Acoustics
Vibration
Structural Dynamics

28 ELIZABETH STREET, LIVERPOOL

Construction Noise & Vibration Management Plan

1 November 2021

Altis Bulky Retail Pty Ltd as trustee for Altis ARET Sub Trust 20

TL868-02F02 Construction Noise Assessment (r1)

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1 Introduction

Renzo Tonin & Associates were engaged by Altis Bulky Retail Pty Ltd to prepare a Construction Noise and Vibration Management Plan (CNVMP) for the proposed mixed-use development at 28 Elizabeth Street, Liverpool. More specifically, this management plan will provide guidelines to reduce noise and vibration impacts to nearby affected receivers during the demolition, excavation and construction works.

In accordance with relevant guidelines, this document addresses the following issues regarding construction noise and vibration for the proposed development during demolition, excavation and construction works:

- Identify potential sources of noise and vibration during the proposed works;
- Specify noise and vibration criteria for the proposed works;
- Describe in detail what actions and measures could be implemented to enable these works to comply with the relevant noise and vibration criteria;
- Describe how the effectiveness of these actions and measures would be monitored during the proposed works, clearly indicating who would conduct the monitoring, how often this monitoring would be conducted, how the results of this monitoring would be recorded and if any non-compliance is detected; and
- Procedures to handle complaints.

The work documented in this report was carried out in accordance with the Renzo Tonin & Associates Quality Assurance System, which is based on Australian Standard / NZS ISO 9001. Appendix A contains a glossary of acoustic terms used in this report.

2 Project description

2.1 Background information

The proposal is for the construction of a 34-storey building at 28 Elizabeth Street, Liverpool with 6 levels of basement parking, retails on ground floor, commercial spaces on Levels 1 to 4 and apartments from Levels 5 to 33. This CNVMP addresses potential noise and vibration impacts during the demolition, excavation, and construction work stages of the development.

2.2 Receiver locations

The following noise sensitive receivers were identified using aerial photography of the land to be the nearest affected receivers.

Table 1 – Sensitive receiver locations

Receiver	Address	Description
Non-residential Receivers		
R1	Corner of George and Elizabeth Street	3 storey commercial building (Westfield Shopping Centre) 31m north-west of site across intersection of Elizabeth and George Street
R2	48 George Street	3 storey height church building (All Saints' Catholic) 26m north of site across Elizabeth Street
R3	29 Campbell Street	2 storey school building (All Saints Catholic Primary School) 30m north of site.
R4	150 George Street	3 storey commercial building (Liverpool Police Station and Court house) 4.5m south of site
R5	129 to 151 George Street	Mix of 2 to 4 storey retail and commercial buildings at 19m west of site across George Street.
Residential Receivers		
R6	9 Elizabeth Street	6 storey apartment building at approximately 156m east of site – the nearest existing residential property to site.

Figure 1 provides details of subject site and surrounding environment.

Figure 1 – Subject site and surrounding noise-sensitive receivers

2.3 Proposed construction

2.3.1 Background

Construction activities associated with the proposed development will result in increased noise levels during construction hours. The works undertaken in the various stages consist of a mixture of both high and low noise activities. This assessment identifies potentially noisy activities, their impacts on surrounding receivers and outlines management strategies to control the impacts of noise and vibration during the demolition, excavation and construction works.

2.3.2 Summary of works

The proposed development is a 34-storey building with 6 levels of basement, 5 levels of retail and commercial floors and 29 floors of apartments.

Construction activities associated with the development will include the following:

- Demolition of existing on-grade slabs on site
- Excavation works
- Civil works
- Construction of a 34-storey building – substructure and building works

The bulk of the demolition and excavation works will be conducted by a 40-tonne tracked machine and other smaller machines. The drilling rig will be a 20-tonne tracked drilling rig. Additional to this will be 50 tonne telescopic crane, piling rig, concrete pumps, trucks and hand-held tools and equipment.

2.3.3 Construction hours

The proposed construction works will be undertaken during standard construction hours, as follows:

- Mondays to Fridays 7:00am to 6:00pm
- Saturdays 8:00am to 1:00pm
- Sundays & Public Holidays No work performed

2.4 Construction traffic

The worksite will generate additional traffic movements in the form of:

- Light vehicle movements generated by construction personnel travelling to and from work
- Heavy vehicle movements generated by:
  - Delivery vehicles bringing raw materials, plant, and equipment to the site
  - Trucks removing demolished material
  - Concrete trucks bringing concrete to the site

When construction-related traffic moves on the public road network, a different noise assessment methodology is appropriate as vehicle movements would be regarded as additional road traffic on public roads rather than as part of the construction site's activities.

Access to the site will be from Elizabeth Street. The average peak vehicle truck movements to/from the site is not expected to significantly alter existing traffic noise due to the high existing traffic volumes along this road.

There are no truck movements during the evening (between 6 pm and 10 pm) or night (between 10 pm and 7am) periods.

3 Existing noise environment

3.1 Noise monitoring location

The criteria for assessment of construction noise at residential receivers (ie Receiver R6) are derived from existing noise environment of an area, excluding noise from the subject development. Background noise surveys are ideally carried out at the nearest or most potentially affected residential properties surrounding a development. An alternative, representative location should be established in case of access restrictions, or a safe and secure location cannot be identified. Furthermore, representative locations may be established in the case of multiple receivers as it is usually impractical to carry out measurements at all locations surrounding a site.

The background noise monitoring data from a previous assessment conducted on Brown Avenue, Liverpool has been adopted for this assessment and used to establish the existing acoustic environment at the nearest residential receivers (R6) to east of the construction site.

Table 2 – Noise monitoring locations

ID	Address	Description
M1	2 Browne Avenue, Liverpool	The noise monitor was installed on front of the property facing Browne Avenue. This noise monitoring location is considered representative of the residential receivers in the Liverpool City Centre.

The graphical outputs from the long-term noise monitoring at location M1 are included in the appendix of DA acoustic report [reference TL868-01F02 Acoustic Assessment for DA (r4) dated 29/10/21]. The graphs were analysed to determine an assessment background level (ABL) for each day, evening and night period in each 24- hour period of noise monitoring and based on the median of individual ABLs an overall single Rating Background Level (RBL) for the day, evening and night period is determined over the entire monitoring period in accordance with the NSW EPA Noise Policy for Industry.

3.2 Existing background & ambient noise levels

The measured existing background and ambient noise levels are presented in Table 3 below.

Table 3 – Measured existing background (L_{90}) & ambient (L_{eq}) noise levels, dB(A)

Location	L_{90} background noise levels			L_{eq} ambient noise levels		
	Day[1]	Evening[2]	Night[3]	Day[1]	Evening[2]	Night[3]
M1 – 2 Browne Avenue, Liverpool	54	51	41	65	64	62

Notes:
1. Day represents the period from 7am to 6pm, Monday to Saturday and 8am to 6pm, Sunday & Public Holidays
2. Evening represents the period from 6pm to 10pm, Monday to Sunday & Public Holidays
3. Night represents the period from 10pm to 7am, Monday to Saturday and 10pm to 8am, Sundays & Public Holidays

Given that demolition, excavation, civil and construction works are anticipated to occur during the day period, only the day period will be assessed for from herein.

4 Noise management plan

This section provides an assessment of construction noise emissions form the site and recommends noise mitigation measures and management measures that can be used to minimise noise impacts at nearby receivers surrounding the site.

4.1 Construction noise criteria

The NSW *Interim Construction Noise Guideline* (ICNG, 2009) provides guidelines for assessing noise generated during the construction phase of developments.

The key components of the guideline that are incorporated into this assessment include:

- Use of L_{Aeq} as the descriptor for measuring and assessing construction noise.
  NSW noise policies, including the INP, RNP and RING have moved to the primary use of L_{Aeq} over any other descriptor. As an energy average, L_{Aeq} provides ease of use when measuring or calculating noise levels since a full statistical analysis is not required as when using, for example, the L_{A10} descriptor.

- Application of reasonable and feasible noise mitigation measures.

  As stated in the ICNG, a noise mitigation measure is feasible if it is capable of being put into practice, and is practical to build given the project constraints.

  Selecting reasonable mitigation measures from those that are feasible involves making a judgement to determine whether the overall noise benefit outweighs the overall social, economic and environmental effects.

The ICNG provides two methods for assessment of construction noise, being either a quantitative or a qualitative assessment. A quantitative assessment is recommended for major construction projects of significant duration, and involves the measurement and prediction of noise levels, and assessment against set criteria. A qualitative assessment is recommended for small projects with a duration of less than three weeks and focuses on minimising noise disturbance through the implementation of reasonable and feasible work practices, and community notification.

Given the scale of the construction works proposed for the project, a quantitative assessment is carried out herein, consistent with the ICNG requirements.

Table 4, reproduced from the ICNG, sets out the noise management levels and how they are to be applied for residential receivers.

Table 4 – Noise management levels at residential receivers

Time of day	Management level $L_{Aeq\ (15\ min)}$ *	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 + 10dB	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: 1. 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 2. 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 + 5dB	• 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 5dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2 *[of the ICNG*.

* Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Table 5 presents the construction noise management levels established for the nearest noise sensitive residential receiver based upon the noise monitoring outlined in Section 3.1. The receiver locations are shown in Figure 1.

Table 5 – Construction noise management levels at residential receivers

Receiver	Location description	Day noise management level $L_{Aeq(15min)}$[1]
R6	9 Elizabeth Street, Liverpool	54 + 10 = **64 dB(A)**

4.1.1 Other sensitive receivers

Table 6 below (reproduced from Table 3 of the ICNG) sets out the noise management levels for other noise sensitive receivers.

Table 6 – Noise management levels at other noise sensitive land uses

Land use	Where objective applies	Management level $L_{Aeq\ (15\ min)}$
Classrooms at schools and other educational institutions	Internal noise level	45 dB(A) internally Or **55 dB(A) externally**
Hospital wards and operating theatres	Internal noise level	45 dB(A)
Places of worship	Internal noise level	45 dB(A) internally or **55 dB(A) externally**
Active recreation areas	External noise level	65 dB(A)
Passive recreation areas	External noise level	60 dB(A)
Community centres	Depends on the intended use of the centre.	Refer to the 'maximum' internal levels in AS2107 for specific uses.
Commercial premises	External noise level	**70 dB(A)**
Industrial premises	External noise level	75 dB(A)

Notes: Noise management levels apply when receiver areas are in use only.

Our site aerial survey has found noise sensitive receivers within proximity of subject site are all non-residentials and noise criteria outlined in Table 6 for commercials premises [R1, R4 & R5], place of worship [R2] and educational institutions [R3] applies.

4.2 Proposed construction noise sources

The plant and equipment that are likely to be used during the construction of the proposed residential development are provided in Table 7 below.

Table 7 – Demolition, excavation and construction equipment & sound power levels, dB(A) re 1pW

Plant item	Plant description	Sound power levels
Demolition		
1.	Truck - Dump	109
2.	20 tonne Excavator with Bucket	106
3.	Bobcat	102

Plant item	Plant description	Sound power levels
Excavation		
4.	Bulldozer	116
5.	30 tonne excavators with bucket x 6[1]	107
6.	Truck - Dump	109
7.	Delivery trucks	108
8.	50 tonne mobile telescopic crane	95
Civil		
9.	20 tonne tracked mobile drilling rig	118
10.	45 tonne bored piling rigs x 2	111
11.	30 tonne excavators with bucket x 6[1]	106
12.	Concrete trucks	108
13.	Delivery trucks	108
14.	50 tonne mobile telescopic crane	95
Substructure and building works		
15.	Concrete trucks	108
16.	Delivery trucks	108
17.	Hand tools	108
18.	Mobile/Tower crane	105
19.	Concrete pump	103
20.	Bobcat	102
21.	Concrete vibrator	99

Notes

1. Assuming 3 will operate concurrently

The sound power levels for the majority of activities presented in the above table are based on maximum levels given in Table A1 of Australian Standard 2436 - 2010 'Guide to Noise Control on Construction, Demolition and Maintenance Sites', the ICNG, information from past projects and/or information held in our library files.

4.3 Construction noise assessment

Noise levels at any receiver locations resulting from construction works would depend on the location of the receiver with respect to the area of construction, shielding from intervening topography and structures, and the type and duration of construction being undertaken. Furthermore, noise levels at receivers would vary significantly over the total construction program due to the transient nature and large range of plant and equipment that could be used.

Table 8 presents noise levels likely to be experienced at the nearby affected receivers based on the construction activities, and plant and equipment associated with the proposed site compound at a range from the furthest to the closest proximity to each receiver location. Noise levels were calculated taking into consideration attenuation due to distance between the construction works and the receiver locations and any intervening structures.

Table 8 – Predicted $L_{Aeq(15min)}$ noise levels for typical construction plant, dB(A)

Plant item	Plant description	Predicted $L_{eq(15min)}$ construction noise levels					
		Receiver R1	Receiver R2	Receiver R3	Receiver R4	Receiver R5	Receiver R6
Noise Management Levels		*70*	*55*	*55*	*70*	*70*	*64*
Demolition							
	Truck - Dump	55-68	57-69	53-69	55-85	57-73	43-52
	20 tonne Excavator with Bucket	52-65	54-66	50-66	52-82	54-70	40-49
	Bobcat	48-61	50-62	46-62	48-78	50-66	36-45
Up to 3 (noisiest) plant operating concurrently		**57-70**	**60-72**	**55-72**	**57-87**	**60-75**	**45-55**
Excavation							
	Bulldozer	62-75	64-76	60-76	62-92	64-80	50-59
	30 tonne excavators with bucket x 6	57-71	60-72	56-72	58-88	60-75	46-55
	Truck - dump	55-68	57-69	53-69	55-85	57-73	43-52
Up to 3 (noisiest) plant operating concurrently		**63-77**	**66-78**	**62-78**	**64-94**	**66-82**	**52-61**
Civil							
	20 tonne tracked mobile drilling rig	64-77	66-78	62-78	64-94	66-82	52-61
	45 tonne bored piling rigs x 2	60-73	62-74	58-74	60-90	62-78	48-57
	30 tonne excavators with bucket x 6	56-70	59-71	55-71	57-87	59-74	45-54
Up to 3 (noisiest) plant operating concurrently		**65-79**	**68-80**	**64-80**	**66-96**	**68-83**	**54-63**
Substructure and building works							
	Concrete trucks	54-67	56-68	52-68	54-84	56-72	42-51
	Delivery trucks	54-67	56-68	52-68	54-84	56-72	42-51
	Hand tools	58-72	61-73	57-73	59-89	61-76	47-56
Up to 3 (noisiest) plant operating concurrently		**57-71**	**60-72**	**55-72**	**57-87**	**60-75**	**45-55**

Based on the predicted construction noise levels in Table 8 above the management noise levels at the non-residential receivers R1 to R5 would be exceeded when the demolition, excavation, civil and construction works are conducted in close proximity to the corresponding receiver location.

Furthermore, construction noise levels are predicted to be greater than the highly noise affected level of 75dB(A) when the three noisiest plant and equipment items are used concurrently in close proximity to the following receiver locations.

Table 9 – Receivers predicted to be highly noise affected

Site Activity	Receiver locations exceeding highly affected noise level of 75dB(A)
Demolition	R4
Excavation	R1 to R5
Civil	R1 to R5
Substructure and building works	R4 and R5

In light of the predicted noise levels above, it is recommended that a feasible and reasonable approach towards noise management measures be applied to reduce noise levels as much as possible to manage the impact from construction noise.

Further details on construction noise mitigation and management measures are provided in Section 4.4 below.

4.4 Construction noise mitigation and management measures

The following recommendations provide in-principle feasible and reasonable noise control solutions to reduce noise impacts to sensitive receivers. Where actual construction activities differ from those assessed in this report, more detailed design of noise control measures may be required once specific items of plant and construction methods have been chosen and assessed on site.

The advice provided here is in respect of acoustics only. Supplementary professional advice may need to be sought in respect of fire ratings, structural design, buildability, fitness for purpose and the like.

4.4.1 General engineering noise controls

Implementation of noise control measures, such as those suggested in Australian Standard 2436-2010 "Guide to Noise Control on Construction, Demolition and Maintenance Sites", are expected to reduce predicted construction noise levels. Reference to Australian Standard 2436-2010, Appendix C, Table C1 suggests possible remedies and alternatives to reduce noise emission levels from typical construction equipment. Table C2 in Appendix C presents typical examples of noise reductions achievable after treatment of various noise sources. Table C3 in Appendix C presents the relative effectiveness of various forms of noise control treatment.

Table 10 below presents noise control methods, practical examples and expected noise reductions according to AS2436 and according to Renzo Tonin & Associates' opinion based on experience with past projects.

Table 10 – Relative effectiveness of various forms of noise control, dB(A)

Noise control method	Practical examples	Typical noise reduction possible in practice		Maximum noise reduction possible in practice	
		AS 2436	Renzo Tonin & Associates	AS 2436	Renzo Tonin & Associates
Distance	Doubling of distance between source and receiver	6	6	6	6
Screening	Acoustic barriers such as earth mounds, temporary or permanent noise barriers	5 to 10	5 to 10	15	15
Acoustic Enclosures	Engine casing lagged with acoustic insulation and plywood	15 to 25	10 to 20	50	30
Engine Silencing	Residential class mufflers	5 to 10	5 to 10	20	20
Substitution by alternative process	Use electric motors in preference to diesel or petrol	-	15 to 25	-	40

The Renzo Tonin & Associates' listed noise reductions are conservatively low and should be referred to in preference to those of AS2436.

Table 11 below identifies possible noise control measures, which are applicable for the construction plant likely to be used on site.

Table 11 – Noise control measures for likely construction plant

Plant description	Screening	Acoustic enclosures	Silencing	Alternative process
Truck - dump	✔	✖	✔	✖
Excavator with bucket	✔	✖	✔	✖
Bobcat	✔	✖	✔	✖
Piling drilling rig	✔	✖	✔	✖
Machine mounted hydraulic drill	✔	✖	✔	✖
Concrete trucks	✔	✖	✔	✖
Delivery trucks	✔	✖	✔	✖
Mobile crane	✔	✖	✔	✖
Concrete pump	✔	✖	✔	✖
Concrete vibrator	✔	✖	✔	✖
Hand tools	✔	✖	✔	✖

4.4.2 Physical noise controls

Physical noise control measures are recommended for implementation at the worst affected neighbouring receiver locations. The following in-principal noise mitigation measure is provided to reduce noise impacts to the neighbouring receivers.

- Erect solid hoarding/ noise screens around the perimeter of the construction site to break the line of site between the high noise generating activities and the windows of the receiver locations.

4.4.3 Regular periodic noise monitoring

The following approach would be adopted with regard to noise monitoring procedures during the construction works.

- Where potential noise impacts are predicted to be within 10 to 15dB(A) of the noise management level, the potential construction noise nuisance is considered to be moderate. Noise monitoring should be carried out to confirm predicted noise impacts within two weeks of commencement of construction. Reasonable and feasible noise reduction measures would be investigated, where necessary.
- Where potential noise impacts are predicted to be more than 15dB(A) above the noise management levels, the potential construction noise nuisance is considered to be high. All reasonable and feasible noise control measures should be implemented prior to the commencement of construction works. Noise compliance monitoring for all major equipment and activities on the site should be undertaken prior to their commencement of work on site. Finally, noise levels during construction should be monitored and where exceeded, further noise reduction measures (where reasonable and feasible) should be implemented eg. restrict working hours, use silencing equipment, etc.

4.4.4 General noise management measures

In addition to physical noise controls, the following general noise management measures should be followed:

- Use less noisy plant and equipment, where feasible and reasonable.
- Plant and equipment should be properly maintained.
- Provide special attention to the use and maintenance of 'noise control' or 'silencing' kits fitted to machines to ensure they perform as intended.
- Strategically position plant on site to reduce the emission of noise to the surrounding neighbourhood and to site personnel.
- Avoid any unnecessary noise when carrying out manual operations and when operating plant.
- Any equipment not in use for extended periods during construction work should be switched off.
- In addition to the noise mitigation measures outlined above, a management procedure would need to be put in place to deal with noise complaints that may arise from construction

activities. Each complaint would need to be investigated and appropriate noise amelioration measures put in place to mitigate future occurrences, where the noise in question is in excess of allowable limits. See Appendix D for an example of a complaint handling procedure and form.

- Good relations with people living and working in the vicinity of a construction site should be established at the beginning of a project and be maintained throughout the project, as this is of paramount importance. Keeping people informed of progress and taking complaints seriously and dealing with them expeditiously is critical. The person selected to liaise with the community should be adequately trained and experienced in such matters.

Where noise level exceedances cannot be avoided, then consideration may be given to implementing time restrictions and/or providing periods of repose for residents, where feasible and reasonable. That is, daily periods of respite from noisy activities may also be scheduled for building occupants during business hours.

Some items of plant may exceed noise limits even after noise treatment is applied. To reduce the overall noise impact, the use of noisy plant may be restricted to within certain time periods, where feasible and reasonable and to be negotiated with Council and the residents. For example, between 10am and 3pm (with one-hour break for lunch between 12pm and 1pm), noisy activities could occur with no noise level restrictions over a limited time period. Residents would be notified of the potential noise impact during this time period so that they can organise their day around the noisy period. Allowing the construction activities to proceed, despite the noise exceedance may be the preferred method in order to complete the works expeditiously.

5 Vibration management plan

5.1 Vibration criteria

Construction vibration is associated with three main types of impact:

- Disturbance to building occupants;
- Potential damage to buildings; and
- Potential damage to sensitive equipment in a building.

Generally, if disturbance to building occupants is controlled, there is limited potential for structural damage to buildings.

Vibration amplitude may be measured as displacement, velocity, or acceleration.

- Displacement (x) measurement is the distance or amplitude displaced from a resting position. The SI unit for distance is the meter (m), although common industrial standards include mm.
- Velocity ($v=\Delta x/\Delta t$) is the rate of change of displacement with respect to change in time. The SI unit for velocity is meters per second (m/s), although common industrial standards include mm/s. The Peak Particle Velocity (PPV) is the greatest instantaneous particle velocity during a given time interval. If measurements are made in 3-axis (x, y, and z) then the resultant PPV is the vector sum (i.e. the square root of the summed squares of the maximum velocities) regardless of when in the time history those occur.
- Acceleration ($a=\Delta v/\Delta t$) is the rate of change of velocity with respect to change in time. The SI unit for acceleration is meters per second squared (m/s^2).Construction vibration goals are summarised below.

Construction vibration goals are summarised below.

5.1.1 Disturbance to buildings occupants

Assessment of potential disturbance from vibration on human occupants of buildings is made in accordance with the DECC '*Assessing Vibration; a technical guideline*' (DECC, 2006). The guideline provides criteria which are based on the British Standard BS 6472-1992 '*Evaluation of human exposure to vibration in buildings (1-80Hz)*'. Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent'. Table 12 provides definitions and examples of each type of vibration.

Table 12 – Types of vibration

Type of vibration	Definition	Examples
Continuous vibration	Continues uninterrupted for a defined period (usually throughout the day-time and/or night-time)	Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).
Impulsive vibration	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	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.
Intermittent vibration	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	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.

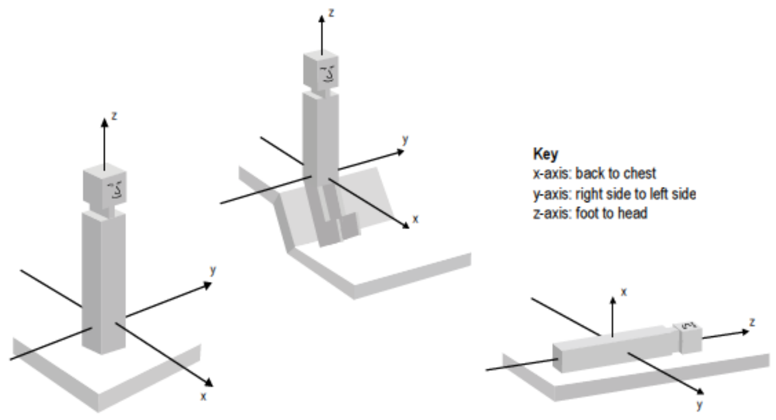
Source: Assessing Vibration; a technical guideline, Department of Environment & Climate Change, 2006

The vibration criteria are defined as a single weighted root mean square (rms) acceleration source level in each orthogonal axis. Section 2.3 of the guideline states:

> *'Evidence from research suggests that there are summation effects for vibrations at different frequencies. Therefore, for evaluation of vibration in relation to annoyance and comfort, overall weighted rms acceleration values of the vibration in each orthogonal axis are preferred (BS 6472).'*

When applying the criteria, it is important to note that the three directional axes are referenced to the human body, i.e. x-axis (back to chest), y-axis (right side to left side) or z-axis (foot to head). Vibration may enter the body along different orthogonal axes and affect it in different ways. Therefore, application of the criteria requires consideration of the position of the people being assessed, as illustrated in Figure 2. For example, vibration measured in the horizontal plane is compared with x- and y-axis criteria if the concern is for people in an upright position, or with the y- and z- axis criteria if the concern is for people in the lateral position.

Figure 2 – Orthogonal axes for human exposure to vibration



The preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and are reproduced in Table 13.

Table 13 – Preferred and maximum levels for human comfort

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous vibration (weighted RMS acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day- or night-time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and places of worship	Day- or night-time	0.020	0.014	0.040	0.028
Workshops	Day- or night-time	0.04	0.029	0.080	0.058
Impulsive vibration (weighted RMS acceleration, m/s^2, 1-80Hz)					
Critical areas[2]	Day- or night-time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and places of worship	Day- or night-time	0.64	0.46	1.28	0.92
Workshops	Day- or night-time	0.64	0.46	1.28	0.92

Notes:
1. Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am
2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specify above. Stipulation of such criteria is outside the scope of their policy and other guidance documents (e.g. relevant standards) should be referred to. Source: BS 6472-1992

The acceptable vibration dose values (VDV) for intermittent vibration are defined in Table 2.4 of the guideline and are reproduced in Table 14.

Table 14 – Acceptable vibration dose values for intermittent vibration (m/s$^{1.75}$)

Location	Daytime[1]		Night-time[1]	
	Preferred value	Maximum value	Preferred value	Maximum value
Critical areas[2]	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

Notes:
1. Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am
2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous of impulsive criteria for critical areas.
Source: BS 6472-1992

5.1.2 Building damage

Potential structural damage of buildings as a result of vibration is typically managed by ensuring vibration induced into the structure does not exceed certain limits and standards, such as British Standard 7385 Part 2 and German Standard DIN4150-3. Currently there is no existing Australian Standard for assessment of structural building damage caused by vibration energy.

Within British Standard 7385 Part 1: 1990, different levels of structural damage are defined:

- *Cosmetic - The formation of hairline cracks on drywall surfaces, or the growth of existing cracks in plaster or drywall surfaces; in addition the formation of hairline cracks in mortar joints of brick/concrete block construction.*
- *Minor - The formation of large cracks or loosening of plaster or drywall surfaces, or cracks through bricks/concrete blocks.*
- *Major - Damage to structural elements of the building, cracks in supporting columns, loosening of joints, splaying of masonry cracks, etc.*

The vibration limits in Table 1 of British Standard 7385 Part 2 (1993) are for the protection against cosmetic damage, however guidance on limits for minor and major damage is provided in Section 7.4.2 of the Standard:

> *"7.4.2 Guide values for transient vibration relating to cosmetic damage*
>
> *Limits for transient vibration, above which cosmetic damage could occur are given numerically in Table 1 and graphically in Figure 1. In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to line 2 are reduced. Below a frequency of 4 Hz, where a high displacement is associated with a relatively low peak component particle velocity value a maximum displacement of 0.6 mm (zero to peak) should be used.*
>
> *Minor damage is possible at vibration magnitudes which are greater than twice those given in Table 1, and major damage to a building structure may occur at values greater than four times the tabulated values."*

Within DIN4150-3, damage is defined as "*any permanent effect of vibration that reduces the serviceability of a structure or one of its components*" (p.2). The Standard also outlines:

> *"that for structures as in lines 2 and 3 of Table 1, the serviceability is considered to have been reduced if*
>
> – *cracks form in plastered surfaces of walls;*
>
> – *existing cracks in the building are enlarged;*
>
> – *partitions become detached from loadbearing walls or floors.*

These effects are deemed 'minor damage. " (DIN4150.3, 1990, p.3)

While the DIN Standard defines the above damage as 'minor', based on the definitions provided in BS7385, the DIN standard is considered to deal with cosmetic issues rather than major structural failures.

British Standard

British Standard 7385: Part 2 '*Evaluation and measurement of vibration in buildings*', can be used as a guide to assess the likelihood of building damage from ground vibration. BS7385 suggests levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur.

The cosmetic damage levels set by BS 7385 are considered 'safe limits' up to which no damage due to vibration effects has been observed for certain particular building types. Damage comprises minor non-structural effects such as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls. 'Minor' damage is considered possible at vibration magnitudes which are twice those given and 'major' damage to a building structure may occur at levels greater than four times those values.

BS7385 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4Hz to 250Hz, being the range usually encountered in buildings. At frequencies below 4Hz, a maximum displacement value is recommended. The values set in the Standard relate to transient vibrations and to low-rise buildings. Continuous vibration can give rise to dynamic magnifications due to resonances and may need to be reduced by up to 50%.Table 15 sets out the BS7385 criteria for cosmetic, minor and major damage.

Table 15 – BS 7385 structural damage criteria

Group	Type of structure	Damage level	Peak component particle velocity[1], mm/s		
			4Hz to 15Hz	15Hz to 40Hz	40Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	Cosmetic	50		
		Minor[2]	100		
		Major[2]	200		
2	Un-reinforced or light framed structures Residential or light commercial type buildings	Cosmetic	15 to 20	20 to 50	50
		Minor[2]	30 to 40	40 to 100	100
		Major[2]	60 to 80	80 to 200	200

Notes: 1. Peak Component Particle Velocity is the maximum Peak particle velocity in any one direction (x, y, z) as measured by a tri-axial vibration transducer.
2. Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2

German Standard

German Standard DIN 4150 - Part 3 '*Structural vibration in buildings - Effects on Structure*' (DIN 4150-3), also provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration and are generally recognised to be conservative.

DIN 4150-3 presents the recommended maximum limits over a range of frequencies (Hz), measured in any direction, and at the foundation or in the plane of the uppermost floor of a building or structure. The vibration limits increase as the frequency content of the vibration increases. The criteria are presented in Table 16.

Table 16 – DIN 4150-3 structural damage criteria

Group	Type of structure	Vibration velocity, mm/s			
		At foundation at frequency of			Plane of floor uppermost storey
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 or 2 and have intrinsic value (eg buildings under a preservation order)	3	3 to 8	8 to 10	8

5.2 Potential vibration impacts to residential and commercial uses

Based on the proposed plant items presented in Section 4.2, vibration generated by construction plant was estimated and potential vibration impacts are summarised in Table 17 below. The assessment is relevant to the identified buildings and other similar type structures in the project area.

Table 17 – Potential vibration for residential and non-residential properties

Receiver Location (Figure 1)	Approx. distance to nearest buildings from works	Type of nearest sensitive buildings	Assessment on potential vibration impacts		
			Structural damage risk	Human disturbance - risk of adverse comment	Vibration monitoring
R1	31m	Commercial/retail	Very Low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R2	26m	Church	Very Low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R3	30m	School	Very Low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R4	4.5m	Commercial (Police station and courthouse)	Low to medium risk of structural damage from construction works	Medium to high risk of adverse comment as a result of construction works	Vibration monitoring recommended at commencement of work

Receiver Location (Figure 1)	Approx. distance to nearest buildings from works	Type of nearest sensitive buildings	Assessment on potential vibration impacts		
			Structural damage risk	Human disturbance - risk of adverse comment	Vibration monitoring
R5	19m	Commercial/retail	Low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R6 (9 Elizabeth Street)	156m	Residential	Very Low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required

Based on the above assessment for the receivers that share boundary with the site, Receivers R4 would be most at risk from vibration impacts from the construction works. The plant equipment likely to generate the highest risk of vibration impacts are excavator activities including rock hammering and digging.

Therefore, measures to monitor and control vibration impacts are provided in the following sections.

5.3 Construction vibration monitoring

Long term vibration monitoring with an alarm system (eg. flashing lights or remote alerts through SMS and/or email) should be conducted at Receivers R3 and R4 where there are high risks of structural damage or human disturbance from vibration impacts.

Attended vibration measurements should be conducted at properties potentially exposed to medium to high risk of structural damage or human disturbance, in particular Receivers R5 and R6, to confirm vibration levels during construction works.

Recommendations for reducing potential vibration impacts, including minimum working distances for construction plant are provided in Section 5.4 below.

5.4 Recommended minimum buffer distances

The pattern of vibration radiation is very different to the pattern of airborne noise radiation, and is very site specific as final vibration levels are dependent on many factors including the actual plant used, its operation and the intervening geology between the activity and the receiver. Accordingly, based on a database containing vibration measurements from past projects and library information, Table 18 below presents the recommended minimum working distances for high vibration generating plant.

Table 18 – Recommended minimum working distances for vibration intensive plant, m

Plant item	Rating / description	Minimum working distance	
		Cosmetic damage	Human response
Excavator[1]	<=30 Tonne (travelling/ digging)	10	15
Loaders[2]		-	5

Plant item	Rating / description	Minimum working distance	
		Cosmetic damage	Human response
Small hydraulic hammer[2]	300kg (5-12 tonne excavator)	2	7
Medium hydraulic hammer[2]	900kg (12-18 tonne excavator)	7	23
Large hydraulic hammer[2]	1600kg (18-34 tonne excavator)	22	73
Pile boring[2]	≤ 800 mm	2 (nominal)	N/A
Pneumatic jack hammer	Hand held	1	Avoid contact with structure
Truck movements[2]	Dump trucks, watercarts, tippers	-	10 m

Notes: 1. TCA Construction Noise Strategy (Rail Projects) November 2011
2. Renzo Tonin & Associates project files, databases & library

Site specific buffer distances should be determined once vibration emission levels are measured from each plant item prior to the commencement of their regular use on site. Where construction activity occurs in close proximity to sensitive receivers, minimum buffer distances for building damage should be determined by site measurements and maintained.

5.5 Vibration management measures

The following vibration management measures are provided to minimise vibration impact from construction activities to the nearest affected receivers and to meet the relevant human comfort and building damage vibration limits:

1. The proper implementation of a vibration management plan is required to avoid adverse vibration disturbance to affected occupancies. Consultation with occupants and property owners is recommended and should be aimed at providing a communication path directly to the contractor.

2. A management procedure will be implemented to deal with vibration complaints. Each complaint will be investigated and where vibration levels are established as exceeding the set limits, appropriate amelioration measures shall be put in place to mitigate future occurrences. An example of a vibration complaint management procedure and complaint form is presented in Appendix E of this report.

3. Carry out vibration testing of actual equipment on site prior to the construction works to determine acceptable buffer distances to the sensitive receivers.

4. Carry out additional vibration monitoring as specified in Appendix D and Section 5.3 when construction activities are at the nearest point to the nominated occupancies. This monitoring may signal to the contractor by way of a buzzer or flashing light etc, when levels approach/exceed the recommended limits in nearby occupancies.

5. Carry out periodic vibration monitoring at all critical or sensitive areas and assess the vibration levels for compliance with the set vibration limits. This monitoring shall be undertaken in accordance with the vibration monitoring program described in Appendix D.

6. Where vibration is found to be excessive, management measures should be considered to ensure vibration compliance is achieved.

7. Before, during and after the excavation, demolition and construction phases we recommend preparation of a dilapidation report on the state of the existing buildings surrounding the construction site.

6 Complaints management

Noise levels generated by construction activities associated with the construction of the development should aim to comply with the noise goals set by the relevant regulations and guidelines.

The building contractor is responsible for implementing this Construction Noise and Vibration Management Plan and ensuring that all reasonable measures are implemented such as the provision of a Noise and Vibration Complaints Program, to minimise the generation of excessive noise and/or vibration levels from the site to nearby sensitive areas

Owners and occupants of nearby affected properties shall be informed by direct mail of a direct 24-hour telephone line where any noise and/or vibration complaints related to the operation of the construction activities will be recorded. Additionally, occupants will be notified of any periods of noisy construction activities at least 24 hours prior to their commencement.

All noise and/or complaints shall be investigated by the site manager in accordance with the Noise / Vibration Complaint Management Procedure identified in Appendix E of this report.

7 Conclusion

A Construction Noise and Vibration Management Plan has been prepared for the construction of the proposed townhouse development 1 Bowtells Drive, Avoca Beach. Specifically, this report aims to manage noise and vibration impacts during the construction works through noise and vibration control measures.

In-principle recommendations are provided in Section 4.4 and Section 5.5 to limit the potential impact of noise and vibration, respectively, generated by construction activities to acceptable levels. In addition, buffer distances for vibration compliance have been provided as guidance; however, should be determined in more detail prior to the start of construction works through on site measurements of vibration.

Procedures to manage complaints are also provided in Section 6 and Appendix E to ensure complaints are dealt with accordingly.

APPENDIX A Glossary of terminology

The following is a brief description of the technical terms used to describe noise to assist in understanding the technical issues presented.

Adverse weather	Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period of time (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of the nights in winter).
Ambient noise	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
Assessment period	The period in a day over which assessments are made.
Assessment point	A point at which noise measurements are taken or estimated. A point at which noise measurements are taken or estimated.
Background noise	Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the L90 noise level (see below).
Decibel [dB]	The units that sound is measured in. The following are examples of the decibel readings of every day sounds: 0dB The faintest sound we can hear 30dB A quiet library or in a quiet location in the country 45dB Typical office space. Ambience in the city at night 60dB CBD mall at lunch time 70dB The sound of a car passing on the street 80dB Loud music played at home 90dB The sound of a truck passing on the street 100dB The sound of a rock band 115dB Limit of sound permitted in industry 120dB Deafening
dB(A)	A-weighted decibels. The A- weighting noise filter simulates the response of the human ear at relatively low levels, where the ear is not as effective in hearing low frequency sounds as it is in hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter.
dB(C)	C-weighted decibels. The C-weighting noise filter simulates the response of the human ear at relatively high levels, where the human ear is nearly equally effective at hearing from mid-low frequency (63Hz) to mid-high frequency (4kHz), but is less effective outside these frequencies.
Frequency	Frequency is synonymous to pitch. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
Impulsive noise	Having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.
Intermittent noise	The level suddenly drops to that of the background noise several times during the period of observation. The time during which the noise remains at levels different from that of the ambient is one second or more.
L_{Max}	The maximum sound pressure level measured over a given period.
L_{Min}	The minimum sound pressure level measured over a given period.

L_1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L_{10}	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
L_{90}	The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L90 noise level expressed in units of dB(A).
L_{eq}	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time.
Reflection	Sound wave changed in direction of propagation due to a solid object obscuring its path.
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound	A fluctuation of air pressure which is propagated as a wave through air.
Sound absorption	The ability of a material to absorb sound energy through its conversion into thermal energy.
Sound level meter	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound pressure level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone.
Sound power level	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power.
Tonal noise	Containing a prominent frequency and characterised by a definite pitch.

APPENDIX B Specification for determining the Sound Power Levels of construction plant

B.1 Scope

This document specifies methods for determination of sound power levels for construction plant including earthmoving equipment and other ancillary plant and equipment used during construction.

B.2 Referenced standards

- AS IEC 61672.1 2004 '*Electroacoustics - Sound Level Meters*'
- AS 2012.1-1990 '*Acoustics - Measurement of airborne noise emitted by earth-moving machinery and agricultural tractors - Stationary test condition - Determination of compliance with limits for exterior noise*'
- ISO 3744:2010 '*Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane*'
- ISO 3746:2010 '*Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Survey method using an enveloping measurement surface over a reflecting plane*'
- ISO 6393:2008 '*Earth-moving machinery - Determination of sound power level - Stationary test conditions*'
- ISO 6395:2008 '*Earth-moving machinery - Determination of sound power level - Dynamic test conditions*'

B.3 Testing procedures – earthmoving machinery

The following procedures are to be followed by personnel suitably qualified and experienced in undertaking acoustic measurements.

Each significant plant item shall be tested in terms of both the 'stationary' and the 'dynamic' testing procedures detailed below.

All sound level meters used must be Type 1 instruments as described in AS IEC 61672.1 2004 '*Electroacoustics - Sound Level Meters*' and calibrated to standards that are traceable to Australian Physical Standards held by the National Measurement Laboratory (CSIRO Division of Applied Physics). The calibration of the meters shall be checked in the field before and after the noise measurement period.

B.4 Stationary testing

Stationary measurements shall be performed on all earthmoving plant according to the method of AS 2012.1-1990 and/or ISO 6393:2008.

In addition to measuring overall A-weighted noise levels, third-octave band frequency $L_{Aeq,T}$ noise levels shall also be measured at each measurement location from 50Hz to 20kHz inclusive. Background noise shall also be recorded in the same third-octave band frequency range, and corrections to measured third-octave band noise levels shall be applied as described in Table 1 of AS2012.1-1990.

Each plant item should be tested in isolation, without any other noisy plant on site operating. Where this cannot be done for practical reasons, then the noise of the plant being tested shall be at least 6dB greater than the background noise from other nearby plant, both in terms of the overall A-weighted level and in all third-octave band frequencies.

Measured third-octave band $L_{Aeq,T}$ noise levels shall also be processed as described in Section 8 of that Standard to establish third-octave band sound power levels.

The overall A-weighted sound power levels shall be determined for $L_{Aeq,T}$, $L_{A10,T}$ and $L_{A1,T}$ noise metrics. The measurement sample time shall be selected so that it is representative of the operating cycle/s of the plant being tested.

Where the plant tested or noise measurements are taken within 3.5 metres of large walls or cliffs, then a reflection correction of up to -2.5dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

All measured noise level data and determined sound power levels shall be included in the test reports.

B.5 Dynamic testing

Details of equipment operation during testing will vary depending on the equipment type. Dynamic measurements shall be performed on all earthmoving plant according to the method in International Standard ISO 6395.

In addition to measuring overall A-weighted noise levels, third-octave band frequency $L_{Aeq,T}$ noise levels shall also be measured at each measurement location from 50Hz to 20kHz inclusive. Background noise shall also be recorded in the same third-octave band frequency range, and corrections to measured third-octave band noise levels shall be applied as described in International Standard ISO 6395.

Each plant item should be tested in isolation, without any other noisy plant on site operating. Where this cannot be done for practical reasons, then the noise of the plant being tested shall be at least 6dB greater than the background noise from other nearby plant, both in terms of the overall A-weighted level and in all third-octave band frequencies.

Measured third-octave band $L_{Aeq,T}$ noise levels shall also be processed to establish third-octave band sound power levels.

Where the plant tested or noise measurements are taken within 3.5 metres of large walls or cliffs, then a reflection correction of up to -2.5dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

The overall A-weighted sound power levels shall be determined for $L_{Aeq,T}$, $L_{A10,T}$ and $L_{A1,T}$ noise metrics. The measurement sample time shall be selected so that it is representative of the operating cycle/s of the plant being tested.

All measured noise level data and determined sound power levels shall be included in the test reports.

B.6 Testing procedures – other construction plant

The following procedures are to be followed by personnel suitably qualified and experienced in undertaking acoustic measurements.

All sound level meters used must be Type 1 instruments as described in AS IEC 61672.1 2004 '*Electroacoustics - Sound Level Meters*'. The calibration of the meters shall be checked in the field before and after the noise measurement period.

Noise measurements shall be performed on all non-earthmoving construction plant according to the methods of either ISO 3744:2010 or ISO 3746:2010, whichever is applicable to the items of plant being tested.

Machinery shall be operated at high idle speed. In the case of drilling, boring and rock-breaking machines, the testing location shall allow for these machines to be operated in rock of characteristics that are typical for the project site.

In addition to measuring overall A-weighted noise levels, third-octave band frequency $L_{Aeq,T}$ noise levels shall also be measured at each measurement location from 50Hz to 20kHz inclusive. Background noise shall also be recorded in the same third-octave band frequency range, and corrections to measured third-octave band noise levels shall be applied as described in Table 1 of AS2012.1-1990.

Each plant item should be tested in isolation, without any other noisy plant on site operating. Where this cannot be done for practical reasons, then the noise of the plant being tested shall be at least 6dB greater than the background noise from other nearby plant, both in terms of the overall A-weighted level and in all third-octave band frequencies.

Measured third-octave band $L_{Aeq,T}$ noise levels shall also be processed as described in Section 8 of that Standard to establish third-octave band sound power levels.

The overall A-weighted sound power levels to be determined shall be in terms of both the $L_{Aeq,T}$, $L_{A10,T}$ and $L_{A1,T}$ noise metrics. The measurement sample time shall be selected so that it is representative of the operating cycle/s of the plant being tested.

Where the plant tested or noise measurements are taken within 3.5 metres of large walls or cliffs, then a reflection correction of up to -2.5dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

All measured noise level data and determined sound power levels shall be included in the test reports.

APPENDIX C Specification for construction noise monitoring

C.1 Scope

This document specifies methods for undertaking noise monitoring during the construction phase of the project.

C.2 Referenced standards and guidelines

- Australian Standard AS IEC 61672.1 2004 '*Electroacoustics - Sound Level Meters - Specifications*'
- Australian Standard AS 1259.2-1990 '*Acoustics - Sound Level Meters*'
- Australian Standard AS 1055-1997 '*Acoustics - Description and Measurement of Environmental Noise*'
- NSW '*Interim Construction Noise Guideline*' (Department of Environment and Climate Change 2009)
- NSW '*Industrial Noise Policy*' (Environment Protection Authority 2000)

C.3 Testing procedures

The following procedures are to be followed by personnel suitably qualified and experienced in undertaking acoustic measurements.

All noise monitoring equipment used must be at least Type 2 instruments as described in AS 1259.2-1990 and calibrated to standards that are traceable to Australian Physical Standards held by the National Measurement Laboratory (CSIRO Division of Applied Physics). The calibration of the monitoring equipment shall also be checked in the field before and after the noise measurement period, and in the case of long-term noise monitoring, calibration levels shall be checked at minimum weekly intervals.

Long-term noise monitoring equipment or Noise Loggers, consist of sound level meters housed in weather resistant enclosures. The operator may retrieve the data at the conclusion of each monitoring period in person or remotely if the logger is fitted with mobile communications.

All environmental noise measurements shall be taken with the following meter settings:

- Time constant: FAST (ie 125 milliseconds)
- Frequency weightings: A-weighting
- Sample period: 15 minutes

All outdoor noise measurements shall be undertaken with a windscreen over the microphone. Windscreens reduce wind noise at the microphones.

Measurements of noise should be disregarded when it is raining and/or the wind speed is greater than 5m/s (18km/h).

C.4 Long-term (unattended) noise monitoring

Noise monitoring shall be undertaken in accordance with the environmental noise measurement requirements stipulated in the reference standards and documents listed above.

Noise monitoring equipment shall be placed at positions which have unobstructed views of general site activities, while acoustically shielded as much as possible from non-construction site noise (eg. road traffic, rail noise and other surrounding noise).

Noise levels are to be recorded at a minimum rate of 10 samples per second. Every 15 minutes, the data is to be processed statistically and stored in memory. The minimum range of noise metrics to be stored in memory for later retrieval is the following A-weighted noise levels: L_{min}, L_{90}, L_{eq}, L_{10}, L_1 and L_{max}.

Where the noise monitors are placed within 3.5 metres of building facades, walls or cliffs, then a reflection correction of up to -2.5dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

Meteorological conditions including wind velocity, wind direction and rainfall shall be monitored over the entire noise monitoring period, either on site or recorded from the nearest weather station to the project site.

C.5 Short-term (attended) monitoring

Where noise complaints or requests from relevant authorities are received, attended short-term noise monitoring shall also be conducted at the requested outdoor location (unless the issue is related to regenerated noise from tunnelling and driveage works) and at any other relevant noise receiver location with closest proximity to the construction activities.

Short-term noise monitoring shall be used to supplement long-term noise monitoring undertaken at nearby locations, and to establish whether noise levels measured by the long-term noise monitors are determined by construction activities carried out on site.

All attended short-term noise monitoring shall be recorded over 15 minute sample intervals. Noise levels are to be recorded at a minimum rate of 10 samples per second. Every 15 minutes, the data is to be processed statistically and stored in memory. The minimum range of noise metrics to be stored in memory and reported is the following A-weighted noise levels: L_{min}, L_{90}, L_{eq}, L_{10}, L_1 and L_{max}.

In addition to measuring and reporting overall A-weighted noise levels, statistical L_{90}, L_{eq}, L_{10} noise levels shall be measured and reported in third-octave band frequencies from 31.5Hz to 8kHz.

Where the noise monitors are placed within 3.5 metres of building facades, walls or cliffs, then a reflection correction of up to -2.5dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

Outdoor noise monitoring is to be undertaken with the microphone at a height of 1.2 – 1.5m from the ground, unless noise measurements are taken from a balcony or veranda, in which case the same microphone height shall apply off the floor.

Noise measurements inside buildings should be at least 1m from the walls or other major reflecting surfaces, 1.2 m to 1.5m above the floor, and 1.5m from windows.

Noise monitoring shall be undertaken in accordance with the environmental noise measurement requirements stipulated in the reference standards and documents listed above.

The following information shall be recorded:

- Date and time of measurements;
- Type and model number of instrumentation;
- Results of field calibration checks before and after measurements;
- Description of the time aspects of each measurement (ie sample times, measurement time intervals and time of day);
- Sketch map of area;
- Measurement location details and number of measurements at each location;
- Weather conditions during measurements, including wind velocity, wind direction, temperature, relative humidity and cloud cover
- Operation and load conditions of the noise sources under investigation
- Any adjustment made for presence or absence of nearby reflecting surfaces; and
- Noise due to other sources (eg traffic, aircraft, trains, dogs barking, insects etc).

APPENDIX D Construction vibration monitoring specification

D.1 Scope

This document specifies methods for undertaking vibration monitoring during the construction phase of the project. Vibration monitoring during construction activities may be carried out for the following reasons:

- To confirm acceptability of construction techniques, or confirm compliance with limits for structural or cosmetic damage of buildings; or
- To assess compliance with vibration limits for human exposure to vibration.

Monitoring may be carried out in response to specific conditions of approval or complaint. However, the recommended work practice is to conduct proactive monitoring and establish procedures that provide greater assurance of compliance with relevant policy guidelines and Standards throughout all phases of the project works. It is noted that this specification does not address monitoring of blasting activities.

D.1.1 Requirements for vibration monitoring

Vibration monitoring is to be carried out at the following times in accordance with this CNVMP:

- At the commencement of operation of each piece of plant equipment or site activity which has the potential to generate significant vibration levels. The objective of this monitoring is to refine the indicative working distances for vibration generating equipment and provide site-specific minimum working distances. Refer to procedure below for establishment Vibration Minimum Working Distances.
- Where vibration complaints or requests from relevant authorities, at the requested location and at any other relevant vibration receiver location with closest proximity to the construction activities. This may be carried out with short-term or long-term monitoring methods.

Vibration amplitude may be measured as displacement, velocity, or acceleration.

- **Displacement** (x) measurement is the distance or amplitude displaced from a resting position. The SI unit for distance is the meter (m), although common industrial standards (including the TfNSW vibration limits) include mm.
- **Velocity** ($v=\Delta x/\Delta t$) is the rate of change of displacement with respect to change in time. The SI unit for velocity is meters per second (m/s), although common industrial standards (including the TfNSW vibration limits) include mm/s. The Peak Particle Velocity (PPV) is the greatest instantaneous particle velocity during a given time interval. If measurements are made in 3-axis (x, y, and z) then the resultant PPV is the vector sum (i.e. the square root of the summed squares of the maximum velocities) regardless of when in the time history those occur.

- **Acceleration** (a=Δv/Δt) is the rate of change of velocity with respect to change in time. The SI unit for acceleration is meters per second squared (m/s^2).

D.2 Referenced standards and guidelines

- AS 2775-2004 *Mechanical vibration and shock – Mechanical mounting of accelerometers*
- AS 2670.2-1990 *Evaluation of human exposure to whole body vibration*
- BS 6472-1992 *Guide to evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)*
- BS 6841–1987 *Guide to measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock*
- BS 7482–1991 Parts 1 and 3: *Instrumentation for the measurement of vibration exposure of human beings*
- BS 7385:1 *Evaluation and Measurement for Vibration in Buildings – Part 1: Guide for measurement of vibrations and evaluation of their effects on buildings*
- BS 7385:2 *Evaluation and Measurement for Vibration in Buildings – Part 2: Guide to Damage Levels from Ground borne Vibration*
- DIN 4150-1999 Part 3 *Structural vibration – Effects of vibration on structures*
- ISO 4866 *Mechanical Vibration & Shock – Vibration of Buildings – Guidelines for the Management of the Vibrations and Evaluation of their Effects on Buildings*
- NSW DEC (EPA) 2006 *Assessing Vibration: A technical guide*

Vibration monitoring shall be undertaken in accordance with the vibration measurement requirements stipulated in the reference Standards and guidelines listed above; however, the following notes of importance are included herein.

D.3 Vibration minimum working distances

Minimum working distances are to be established for each vibration generating item of equipment, as identified, to provide a site-specific minimum working distances.

The testing regime should commence at a suitable time to allow sufficient time to amend construction techniques as necessary, without affecting the overall construction program.

Minimum working distances are to be established using identical equipment or simulated practices at a location removed from the sensitive structure or receiver.

Sufficient measurements are to be carried out in accordance with the relevant Standards to confirm the minimum working distances and confirm the acceptable work practices that are likely to be compliant given the proximity of actual works to sensitive receivers and structures.

Consultation between consultants, engineers and the construction team may be required where revision to work practices is required.

D.3.1 Personnel and equipment

The following procedures are to be followed by personnel suitably qualified and experienced in undertaking vibration measurements.

All vibration monitoring equipment used must be calibrated at least once every two years to Standards that are traceable to Australian Physical Standards held by the National Measurement Laboratory (CSIRO Division of Applied Physics).

Vibration monitors consist of a computer unit connected by cable to a tri-axial vibration transducer which senses vertical, axial and horizontal vibration, or three separate uni-axial vibration transducers positioned in the vertical, axial and horizontal axes. The parameters to be measured differ dependent upon the relevant Standards but may include:

Assessment type	Type of vibration	Relevant standard/guideline	Measurement parameters
Human comfort	Continuous and impulsive	DECC guideline BS 6472-1992	RMS acceleration, 1-80Hz. 1/3 octave weighted as defined in BS6841-1987
	Intermittent vibration	DECC guideline BS 6472-1992	RMS acceleration, 1-80Hz Vibration Dose Values (VDVs) in accordance with BS6472-1992
Structural damage	Non-blasting	DIN 4150-1999 Part 3	Peak-particle velocity (PPV), 1-100Hz
	Non-blasting	BS 7385 Part 2	Peak-particle velocity (PPV), 4-250Hz
Structural damage – sensitive structures	Non-blasting	DIN 4150-1999 Part 3	Peak-particle velocity (PPV), 1-100Hz

Short-term vibration monitors should allow real-time analysis of vibration levels to assist assessment and feedback on the subject operations and procedures.

D.3.2 Monitoring procedure

Vibration monitoring equipment should be installed in accordance with the following guidance:

- At a location equivalent to the site and ground conditions at the sensitive receiver location. The working distances should not be established via immediate measurement and activities near the sensitive structure.
- The surface should be solid and rigid in order to best represent the vibration levels entering the building/structure under investigation.
- The vibration sensor or transducer should not be mounted on loose gravel or other unstable surfaces.

- The vibration geophone or transducer(s) should be directly mounted to the vibrating surface using bees wax, double sided adhesive tape, or magnetically fixed to a mounting plate fastened to the vibrating surface.
- Where a suitable mounting surface is unavailable, a metal stake (at least 300mm in length) with a mounting plate should be driven into solid ground adjacent to the building of interest. The vibration sensor or transducer shall be fixed on top of the mounting plate.

The following information shall be recorded:

- Date and time of measurements;
- Type and model number of instrumentation;
- Description of the time aspects of each measurement (i.e. sample times, measurement time intervals and time of day);
- Sketch map of area;
- Measurement location details (including distance from vibrating source) and number of measurements at each location;
- Operation and load conditions of the vibrating plant under investigation and distance from the measurement location; and
- Possible vibration influences from other sources (e.g. other mechanical plant, traffic, railway).

D.4 Long-term (unattended) monitoring

Long-term unattended vibration monitoring shall be undertaken continuously whilst the vibrating plant is operational within the pre-determined ‘minimum working distances’ from potentially affected buildings or sensitive structures. Long-term unattended vibration monitoring is generally carried out for the assessment of structural or cosmetic damage rather than human exposure.

D.4.1 Personnel and equipment

The following procedures are to be followed by personnel suitably qualified and experienced in undertaking vibration measurements.

All vibration monitoring equipment used must be calibrated at least once every two years to Standards that are traceable to Australian Physical Standards held by the National Measurement Laboratory (CSIRO Division of Applied Physics).

Vibration monitors consist of a computer unit connected by cable to a tri-axial vibration transducer which senses vertical, axial and horizontal vibration, or three separate uni-axial vibration transducers positioned in the vertical, axial and horizontal axes.

Long-term monitoring for the management of structural and cosmetic damage should include the following:

- Vibration levels are to be monitored continuously with the following parameters being stored at a maximum interval period of 5 minutes:
  - Peak-particle velocity (PPV) between 1 Hz and 100 Hz for each direction of the tri-axial geophone (or transducers) and vector-sum peak-particle velocity [DIN4150.3];
  - Peak-particle velocity (PPV) between 4 Hz and 250 Hz for each direction of the tri-axial geophone (or transducers) and vector-sum peak-particle velocity [BS 7385.2].
- Vibration levels are to be stored at the pre-defined intervals in the logger memory for record, data analysis or post-processing. Data may be retrieved at the conclusion of each monitoring period either by operator download or remotely via a telephone modem if the logger is fitted with a remote communications option.
- Monitors should be fitted with an audible, visual, SMS or email alert system, triggered to provide warning when the measured level of vibration approaches or exceeds the limits defined by the relevant Standard.
- Where the trigger limits are exceeded, a detailed waveform recording should be stored including a detailed frequency spectrum for assessment against the frequency limit curve.

D.4.2 Monitoring location and mounting

Vibration monitoring equipment should be installed in accordance with the following guidance:

- Equipment should be positioned at the footings or foundations of the building of interest, closest to the vibrating plant.
- The mounting surface should be solid and rigid in order to best represent the vibration levels entering the structure of the building under investigation.
- The vibration geophone or transducer(s) should not be mounted on loose tiles, loose gravel or other unstable surfaces.
- The vibration geophone or transducer(s) should be directly mounted to the vibrating surface using bees wax, double sided adhesive tape, or magnetically fixed to a mounting plate fastened to the vibrating surface.
- Where a suitable mounting surface is unavailable, a metal stake (at least 300mm in length) with a mounting plate should be driven into solid ground adjacent to the building of interest. The vibration sensor or transducer shall be fixed to the mounting plate.

D.5 Vibration measurements in response to complaints

Proactive vibration monitoring and establishment of procedures that comply with the policy guidelines and Standards is the recommended work practice to reduce the risk of complaint regarding vibration from the site.

There may however be cases where specific monitoring is required to investigate a complaint or issue identified during the project works. Vibration monitoring may be carried out using either short-term or long-term methodologies depending on the nature of the complaint. Short-term attended manned procedures would generally be carried out when measurements are required inside a property or where immediate action and detailed observations are required to be made at the time of measurements. Short-term monitoring would generally follow the procedures outlined for the establishment of Minimum Working Distances. Long-term monitoring would be carried out as described in section D.4 above.

APPENDIX E Noise / vibration complaint management procedure

Compliant Received

Details of complaint are recorded on 'Noise / Vibration Complaint Form'

Construction Site Manager to review complaint form

Construction manager handles complaint and responds accordingly

Issue Noise and Vibration Complaint Form to acoustic consultants (Renzo Tonin & Associates) by fax or email

Acoustic consultant to review complaint form and discuss action with contractor

Acoustic consultant to attend site and investigate complaint

Acoustic consultant to assess compliance against statutory limits

If compliant, acoustic consultant to issue 'Compliance Certificate' detailing assessment and findings

If non-compliant, consultant to liaise with contractor to determine options for noise control

Contractor to select their preferred noise and/or vibration control options

Consultant to issue report detailing the noise and/or vibration control measures to be adopted

Implementation - responsibility of building contractor

Contractor to notify complainant of action taken

NOISE AND VIBRATION COMPLAINT FORM

Project title: ____________________ **Date:** ____________

Site contractor: ____________________ **Phone:** ____________

Site contact: ____________________ **Email:** ____________

Complaint details

Received by (circle): Phone / Email / In person / Other: ____________

Name: ____________________ H Ph: ____________

Address: ____________________ W Ph ____________

Email: ____________________ M Ph ____________

Describe when the problem occurred (date and time), what equipment caused the complaint (if known) and where person was standing when he/she experienced the noise:

Investigation

Question foreman responsible on site and obtain information on what equipment or processes would most likely have caused the complaint:

Following approval from the Project Manager, email/fax this form to Renzo Tonin & Associates