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29 May 2025

Lucais Haldane
Project Manager
Capital Insight
99 Walker Street
North Sydney NSW 2060

Via email

Dear Lucais,

TAFE Bankstown – Padstow Building A Animal Studies Facility Operational and Construction Noise Emissions Assessment

Bankstown TAFE proposes to refurbish internal spaces in an existing building (Building A) to provide new TAFE Animal Studies Facility. An operational and construction noise impact review letter is required for project approval for a Review of Environmental Factors (REF).

The project will involve new plant and equipment. This plant and equipment need to be assessed to ensure compliance with environmental noise emissions criteria. Construction activities also require assessment.

This letter provides a statement of design compliance of new plant and equipment and construction activities with applicable environmental noise criteria.

We trust that this information meets your needs at this time. Please do not hesitate to contact us if you require anything further.

Yours sincerely,

Sav Shimada
Acoustic Engineer, Director

1 Background

Bankstown TAFE proposes to refurbish internal spaces in an existing building (Building A) to provide new TAFE Animal Studies Facility. An operational and construction noise impact review letter is required for the project approval for a Review of Environmental Factors (REF).

The focus of the assessments is impacts to nearby noise-sensitive receivers off campus, although residential colleges or educational / research / maintenance buildings on campus will also be reviewed as part of our environmental due diligence. A desktop study is sufficient to confirm environmental noise compliance at off-campus receivers.

2 Operational hours and proposed use

Acoustic Studio has been advised that the project qualifies as development with approval via a Review of Environmental Factors, under the State Environmental Planning Policy (SEPP) (Transport and Infrastructure 2021), Clause 3.54 'Development Permitted without Consent'.

The Project Manager, Capital Insight, has advised Acoustic Studio:

- The use will not change from prior to the refurbishment and the original approved purpose of the building as a tertiary education building (for TAFE).
- The proposed hours of operation for the proposed new plant and equipment are generally from 7:30am to 10pm (Monday to Thursday), and 7:30am to 6pm Friday. Occasional Saturday and Sunday use may occur by arrangement, and this is likely to be daytime use (8am to 6pm).

3 Local environment

Figure 1 shows an aerial view of the site and surrounding areas (from google maps, accessed 23 May 2025). The proposed Animal Studies Facilities Building A is located over 25m from the nearest residential receivers along Raine Road to the east, with direct line of sight between the project site and these residential receivers. The nearest on campus receiver buildings are educational buildings located 10m or more from the site.

The project site at TAFE Padstow is located in the Canterbury-Bankstown Council local area.

The site is located within a suburban environment characterised by low levels of local road traffic activity throughout the day and decreasing noise levels in the evening and night.

Sav Shimada of Acoustic Studio visited site on 13 February 2025 and 22 May 2025. Both site inspections were during daytime standard TAFE operating hours.

Traffic noise from major road infrastructure including the M5 Motorway is clearly audible at the street (Raine Road), despite being at a distance of more than 600m from the site. Road traffic noise contributes to a continuous background noise level on Raine Street to the east, and Cahors Road to the north.

The attended measurements of background noise carried out by Sav Shimada of Acoustic Studio, on 22 May 2025 at around 10:30-11am, were between 48-52dB(A) near the Raine Road footpath. The sound level measurements were dominated by distant traffic noise, and did not include any local road traffic passby events.

Existing noise sources within the TAFE campus are primarily from mechanical plant serving buildings. An existing roof-mounted exhaust fan was operating at the time of the 22 May 2025 site inspection. The sound level from the existing fan was approximately 55dB(A) at approximately 15-17m from the fan, with direct line of sight.

Figure 1 **Aerial view of project site and surrounding area, showing residential receiver locations off campus, and the project buildings**

Source: Google maps, accessed 23 May 2025

4 Assessment approach

4.1 Relevant Standards and Guidelines

The following acoustic standards and guidelines have been considered in establishing noise and vibration criteria and assessment for this project.

[1] NSW Protection of the Environmental Operations (POEO) Act 1997.

[2] NSW Department of Environment and Climate Change (DECC) *Interim Construction Noise Guideline* (ICNG) 2009.

[3] NSW Department of Environment and Conservation (DEC) *Assessing Vibration: A Technical Guideline* (AVTG) 2006.

[4] NSW EPA *Road Noise Policy* (RNP) 2011.

[5] NSW EPA *Noise Policy for Industry* (NSW NPI) 2017.

[6] Australian Standard AS 2436:2010 *Guide to Noise and Vibration Control on Construction, Demolition & Maintenance Sites*

[7] Australian Standard AS 1055:1997 *Acoustics – Description and Measurement of Environmental Noise*

[8] AS2107 – *Acoustics – Recommended design sound levels and reverberation times for building interiors*

[9] Australian Standard AS 2670.2:1990 *Evaluation of human exposure to whole-body vibration – Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)*

[10] British Standards Institution BS 6472:1992 *Evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)*

[11] British Standard BS7385: Part 2: 1993 *Evaluation and measurement for vibration in buildings Guide to damage levels from ground borne vibration*

[12] Local Council Guidelines, including:

- Canterbury-Bankstown Council Local Environment Plan (LEP) 2023
- Canterbury-Bankstown Council Development Control Plan (DCP) 2023

4.2 Derivation of the Environmental Noise Criteria

Acoustic Studio has been advised that the project qualifies as development permitted without consent, under the State Environmental Planning Policy (SEPP) (Transport and Infrastructure), Clause 3.54.

We understand that the noise emissions criteria that apply to the project can be taken from the recent approvals for development at the TAFE Padstow Campus, however no recent noise reports with campus-specific noise emissions criteria are available.

The noise emissions criteria are typically set:

- Noise emissions not to exceed 5dB above background noise level at or within the boundary of the most affected receiver. Noise emissions are to include any modifying factors for tonal, impulsive, low frequency or intermittent noise, as described in the NPI;
- Plant and equipment forming part of the upgrade must not generate offensive noise as defined in the Protection of Environment, Operations Act (POEO, 1997);

Vibration transmission criteria also apply. We note that vibration transmission from the type of plant associated with the development will not be perceptible at distances of more than 20m, therefore vibration is not assessed further in this letter.

Operational airborne noise criteria are derived in accordance with the NPI, as described in Appendix A. Construction noise management levels are derived in accordance with NSW EPA Interim Construction Noise Guideline (ICNG, 2009), as described in Appendix B.

The airborne operational and construction noise criteria at residential or hotel receivers are set relative to the existing background noise levels, which should ideally be measured using a minimum of one week's worth of noise logger data. In the absence of noise logger data from the area, Acoustic Studio has referenced the NSW Noise Policy for Industry (NPI, 2017) for typical and minimum background noise levels (or Rating Background Levels (RBLs) which apply at residential receiver locations.

The NPI assessment for residential receivers distinguishes between three different time periods: Day, Evening and Night time periods. Typically the night time noise targets are the lowest, and hence the most stringent, and can be used as a limiting noise criterion. Compliance with night time noise targets therefore indicate compliance with day-time and evening noise targets, and can be used as a screening test for compliance for the project.

Since noise logger data is not available, Acoustic Studio has taken a conservative approach and assume that the background noise levels are "minimum assumed RBLs" from Table 2.1 of the NPI.

For temporary construction noise, it is appropriate to adopt a more realistic estimate of background noise levels, as presented in Table 2.3 of the NPI.

5 Operational environmental noise criteria

Appendix A provides background information on how Acoustic Studio has derived conservative operational noise emissions targets for this project. Acoustic Studio recommends that the following conservative project noise emissions targets apply at residential receivers for the purpose of the environmental noise assessment of plant operating between 7am and 10pm:

- Day time (7am to 6pm): 40dB$L_{Aeq(15min)}$
- Evening (6pm to 10pm): 35dB$L_{Aeq(15min)}$

Offensive noise checks would apply a 5dB penalty to the predicted A-weighted noise levels if the noise is tonal, or if the low frequency noise dominates (defined as the C-weighted level minus the A-weighted level from the noise being 15dB or more). This is in accordance with NPI Table C.1, which applies "modifying factors" for noise types which are known to cause annoyance.

The plant and equipment noise targets at non-residential receivers, when they are in use, are:

- 40dB$L_{Aeq(busiest\ 1\text{-}hr)}$ – inside school classrooms (assumed to be similar to lecture theatres, tutorial rooms and class rooms)
- 65dBL_{Aeq} – commercial (eg outside food and beverage areas and outside office / administrative spaces)
- 55dBL_{Aeq} – active recreation area (e.g. Playford Park; this has also been applied as a non-mandatory target for pedestrian walkways and outdoor areas on campus)
- 50dBL_{Aeq} – passive recreation area (e.g. outdoor eating and study areas)

6 Environmental operational noise sources

The project mechanical consultant, Steensenvarming, has advised Acoustic Studio that most outdoor plant will be located at ground level, and at rooftop level. Much of the plant will be enclosed within the building envelope.

Some new exhaust fans will be installed as part of this project, with ductwork connected to the building envelope.

The environmental noise sources are:

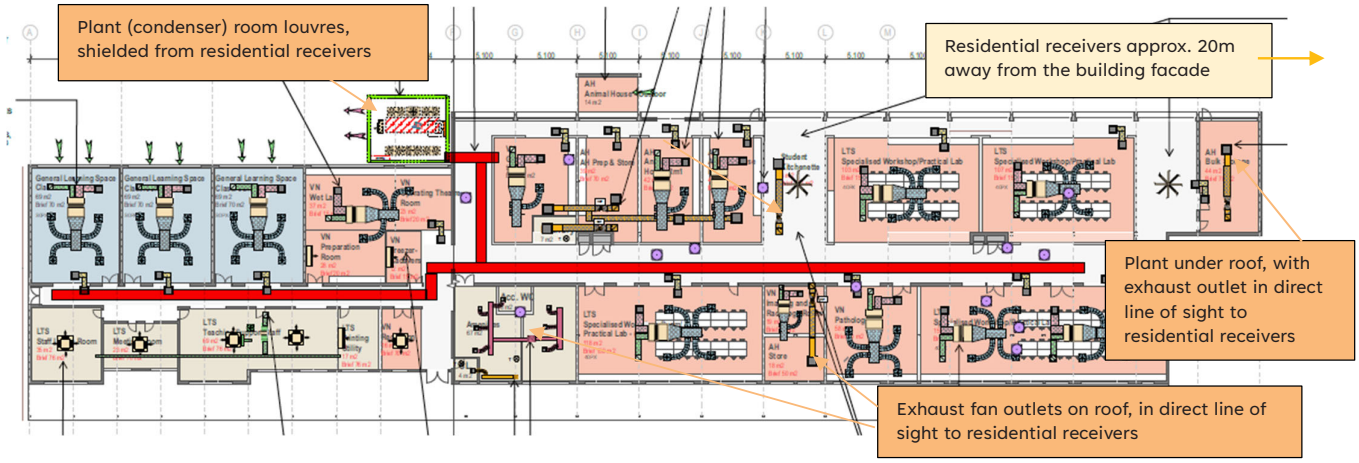
- Outdoor condenser units
- Exhaust fans
- Inlet and outlet ducts serving fan coil units and outside air fans.

The indicative location of plant is shown in the mechanical plans in Figure 2. The internal layout of the building is subject to change, which means that some of the duct inlets and outlets may change. However, the location of the exhaust fan outlet in the eastern-most part of the building, and the outdoor condenser units to the north, will both remain as shown in Figure 2. These are the dominant environmental noise sources from the proposed development.

The dominant noise sources will be located on the eastern side of the building. The nearest receivers to the east are approximately 30m from the nearest duct outlets on the eastern side of the building, and are not shielded from view. The outdoor condenser units are over 80m distant from the nearest residential receivers, and are shielded by the building itself.

Outdoor condenser units, small in-line fans, and fan coil units are not typically associated with tonal and low frequency noise characteristics, and therefore an analysis of the sound level spectrum is required to carry out the checks defined in the NPI.

Figure 2 Environmental noise sources (layout indicative; floor plan layout may be modified)



Source: Steensenvarming mechanical consultants, 16 April 2025

7 Cumulative operational noise impact

It is important to assess the potential for the cumulative impacts of different developments at the TAFE Padstow campus, to ensure that they do not result in "creeping background" noise levels and maintain acoustic amenity consistent with current existing background and ambient noise levels.

The conservatively assumed low background noise levels for this project are expected to be 5-10dB below the actual background noise levels. Therefore the noise emissions criteria adopted for this project are likely to be similar to, or approximately 5dB less than, existing background noise levels. It is unlikely that the noise generated by the proposed development new plant will contribute to overall noise emissions from TAFE Padstow campus.

If there are future projects in the area, it is possible that the nature and location of noise-generating plant for those new projects would contribute to overall environmental noise emissions from TAFE Padstow campus. Any future development would need to consider the potential for cumulative noise impacts.

8 Animal noise

Acoustic Studio has reviewed the animal facilities for the potential for animal noise to cause noise disturbance.

While there are no noise emissions criteria that apply to animal noise, reference may be made to offensive noise checklists for local councils (e.g. for barking dogs).

The proposed outdoor animal enclosures will primarily be for small animals that are not noisy.

The indoor "dog run" and fenced-off outdoor area for dogs will only be used to allow dogs to have occasional supervised breaks. Only about three dogs will be in the whole facility at any one time. Dogs can be separated if needed inside the facility. Based on this proposed use, it is unlikely that barking dogs will be an issue.

9 Assessment of environmental operational noise compliance

Acoustic Studio has reviewed the proposal and makes the following statements:

- Steensenvarming has provided Acoustic Studio with indicative sound levels for new outdoor condenser units. There are approximately 5 outdoor condenser units and are stated to be 65dB(A) at 1m. The distance attenuation over 80m is approximately 38dB relative to 1m. At least 5dB shielding is expected between the condensers and the most affected residences. The predicted sound level from all outdoor condenser units, at the nearest residence, is 29dB(A).

- In-duct noise levels for Fan Coil Units (FCUs) are typically approximately 55-65dB(A) at 1m. Exhaust fan and outside air fan in-duct noise is typically in the order of 60-65dB(A) at 1m without internal duct lining. Environment-side ducts will be internally lined, providing at least 5dB attenuation. For the purpose of the noise emissions predictions, the location of environment-side air inlets and outlets are assumed to have no shielding from residential receivers, although many would have 5-10dB shielding (depending on the location of the inlets and outlets). The distance attenuation ranges from 30dB to 39dB, depending on the location of the duct inlets and outlets in the roof. The total predicted sound level from all environment-side ducts, at the nearest residences, is 32dB(A).
- Exhaust and outside air fan and FCU case-radiated noise is typically in the order of 50-60dB(A) at 1m without acoustic enclosures. These are shown enclosed in the roof void at high level, with at least 10dB attenuation through lightweight roof structures. The distance attenuation ranges from 30dB to 39dB, depending on the location of the fans and FCUs in the roof void. The total predicted sound level from all environment-side ducts, at the nearest residences, is 22dB(A);
- Condensers, fan coil units and small axial exhaust fans are unlikely to exhibit low frequency dominance, tonality, impulsive or intermittent noise. The noise characteristics are noted in the NPI as attracting a "penalty", as part of the "offensive noise" check. The equipment selection indicates that no penalty would apply;
- This results in total plant noise being 34dB(A) at the nearest residential receiver, which complies with the most stringent assumed 35dB(A) evening target.

Based on the above, noise emissions from the proposed TAFE Padstow Animal Studies Facility project are expected to comply with applicable noise targets at the most-affected residential receivers.

10 Construction noise and vibration assessment

A construction noise and vibration impact assessment is required for the project approval for a Review of Environmental Factors (REF).

The works are expected to last for approximately 6 months.

The key acoustic considerations for the project are potential impacts from demolition and construction plant and activities associated with:

- Airborne noise from demolition and construction plant and activities on site.
- Vibration from demolition and construction activities on site (unlikely).
- Road traffic noise from construction-related vehicles accessing and departing the site.

Each of these aspects has been assessed in this Construction Noise and Vibration Impact Assessment.

10.1 Proposed Construction Hours

Standard construction hours are defined in the ICNG as follows:

- Monday to Friday - 7:00am to 6:00pm
- Saturday - 8:00am to 1:00pm
- Sunday and Public Holidays – No works.

The proposed works would adhere to the local restrictions on work hours.

10.2 Background noise levels

The ICNG sets airborne noise management levels (NMLs) at residential receivers relative to the existing background noise levels. Ideally the background noise levels would be measured using a minimum of one week's worth of noise logger data. In the absence of noise logger data from the area, Acoustic Studio has referenced the NSW Noise Policy for Industry (NPfI, 2017) and TfNSW for typical background noise levels (or Rating Background Levels (RBLs) which apply at residential receiver locations. Appendix B details the reference RBLs and how the construction airborne NML has been derived for this project.

The NPfI assessment for residential receivers distinguishes between three different time periods: Day, Evening and Night time periods. Only daytime background noise levels are relevant for the construction activities, as construction is only planned for daytime hours (defined as 7am to 6pm).

Making assumptions about background noise levels is acceptable because:

- Construction activities are temporary in nature, and therefore the ICNG focusses on practical mitigation measures rather than numeric assessments and compliance with numeric criteria. The daytime noise management level is not considered to be a limit that must be met, but rather a target to work towards;
- In all cases, standard noise and vibration management measures should be implemented where reasonable and feasible. Therefore the same site management measures would apply, regardless of the predicted excess above a conservatively assumed, or accurately measured, NML at this site; and
- Due to the nature and location of the proposal, it is highly unlikely that non-standard construction noise controls will be needed to meet the low assumed noise management level. Therefore there are no adverse cost implications for the project.

The assumed daytime RBL at the nearest residential receivers is 45dB(A).

11 Construction Noise and Vibration

11.1 Construction Noise and Vibration – Human Comfort

The primary reference for managing noise and vibration from construction and maintenance is the Environment Protection Authority (EPA) *Interim Construction Noise Guideline* ("ICNG", 2009).

This Guideline emphasises identifying potential impacts and how these may be managed and mitigated. A qualitative assessment is required for all works. For longer duration works lasting more than three weeks, or for short-duration works with potential impacts, an additional quantitative assessment step with noise predictions is required.

The ICNG focuses on airborne noise impacts, and makes reference to the EPA's *Assessing Vibration: A Technical Guideline* (AVATG, 2006), which provides useful guidance on assessing and managing vibration impacts from works, and the EPA's Road Noise Policy (RNP, 2011) for noise impacts from construction-related vehicles on public roads outside of the works premises.

Table 1 Summary of applicable guidelines

Acoustic Consideration	Applicable Standard / Guideline	Relevant Section in Report
Construction Noise and Vibration		
Noise	Interim Construction Noise Guideline [2 in Section 4.1]	Section 11.5, 11.4, 11.6
Vibration	Assessing Vibration, a Technical Guideline [3 in Section 4.1]	
Traffic Noise generation (off site)	Road Noise Policy [4 in Section 4.1]	

The ICNG and the associated AVATG and RNP present quantitative (numeric) noise and vibration management levels which are considered to represent an acceptable construction noise and vibration level different receiver types. These are based on human comfort.

Appendix B outlines the relevant Project Specific Noise and Vibration Targets based on the measured background and ambient noise levels at nearby residential receivers, and application of the relevant standards and guidelines for this project.

The conservatively determined **Noise Management Level at the nearest residential receivers is 55dB(A)**, for works carried out during standard construction hours. Outside standard construction hours, for example if Saturday afternoon works were considered, the NML is 50dB(A).

11.2 Construction Vibration

The ICNG focuses on airborne noise impacts, and makes reference to the EPA's *Assessing Vibration: A Technical Guideline* (AVATG, 2006) provides useful guidance on assessing and managing vibration impacts from works.

For vibration-related damage to buildings and structures, there is no Australian Standard or Guideline which directly applies. Industry standard in NSW is to assess structural effects from vibration in accordance with British Standard BS7385 [10 in Section 4.1].

Appendix B outlines the vibration criteria which would apply to different types of structure, and infrastructure systems such as buried pipes.

The process for assessing potential vibration impacts is to carry out a screening test to determine if vibration-generating activities are located within the potential vibration impact zone of buried structures. If vibration-generating activities are located inside the recommended minimum distance, then a more detailed vibration review is warranted.

All off-site buildings are outside the recommended minimum working distance from unreinforced buildings, and no vibration-related construction impacts are predicted.

11.3 Description of Proposed Works

According to information provided by the Project Manager, the construction will be carried out during approximately 6 months and involves:

- Partial demolition of existing internal components of Building A, including internal walls and doors, disconnection of services, and temporary propping
- Construction of internal strengthening structures, walls, doors, floor, ceilings, joinery, metalwork and fitments
- Installation of external and internal plant, including new grilles and louvres at the building envelope
- Internal refurbishment works including new partitions, finishes and furnishings
- Minor external works including an outdoor animal shelter / housing for small animals, landscaping works.

Table 2 describes the phases of work, typical plant and activities expected to carry out the work, and likely subjective impacts. Typical sound levels are presented in the table. These are taken from a range of sources[1]. Listed sound pressure levels are presented as $dBL_{Aeq(15min)}$ sound pressure level at 10m from the plant, and account for duration characteristics of works (for example, continuous noise or intermittent noise during any 15-minute assessment interval). The 5dB penalty of "annoying" characteristics is not included in the sound level data in Table 2 below. The 5dB penalty is added to the predicted total construction noise level, from all concurrent activities, if annoying characteristics are considered to be present.

Table 2 Indicative work phases and subjective impact considerations

Noise Scenario / Activity	List of plant and typical noise level ($dBL_{Aeq,15min}$) at 10m without penalty	Notes on subjective impact
Site setup	Hand tools (74) Utility vehicles (75) Truck, forklift (79) Generator (4 stroke petrol) (75) Generator, 37kVA (52)	Mains power will likely be used, therefore no requirement for a portable generator. Impacts expected to be low, similar to existing operational noise from the nearby maintenance facility.
Building demolition	Mobile Franna crane (70) Excavator, max. 8T with bucket (75) Elevated work platform (74) Steel / concrete saw* (87) Hand-held jackhammer* (88)	High vibration: N** Tones and impulses: Y – *steel / concrete saw, jackhammer and tonal movement alarms

[1] TfNSW *Construction Noise and Vibration Guideline – Public Transport Infrastructure* (September 2023), TfNSW RMS Construction Noise and Vibration Guideline (CNVG, 2018), AS2436:2010, UK DEFRA 2005, internal Acoustic Studio records and database

	Sledgehammer (84) Truck, front end loader (84) Medium-rigid 20T truck (75) Hand tools (petrol / electric) (74) Dump truck (tipping material) (79)	
Construction including external plant slab	Mobile Franna crane (70) Alimak or Man material hoist (79) Truck, front end loader (83) Skidsteer loader ½ tonne (76) Hand tools (74) Concrete mixer (81) Concrete pump (80) Concrete vibrator (electric / motorised) (72) Hammer drill / percussive drill (83) Rattle gun / impact wrench* (73)	High vibration: N Tones and impulses: Y – Hand tools (e.g. rattle gun) and tonal movement alarms
Internal works	Hammer / percussive drill (83) Electric core drill (85) Rattle gun / impact wrench* (73) Electric hand tools (74) Electric hand-held drill (63) Utility vehicles (75)	High vibration: N Tones and impulses: Y – Hand tools and tonal movement alarms
Landscaping and outdoor enclosures (minor)	Chainsaw, petrol[2] (83) Excavator (75) Small compactor (78) Small vibratory roller* / smooth drum roller[2] (80) Wacker packer (72) Soft Landscaping works[2] (<80) Tip truck (tipping soil) (62)	High vibration: N (if vibratory roller used, vibration is generated but not perceptible at residential location) Tones and impulses: Y – tonal movement alarms [2] Minor hedge removal, minor repairs in carpark if needed, new turf

Note: * Plant with impulsive or tonal content are considered to be more annoying, and include tonal metal or concrete saw cutting noise, impulsive breaking of material, and tonal reversing and vertical movement alarms on vehicles, mobile cranes and EWPs. Plant associated with perceptible vibration can also be annoying.
** Vibration not perceived at residential locations

To gauge the level of risk of the works disturbing nearby residential receivers, the sound levels of the main plant items range from 70dB(A) to 93dB(A) at 10m from each plant item. The 93dB(A) includes a 5dB penalty applied to "annoying" noise characteristics from a jackhammer and concrete / steel saw.

The distance attenuation without any screening to the nearest residential receivers is at least 10dB relative to 10m from the noise source. Greater attenuation up to 19dB relative to 10m will occur for works more distant to the nearest receivers (i.e. as works move west along the building).

Therefore the predicted range in construction noise levels at any residential receiver is 45-73dB(A) at residences to the east. At worst, temporary noise impacts from the loudest plant (jackhammer, chainsaw) would be up to 13-18dB above the 55dB(A) assumed day-time Noise Management Level (NML).

This noise would be temporary, and the highest noise events from chainsaws and jackhammering would not be continuous throughout the work day. Typical construction support activities, apart from the "high noise" saws, breakers and jackhammers, are likely to be 45-61dB(A) at the nearest affected receivers.

The NML is not a noise limit. Instead the ICNG applies the NML to represent the construction noise level which is deemed acceptable to most people, without any further mitigation measures. If the NML is exceeded, then reasonable and feasible mitigation measures should be applied.

In accordance with the ICNG, since the noisier activities are predicted to exceed the applicable NML, and because subjectively impactful plant and activities have been identified, feasible and reasonable noise mitigation measures shall apply.

11.4 Construction Vibration screening review

The distance attenuation over 25m to the nearest residential receivers is sufficient to ensure that vibration from the works would not be perceptible at any residential receiver.

This assessment assumes that there are no particularly susceptible underground services (such as sensitive ductwork, pipes or infrastructure) in the vicinity of high vibration plant.

If public buried structures are located inside the recommended minimum working distance from the work, there is a risk of vibration-induced damage. It is the Contractor's responsibility to check for nearby buried structures, and avoid vibration-generating works within the safe working distances presented in Appendix B.3 Buried pipework and services.

11.5 Construction Noise and Vibration Mitigation Measures

The checklist for work practices from the ICNG, Section 5.2, should be referenced when planning with works.

Construction should all be carried out during the standard daytime working hours where possible. The noisiest activities such as saw cutting, jackhammering and should take place during standard work hours, i.e. 7am to 6pm on weekdays or Saturday between 8am and 1pm. Outside these periods, for example Saturday afternoon 1pm to 4pm, mitigation measures may need to be implemented.

Equipment that may be considered loud are the jackhammer and concrete saw. These plant items also attract an "annoying" noise penalty due to impulsive and tonal noise content. Work involving this equipment should implement noise screening such as noise curtains or solid hoarding, to break the line of sight between the works and the residential receivers and provide at least 10dB noise shielding.

Waste materials can generate impulsive noise if dropped from heights. Damped waste chutes can mitigate this noise, if it is not possible to carefully shift large building elements onto truck beds by crane. Truck beds can be damped with rubber or carpet sheeting to reduce impact noise.

Electric tools including chainsaws should be selected instead of petrol or pneumatic tools where possible.

A common cause of annoyance is tonal movement alarms on vehicles, cranes and elevated work platforms. Consideration should be made to use non-tonal reversing and vertical movement alarms, if such plant is available.

Procurement managers responsible for hire or purchase of equipment should consider noise and vibration. For plant items known to generate high noise or vibration levels, such as saws, breakers and jackhammers, hire companies should provide quality assurance relating to maintenance of plant and equipment, such as regular inspections of features affecting noise (eg mufflers), and periodic or spot-check noise level measurements.

Measured sound levels should be within the recommended maximum noise levels provided in AS 2436-2010 *Guide to Noise Control on Construction, Maintenance and Demolition Sites*. The smallest and quietest tool should be selected that is suitable for carrying out the work.

11.6 Construction-related Traffic Noise Impact

Construction-related road traffic is a temporary noise source but one which requires assessment and management, particularly for heavy vehicles accessing the site.

Construction vehicles likely to be generated by the proposed construction activities include:

- Articulated trucks for the delivery of machinery (including mobile cranes);
- Trucks to collect demolition materials;
- General vehicles such as medium rigid trucks, tradespeople's utilities and courier vans.

The temporary additional traffic increase due to construction would not result in an increase of 2 dB, which is considered to be noticeable (as noted in Appendix B.4).

However, it is also important to recognise that heavy vehicles associated with construction can generate maximum noise levels which are higher than general car traffic, and can lead to greater disturbance than cars.

Driver behaviour should be managed to minimise impacts.

Engine braking should be avoided, speed limits strictly observed, and heavy braking and accelerating avoided. These noise avoidance driver behaviours may need to be enforced through observation and monitoring, and all contractors and subcontractors are to be made aware of the need for noise-considerate driver behaviour when travelling to and from the work site.

Truck arrivals to and departures from site should be scheduled to occur outside the busiest traffic periods, but where possible should also avoid noise-sensitive night time periods.

Over-sized vehicles and deliveries may be required out of standard work hours to meet road safety requirements (for example, under a Road Occupancy Licence).

11.7 Complaints Management

The following procedures are an example of the procedures that would be specifically adopted for complaints relating to noise and vibration.

Upon receipt of a complaint The Contractor would:

- Try to ascertain from the complaint which appliance is causing the problem i.e. inside or outside the site and in what position;
- Establish from the monitoring equipment if the allowable noise levels have been complied with;
- Establish if the appliance positioning has previously been highlighted as a problem area. If not and the noise levels are above the allowable limit, then the equipment and its position shall be noted;
- Move machinery if the allowable levels have been exceeded or take other acoustic remedial action.

Any activity which is directed to cease due to excessive noise would not recommence until the Project Manager is satisfied that the feasible and reasonable noise mitigation measures are being implemented, and has given permission to recommence the activity.

The Site Supervisor shall ensure that a report of any incident is provided to the Project Manager. The Project Manager would provide a report on the incident to the relevant stakeholders, if requested.

The Contractor shall provide a telephone contact number and this number would be prominently displayed on the site. Research staff should be provided with the contact name and number, particularly for vibration-generating works, to request that works are stopped if equipment is found to be affected by vibration.

Appendix A Summary of Operational Noise Guidelines

The airborne noise criteria at residential or hotel receivers are set relative to the existing background noise levels, which should ideally be measured using a minimum of one week's worth of noise logger data. In the absence of noise logger data from the area, Acoustic Studio has referenced the NSW Noise Policy for Industry (NPfI, 2017) for typical and minimum background noise levels (or Rating Background Levels (RBLs)) which apply at residential receiver locations.

The NPI assessment for residential receivers distinguishes between three different time periods: Day, Evening and Night time periods. Typically the night time noise targets are the lowest, and hence the most stringent, and can be used as a limiting noise criterion. Compliance with night time noise targets therefore indicate compliance with day-time and evening noise targets, and can be used as a screening test for compliance for the project.

The NPI sets two methods to determining project-specific noise trigger levels at residential receivers (excluding hotels which have trigger levels set at 5dB above the residential level):

- The Intrusiveness level is set at 5dB above the background noise level; and
- The Amenity level is a pre-defined level based on the area (in this case, suburban residential).

By assuming "minimum" background noise levels, we are likely underpredicting background levels by 5-10dB, as explained in the following page. However, this conservative approach is acceptable for the operational noise assessment because:

- Compliance with the low assumed criterion will ensure compliance with the actual background + 5dB criteria; and
- Due to the nature and location of the proposal, it is highly unlikely that noise controls will be needed to meet the low assumed criterion. Therefore there are no adverse cost implications for the project.

Figure 3 Excerpt from Noise Policy for Industry Table 2.1, with minimum assumed RBLs for assessing intrusive operational noise, and Table 2.3 showing typical RBLs in different residential receiver categories

Minimum assumed RBLs apply in this policy. These result in minimum intrusiveness noise levels as follows:

Table 2.1: Minimum assumed RBLs and project intrusiveness noise levels.

Time of day	Minimum assumed rating background noise level (dB[A])	Minimum project intrusiveness noise levels ($L_{Aeq,15min}$ dB[A])
Day	35	40
Evening	30	35
Night	30	35

Table 2.3: Determining which of the residential receiver categories applies.

Receiver category	Typical planning zoning – standard instrument*	Typical existing background noise levels	Description
Rural residential	RU1 – primary production RU2 – rural landscape RU4 – primary production small lots R5 – large lot residential E4 – environmental living	Daytime RBL <40 dB(A) Evening RBL <35 dB(A) Night RBL <30 dB(A)	**Rural** – an area with an acoustical environment that is dominated by natural sounds, having little or no road traffic noise and generally characterised by low background noise levels. Settlement patterns would be typically sparse. Note: Where background noise levels are higher than those presented in column 3 due to existing industry or intensive agricultural activities, the selection of a higher noise amenity area should be considered.
Suburban residential	RU5 – village RU6 – transition	Daytime RBL<45 dB(A) Evening RBL<40 dB(A)	**Suburban** – an area that has local traffic with characteristically intermittent traffic flows or with some limited commerce or industry. This area often has the

	R2 – low density residential R3 – medium density residential E2 – environmental conservation E3 – environmental management	Night RBL <35dB(A)	following characteristic: evening ambient noise levels defined by the natural environment and human activity.

The background noise levels are likely to be “suburban residential” from Table 2.3:

- Day (7am to 6pm): 45dB$L_{A90(15min)}$
- Evening (6pm to 10pm): 40dB$L_{A90(15min)}$
- Night (10pm to 7am): 35dB$L_{A90(15min)}$

However, since noise logger data is not available, Acoustic Studio has taken a conservative approach and assume that the background noise levels are “minimum assumed RBLs” from Table 2.1 of the NPI:

- Day (7am to 6pm): 35dB$L_{A90(15min)}$
- Evening (6pm to 10pm): 30dB$L_{A90(15min)}$
- Night (10pm to 7am): 30dB$L_{A90(15min)}$

These minimum RBLs are 10dB lower than typical suburban residential areas during Day and Evening hours (7am to 10pm), and 5dB lower at night (10pm to 7am). Therefore meeting the criteria set relative to minimum assumed RBLs guarantees compliance with the criteria set relative to the actual RBLs, as they are 5-10dB higher than assumed.

The ANLs applicable to residential receivers near or in the TAFE campus are:

- Day time (7am to 6pm): 55dB$L_{Aeq(11hr)}$ – suburban residential
- Evening (6pm to 10pm): 50dB$L_{Aeq(4hr)}$ – suburban residential
- Night (10pm to 7am): 40dB$L_{Aeq(11hr)}$ – suburban residential

The NPI allows a direct comparison between the 15-minute intrusiveness target and the period amenity target by assigning a correction:

Amenity target = ANL(period) – 5dB + 3dB conversion to 15-minute level

This means the project-specific residential noise level targets are:

- Day time (7am to 6pm): 53dB$L_{Aeq(15min)}$ (Amenity), 40dB$L_{Aeq(15min)}$ intrusiveness
- Evening (6pm to 10pm): 48dB$L_{Aeq(15min)}$ (Amenity), 35dB$L_{Aeq(15min)}$ intrusiveness
- Night (10pm to 7am): 38dB$L_{Aeq(15min)}$ (Amenity), 35dB$L_{Aeq(15min)}$ intrusiveness

These targets are non-mandatory on campus and mandatory off campus.

The most stringent (lower) of the Amenity and Intrusiveness targets is used to assess environmental noise for the project. Therefore the conservatively assumed Intrusiveness target would apply to this project.

For the internal noise level assessment, the most stringent criteria for a residential building is for a bedroom or sleeping area. AS2107 recommends 35dB(A) internal noise levels in bedrooms that are not on busy roads.

Assuming that the windows of a bedroom can be kept open to achieve natural ventilation, the NPI assumes a 10dB attenuation from outside to inside through an open window.

The Amenity Noise Level at non-residential receivers, when they are in use, are:

- 40dB$L_{Aeq(busiest\ 1\text{-}hr)}$ – inside school classrooms (assumed to be similar to lecture theatres, tutorial rooms and class rooms)
- 65dBL_{Aeq} – commercial (eg outside food and beverage areas and outside office / administrative spaces)
- 55-60dBL_{Aeq} – active recreation area (e.g. sports fields; this has been applied to pedestrian walkways and outdoor areas on campus)
- 50dBL_{Aeq} – passive recreation area (e.g. outdoor eating and study areas).

Appendix B Summary of Construction Noise and Vibration Guidelines

B.1 Noise

The relevant guideline applied for the assessment of construction noise is the ICNG. This guideline provides construction Noise Management Levels for Residential, Commercial, and Industrial noise receivers as follows.

Table 3 Residential construction Noise Management Levels for airborne noise as outlined in the ICNG

Time of Day	Management level LAeq (15 min)	How to Apply
Recommended standard hours: **Monday to Friday** **7 am to 6 pm** **Saturday 8 am to 1 pm** **No work on Sundays or public holidays**	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured LAeq (15 min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details
	Highly noise affected 75dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by 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.
Outside recommended standard hours:	Noise affected RBL + 5 dB	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community.

Residential Receivers

Section 4 of the ICNG provides recommendations for standard hours of work and suggests construction Noise Management Levels that aim to minimise the likelihood of annoyance caused to noise sensitive receivers. These consider both airborne and ground borne noise level impacts.

Table 3 outlines the methodology for determining construction Noise Management Levels (NML) at nearby residential receivers surrounding the development site based on existing background noise levels. The NML is set relative to the Rating Background Level (RBL), or "background" noise level.

Ambient and background noise levels are directly measured using a noise logger, capturing at least seven days' worth of valid data, in according with methodology described in the NSW EPA *Industrial Noise Policy for Industry* (NPfI, 2017). Because noise logging has not been carried out for this project, due to the low risk profile of the works and distance from sensitive receivers, the NPI, AS1055 and Table 1.1.1 in the TfNSW *Construction Noise and Vibration Guideline – Public Transport Infrastructure* (September 2023) have been referenced to estimate background noise levels which apply at residential receiver locations.

As stated in Appendix A, the NPfI assessment for residential receivers distinguishes between three different time periods: Day, Evening and Night time periods. Only daytime background noise levels are relevant for the construction activities, as construction is only planned for daytime hours (defined as 7am to 6pm).

The background noise levels are likely to be "suburban residential" from Table 2.3:

- Day (7am to 6pm): 45dB$L_{A90(15min)}$

For reference, the "minimum assumed RBLs" from Table 2.1 of the NPI are for any residential area including in rural areas:

- Day (7am to 6pm): 35dB$L_{A90(15min)}$

The minimum Daytime RBL is 10dB lower than typical suburban residential areas.

By assuming "minimum" background noise levels, we are likely underpredicting background levels by approximately 10dB, as explained below and in the following page. This conservative approach is acceptable if:

- Compliance with the low assumed criterion will ensure compliance with the actual background + 5dB criteria;
- The daytime noise management level is not considered to be a limit that must be met, but rather a target to work towards. In all cases, standard noise and vibration management measures should be implemented where reasonable and feasible. Therefore the same site management measures would apply, regardless of the predicted excess above a conservatively or realistically assumed NML at this site; and
- Due to the nature and location of the proposal, it is highly unlikely that non-standard construction noise controls will be needed to meet the low assumed noise management level. Therefore there are no adverse cost implications for the project.

However, if the NMLs based on "minimum" background noise levels result in predicted excess up to 10dB, resulting in a requirement to mitigate the noise beyond typical construction management methods, this can adversely affect the project in a manner that is not commensurate with the actual likely impacts on residential receivers. In this case, a more realistic RBL should apply, based on the residential area category.

A further demonstration that the assumed RBLs are conservative is Table 1.1.1 in the TfNSW *Construction Noise and Vibration Guideline – Public Transport Infrastructure* (September 2023). Table 1.1.1 (copied overleaf for reference) presents typical background noise levels in residential areas. The R2 or R3 categories are aligned with the local residential receivers near the project worksite. Table 1.1.1 suggests that typical daytime background noise levels in R2 and R3 categories are 45-50dB(A), i.e. 10-15dB above the assumed minimum in Table 2.1 of the NPI.

Figure 4 Excerpt from TfNSW Construction Noise and Vibration Guideline – Public Transport Infrastructure, Table 1.1.1 in Appendix B.1.1, showing typical background noise levels in different residential receiver categories

B.1.1 Estimated

Assumed background noise levels based on Australian Standard AS1055 may be used as an estimate for simple noise assessments. Note that existing data from other projects or short-term attended measurements should be used to assist in establishing noise management levels where possible.

Table A1: Typical background noise levels for different areas surrounding Transport projects

Noise area category	Description of area surrounding Transport project	RBL Day	RBL Evening	RBL Night
R0	Area of rural isolated residences separated by over 500m from transport corridors	30	30	30
R1	Areas with negligible transportation	40	35	30
R2	Areas with low density transportation	45	40	35
R3	Areas with medium density transportation OR some commerce or industry	50	45	40
R4	Areas with dense transportation OR with some commerce or industry	55	50	45
R5	Areas where it is predominantly commercial and densely concentrated skyscrapers	60	55	50

These estimated background noise levels are summarised in Table 4 Indicative range of daytime background noise levels. below. Although the site inspection indicated a steady stream of road traffic noise from the nearby M5 Motorway, without long term noise logger sound level measurement data to confirm, it is appropriate to apply the more conservative "low density transportation" assumed background noise level (45dB(A)) for this project.

Table 4 Indicative range of daytime background noise levels.

Residential Area	RBL, dBLA90	
	Day	Reference
Residential, minimum background (for any type of area including rural)	30	NPI Table 2.1
Residential rural	40	NPI Table 2.3
Residential suburban	45	NPI Table 2.3
Residential R2, low density transportation	45	TfNSW CNVG – PTI Table 1.1.1
Residential R2, medium density transportation	50	TfNSW CNVG – PTI Table 1.1.1

Non-Residential Receivers: Commercial, Industrial and Educational Receivers

The ICNG also provides recommended construction Noise Management Levels for commercial, industrial and educational facilities surrounding a construction site, which are as follows:

Table 5 Industrial, commercial, educational and hospital construction Noise Management Levels for airborne noise

Occupancy	Management level $L_{eq,15\ min}$, dB(A)
Offices, retail outlets, commercial	70 - External
Hospital wards and operating theatres	45 - Internal / 65 - External[2]
Classrooms at schools and other educational institutions	45 - Internal / 65 - External[3]

In summary, the following project specific noise management levels apply, using the background noise level assumptions for the residential receivers:

- At residential receivers: 55dB(A) – Day (standard), 50dB(A) Saturday 1pm to 4pm
- At commercial receivers including buildings with offices and general research facilities: 65dB(A) external.

Ground-Borne Noise

The ICNG also recommends ground-borne Noise Management Levels at residences affected by nearby construction activities. Ground-borne noise is noise generated by vibration transmitted through the ground into a structure and can be more noticeable than airborne noise.

The ground-borne noise levels presented below are for evening and night-time periods only, as the objective is to protect the amenity and sleep of occupants during the more sensitive time periods. The ICNG does not require assessment of day-time ground borne noise levels from construction activities.

Because the works periods are restricted to daytime only, ground borne noise is not assessed further in this report.

Table 6 Residential construction Noise Management Levels for ground-borne noise

Time of Day	Noise Management level $L_{eq,15\ min}$, dB(A)
Evening (6pm to 10pm)	40 - Internal
Night (10pm to 7am)	35 - Internal

B.2 Source sound levels

Table 2 describes the phases of work, typical plant and activities expected to carry out the work, and likely subjective impacts. Typical sound levels are presented in the table. These are taken from a range of sources[4]. Listed sound pressure levels are presented as $dBL_{Aeq(15min)}$ sound pressure level at 10m from the plant, and account for duration characteristics of works (for example, continuous noise or intermittent noise during any 15-minute assessment interval). The 5dB penalty of "annoying" characteristics is not included in the sound level data in Table 2 below. The 5dB penalty is added to the predicted total construction noise level, from all concurrent activities, if annoying characteristics are considered to be present.

[2] Minimum 20 dB loss from a closed façade typical of commercial or hospital ward.
[3] Where internal noise levels are specified, the NSW NPI assessment methodology states that in cases where the gaining of internal access for monitoring is difficult, then external noise levels 10 dB above internal noise levels apply assuming a window opened sufficiently to provide ventilation.
[4] TfNSW *Construction Noise and Vibration Guideline – Public Transport Infrastructure* (September 2023), TfNSW RMS Construction Noise and Vibration Guideline (CNVG, 2018), AS2436:2010, UK DEFRA 2005, internal Acoustic Studio records and database

Table 7 Indicative work phases and subjective impact considerations

Noise Scenario / Activity	List of plant and typical noise level ($dBL_{Aeq,15min}$) at 10m without penalty	Notes on subjective impact
Site setup	Hand tools (74) Utility vehicles (75) Truck, forklift (79) Generator (4 stroke petrol) (75) Generator, 37kVA (52)	Mains power will likely be used, therefore no requirement for a portable generator. Impacts expected to be low, similar to existing operational noise from the nearby maintenance facility.
Building demolition (internal)	Mobile Franna crane (70) Excavator, max. 8T with bucket (75) Elevated work platform (74) Steel / concrete saw* (87) Hand-held jackhammer* (88) Sledgehammer (84) Truck, front end loader (84) Medium-rigid 20T truck (75) Hand tools (petrol / electric) (74) Dump truck (tipping material) (79)	High vibration: N** Tones and impulses: Y – *steel / concrete saw, jackhammer and tonal movement alarms
Construction (including external plant slab)	Mobile Franna crane (70) Alimak or Man material hoist (79) Truck, front end loader (83) Skidsteer loader ½ tonne (76) Hand tools (74) Concrete mixer (81) Concrete pump (80) Concrete vibrator (electric / motorised) (72) Hammer drill / percussive drill (83) Rattle gun / impact wrench* (73)	High vibration: N Tones and impulses: Y – Hand tools (e.g. rattle gun) and tonal movement alarms
Internal works	Hammer / percussive drill (83) Electric core drill (85) Rattle gun / impact wrench* (73) Electric hand tools (74) Electric hand-held drill (63) Utility vehicles (75)	High vibration: N Tones and impulses: Y – Hand tools and tonal movement alarms
Landscaping (minor)	Chainsaw, petrol[2] (83) Excavator (75) Small compactor (78) Small vibratory roller* / smooth drum roller[2] (80) Wacker packer (72) Soft Landscaping works[2] (<80) Tip truck (tipping soil) (62)	High vibration: N (if vibratory roller used, vibration is generated but not perceptible at residential location) Tones and impulses: Y – tonal movement alarms [2] Minor vegetation removal

Note: * Plant with impulsive or tonal content are considered to be more annoying, and include tonal metal or concrete saw cutting noise, impulsive breaking of material, and tonal reversing and vertical movement alarms on vehicles, mobile cranes and EWPs. Plant associated with perceptible vibration can also be annoying.
** Vibration not perceived at residential locations

Table 8 presents the range of noise impacts predicted from each work phase.

Table 8 Indicative work phase predicted sound level at most affected receiver

Noise Scenario / Activity	Noise level prediction components	Quietest plant	Noisiest plant
Site setup		Hand tools	Generator (4 stroke petrol) (75)
	1. Noise level ($dBL_{Aeq,15min}$) range, at 10m without penalty	74	75
	2. Distance attenuation (dB), over 30m, relative to 10m	-10	-10
	3. Shielding from buildings	-5	-5
	4. Attenuation from enclosure / screening / windows	0	0
	5. Penalty for annoying noise characteristic	0	0
	Predicted noise level range at receiver ($dBL_{Aeq,15min}$)	59	60
Building demolition (internal)		Mobile Franna crane	Hand-held jackhammer*
	1. Noise level ($dBL_{Aeq,15min}$) range, at 10m without penalty	70	88
	2. Distance attenuation (dB), over 30m, relative to 10m	-10	-10
	3. Shielding from buildings	-5	-5
	4. Attenuation from enclosure / screening / windows	-10	-10
	5. Penalty for annoying noise characteristic	0	5
	Predicted noise level range at receiver ($dBL_{Aeq,15min}$)	45	68
Construction (including external plant slab)		Concrete vibrator (electric / motorised)	Concrete mixer
	1. Noise level ($dBL_{Aeq,15min}$) range, at 10m without penalty	72	81
	2. Distance attenuation (dB), over 30m, relative to 10m	-10	-10

	3. Shielding from buildings	-10	-10
	4. Attenuation from enclosure / screening / windows	0	0
	5. Penalty for annoying noise characteristic	0	0
	Predicted noise level range at receiver ($dBL_{Aeq,15min}$)	52	61
Internal works		Electric hand-held drill	Electric core drill
	1. Noise level ($dBL_{Aeq,15min}$) range, at 10m without penalty	63	85
	2. Distance attenuation (dB), over 30m, relative to 10m	-10	-10
	3. Shielding from buildings	-5	-5
	4. Attenuation from enclosure / screening / windows	-10	-10
	5. Penalty for annoying noise characteristic	0	0
	Predicted noise level range at receiver ($dBL_{Aeq,15min}$)	38	60
Landscaping (minor)		Tip truck (tipping soil)	Chainsaw
	1. Noise level ($dBL_{Aeq,15min}$) range, at 10m without penalty	62	83
	2. Distance attenuation (dB), over 30m, relative to 10m	-10	-10
	3. Shielding from buildings	-5	-5
	4. Attenuation from enclosure / screening / windows	0	0
	5. Penalty for annoying noise characteristic	0	5
	Predicted noise level range at receiver ($dBL_{Aeq,15min}$)	47	73

B.3 Vibration

Construction vibration is to be assessed in terms of:

- Human comfort
- Disruption to sensitive equipment
- Structural damage

Relevant management levels for each of these are detailed in the sections that follow.

Human Comfort

The DEC AVTG provides suitable criteria that can be applied to the assessment of vibration and human comfort. The guideline makes reference to the British Standard BS 6472: 1992, which shares many similarities to the Australian Standards AS 2670.2: 1990. This guideline presents preferred and maximum vibration values for use in assessing human responses to vibration plus targets for critical areas in hospital and educational buildings, and provides recommendations for measurement and evaluation techniques.

Vibration and its associated effects are usually classified as continuous, impulsive or intermittent:

- **Continuous vibration** continues uninterrupted for a defined period (usually throughout daytime and/or night-time). This type of vibration is assessed on the basis of weighted rms acceleration values.
- **Impulsive vibration** is a rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds.
- **Intermittent vibration** can be defined as interrupted periods of continuous (e.g. a drill) or repeated periods of impulsive vibration (e.g. a pile driver), or continuous vibration that varies significantly in magnitude. It may originate from impulse sources (e.g. pile drivers and forging presses) or repetitive sources (e.g. pavement breakers), or sources which operate intermittently, but which would produce continuous vibration if operated continuously (for example, intermittent machinery, railway trains and traffic passing by). This type of vibration is assessed on the basis of vibration dose values.

Examples of these vibration types are provided in the table below.

Table 9 Examples of vibration types

Continuous	Impulsive	Intermittent
Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).	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.	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 relevant criteria for human exposure to continuous and impulsive vibration are detailed in Table 10. Vibration levels are assessed through the consideration of the summation of effects for vibration levels at frequencies from 1 to 80 Hz for all axes.

BS 5228-2:2009 also notes that:

- Above peak component particle velocities (PPVs) of 0.14 mm/s to 0.3 mm/s, vibrations can disturb, startle, cause annoyance or interfere with work activities
- Vibrations of 1.0 mm/s will likely cause complaint in residential environments, but can be tolerated if prior warning and explanation has been given to residents.

We therefore recommend that, as screening criteria, the “preferred” values for continuous vibration in terms of PPVs from AVaTG, are adopted; these are reproduced in Table 10 below.

Table 10 Preferred and maximum weighted rms values for continuous and impulsive vibration velocity (mm/s) 1-80 Hz

Location	Assessment period	rms velocity		Peak velocity	
		Preferred	Maximum	Preferred	Maximum
Continuous vibration					

Critical areas[1]	Day or night time	**0.10**	0.20	**0.14**	0.28
Residences	Day time	**0.20**	0.40	**0.28**	0.56
	Night time	**0.14**	0.28	**0.2**	0.4
Offices, schools, educational institutions and places of worship	Day or night time	**0.40**	0.80	**0.56**	1.1
Workshops	Day or night time	**0.80**	1.6	**1.1**	2.2
Impulsive vibration					
Critical areas	Day or night time	0.10	0.20	0.14	0.28
Residences	Day time	6.0	12.0	8.6	17.0
	Night time	2.0	4.0	2.8	5.6
Offices, schools, educational institutions and places of worship	Day or night time	13.0	26.0	18.0	36.0
Workshops	Day or night time	13.0	26.0	18.0	36.0

Note 1: Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring.

Where the screening criteria in Table 10 are predicted to be exceeded, notification should be provided to the sensitive receivers.Where the vibration levels are predicted or measured to exceed a PPV of 1 mm/s (or 1.1 mm/s for workshops), attended vibration should be undertaken at the commencement of the activity, or in response to complaints, and compared to the corresponding criteria in this Appendix, applying the more conservative W_b weighting for vertical vibration.

Human exposure to intermittent vibration is assessed using the Vibration Dose Value (VDV). The VDV accumulates the vibration energy experienced over an extended period (daytime and night-time periods) from intermittent events. Table 11 sets out the acceptable VDV values for intermittent vibration. Some vibration monitoring devices can directly estimate VDVs; however, many construction vibration monitors only measure PPV and the VDV is estimated or calculated after the measurement period.

Table 11 Acceptable vibration dose values for intermittent vibration ($m/s^{1.75}$)

Location	Daytime		Night-time	
	Preferred value	Maximum value	Preferred value	Maximum value
Critical areas[1]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Note 1: Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring.

Sensitive Equipment

Areas with sensitive equipment may require a higher degree of vibration isolation than the values in Table 10 and Table 11.

Where it has been identified that vibration sensitive scientific and/or medical equipment is in use within a vibration-sensitive receiver, the vibration limits specified by the manufacturer should be sought. Where these are not available,

it is recommended to consult the vibration criterion (VC) curves, which, in their latest evolution, are described in Amick et al. (2005)[5], and are detailed below.

Vibration Criterion (VC) curves are used to provide the basis for the design and protection of highly vibration sensitive equipment. Table 12 details the VC curves applicable to a range of highly sensitive equipment that is to be referred to and considered in conjunction with manufacturer guidelines specific to each type of equipment.

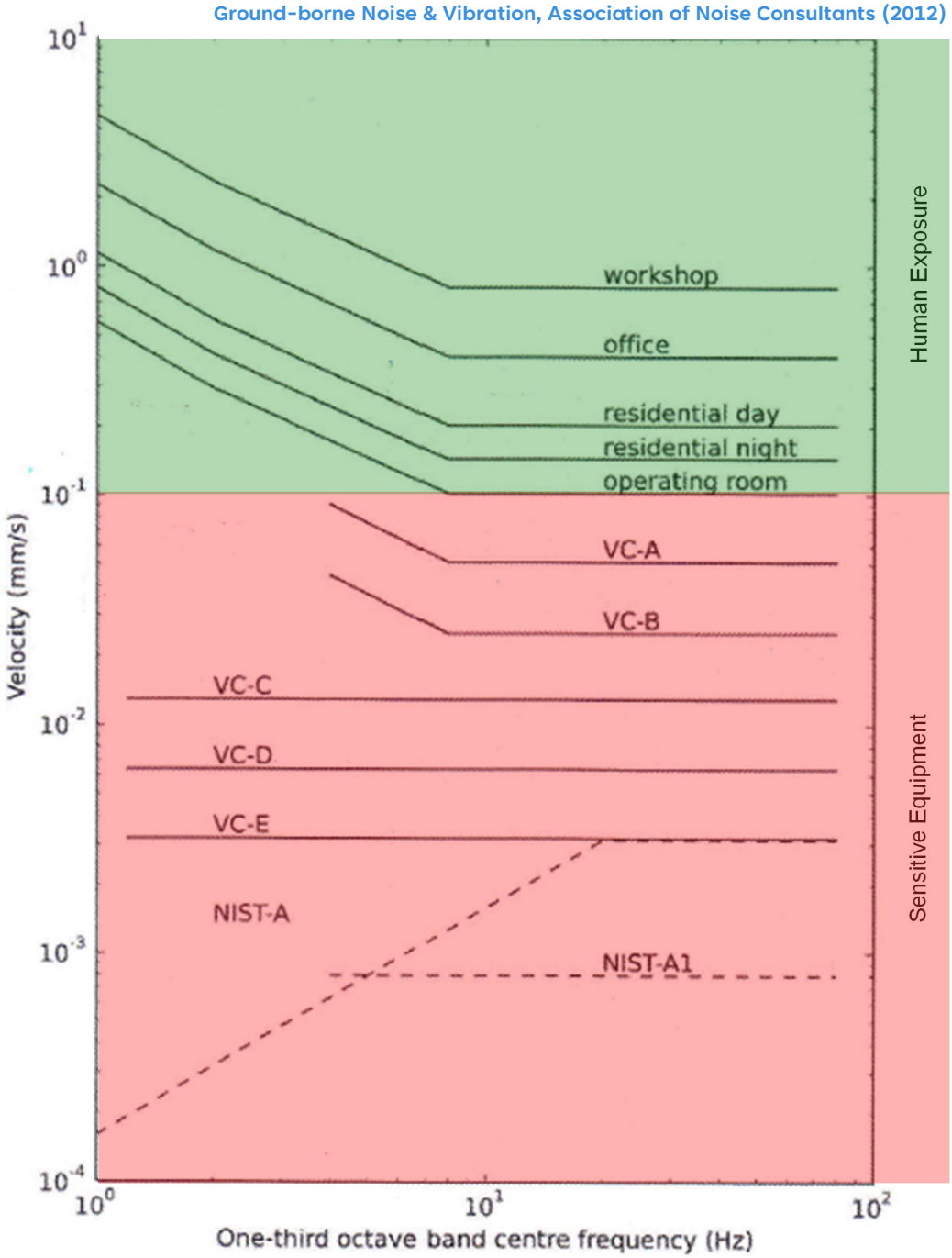
Table 12 VC Curves for Highly Sensitive Equipment (RMS velocity)

Curve	Max Value 8-80Hz Microns / sec, rms	Detail Size Microns	Equipment Types / Requirements
VC-A	50	8	Bench Microscopes < 400 x Magnification, optical and other precision balances, coordinate measuring machines and optical comparators
VC-B	25	3	Bench Microscopes > 400 x Magnification, microsurgery and neurosurgery
VC-C	12.5	1	Electron Microscopes < 30,000 x magnification, magnetic resonance imagers and microelectronics manufacturing equipment
VC-D	6	0.3	Electron Microscopes > 30,000 x magnification, mass spectrometers and cell impact equipment
VC-E	3	0.1	Un Isolated laser and optical research systems

Figure 5 shows the relationship between criteria for highly sensitive equipment and human exposure criteria shown in Table 10.

[5] https://colingordon.com/research/evolving-criteria-for-research-facilities-vibration/

Figure 5 VC Curves - Source: ANC Guidelines – Measurement and Assessment of Ground-borne Noise & Vibration, Association of Noise Consultants (2012)



It is also recommended to perform a vibration survey within the room housing the equipment, while it is in use. This may assist in determining an appropriate VC curve in which the equipment can satisfactorily operate. The vibration survey should carefully consider the potentially very low levels of vibration and how these will be captured, and it is recommended that a vibration engineering specialist is engaged to perform such monitoring.

Structural Damage

Vibration-induced damage of buildings and structures is a common concern, but it is actually rare in practice. This explains why there is limited reliable data on the threshold of vibration-induced damage in buildings and there is no directly relevant Australian Standard. There are guidelines available in a number of international standards, although these vary significantly.

British Standard

NSW standard industry practice applies BS7385: Part 2: 1993 to assess the potential for vibration-induced damage. This standard was developed from an extensive review of UK data, relevant national and international documents and other published data, which yielded very few cases of vibration-induced damage. This standard contains the most up-to-date research on vibration damage in structures. Part 2 of the standard gives specific guidance on the levels of vibration below which building structures are considered to be at minimal risk.

The Standard proposes the following limits on the foundations of the buildings:

Table 13 Transient Vibration Guide Values for Cosmetic Damage

Structural type	Peak component particle velocity in frequency range of predominant pulse	
	4 Hz to 15 Hz	15Hz and above
Unreinforced or light framed structures **Residential or light commercial type buildings**	15mm/s @ 4Hz increasing to 20mm/s @ 15Hz	20mm/s @ 15Hz increasing to 50mm/s @ 40Hz and above

The standard states in Annex A, that ... *"the age and existing condition of a building are factors to consider in assessing the tolerance to vibration… If a building is in a very unstable state, then it will tend to be more vulnerable to the possibility of damage arising from vibration or any other ground-borne disturbance"… It is recommended that buildings of importance be considered on a case-by-case* basis with detailed engineering analysis being carried out if necessary.

Annex B of the Standard gives a breakdown of data that would be recorded. Included in this are details of the building structure, such as general condition of the structure, list of defects, photographs, details of all major extensions, repairs and renovations. A crack exposure report would be prepared both pre and post exposure, both internally and externally.

Australian Standard

There is no specific Australian Standard referring to structural vibration in buildings. There is however AS 2187.2 - 2006, which, in Appendix J, recommends maximum peak particle velocities, measured at the ground surface due to blasting. The lower recommended peak particle velocity is 10 mm/s. The standard states however, that structures that may be particularly susceptible to ground-borne vibration would be examined on an individual basis. It is suggested that in the absence of a particular site-specific study then a maximum peak particle velocity of 5 mm/s is used.

Summary

Table 14 gives a summary of vibration limits recommended in relevant standards and guidelines for minimising the risk of vibration-induced damage to buildings.

Table 14 Summary of vibration limits for protecting building structures from vibration-induced damage

Standard	Type of building	Recommended vibration limit	Comments
DIN 4150	Structures of particular sensitivity or worthy of protection	3 mm/s to 20 mm/s @ < 10 Hz 3-40 mm/s @ 10-50 Hz 8-50 mm/s @ 50 Hz+ Also measurement at the top floor with limit of 8 mm/s to 40 mm/s across frequency range	Limit is for peak particle velocity in x, y, and z directions. Measurement on the top floor in x and y directions only
BS 7385	Un-reinforced or light framed	15 mm/s @ 4 Hz rising to 20 mm/s @ 15 Hz then rising to 50 mm/s @ 40 Hz and above	Limit is for peak particle velocity in x, y, and z directions
AS 2187	Houses and low-rise residential, commercial buildings not of reinforced or steel construction	5 mm/s	For buildings particularly susceptible to vibration. Limit is for peak resultant particle velocity, measured on the ground adjacent to the structure

Table 15 Recommended indicative minimum working distances for vibration-generating plant and equipment. Note that these are estimated only, and will depend on site ground characteristics, building construction, equipment size and usage, and time + duration of vibration-generating activities (for human response and sensitive equipment), among other factors.

Plant item	Approx. size / weight / model	Minimum distance – cosmetic damage – residential / light framed (BS 7385)[1]	Minimum distance – structurally unsound heritage 2.5mm/s (DIN 4150)[2]	Minimum distance – human response (Day) (AVTG)[1]
Vibratory roller	< 50kN (1-2 tonne)	5m	11m	15m
(steady state; start up and power down distances may be larger)	50-100kN (2-4 tonne)	6m	14m	20m
	100-200kN (4-6 tonne)	12m	27m	40m
	200-300kN (7-13 tonne)	15m	33m	100m
	> 300kN (13-18 tonne)	20m	44m	100m
	> 300kN (> 18 tonne)	25m	55mm	100m
Vibratory roller – smooth drum	4-6 tonnes	12m	27m	40m
Padfoot roller (non-vibratory)		8m	15m	35m

Small hydraulic hammer	(3-5 tonne excavator)	2m	6m	15m
Small hydraulic hammer	300kg (5-12 tonne excavator)	2m	5m	7m
Medium hydraulic hammer	900 kg (12-18 tonne excavator)	7m	15m	23m
Large hydraulic hammer	1600kg (18-34 tonne excavator)	22m	55m	73m
Large hydraulic hammer	47T	30m	60m	80m
Jackhammer	Handheld	1m (nominal)	3m	Avoid contact with structure
Rotary rock grinder		8m	20m	40m
Ripper		2m	6m	15m
Plate compactor		11m	23m	43m
Compactor (non-vibratory)	32 tonne	15m	30m	40m
Large trucks, large bulldozers	(D10 with ripper)	4m	7m	13m
Excavator, tracked	< 30 tonne, travelling / digging	4m	9m	15m
Tracked crane, idling		1m	4m	10m
Concrete saw	on ground slabs and pavements	1m	2m	2m

[1] Transport for NSW Infrastructure and Services *Construction Noise and Vibration Strategy* (2018)
[2] Acoustic Studio derived from TfNSW data and applying distance attenuation across assumed soil on rock, per methodology described in Amick & Gendreau, *Construction Vibrations and their Impact on Vibration-Sensitive Facilities*, ASCE Construction Congress 6 (2000)

Buried pipework and services

BS 7385-2 does not provide any specific guidance for underground pipelines and structures, and simply notes that "*structures below ground are known to sustain higher levels of vibration and are very resistant to damage unless in poor condition*".

DIN 4150-3 does provide guidance for underground structures and underground pipelines, but this guidance is only applicable to underground structures and pipelines that have been manufactured and applied/laid "*using current technology*". The guideline values are quite lenient and reflect numerous studies, which indicate that appropriate PPV limits could be in the order of at least 100 mm/s. These criteria are reproduced in Appendix A.4. If the underground structures or pipelines are known to be in good condition and applied/laid "*using current technology*" then these limits could be considered.

In practice however, the age, technology used to construct the structure and condition of these items is rarely known and difficult to source. It is therefore proposed to adopt the limits for underground services from BS 5228-2:2009, which are:

- PPV of 30 mm/s for transient vibrations
- PPV of 15 mm/s for continuous vibration

BS 5228-2:2009 also notes that:

In the event of encountering elderly and dilapidated brickwork sewers, the base data should be reduced by 20% to 50%

Infrastructure

Guidance regarding damage to infrastructure items is limited, due to the very high levels of vibration required to induce damage on these structures. ACARP Ref. C14057 *Effect of Blasting on Infrastructure* provides "recommended 'safe' vibration limits without more detailed analysis" for blasting, these have been reduced by 50% in accordance with common practice for continuous vibrations and provided as recommended limits in Table 16. Where a range of values is presented, only the lower end of the range is presented in Table 16. Some items covered by DIN 4150-3 and BS 5228-2:2009 are also included in Table 16.

Table 16 Recommended guide values for infrastructure from ACARP Ref. C14057, BS 5228-2:2009 and DIN 4150-3

Item	Recommended PPV Limit for continuous vibrations	Notes
Public roads	50 mm/s	
Railway lines	50 mm/s	
Concrete bridges	50 mm/s	Without traffic loads
Conveyor structures	50 mm/s	From AS 2187.2-2006
Power lines – Timber poles	50 mm/s	
Power lines – Concrete poles	50 mm/s	From AS 2187.2-2006
Power lines – steel towers	50 mm/s	From AS 2187.2-2006
Electrical substations (Buckholz switches)	5 mm/s	
Fixed mine plant and buildings	50 mm/s	Where brick masonry and plaster board feature in the construction, BS 7385-2 should be adopted
Underground workings	50 mm/s	
Surface pipelines	50 mm/s	
Buried communications cables and pipelines	50 mm/s	
Dams	50 mm/s	
Retaining walls	4 mm/s at the toe 16 mm/s at the crest	From BS 5228-2:2009 Propped or tied walls or mass gravity walls can be subject to values 50% to 100% greater than these limits
Civil engineering structures such as reinforced concrete constructions used as abutments or block foundations	40 mm/s	From DIN 4150-3

Regarding the limits presented in ACARP Ref. C14057, it notes that:

"an observation approach is recommended with a protocol adopted to monitor PPV levels and make sufficient observations to determine if unplanned movement is detected and to reduce PPV limits at the first signs of unacceptable deterioration"

B.4 Construction-related traffic

Any additional traffic generated by this proposal during construction phase may be assessed in accordance with the following guidelines:

- NSW EPA *Road Noise Policy* (RNP, 2011).

- Australian Standard AS 3671-1989 *Acoustics – Road traffic noise intrusion – Building Siting and Construction* (for guidance only; applies to siting of the receiver buildings).

The RNP is applicable to traffic-generating developments including major road infrastructure developments. The emphasis is on achieving a reasonable balance between what is achievable on different road types and the sensitivity of different receiver types to road traffic noise. This is not directly relevant to this proposal as it does not include any new or upgraded road infrastructure.

The Australian Standard has a different emphasis, in that it aims to identify appropriate intrusive road traffic noise criteria in different building types. This is not relevant to the proposed development.

In the absence of directly applicable guidelines, policies or standards for assessing road traffic noise impacts from the construction phase of a project, Acoustic Studio's approach is to examine the increase in traffic noise events and levels for most-affected sensitive receivers.

If construction-related traffic occurs during night-time hours (10pm to 7am), then the potential for sleep disturbance must be assessed.

The sleep disturbance criterion L_{AMax} not exceeding the $L_{A90,\ (15\ minute)}$ by more than 15 dB(A) is a screening criterion, not an absolute goal for the purpose of assessing impact from a project. It applies outside bedroom windows during the night-time period.

If the Sleep Disturbance screening criterion is exceeded, the detailed analysis should cover the extent to which the maximum noise level exceeds the background level and the number of times this happens during the night-time period. Some guidance on possible impact is contained in the review of research results in the RNP.

Other factors that may be important in assessing the extent of impacts on sleep include:

- How often high noise events will occur
- Time of day (normally between 10pm and 7am)
- Whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).

A further consideration for sleep awakening is whether the environmental noise has changed. The RNP Section 5.3 "Response to a Change in Noise Level" states:

> *While people may express a certain tolerance for their existing noise environment, they may feel strongly about increases in noise […] The difference in reported awakenings from sleep was equivalent to a difference of 7 dB in maximum noise levels*

The RNP Section 5.4 "Sleep Disturbance" states that:

> *From the research on sleep disturbance to date it can be concluded that:*
>
> - *Maximum internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep*
> - *One or two noise events per night, with maximum internal noise levels of 65–70 dB(A), are not likely to affect health and wellbeing significantly*

The internal noise levels provided in the RNP are related to potential sleep awakenings.

Typically noise impact assessments consider the worst case scenario, when residential receivers have windows open sufficiently to provide natural ventilation. This would result in approximately 10 dB attenuation from outside to inside, through the open window. This situation is considered likely during warmer seasons.

When windows are closed, the likely sound attenuation through standard windows with poor seals (common in older houses) is approximately 20 dB.

Based on a minimum attenuation of 10 dB(A) with windows open, the first conclusion of the RNP suggests that short term external noises of 60 to 65 dB(A) are unlikely to cause awakening reactions. In addition, external levels of 75 to 80 dB(A) are unlikely to affect health and wellbeing significantly, provided that these events occur no more than twice in one night.