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UTS BROADWAY BUILDING

EXCAVATION NOISE & VIBRATION MANAGEMENT PLAN

TE914-01F02 (REV 1) ENVMP

23 SEPTEMBER 2010

Prepared for:

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1 INTRODUCTION

Renzo Tonin & Associates were engaged to prepare an Excavation Noise and Vibration Management Plan (ENVMP) for the proposed University of Technology, Sydney (UTS) Broadway Building development on the corners of Jones Street, Broadway and Wattle Street, Ultimo. This management plan will provide guidelines to reduce noise and vibration impacts to nearby affected receivers during excavation works.

In accordance with relevant guidelines, this document:

- Identifies the potential sources of noise and vibration during the proposed works;
- Specifies the noise and vibration criteria for the proposed works;
- Describes in detail what actions and mitigation measures could be implemented to enable these works to comply with the relevant noise and vibration criteria;
- Describes how the effectiveness of these actions and mitigation 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
- Describes 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 the Australian Standard / NZS ISO 9001.

2 PROJECT DESCRIPTION

2.1 Location

The construction site is located on the corners of Jones Street, Broadway and Wattle Street, Ultimo and is bound by Jones Street to the east, Broadway to the south and Wattle Street to the west. UTS building CB10 bounds the site to the north and shares a common boundary with the site. Other UTS buildings to the east, commercial properties to the west and residential apartments to the northwest surround the site.

The nearest and potentially worst affected sensitive receivers were identified during a site inspection. These sensitive receivers are as follows:

- **Receiver R1** – **UTS Building CB10**
  Building with teaching spaces, offices and commercial spaces located directly adjacent to the north of the construction site and sharing a common boundary.

- **Receiver R2 – 129-133 Broadway, Ultimo**
  Commercial development located approximately 45m across Wattle Street to the west of the construction site.

- **Receiver R3** – **513-519 Wattle Street, Ultimo**
  Mixed use development with commercial premises on the ground level and residential apartment units on the upper levels located approximately 50m across Wattle Street to the northwest of the construction site.

Figure 1 is a locality map showing the site and its surrounding area.

In addition to the above receiver locations and given that UTS Building CB10 is a multi-level building; each floor level of UTS Building CB10 was also assessed for excavation noise impacts.

2.2 Proposed Excavation Activities

The proposal includes three phases of construction which consist of demolition, excavation and construction of the UTS Broadway Building development. However, this management plan will only address the excavation phase of the development.

Excavation will involve the preparation of the ground ready for construction works and will be the noisiest activity. Excavation works are anticipated to be undertaken for a period of approximately six (6) months.

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Title : Figure 1 - Site, Surrounds, Receivers & Measurement Location

Date : 15/07/10

Scale: NTS

Project: UTS Broadway Building

Ref : TE914-01P01 (rev 0)

3 EXISTING ACOUSTIC ENVIRONMENT

Appropriately secure locations were unable to be found for long term, unattended noise monitoring. Instead, several short term attended background noise measurements were conducted during different periods of the day, corresponding to the construction hours, on Tuesday 15th June 2010 and Wednesday 16th June 2010. Measurements were conducted in the 'free field', away from any reflective surfaces.

The following noise monitoring location was selected for the purpose of this assessment.

- **Location S1 – 513-519 Wattle Street, Ultimo**
  Eastern side of building on the footpath facing Wattle Street. The noise environment at this location was dominated by traffic noise from Wattle Street and distance traffic from Broadway. The background noise levels at this location are considered to be representative of Receiver R3.

3.1 Noise Monitoring Results

The results of the short term measurements are shown below.

Table 3.1 – Measured Existing Background (L_{90}) & Ambient (L_{eq}) Noise Levels, dB(A)

Location	L_{90} Background Noise Level	L_{eq} Ambient Noise Level
Location S1 – 513-519 Wattle Street	66	72

4 NOISE MANAGEMENT PLAN

4.1 Purpose

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

4.2 Noise Criteria

4.2.1 Interim Construction Noise Guideline

Chapter 171 of the NSW *Environmental Noise Control Manual* (ENCM, Environment Protection Authority 1994) provides guidelines for assessing noise generated during the construction phase. However, the Department of Environment, Climate Change and Water (DECCW – formerly DECC) has recently released its *NSW Interim Construction Noise Guideline* (ICNG). This document is the DECCW's standard policy for assessing construction noise. This new guideline supersedes Chapter 171 of the ENCM.

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

1. Use of L_{Aeq} as the descriptor for measuring and assessing construction noise.

   In recent years NSW noise policies including DECCW's NSW Industrial Noise Policy (INP) and the NSW Environmental Criteria for Road Traffic Noise (ECRTN) 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.

   Consistent with the ICNG we recommend the use of L_{Aeq} as the key descriptor for measuring and assessing construction noise.

2. 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.

3. Quantitative and qualitative assessment

   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 significant scale of the excavation works proposed for the UTS Broadway Building site, a quantitative assessment is carried out herein, consistent with the ICNG's requirements.

Management Levels

Table 4.1 below (reproduced from Table 2 of the ICNG) sets out the noise management levels and how they are to be applied for residential receivers. The guidelines intend to provide respite for residents exposed to excessive construction noise outside the recommended standard hours whilst allowing construction during the recommended standard hours without undue constraints.

In Table 4.1 below, the rating background level (RBL) is used when determining the management level. The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours).

Table 4.1 – Noise at Residences Using Quantitative Assessment

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(A)	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq\ (15\ min)}$ 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)	• 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 *NSW Interim Construction Noise Guideline*.

Time of Day	Management Level $L_{Aeq\ (15\ min)}$ *	How to Apply

** 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.*

The background noise level measured at the measurement location was considered to be representative of the RBL for the residential apartment on Wattle Street (Receiver R3) affected by excavation noise from the site. Therefore, the measured background noise level is suitable for setting construction noise criteria for residential receivers, consistent with a conservative assessment. Based on the background noise level measured and excavation work proposed for the day time period only, the construction noise criteria for the residential receivers during the day period are summarised below.

Table 4.2 – Summary of Construction Noise Management Levels, dB(A)

Time of Day	Management Level $L_{Aeq(15min)}$	Base Management Level $L_{Aeq(15min)}$
During recommended standard hours (day)	RBL + 10dB(A)	66 + 10 = **76**

Given that the base management level is higher than the 'highly noise affected' level of 75dB(A), as stipulated in the ICNG and presented in Table 4.1 above, the applicable noise management level to be used for the assessment of construction noise at the residential receiver will be **75dB(A)**.

Sensitive Land Uses

Table 4.3 below (reproduced from Table 3 of the ICNG) sets out the noise management levels for sensitive land uses. Given that Receiver R1 (UTS Building CB10) includes teaching spaces, the management levels for school classrooms would be applicable.

Table 4.3 – Noise at Other Sensitive Land Uses Using Quantitative Assessment

Land use	Management level, $L_{Aeq\ (15\ min)}$
Classrooms at Schools and other educational institutions[1]	Internal noise level = 45 dB(A)

Notes: 1. Applicable for the internal teaching spaces in UTS Building CB10 directly affected by construction noise

As a general rule, masonry / brick type building structures would typically provide a 15dB(A) reduction from external noise levels to internal noise levels. Therefore, the equivalent external management noise level for classrooms is **60dB(A)**.

Commercial Premises

Commercial premises are located near the proposed UTS Broadway Building construction site and in accordance with Section 4.1.3 of the ICNG, commercial properties should be assessed for construction noise impacts. The noise management levels presented in the ICNG for commercial premises are reproduced in Table 4.4 below.

Table 4.4 – Noise at Commercial Premises Using Quantitative Assessment

Type of Premises	Management level, $L_{Aeq\ (15\ min)}$
Commercial (such as offices and retail outlets)	External noise level = 70 dB(A)

4.2.2 Australian Standard 2107:2000

In addition to the DECCW's ICNG, recommended internal noise levels for different types of occupancies are provided in Australian Standard 2107:2000 'Acoustics – Recommended design sound levels and reverberation times for building interiors'. Table 1 of the standard provides recommended design sound levels within internal areas which would be applicable to affected internal areas of UTS Building CB10. The recommended internal noise levels are presented below and are for internal areas not addressed by the ICNG.

Table 4.5 – AS2107:2000 Recommended Internal Design Sound Levels

Type of Occupancy	Recommended Design Sound Level, L_{Aeq}, dB(A)	
	Satisfactory	Maximum
Office areas	40	45
Retail stores	45	50

4.2.3 Time Restrictions

In accordance with the ICNG, the standard work hours are:

- Monday to Friday, 7am to 6pm.
- Saturday, 7am to 1pm if inaudible on residential premises, otherwise 8am to 1pm.
- No construction work to take place on Sundays or Public Holidays.

4.3 Proposed Excavation Noise Sources

The construction of the proposed UTS Broadway Building will be conducted in three main phases. Phase 1 of the construction relates to demolition of the existing buildings on the proposed site. Phase 2 of the construction consist mainly of excavation works which involves excavating through Class I/II sandstone bedrock and fill on the site. The final phase of the construction is the construction of the proposed UTS Broadway Building. However, as part of this management plan, only the excavation phase will be addressed.

Actual construction plant and equipment to be used during the excavation phase of the development are not yet known. Therefore, typical plant and equipment likely to be used during the excavation works are provided in Table 4.6 below.

Table 4.6 – Typical Excavation Equipment & Sound Power Levels, dB(A)

Plant Item	Plant Description	L_{Aeq} Sound Power Levels
1	Rock Breaker	117
2	Rock Saw	116
3	Bulldozer	109
4	Rock Ripper	108
5	Excavator	107
6	Dump Trucks	105

The sound power levels for the majority of activities presented in the above table are based on maximum levels given in Table D2 of Australian Standard 2436 - 2010 "Guide to Noise Control on Construction, Maintenance and Demolition Sites", information from past projects and information held in our library files.

4.4 Estimated Noise Levels

The estimated noise levels at the nearest affected receiver locations affected by excavation activities were calculated and are shown in Table 4.7 below. It must be noted that for a conservative assessment the predicted noise levels based on a 'worst case' scenario where all the excavation plant and equipment are operating concurrently are also presented.

Table 4.7 – Predicted Excavation L_{Aeq} Noise Levels at Receiver Locations, dB(A)

Plant Item	Plant Description	Receiver R1	Receiver R2	Receiver R3
1	Rock Breaker	92	76	75
2	Rock Saw	91	75	74
3	Bulldozer	83	67	66
4	Rock Ripper	84	67	67
5	Excavator	82	66	65
6	Dump Trucks	80	63	63
All Equipment Operating Concurrently		**96**	**79**	**78**

The predicted noise levels above are based on excavation plant and equipment generally operating in the areas closest to the corresponding nearby critical receivers. Calculations take into consideration attenuation due to distance between the receiver and the excavation activity only and do not consider shielding provided by intervening structures. Furthermore, the predicted noise levels are based on no noise mitigation treatment applied to plant and equipment on site.

In addition to the nominated receiver locations, predicted excavation noise levels for each floor level of UTS Building CB10 were also predicted and are presented in the table below.

Table 4.8 – Predicted Excavation L_{Aeq} Noise Levels at CB10 Floor Levels, dB(A)

Plant Item	Plant Description	UTS Building CB10 Floor Level												
		L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14
1	Rock Breaker	92	91	90	88	86	85	83	82	81	80	79	78	78
2	Rock Saw	91	90	89	87	85	84	82	81	80	79	78	77	77
3	Bulldozer	83	82	81	79	77	76	74	73	72	71	70	69	69
4	Rock Ripper	84	83	81	79	78	76	75	74	73	72	71	70	69
5	Excavator	82	81	80	78	76	75	73	72	71	70	69	68	68
6	Dump Trucks	80	79	77	75	74	72	71	70	69	68	67	66	65
All Equipment Operating Concurrently		**96**	**95**	**93**	**91**	**90**	**88**	**87**	**86**	**85**	**84**	**83**	**82**	**81**

Based on Table 4.7 and Table 4.8 noise emission from excavation activities will generally exceed the set noise criteria for all locations. Noise mitigation measures should therefore be considered to minimise noise impact during excavation activities.

4.5 Noise Mitigation Measures

4.5.1 General Engineering Noise Controls

Implementation of noise control measures, such as those suggested in Australian Standard 2436-1981 *Guide to Noise Control on Construction, Maintenance and Demolition Sites* are expected to reduce predicted construction noise levels. Reference to Australian Standard 2436-1981, Appendix E, Table E1 suggests possible remedies and alternatives to reduce noise emission levels from typical construction equipment. Table E2 in Appendix E presents typical examples of noise reductions achievable after treatment of various noise sources. Table E3 in Appendix E presents the relative effectiveness of various forms of noise control treatment.

Table 4.9 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 4.9 – 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 & Assoc.	AS 2436	Renzo Tonin & Assoc.
Screening	Acoustic barriers such as earth mounds, temporary or permanent noise barriers	7 to 10	5 to 10	15	15
Acoustic Enclosures	Engine casing lagged with acoustic insulation and plywood	15 to 30	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	15 to 25	60	40

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

To ensure efficient noise attenuation performances are achieved using any of the methods listed above, it is recommended acoustic engineers work closely with the excavation contractors and carry out noise testing of works.

Typical noise treatment options that may be considered for the excavation activities on the site are summarised below. Note that the ability to implement these measures is subject to site practicality.

1. Noise Control Kits

Where possible, 'noise control kits' could be fitted to plant engines to reduce noise level emissions. Such 'noise control kits' comprise:

- high performance 'residential-grade' exhaust mufflers,
- additional engine cowling / enclosure lined inside with sound absorbent industrial-grade foam, and
- air intake and discharge silencers / louvres.

Although noise levels will be highest during rock breaking, sawing and ripping activities, noise control kits will provide noise attenuation to engines of the plant that operate continuously on site, for example bulldozers and excavators.

2. Partial Acoustic Enclosures

Where noise exceedances occur, partial acoustic enclosures may be constructed around noisy plant and equipment or areas where activities are less transient, for example the area used to load trucks with sandstone and fill. A partial enclosure can be constructed from 10mm plywood, located on site as close as practical to the plant. The inner face of the plywood enclosure should be lined with 50mm acoustic insulation (eg. Tontine AcoustiSorb2 or TBL 32/50, hydrophobic mineral wool, or equivalent).

Acoustic enclosures should be checked by a suitable acoustic engineer once it is constructed.

3. Hoarding

Where stationary equipment (ie. non-transient activities) are used on site, temporary hoarding between the source and receiver may be erected. The hoarding should be constructed from any durable material with sufficient mass to prevent direct noise transmission eg. steel, aluminium, fibrous-cement, timber, polycarbonate, or any combination of such materials, provided they withstand the weather elements.

Hoarding should be checked by a suitable acoustic engineer once erected.

4. Truck Movement

Potential noise impact from truck movement will be limited by managing the movement of trucks on site. The number of trucks on site should be kept to a minimum, where possible.

4.5.2 Specific Noise Mitigation Measures to UTS Building CB10

Noise sensitive areas within UTS Building CB10 generally consist of teaching spaces, offices and commercial spaces. Some of these noise sensitive areas have windows that overlook the construction site and are directly exposed to noise impacts from excavation activities proposed for the site. Therefore, to reduce airborne noise through the existing windows on the southern façade of the CB10 building, acoustic treatment to the windows would be required. The noise mitigation measures required to reduce airborne noise to internal areas on the southern side of the CB10 building are as follows:

Table 4.10 – Noise Mitigation Measures to Southern Windows of Building CB10

Floor Level	Type of Mitigation Measure to Windows
Levels 2 to 8	2 layers of 12mm thick Compressed Fibre Cement (CFC) / 100mm air gap / 50mm acoustic insulation with min. density of $25kg/m^3$
Levels 9 to 12	1 layer of 10mm thick glass / 100mm air gap
Levels 13 to 14	1 layer of 15mm thick Perspex / 10mm air gap

The CFC, glass and Perspex sheets should be fixed to a metal frame, which in turn is fixed to the internal window recess. The frame should be sealed air tight to the recess and the CFC, glass and Perspex sheets should be sealed air tight to the frame with mastic sealant. Furthermore, the CFC and Perspex sheets should overlap a minimum of 50mm above, below and either side of the window recess and sealed air tight with mastic sealant.

4.5.3 Noise Management Measures

In addition to physical and engineering mitigation measures described above, the following noise management measures shall be considered to minimise adverse noise impacts to nearby receivers.

1. Time Management

Where noise level exceedances cannot be avoided or where physical noise control measures are not reasonable or feasible, then consideration should be given to implementing time restrictions and/or providing periods of repose for neighbours. For example, daily periods of respite from noisy activities, such as rock breaking and cutting may be scheduled for building occupants in UTS Building CB10 during business hours or potential for noisy activities to be scheduled outside exam periods or during semester breaks.

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 should be restricted to within certain time periods, to be negotiated with stakeholders.

2. Relocation of Affected People

Given that some of the areas in the CB10 building potentially affected by noise impacts from the excavation activities are teaching spaces, relocation of classes to quieter areas of the building or to a different building altogether may be considered as an option.

Office areas impacted by the excavation activities may also be considered for relocation if deemed necessary after consultation with affected stakeholders.

3. General

- 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 should be switched off.
- Good relations with people living and working in the vicinity of the construction site should be established at the beginning of the works and be maintained throughout the works, as this is of paramount importance.
- Keep stakeholders informed of progress.
- Take complaints seriously and deal with them expeditiously. The person selected to liaise with the stakeholders should be adequately trained and experienced in such matters.

4. Regular Periodic Noise Monitoring

Noise monitoring should be undertaken at the commencement of works and regular periods at all affected receiver locations identified in this study to provide feedback to management on any noise exceedances, so necessary actions can be taken. Noise monitoring should be undertaken in accordance with Appendix C.

5. Complaints Handling Procedure

A complaint handling procedure should be put in place to deal with noise complaints that may arise from excavation activities. A contact number for complaints to be made on should be established for affected stakeholders to inform the site of unsatisfactorily high noise levels. This number should be displayed clearly on signage at the site perimeter. 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.

5 VIBRATION MANAGEMENT PLAN

5.1 Vibration Sources

Typical vibration levels from excavation plant and equipment most likely to cause significant vibration are summarised below. The information was sourced from a variety of reference materials available in the Renzo Tonin & Associates library.

Table 5.1 – Typical Ground Vibration Generated by Excavation Plant

Plant	Typical ground vibration
Bulldozers / Excavators	Typical ground vibration levels from bulldozers/ excavators are similar to those from jackhammers. They range from 1 mm/s to 2 mm/s at distances of approximately 5 m and at distances greater than 20m, vibration levels are usually below 0.2 mm/s.
Rock Saw / Rock Ripper	Typical ground vibration levels from rock saws and rock rippers operating on hard rock range from 1 mm/s to 3 mm/s at distances of approximately 4m.
Rock Breaker	Typical ground vibration levels from rock breakers hammering hard rock and sandstone range from 1 mm/s to 5 mm/s at distances of approximately 5m depending on the size of the breaker. At distances greater than 20m, vibration levels are usually below 0.5 mm/s. Use of smaller machines can reduce levels of vibration significantly.
Truck traffic	Typical vibration from heavy trucks passing over normal (smooth) road surfaces generate relatively low vibration levels in the range of 0.01 - 0.2mm/s at the footings of buildings located 10 - 20m from a roadway. Very large surface irregularities can cause levels up to five to ten times higher. In general, ground vibration from trucks is usually imperceptible in nearby buildings. The rattling of windows and other loose fittings that is sometimes reported is more likely to be caused by airborne acoustic excitation from very low frequency (infrasonic) noise radiated by truck exhausts and truck bodies. While this may cause concern to the occupants, the phenomenon is no different from the rattling caused by wind or people walking or jumping on the floor and fears of structural damage or even accelerated ageing are usually unfounded.

Vibration management strategies implemented on site shall consider these items of plant and excavation activities involving these items of plant.

5.2 Vibration Criteria

The management objective for the site is to limit vibration from excavation activities so as to avoid building damage and human discomfort associated with the excavation works for the UTS Broadway Building site.

The effects of ground vibration on buildings near construction sites may be broadly defined by the following three categories:

1. Disturbance to building occupants - Vibration in which the occupants or users of the building are inconvenienced or possibly disturbed,
2. Effects on building contents - Vibration where the building contents may be affected, and,
3. Effects on building structures - Vibration in which the integrity of the building or structure itself may be prejudiced.

In general, vibration criteria for human disturbance (1) are more stringent than vibration criteria for effects on building contents (2) and building structural damage (3). Hence, compliance with the more stringent limits dictated by Category 1, would ensure that compliance is also achieved for the other two categories.

<u>Category 1</u> – Disturbance to Buildings Occupants

For disturbance to human occupants of buildings, we refer to the DECCW's *'Assessing Vibration; a technical guideline'*, published in February 2006. This document provides criteria which are based on the British Standard BS 6472-1992, *'Evaluation of human exposure to vibration in buildings (1-80Hz)'*.

Vibration sources are defined as C*ontinuous, Impulsive or Intermittent.* Section 2 of the technical guideline defines each type of vibration as follows:

> ***'Continuous*** *vibration continues uninterrupted for a defined period (usually throughout the day-time and/or night-time).*
>
> ***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 or repeated periods of impulsive vibration that varies significantly in magnitude'.*

The criteria are to be applied to 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).'*

Preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and are reproduced below.

Table 5.2 – Preferred and Maximum Weighted rms Values for Continuous and Impulsive Vibration Acceleration (m/s²) 1-80Hz

Location	Assessment period[1]	Preferred values		Maximum values	
		z axis	x & y axis	z axis	x & y axis
Continuous vibration					
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					
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 7.00 am to 10.00 pm and night-time is 10.00pm to 7.00 am

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 specified 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

Intermittent vibration is to be assessed using vibration dose values (VDVs). The VDV method is a fourth power approach which is more sensitive to peaks in the acceleration waveform and makes corrections to the criteria based on the duration of the source's operation. The VDV can be calculated using the overall weighted rms acceleration of the vibrating source in each orthogonal axis and the total period during which the vibration may occur. Weighting curves are provided in each orthogonal axis in the guideline. Preferred and maximum VDV values are defined in Table 2.4 of the guideline and are reproduced below.

Table 5.3 – Acceptable Vibration Dose Values for Intermittent Vibration ($m/s^{1.75}$)

Location	Daytime[1]		Night-time[1]	
	Preferred values	Maximum values	Preferred values	Maximum values
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 7.00 am to 10.00 pm and night-time is 10.00pm to 7.00 am

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 or impulsive criteria for critical areas. Source: BS 6472-1992

Based on Table 5.2 and Table 5.3 above, UTS Building CB10 (Receiver R1) and the commercial building across Wattle Street (Receiver R2), will be assessed against the criteria for 'Offices, schools, educational institutions and places of worship'. For the occupants of the residential apartments on Wattle Street (Receiver R3) the assessment of vibration will be against the criteria for 'Residences'.

Category 2 – Effects on building contents

The typical frequency range of construction induced ground vibration is approximately 8 Hz to 100 Hz. Over this range the threshold of visible movement of building contents such as plants, pictures, blinds etc is approximately 0.5 mm/s. At vibration levels higher than 0.9 mm/s, audible rattling of loose objects such as crockery can be expected.

Category 3 – Structural Damage to Buildings

Currently there exists no Australian Standard for assessment of structural building damage caused by vibrational energy. Therefore, reference is made to both the British and German standards below which are relevant to the assessment of structural damage.

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.

BS7385 recommends that the peak particle velocity is used to quantify vibration and specifies damage criteria for frequencies within the range 4Hz to 250Hz, which is the range usually encountered in buildings. At frequencies below 4Hz, a maximum displacement value is recommended. The levels from the standard are given below in Table 5.4.

Table 5.4 – BS 7385 Structural Damage Criteria

Group	Type of Structure	Peak component particle velocity, mm/s		
		4Hz to 15Hz	15Hz to 40Hz	40Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings		50	
2	Un-reinforced or light framed structures Residential or light commercial type buildings	15 to 20	20 to 50	50

The peak vibration limits set for minimal risk of 'cosmetic' damage are: 15mm/s for un-reinforced or light framed structures, for example residential or light commercial buildings (Line 2; increasing as the frequency content of the vibration increases) and 50mm/s for reinforced or framed structures, for example industrial and heavy commercial buildings (Line 1; constant across all frequencies). '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.

These values 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%.

The levels set by this standard are considered 'safe limits' up to which no damage due to vibration effects has been observed for certain particular types of buildings. 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.

This standard states that it considers sources of vibration including blasting, demolition, piling, ground treatments, compaction, construction equipment, tunnelling, road and rail traffic and industrial machinery.

As stated in the standard, it sets guide values for building vibration based on the lowest levels above which damage has been credibly demonstrated. That is, it gives guidance on the levels of vibration above which building structures could be damaged.

German Standard

The German standard DIN 4150 - Part 3 - "Structural vibration in buildings - Effects on Structures", also provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration. This standard too, presents recommended maximum limits over a range of frequencies measured in any direction at the foundation or in the plane of the uppermost floor.

The minimum 'safe limit' of vibration at low frequencies for commercial and industrial buildings is 20mm/s. For dwellings it is 5mm/s and for particularly sensitive structures (eg historical with preservation orders etc), it is 3mm/s. These limits increase as the frequency content of the vibration increases. These values are presented in Table 5.5 below and are generally recognised to be conservative.

Table 5.5 – DIN 4150-3 Structural Damage Criteria

Group	Type of Structure	Vibration Velocity, mm/s			
		At Foundation at Frequency of			Plane of Floor Uppermost Storey
		< 10Hz	10Hz - 50Hz	50Hz - 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

5.3 Buffer Distances for Vibration Control

The relationship between vibration and the probability of causing human annoyance or damage to structures is complex. This complexity is mostly due to the magnitude of the vibration source, the particular ground conditions between the source and receiver, the foundation-to-footing interaction and the large range of structures that exist in terms of design (eg dimensions, materials, type and quality of construction and footing conditions). The intensity, duration, frequency content and number of occurrences of a vibration, all play an important role in both the annoyance caused and the strains induced in structures.

As the pattern of vibration radiation is very different to the pattern of airborne noise radiation, and is very site specific, below are some indicative minimum 'buffer' distances determined for some common construction plant with data available from recent projects, which assist to avoid human discomfort in terms of perceptible (or tactile) vibration during daytime construction hours. The buffer distances below are applicable to residential type receivers only and for commercial type receivers, for which UTS Building CB10 is considered to be, buffer distances will be lower and less stringent due to the higher limits applicable to these types of occupancies.

It is noted that since the human comfort criteria is more stringent than the structural damage criteria, if compliance is achieved for the assessment of human comfort, then compliance will also be achieved for the assessment of structural damage to buildings.

Table 5.6 – Recommended Minimum Buffer Distances for Excavation Plant

Plant Item	Recommended Minimum Buffer Distance (m)
Bulldozers / Excavators	5
Rock breaker - small	5
Rock breaker - medium	7
Rock breaker - large	15
Truck movements	10

Note: Above buffer distances are applicable to residential buildings only.

It is noted that these are indicative distances only and more detailed 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.

Furthermore, periodic vibration monitoring should be conducted at all critical or sensitive areas and the vibration levels are to be tested for compliance with the set vibration limits. This monitoring shall be undertaken in accordance with the vibration monitoring methods described in Appendix D of this report.

5.4 Vibration Management Measures

Further to buffer distances, to ensure vibration impacts are minimised during the excavation period, the following vibration management control measures are provided:

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 excavation works to determine acceptable buffer distances to the sensitive receivers.

4. Carry out additional vibration monitoring as specified in Appendix D when excavation 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 shall be implemented to ensure vibration compliance is achieved. Management measures may include modification of excavation methods such as using smaller construction plant, establishment of safe buffer zones and if necessary, time restrictions for the most excessive vibration activities. Time restrictions are to be negotiated with affected receivers.

7. Before excavation works, preparation of a dilapidation report on the state of the existing buildings surrounding the construction site is recommended.

It should be noted that the above management measures as well as the indicative buffer distances, are applicable to all buildings and their occupants surrounding the UTS Broadway Building site. Although emphasis is on UTS Building CB10, it is noted that should vibration compliance be achieved at Building CB10, then compliance would also be achieved at other surrounding buildings (eg. UTS Building CB02), given that Building CB10 is closest to the construction site.

6 COMPLAINTS MANAGEMENT

Noise and vibration levels generated by excavation activities associated with the excavation works at the UTS Broadway Building site should aim to comply with the noise and vibration goals set by the relevant regulations and guidelines.

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

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 excavation activities will be recorded. Additionally, occupants will be notified of any periods of noisy excavation activities at least 24 hours prior to their commencement.

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

7 CONCLUSION

An Excavation Noise and Vibration Management Plan (ENVMP) has been prepared for the UTS Broadway Building construction site on the corners of Jones Street, Broadway and Wattle Street, Ultimo. Specifically, this report aims to manage noise and vibration impact during the excavation works through noise and vibration management measures, to achieve compliance with relevant guidelines and standards.

In-principle recommendations are provided in Section 4.5 and Section 5.4 to limit the potential impact of noise and vibration generated by excavation 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 excavation 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 ACOUSTIC TERMS

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 $\mathbf{L_{90}}$ 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	Martin Place 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 ear is not as effective in hearing low frequency sounds as it is 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.

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 L_{90} 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

B1. 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.

B2. REFERENCED STANDARDS

- Australian Standard 1259 – 1990: "Acoustics - Sound Level Meters",
- Australian Standard 2012.1-1990: "Acoustics - Measurement of airborne noise emitted by earth-moving machinery and agricultural tractors - stationary test condition - Part 1: Determination of compliance with limits for exterior noise"
- ISO 6395: "Acoustics & Measurement of airborne noise emitted by earthmoving machinery - Dynamic test conditions"
- AS1217.5-1985: "Acoustics – Determination of sound power levels of noise sources – Part 5 – Engineering methods for free-field conditions over a reflecting plane"
- AS1217.7-1985: "Acoustics – Determination of sound power levels of noise sources – Part 5 – Survey method"

B3. 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 Australian Standard 1259.2-1990 "Acoustics - 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.

B3.1 STATIONARY TESTING

Stationary measurements shall be performed on all earthmoving plant according to the method of AS2012.1-1990.

In addition to measuring overall A-weighted noise levels, octave band frequency $L_{Aeq,T}$ noise levels shall also be measured at each measurement location from 63Hz to 8kHz inclusive. Background noise shall also be recorded in the same octave band frequency range, and corrections to measured 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 5dB greater than the background noise from other nearby plant, both in terms of the overall A-weighted level and in all octave band frequencies.

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

The overall A-weighted sound power levels to be determined shall be in terms of both the $L_{Aeq,T}$ and $L_{A10,T}$ 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.

B3.2 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, octave band frequency $L_{Aeq,T}$ noise levels shall also be measured at each measurement location from 63Hz to 8kHz inclusive. Background noise shall also be recorded in the same octave band frequency range, and corrections to measured 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 5dB greater than the background noise from other nearby plant, both in terms of the overall A-weighted level and in all octave band frequencies.

Measured octave-band $L_{Aeq,T}$ noise levels shall also be processed to establish 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 to be determined shall be in terms of both the $L_{Aeq,T}$ and $L_{A10,T}$ 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.

B4. 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 Australian Standard 1259.2-1990 "Acoustics - 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 AS1217.5-1985 or AS1217.7-1985, 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, octave band frequency $L_{Aeq,T}$ noise levels shall also be measured at each measurement location from 63Hz to 8kHz inclusive. Background noise shall also be recorded in the same octave band frequency range, and corrections to measured 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 5dB greater than the background noise from other nearby plant, both in terms of the overall A-weighted level and in all octave band frequencies.

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

The overall A-weighted sound power levels to be determined shall be in terms of both the $L_{Aeq,T}$ and $L_{A10,T}$ 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

C1. SCOPE

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

C2. REFERENCED STANDARDS & GUIDELINES

- Australian Standard 1259–1990: "Acoustics - Sound Level Meters",
- Australian Standard 1055-1989 "Acoustics - Description and Measurement of Environmental Noise",
- NSW Environment Protection Authority's "Environmental Noise Control Manual", and
- NSW Environment Protection Authority's "Industrial Noise Policy".

C3. 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 Australian Standard 1259.2-1990 "Acoustics - 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 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 and computers housed in weather resistant enclosures. The operator may either retrieve the data at the conclusion of each monitoring period either in person or via a telephone modem if the logger is fitted with a mobile phone option. The nominated long-term environmental noise level monitors are to be of the RTA Technology Pty Ltd [phone (02) 8218 0500] type or equivalent.

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 the wind speed is greater than 5 m/s (18 km/hr).

C3.1 LONG-TERM (UNATTENDED) 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, whilst 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 such as wind velocity, wind direction and rainfall shall also be either monitored on site or recorded from the nearest weather station to the project site, over the entire noise monitoring period.

C3.2 SHORT-TERM (ATTENDED) MONITORING

Attended short-term noise monitoring shall be conducted at noise receiver locations with closest proximity to the construction activities.

Short-term noise monitoring shall be conducted within the first month of commencement of construction works, and then every 1 to 2 months thereafter, dependent on the level of complaint from construction activities.

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 are 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.

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 verandah, in which case the same microphone height shall apply off the floor.

Conditions such as wind velocity, wind direction, temperature, relative humidity and cloud cover shall also be recorded during short-term noise monitoring.

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
- Operation and load conditions of the noise sources under investigation
- Any adjustment made for presence or absence of nearby reflecting surfaces
- Noise due to other sources (eg traffic, aircraft, trains, dogs barking, insects etc)

APPENDIX D - SPECIFICATION FOR CONSTRUCTION VIBRATION MONITORING

D1. SCOPE

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

D2. REFERENCED STANDARDS & GUIDELINES

- AS 2775 Mechanical Mounting of Accelerometers
- AS 2670.2 Part 2: Evaluation of human exposure to whole body vibration
- EPA ENCM Chapter 174 – Vibration in Buildings
- DIN 4150.3 Structural Vibration in Buildings – Effects on Structures
- 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 Groundborne Vibration
- ISO 4866 Mechanical Vibration & Shock – Vibration of Buildings – Guidelines for the Management of the Vibrations and Evaluation of their Effects on Buildings

D3. TESTING PROCEDURES

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). The monitoring system should also have a measurement frequency range down to 1Hz.

Long-term vibration monitoring equipment or Vibration Loggers consist of a computer unit connected by cable to a triaxial vibration transducer which senses vertical, axial and horizontal vibration. Vibration levels are continuously monitored, and the data is processed statistically and stored in the computer memory. The operator may either retrieve the data at the conclusion of each monitoring period either in person or via a telephone modem if the logger is fitted with a mobile phone option. The nominated long-term Vibration Loggers are to be of the RTA Technology Pty Ltd [phone (02) 8218 0570] type or equivalent.

D3.1 LONG-TERM (UNATTENDED) MONITORING

Vibration monitoring shall be undertaken at vibration sensitive locations determined to fall within the 'buffer distances' established for each item of plant during the commencement of use of each plant on site.

Vibration monitoring shall be undertaken over the following period(s):

- Continuously whilst the vibrating plant is operational within the pre-determined 'buffer distances' from the potentially affected building.

  Vibration monitoring equipment shall be placed outside at the footings or foundations of the building of interest, closest to the vibrating plant.

  Vibration 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 vibration metrics to be stored in memory for later retrieval is the following:

- Vector-sum root-mean-square (rms) – maximums and statistical metrics
- Vector-sum peak-particle velocity (ppv) – maximums and statistical metrics.

  Vibration monitoring shall be undertaken in accordance with the vibration measurement requirements stipulated in the reference standards and documents listed above. The following notes of importance are included here:

- Vibration monitoring equipment shall be placed outside at the footings or foundations of the building of interest, closest to the vibrating plant.
- The surface should be solid and rigid in order to best represent the vibration levels entering the structure of the building under investigation
- The vibration sensor or transducer shall not be mounted on loose tiles, loose gravel or other resilient surfaces
- The vibration sensor or transducer shall be directly mounted to the vibrating surface using bees wax or a magnetic mounting plate onto a steel plate or bracket either fastened or glued to the surface of interest
- Where a suitable mounting surface is unavailable, then a metal stake of at least 300mm in length shall be driven into solid ground adjacent to the building of interest and the vibration sensor or transducer shall be mounted on that.

D3.2 SHORT-TERM (ATTENDED) MONITORING

Where vibration complaints or requests from relevant authorities are received, attended short-term vibration monitoring shall also be conducted at the requested location and at any other relevant vibration receiver location with closest proximity to the construction activities.

Short-term vibration monitoring shall be used to supplement long-term vibration monitoring undertaken at nearby locations, and to check whether or not the vibration levels measured by the long-term vibration monitors are caused by construction activities carried out on site.

All attended short-term vibration monitoring shall be recorded over 15 minute sample intervals. Vibration levels are to be recorded at a minimum rate of 10 samples per second. The minimum range of vibration metrics to be stored in memory and reported are the following:

- root-mean-square (rms) – maximums and statistical levels
- peak-particle velocity (ppv) – maximums and statistical levels.

In addition to measuring and reporting overall vibration levels, statistical vibration levels shall also be measured and reported in third-octave band frequencies from 1Hz to 250Hz.

Vibration monitoring shall be undertaken in accordance with the vibration measurement requirements stipulated in the reference standards and documents listed above. The following notes of importance are included here:

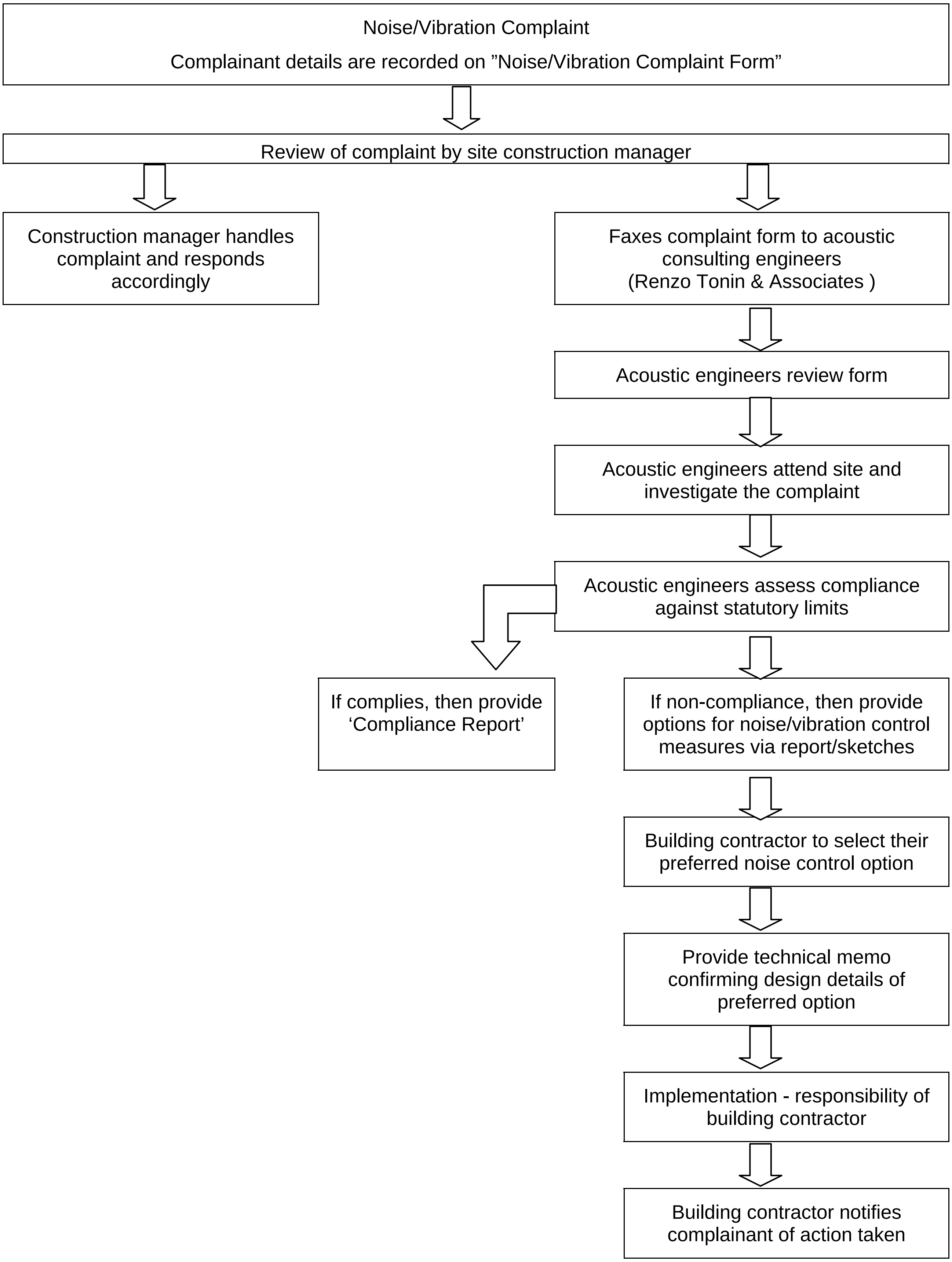
- vibration monitoring equipment shall be placed outside at the footings or foundations of the building of interest, closest to the vibrating plant.
- the surface should be solid and rigid in order to best represent the vibration levels entering the structure of the building under investigation
- the vibration sensor or transducer shall not be mounted on loose tiles, loose gravel or other resilient surfaces
- the vibration sensor or transducer shall be directly mounted to the vibrating surface using either bees wax or a magnetic mounting plate onto a steel washer, plate or bracket which shall be either fastened or glued to the surface of interest
- where a suitable mounting surface is unavailable, then a metal stake of at least 300mm in length shall be driven into solid ground adjacent to the building of interest, and the vibration sensor or transducer shall be mounted on that.

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 (ie sample times, measurement time intervals and time of day)
- Sketch map of area
- Measurement location details and number of measurements at each location
- Operation and load conditions of the vibrating plant under investigation

- Possible vibration influences from other sources (eg domestic vibrations, other mechanical plant, traffic, etc)

APPENDIX E - NOISE / VIBRATION COMPLAINT MANAGEMENT PROCEDURE



NOISE/VIBRATION COMPLAINT FORM

<table>
<tr><th colspan="8">COMPLAINANT'S DETAILS</th></tr>
<tr><td>Date :</td><td></td><td>Received by (tick a box) :</td><td colspan="5">Phone ☐ Written in ☐ Person ☐</td></tr>
<tr><td colspan="2">Complaint Received By:</td><td></td><td colspan="2">Complainant's Name:</td><td colspan="3"></td></tr>
<tr><td colspan="2">Complainant's Address:</td><td colspan="6"></td></tr>
<tr><td colspan="2">Complainant's Contact Numbers:</td><td>Home:</td><td></td><td>Work:</td><td></td><td>Mob:</td><td></td></tr>
</table>

COMPLAINT DETAILS

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/vibration:

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INVESTIGATION

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

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Please fax this form to Renzo Tonin & Associates Pty Ltd for processing after obtaining approval from the Project Manager - Fax: (02) 8218 0501