stages of the project. No particular issues with achieving appropriate noise levels are envisaged.

It is envisaged that the mechanical plant noise sources will be controllable by common engineering methods that may consist of:

- Judicious location and selection of low noise plant
- Noise barriers (eg for roof plant)
- Silencers and acoustic louvres
- Acoustically lined ductwork
- Vibration isolators

A preliminary investigation has been undertaken of potential noise impacts from proposed cooling towers at Level 10 in the southwest corner of the development to the nearest affected residential units within the development. The following glazing is predicted to sufficiently attenuate noise intrusion to these spaces:

- 6mm glass / 12mm air gap / 10mm glass

The selected mechanical equipment must be reviewed and assessed for conformance with established criteria at the detailed design stage of the project when specific plant selection and location is determined.

Appendix A

Glossary

Decibel (dB)

The ratio of sound pressures which we can hear is a ratio of 106:1 (one million : one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound level' (L) and the associated measurement unit is the decibel (dB). As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply. Some typical noise levels are given below:

Noise Level dB(A)	Example
130	Threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside disco
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud radio (in typical domestic room)
60	Office or restaurant
50	Domestic fan heater at 1m
40	Living room
30	Theatre
20	Remote countryside on still night
10	Sound insulated test chamber
0	Threshold of hearing

'A'-Weighted Sound Level dB(A)

The unit generally used for measuring environmental, traffic or industrial noise is the A-weighted sound pressure level in decibels, denoted dB(A). An A-weighting network can be built into a sound level measuring instrument such that sound levels in dB(A) can be read directly from a meter. The weighting is based on the frequency response of the human ear and has been found to correlate well with human subjective reactions to various sounds. An increase or decrease of approximately 10 dB corresponds to a subjective doubling or halving of the loudness of a noise. A change of 2 to 3 dB is subjectively barely perceptible.

Sound Power and Sound Pressure

The sound power level (Lw) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (Lp) varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located.

Frequency

The rate of repetition of a sound wave. The subjective equivalent in music is pitch. The unit of frequency is the Hertz (Hz), which is identical to cycles per second. A thousand hertz is often denoted kilohertz (kHz), eg 2 kHz = 2000 Hz. Human hearing ranges from approximately 20 Hz to 20 kHz. The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the band below it. For design purposes, the octave bands between 63 Hz to 8 kHz are generally used. For more detailed analysis, each octave band may be split into three one-third octave bands or, in some cases, narrow frequency bands.

Equivalent Continuous Sound Level (L_{Aeq})

Another index for assessment for overall noise exposure is the equivalent continuous sound level, L_{eq}. This is a notional steady level, which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level.

Statistical Noise Levels

For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index that allows for this variation. 'A'-weighted statistical noise levels are denoted L_{A10}, dBL_{A90} etc. The reference time period (T) is normally included, eg. $dBL_{A10, 5min}$ or $dBL_{A90, 8hr.}$

$L_{A90, T}$

Refers to the sound pressure level measured in dB(A), exceeded for 90% of the time interval (T) –i.e. measured noise levels were greater than this value for 90% of the time interval. This is also often referred to the background noise level.

$L_{A10, T}$

Refers to the sound pressure level measured in dB(A), exceeded for 10% of the time interval (T). This is often referred to as the average maximum noise level and is frequently used to describe traffic noise.

$L_{A10, 1 hr}$

For traffic noise, $L_{A10\ (1hr)}$ is the highest hourly L_{A10} noise level measured over each day of a measurement period. $L_{A10\ (1hr)}$ is the average maximum noise level resulting from the "worst hour" of the traffic flow.

$L_{A10,\ 18\ hr}$

$L_{A10\ (18hr)}$ refers to the arithmetic average of the eighteen 1-hour L_{A10} traffic noise levels over the time period from 6:00 am to midnight. $L_{A10\ (18hr)}$ is representative of the average maximum traffic noise level from each day of measurements.

$L_{A1,\ T}$

Refers to the sound pressure level measured in dB(A), exceeded for 1% of the time interval (T). This is often used to represent the maximum noise level from a period of measurement.

Assessment Background Level (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background LA90 noise levels – i.e. the measured background noise is above the ABL 90% of the time.

Rating Background Level (RBL)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey.

Reverberation Time (T60)

The time, in seconds, taken for a sound within a space to decay by 60 dB after the sound source has stopped is denoted at the reverberation time. The RT is an important indicator of the subjective acoustic within an auditorium. A large RT subjectively corresponds to an acoustically 'live' or 'boomy' space, while a small RT subjectively corresponds to an acoustically 'dead' or 'flat' space.

Examples of typical design reverberation times are provided below:

Mid-frequency Reverberation Time, s	Example
< 0.1	Anechoic
0.1 – 0.4	Call centres
0.4 – 0.6	Library
0.6 – 0.8	Offices / board rooms
0.8 – 1.0	Small auditorium for speech
1.0 – 1.2	Music studios

Mid-frequency Reverberation Time, s	Example
1.2 – 1.5	Chamber music venues
1.5 – 2.0	Orchestral music venues
2.0 – 3.0	Church
3.0 – 8.0	Cathedral

Vibration

Vibration may be expressed in terms of displacement, velocity and acceleration. Velocity and acceleration are most commonly used when assessing structureborne noise or human comfort issues respectively. Vibration amplitude may be quantified as a peak value, or as a root mean squared (rms) value.

Vibration amplitude can be expressed as an engineering unit value e.g. 1mms-1 or as a ratio on a logarithmic scale in decibels:

Vibration velocity level, LV (dB) = 20 log (V/Vref),

(where the preferred reference level, Vref, for vibration velocity = 10-9 m/s).

The decibel approach has advantages for manipulation and comparison of data.

Structureborne Noise

The transmission of noise energy as vibration of building elements. The energy may then be re-radiated as airborne noise. Structureborne noise is controlled by structural discontinuities, i.e. expansion joints and floating floors.

Appendix B

Noise Logging Graphs

Figure 4: 24hr average unattended noise logging results – Logger Location 1

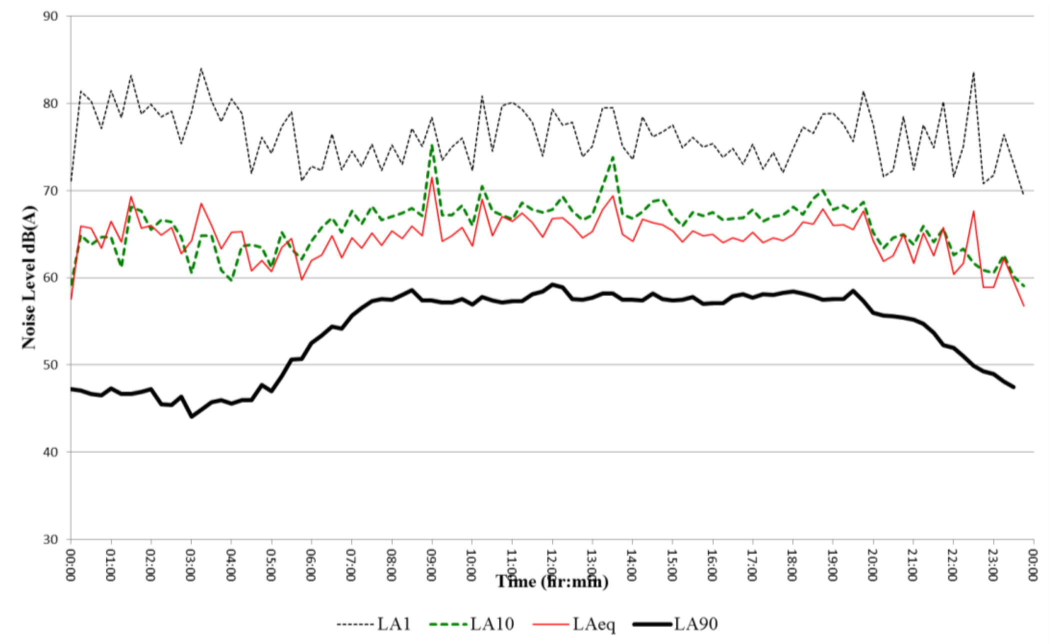
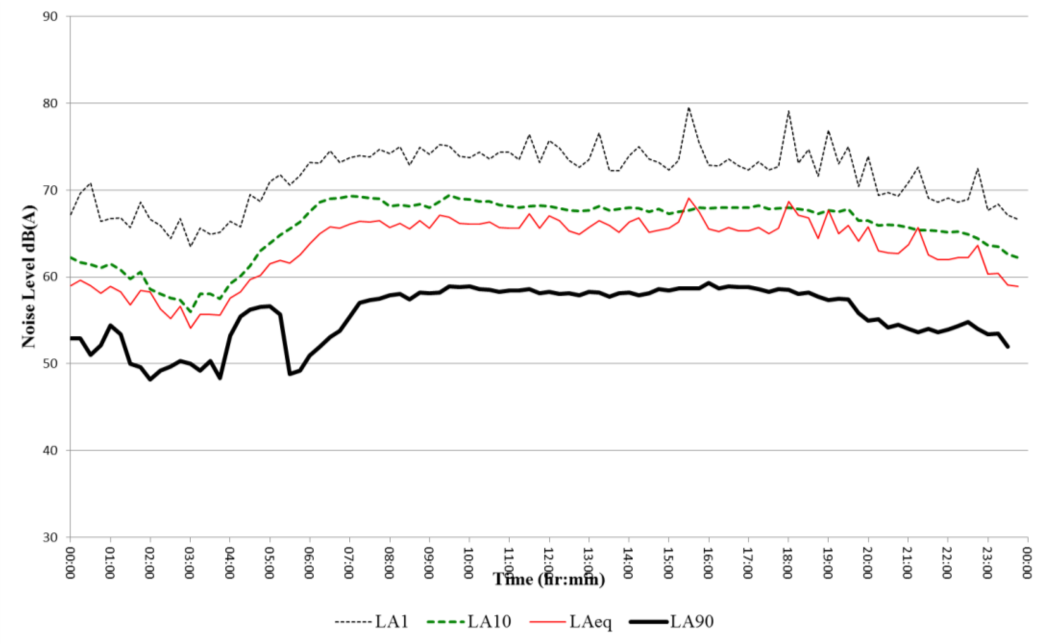


Figure 5: 24hr average unattended noise logging results – Logger Location 2



N.B. It is noted that there is a peak in L_{90} levels between 4am and 5:30am at this logger location. This is considered to be due to the influence of mechanical plant local to the logger location. Where appropriate, this data has been excluded from processing to determine assessment criteria.

Figure 6: 24hr average unattended noise logging results – Logger Location 3