Acoustics
Vibration
Structural Dynamics

MACQUARIE TELECOM IC3W

Construction Noise & Vibration Management Plan

12 June 2024

FDC

TM162-06F02 CNVMP (r3)

40 YEARS 1982 - 2022 ACOUSTIC ENGINEERING EXCELLENCE

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1 Introduction

Renzo Tonin & Associates ('RT&A') has been engaged by FDC to prepare a Construction Noise and Vibration Management Plan ('CNVMP') for the construction of the expansion to the existing data centre at 17-23 Talavera Road, Macquarie Park (State Significant Development SSD-24299707). The expansion is known as IC3 West ('the Project').

As part of the State Significant Development Application ('SSDA'), a noise and vibration assessment report was prepared for the Project by RT&A[1], which included a preliminary assessment of construction noise and vibration. RT&A have also prepared a CNVMP which specifically addressed the early works stormwater and sewer realignment component of the Project[2].

The scope of this CNVMP is to describe how noise and vibration impacts during the construction of the Project will be managed. This CNVMP will:

- Identify the site, proposed works and nearby noise sensitive development.
- Present information about ambient noise levels in the vicinity of the site.
- Identify relevant noise and vibration objectives.
- Assess likely noise and vibration impacts from the works.
- Identify noise and vibration mitigation / management measures for the works to avoid or minimise noise and vibration impacts, and how these measures are to be implemented (where feasible and reasonable).

The work documented in this report was carried out in accordance with 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.

Renzo Tonin & Associates is a member firm of the Association of Australasian Acoustical Consultants ('AAAC') and the author of this CNVMP, Chris Chan, is a member of the Australian Acoustical Society ('AAS').

1.1 Consent conditions

This CNVMP has been prepared with respect to the relevant consent conditions in SSD-24229707 which are summarised in Table 1-1.

[1] Renzo Tonin & Associates, TM162-03F02 Acoustic Assessment (r3), Macquarie Data Centres IC3 Super West Noise and Vibration Report for SSDA, 4 November 2022

[2] Renzo Tonin & Associates, TM162-05F02 Stormwater and Sewer Realignment CNVMP (r3), Macquarie Data Centre IC3 Super West – Stormwater and Sewer Realignment Works Construction Noise and Vibration Management Plan, 24 January 2024

Table 1-1: Consent condition requirements

<table>
<tr><th>Requirement</th><th>CNVMP section where this is addressed</th></tr>
<tr><td>

NOISE

Hours of Work

B1. The Applicant must comply with the hours detailed in Table 1 below.

Table 1 *Hours of work*

<table>
<tr><th>Activity</th><th>Day</th><th>Time</th></tr>
<tr><td>Construction</td><td>Monday – Friday
Saturday</td><td>7 am to 7 pm
8 am to 3 pm</td></tr>
<tr><td>Operation
(excluding back-up generator testing)</td><td>Monday – Sunday</td><td>24 hours</td></tr>
<tr><td>Back-up generator testing</td><td>Monday – Friday</td><td>7 am to 6 pm</td></tr>
</table>

B2. Works outside of the hours identified in condition B1 may be undertaken in the following circumstances:
(a) works that are inaudible at the nearest sensitive receivers;
(b) works agreed to in writing by the Planning Secretary;
(c) for the delivery of materials required outside these hours by the NSW Police Force or other authorities for safety reasons; or
(d) where it is required in an emergency to avoid the loss of lives, property or to prevent environmental harm.

</td><td>Section 3.1</td></tr>
<tr><td>

Construction Noise Limits

B3. The development must be constructed to achieve the construction noise management levels detailed in the ICNG (as may be updated or replaced from time to time). All feasible and reasonable noise mitigation measures must be implemented and any activities that could exceed the construction noise management levels must be identified and managed in accordance with the management and mitigation measures in Appendix 2 of this consent.

</td><td>Section 3.2
Section 4</td></tr>
<tr><td>

Construction Noise and Vibration Management Plan

B4. Prior to the commencement of construction, the Applicant must prepare a Construction Noise and Vibration Management Plan (CNVMP) for the development to the satisfaction of the Planning Secretary. A copy of the CNVMP must be included in the development's CEMP (see condition C2), and must:
(a) be prepared by a suitably qualified and experienced noise expert(s);
(b) describe procedures for achieving the noise management levels in the ICNG (as may be updated or replaced from time to time);
(c) describe the measures that would be implemented to manage high noise-generating works (such as piling);
(d) include strategies that have been developed in consultation with adjoining businesses for managing high noise-generating works, including those works that will be undertaken in close proximity to Excelsia College;
(e) describe the consultation that would be undertaken with adjoining businesses during construction, including direct consultation with Excelsia College to develop the strategies outlined in condition B4(d); and
(f) include a complaints management system that would be implemented for the duration of construction.

</td><td>Section 4.6
Section 6.3
APPENDIX B
APPENDIX D</td></tr>
<tr><td>

VIBRATION

Vibration Criteria

B8. Vibration caused by construction at any residence or structure outside the site must be limited to:
(a) for structural damage, the latest version of *DIN 4150-3:2016-12 Vibration in buildings – Part 3: Effects on Structures* (German Institute for Standardisation); and
(b) for human exposure, the acceptable vibration values set out in the *Environmental Noise Management Assessing Vibration: A technical guideline* (DEC, 2006) (as may be updated or replaced from time to time).

B9. The limits in condition B8 apply unless otherwise outlined in the development's CNVMP (see condition B4).

</td><td>Section 3.3
Section 5
APPENDIX C</td></tr>
</table>

1.2 Site description

The site is located at 17-23 Talavera Road, Macquarie Park (LOT 527 DP 752035). The site is currently occupied by the existing data centre buildings, including the IC2 building on the northern half of the site and the IC3e building in the south-eastern corner of the site. The subject IC3w building will be located in the south-western corner of the site. The site has a total area of approximately 20,000m^2 and is accessed via Talavera Road.

The site is described through its current commercial setting as an existing Data Centre (LDA/2018/0322), which is surrounded by other commercial premises fronting Talavera Road and forms part of the wider Macquarie Park Corridor.

Macquarie Park Corridor is a strategic centre of Macquarie Park, being a health and education precinct and an important economic / employment powerhouse in Sydney's North District. It is situated approximately 12.5km to the north-west of the Sydney CBD and 11.3km north-east of Parramatta. It is within close proximity to bus and rail public transport routes, and has direct links to the wider regional road network including Talavera Road, Lane Cove Road, Epping Road and the M2 Motorway.

The site is bound by Talavera Road to the north, commercial premises to the east and west, and an education premises to the south. The nearest residential receivers are located north of the M2 Motorway, approximately 310m from the site.

Figure 1 presents an aerial view showing the Project site and surrounding area.

1.3 Nearest noise and vibration sensitive receivers

The site is surrounded by commercial premises to the north, east and west and an education premises to the south. The nearest residential receivers are located to the north of the M2 Motorway, approximately 310m from the site.

The receiver locations that have been assessed are set out in Table 1-2 and Figure 1.

Additionally, the nearby receivers have been grouped into Noise Catchment Areas (NCAs) based upon areas with similar acoustic environments. This has undertaken to allocate the appropriate ambient background noise and noise management levels to each receiver.

The location of these noise catchment area boundaries are also shown in Figure 1.

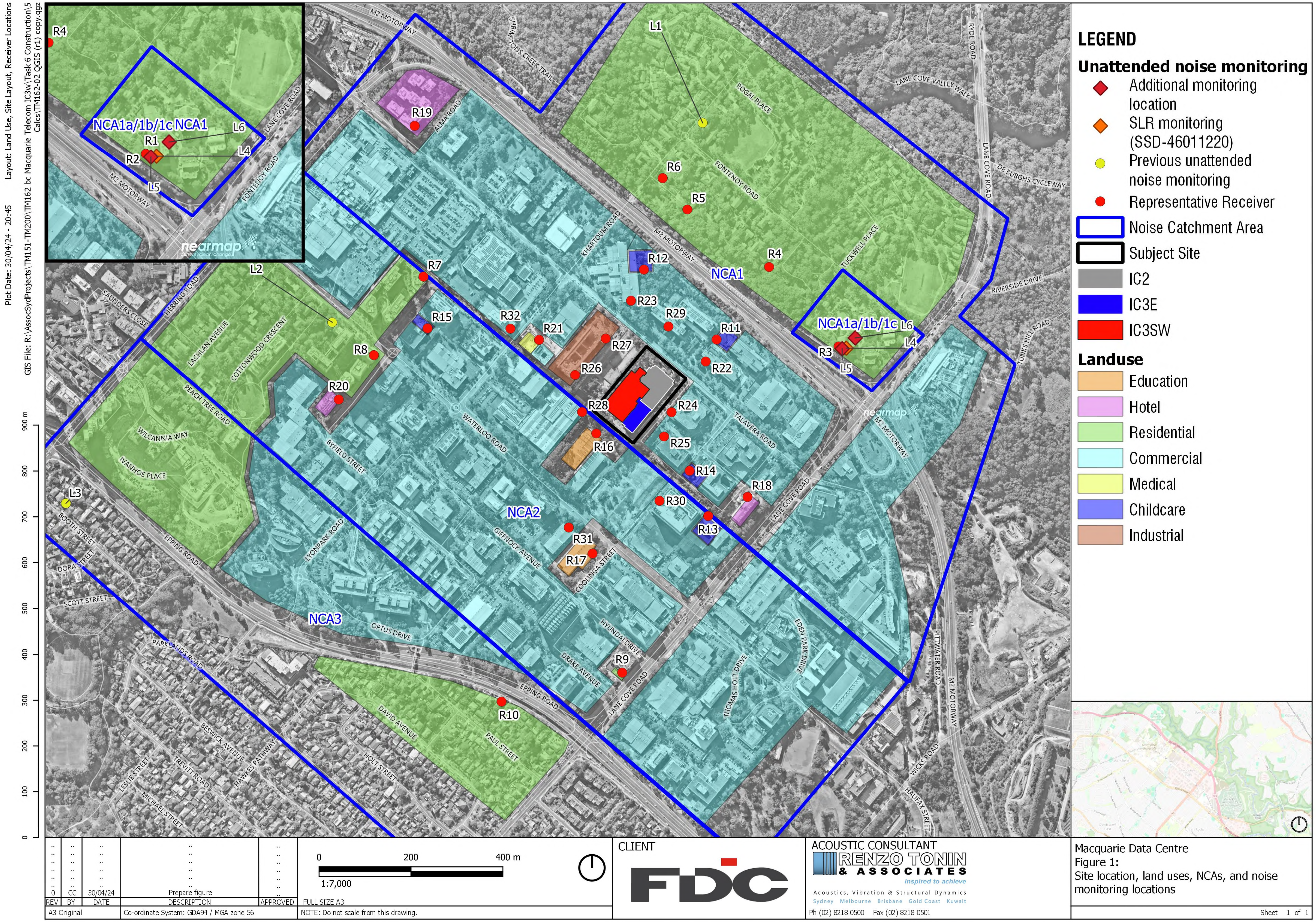
Table 1-2: Assessment locations

Receiver number	Address / location	Receiver type	Noise Catchment Area (NCA)	Approximate distance to subject site, metres
R1	1-15 Fontenoy Road Level 1	RES	1a	350
R2	1-15 Fontenoy Road Level 4	RES	1b	350
R3	1-15 Fontenoy Road Level 7	RES	1c	350
R4	25 Fontenoy Road, Macquarie Park	RES	1	310
R5	7 Tasman Place	RES	1	320
R6	33 Tasman Place, Macquarie Park	RES	1	370
R7	101 Waterloo Road, Macquarie Park	RES	2	470
R8	80 Waterloo Road, Macquarie Park	RES	2	490
R9	384-386 Lane Cove Road, Macquarie Park	RES	2	500
R10	136 Epping Road, North Ryde	RES	3	635

Receiver number	Address / location	Receiver type	Noise Catchment Area (NCA)	Approximate distance to subject site, metres
R11	24 Talavera Road, Macquarie Park - North Ryde Early Learning Centre	OSR_CHC	1	110
R12	40-52 Talavera Road, Macquarie Park (Guardian Childcare)	OSR_CHC	1	160
R13	34-41 Waterloo Road, Macquarie Park (Only About Children Macquarie Park Station)	OSR_CHC	2	220
R14	Building B/11 Talavera Road, Macquarie Park (Macquarie Early Learning Centre)	OSR_CHC	2	130
R15	97 Waterloo Road, Macquarie Park (Greenwood North Ryde)	OSR_CHC	2	390
R16	63-71 Waterloo Road, Macquarie Park - **Excelsia College**	OSR_EDU	2	Common boundary
R17	44 Waterloo Road, Macquarie Park - Macquarie University (School of Engineering)	OSR_EDU	2	225
R18	7/11 Talavera Road, Macquarie Park (Marriot Hotel)	OSR_HOT	1	270
R19	88 Talavera Road, North Ryde (Meriton Suites)	OSR_HOT	1	680
R20	10 Byfield St, Macquarie Park (Holiday Inn Express)	OSR_HOT	2	550
R21	11 Khartoum Road, Macquarie Park (WiSE Medical)	OSR_MED	1	140
R22	24 Talavera Road, Macquarie Park	OSR_COM	1	60
R23	19-25 Talavera Road, Macquarie Park	OSR_COM	1	105
R24	15 Talavera Rd, North Ryde	OSR_COM	1	Common boundary
R25	11 Talavera Rd, Macquarie Park	OSR_COM	1	Common boundary
R26	11-17 Khartoum Road, Macquarie Park (Stockland Data Centre)	OSR_COM	1	60
R27	11-17 Khartoum Road, Macquarie Park (Stockland Data Centre)	OSR_COM	1	60
R28	1-5 Khartoum Road, Macquarie Park	OSR_COM	2	Diagonally adjacent
R29	26 Talavera Road, Macquarie Park	OSR_COM	1	60
R30	7 Harvest Street, Macquarie Park	OSR_COM	2	140
R31	50 Waterloo Road, Macquarie Park	OSR_COM	2	230
R32	8 Khartoum Road, Macquarie Park	OSR_COM	1	250

Notes: RES = Residential, IND = Industrial, COM = Commercial, CHC = Childcare, EDU = Educational, MED = Medical

Figure 1: Site location, land uses, NCAs, representative receivers and noise monitoring locations



1.4 Summary of construction works

Table 1-3 presents a high-level programme of the construction works as advised FDC.

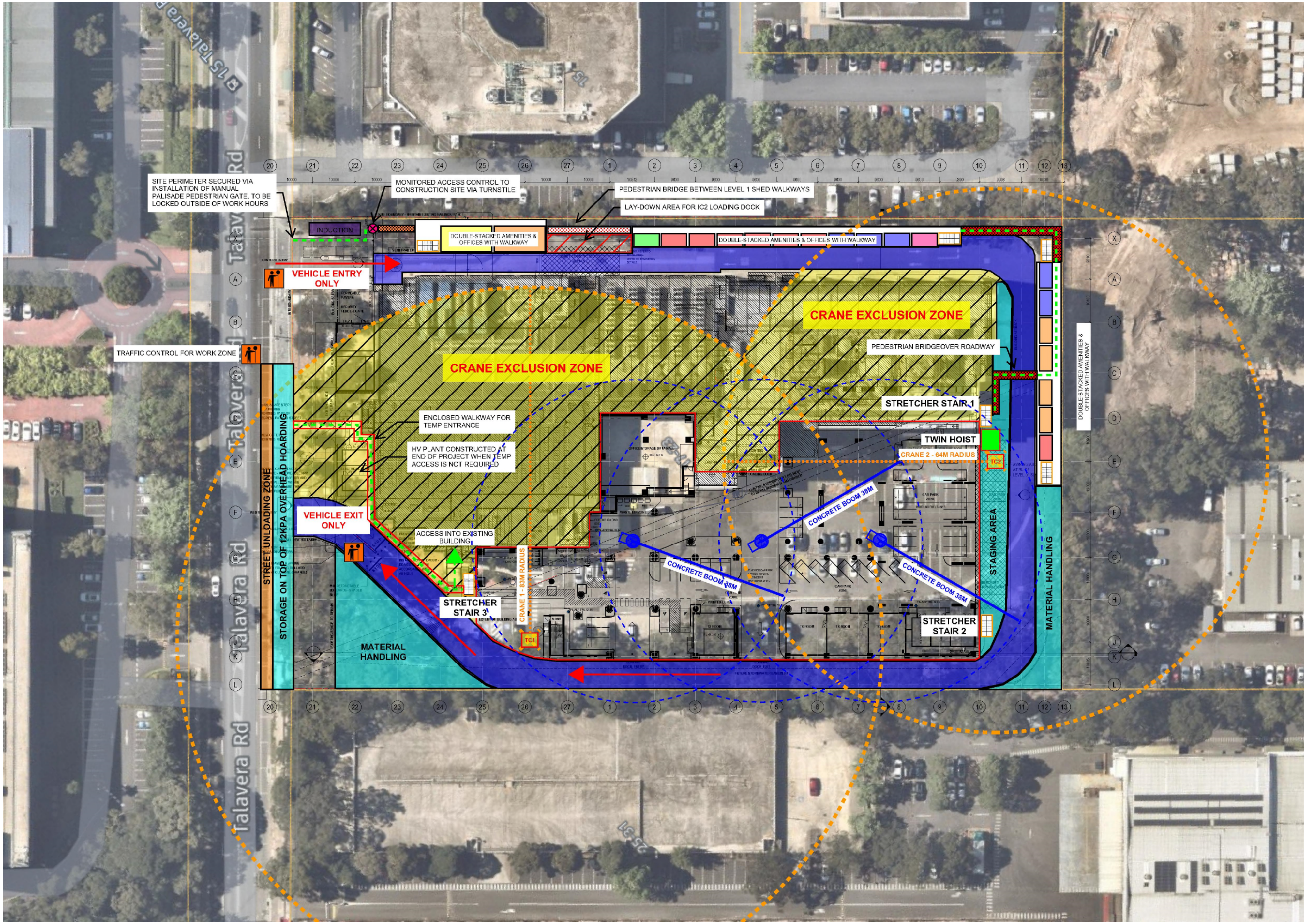
Table 1-3: Indicative construction works schedule and durations

Stage	Duration of works	Brief description of works
1. Site establishment	20 days	• Site shed, amenities and site access set up
2. Minor demolition works	12 days	• Demolition and removal of existing landscaping, asphalt and concrete
3. Earthworks and substructure	146 days	• Trim, fill and prepare building platform • Piling works (piling, reinforcement, concrete) • Strip footing form, reo, pour
4. Structure and facade	320 days	• Form, reo, pour all concrete components of the building • Erect all structural steel • Install all facade components
5. Services and finishes	284 days	• Install of all building services and finishes • Overlaps partly with Stage 4

The proposed works will result in increased noise level during construction. The works undertaken can 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 construction stages of the Project.

Figure 2 presents the site establishment plan from FDC.

Figure 2: Site establishment plan



2 Existing noise environment and noise / vibration sensitive receivers

Criteria for the assessment of operational and construction noise are usually derived from the existing noise environment of an area, excluding noise from the subject development.

Fact Sheet B of the NSW EPA *Noise Policy for Industry* (NPfI) outlines two methods for determining the background noise level of an area, being 'B1 – Determining background noise using long-term noise measurements' and 'B2 – Determining background noise using short-term noise measurements'. This assessment has used long-term noise monitoring.

As the noise environment of an area almost always varies over time, background and ambient noise levels need to be determined for the operational times of the proposed development. For example, in a suburban or urban area the noise environment is typically at its minimum at 3am in the morning and at its maximum during the morning and afternoon traffic peak hours. The NPfI outlines the following standard time periods over which the background and ambient noise levels are to be determined:

- Day: 07:00-18:00 Monday to Saturday and 08:00-18:00 Sundays & Public Holidays
- Evening: 18:00-22:00 Monday to Sunday & Public Holidays
- Night: 22:00-07:00 Monday to Saturday and 22:00-08:00 Sundays & Public Holidays

2.1 Environmental noise monitoring

At the time of preparing the SSDA noise and vibration assessment report, the COVID-19 pandemic and lockdowns within Greater Sydney were impacting the ambient noise environment and restricting the possibility of undertaking noise monitoring for the purposes of establishing background noise levels.

As such, the SSDA noise and vibration assessment report relied on noise measurement data collected by RT&A at 82 Waterloo Road, Macquarie Park (in 2016) and noise data presented within the AECOM prepared *Macquarie Park Data Centre - Environmental Impact Statement – Appendix J Noise and Vibration Assessment' (reference: 60628128-RPNV-02, Revision B, dated 9 November 2020)* (EIS 2020). The EIS 2020 was sourced via the DPHI Planning Portal and was prepared for 11-17 Khartoum Road and 33-39 Talavera Road, Macquarie Park, which is located in proximity to the Project site.

Additional noise measurements have recently been conducted which improve the understanding of the local noise environment. Measurements were conducted on the elevated balconies of the residential apartment tower at 1-15 Fontenoy Road, Macquarie Park by RT&A (in 2024) and by SLR Consulting as part of *SSDA Noise Impact Assessment Macquarie Park Logistics Warehouse (SSD-46011220) (reference: 610.30904.00100-R01-v1.3-20230120, dated January 2023)*. The noise impact assessment by SLR Consulting was sourced via the DPHI Planning Portal and was prepared for a proposed warehouse facility at 4-38 Talavera Road, Macquarie Park, which is located in proximity to the Project site.

The measured background noise levels around the Project site are summarised in Table 2-1.

Table 2-1: Long-term noise monitoring results, dB(A)

ID	Monitoring location	Rating Background Level (RBL), $L_{A90,15min}$		
		Day[1]	Evening[2]	Night[3]
L1	Unit 6, 37 Khartoum Road, Macquarie Park	45	45	38
L2	82 Waterloo Road, Macquarie Park[4]	52	48	40
L3	7 Booth Street, Marsfield	42	42	33
L4	1-15 Fontenoy Road, Macquarie Park, Level 3	60	56	45
L5	1-15 Fontenoy Road, Macquarie Park, Level 7, Unit 188	70	64	51
L6	1-15 Fontenoy Road, Macquarie Park, Level 7, Unit 192	57	55	48

Notes:
1. Day: 7:00am to 6:00pm Monday to Saturday and 8:00am to 6:00pm Sundays and public holidays
2. Evening: 6:00pm to 10:00pm Monday to Sunday and public holidays
3. Night 10:00pm to 7:00am Minday to Saturday and 10:00pm to 8:00am Sundays and public holidays
4. As required by the NPfI, the external ambient noise levels presented are free-field noise levels (ie. no facade reflection)

3 Construction noise and vibration objectives

3.1 Construction hours

3.1.1 Standard construction hours

The NSW Interim Construction Noise Guideline (ICNG) recommends the following standard construction hours:

- Monday to Friday 7:00am to 6:00pm
- Saturday 8:00am to 1:00pm
- Sunday and public holidays No work performed

However, Condition B1 of the Development Consent (January 2024) approves extended works hours up to 7:00pm on Monday to Friday and up to 3:00pm on Saturdays.

Therefore, the approved standard hours are:

- Monday to Friday 7:00am to 7:00pm
- Saturday 8:00am to 3:00pm
- Sunday and public holidays No work performed

We are advised that the construction works are proposed to take place during these approved hours.

3.1.2 Works outside standard construction hours

There are no out-of-hours ('OOH') works proposed for the construction of the subject expansion to the existing data centre.

As per Consent Condition B2, construction works may be undertaken outside the approved hours identified in Condition B1 in the following circumstances, what are to be confirmed following approval:

1. Works that are inaudible at the nearest sensitive receivers
2. Works agreed to in writing by the Planning Secretary
3. For the delivery of materials required outside these hours by the NSW Police force or other authorities for safety reasons
4. Where it is required in an emergency to avoid the loss of lives, property or to prevent environmental harm.

3.2 Noise management levels (NMLs)

3.2.1 NSW *Interim Construction Noise Guideline* (ICNG)

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:

- Identification and minimisation of noise from construction works
- Encourage construction during standard hours, unless approval is given for works that cannot be undertaken during these hours
- 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.
- Establishment of 'Noise Management Levels'. These are noise levels which if exceeded, trigger the need to consider the application of feasible and reasonable noise mitigation. They are not intended to act as a prohibition on an activity if the trigger level is expected to be exceeded.
- 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, a quantitative assessment is carried out herein, consistent with the ICNG requirements.

Table 3-1, reproduced from the ICNG, sets out the noise management levels and how they are to be applied for residential receivers.

Table 3-1: 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 3-2 sets out the ICNG noise management levels for other noise sensitive receiver locations. As identified for residential receivers, a 'highly affected' noise objective of $L_{Aeq(15min)}$ 75dB(A) is adopted for all noise sensitive receivers, with exceedances addressed as described in Table 3-1.

Table 3-2: 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 External noise level[1]	45 dB(A) 65 dB(A)
Hospital wards and operating theatres	Internal noise level External noise level[1]	45 dB(A) 65 dB(A)
Places of worship	Internal noise level External noise level[1]	45 dB(A) 65 dB(A)
Active recreation areas	External noise level	65 dB(A)

Land use	Where objective applies	Management level $L_{Aeq\ (15\ min)}$
Passive recreation areas	External noise level	60 dB(A)
Commercial premises	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)

Notes:
1. External noise levels based on internal noise level in ICNG and assumes 20dB attenuation through a closed window
2. Noise management levels apply when receiver areas are in use only.

3.2.2 Summary of construction noise management levels

Table 3-3 presents the construction noise management levels established for the nearest noise sensitive residential receivers and other sensitive receivers in accordance with the ICNG. The assessment locations and nearby sensitive receivers for the construction assessment are identified in Section 1.3.

With respect to NCA1, the additional noise measurements recently conducted on the elevated balconies of the residential apartment tower at 1-15 Fontenoy Road, Macquarie Park (NCA1b and NCA1c) found the upper level receivers to be subject to higher ambient noise levels as they have a greater exposure to the M2 Motorway. As a conservative approach, this assessment has still applied the lower background noise level of 45dB(A) measured at Location L1 (Unit 6, 37 Khartoum Road, Macquarie Park) to all receivers in NCA1, including elevated receiver locations within NCA1b and NCA1c.

Table 3-3: Construction noise management levels

ID	Location description	Noise management level $L_{Aeq(15min)}$ Monday to Fridays (7am to 6pm) Saturdays (8am to 1pm)
NCA1	Residences on north-eastern side of the M2 Motorway	55
NCA1a	Residences on ground floor and Level 1 of 1-15 Fontenoy Road, Macquarie Park	55
NCA1b	Residences on Levels 2-4 of 1-15 Fontenoy Road, Macquarie Park	55
NCA1c	Residences on Levels 5-7 of 1-15 Fontenoy Road, Macquarie Park	55
NCA2	Residences west of site near Waterloo Road	62
NCA3	Residences south-west of site near Epping Road	52
R11-R15	Childcare centre – classroom (external)	65[1,2]
	Childcare centre - playground	65[1]
R16-R17	Education - classroom (external)	65[1,2]
R21	Medical - operating theatres (external)	65[1,2]
R22-R32	Commercial	70[1]

Notes:
1. Noise management levels apply when receiver areas are in use only.
2. External noise management level assuming a 20 dB(A) outside-to-inside loss through a closed window.
3. Noise management levels based on daytime RBL. Analysis of the long-term noise monitoring data reveals L_{A90} levels from 6:00am to 7:00am and 6:00pm to 7:00pm Mondays to Friday; 6:00am to 7:00am Saturday; and 7:00am to 8:00am Sunday are typically louder than the quietest part of the day.

3.3 Construction Vibration Objectives

As presented in Section 1.1, Conditions B8 and B9 refer to the construction vibration objectives approved for the SSD.

VIBRATION

Vibration Criteria

B8. Vibration caused by construction at any residence or structure outside the site must be limited to:

(a) for structural damage, the latest version of DIN 4150-3:2016-12 Vibration in buildings – Part 3: Effects on Structures (German Institute for Standardisation); and

(b) for human exposure, the acceptable vibration values set out in the Environmental Noise Management Assessing Vibration: A technical guideline (DEC, 2006) (as may be updated or replaced from time to time).

B9. The limits in condition B8 apply unless otherwise outlined in the development's CNVMP (see condition B4).

It is interpreted that Condition B8 does not prevent the consideration of British Standard 7385: Part 2 '*Evaluation and measurement of vibration in buildings*' in the CNVMP as per Condition B9.

3.3.1 Disturbance to building occupants

The acceptable vibration values to assess the potential for human annoyance from vibration are set out in the NSW 'Environmental Noise Management Assessing Vibration: A Technical Guideline' (AVTG).

To assess the potential for vibration impact on human comfort, an initial screening test will be done based on peak velocity units, as this metric is also used for the cosmetic damage vibration assessment. The screening test is based on the continuous vibration velocity (i.e. vibration that continues uninterrupted for a defined period). If the predicted vibration exceeds the initial screening test, the total estimated Vibration Dose Value (i.e. eVDV) will be determined based on the level and duration of the vibration event causing exceedance.

The initial screening test values and VDVs recommended in BS 6472-1992 for which various levels of adverse comment from occupants may be expected, are presented in Table 3-4. The 'Low probability of adverse comment eVDV' represent the preferred and maximum value presented in the AVTG.

Table 3-4: Vibration management levels for disturbance to building occupants

Place and Time	Initial screening test Velocity, PEAK, mm/s (>8Hz)	Low probability of adverse comment eVDV $m/s^{1.75}$	Adverse comment possible eVDV $m/s^{1.75}$	Adverse comment probable eVDV $m/s^{1.75}$
Critical areas (day or night)[1]	0.28	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8
Residential buildings 16 hr day[2]	0.56	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential buildings 8 hr night[2]	0.40	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8
Offices, schools, educational institutions and places of worship (day or night)	1.10	0.4 to 0.8	0.8 to 1.6	1.6 to 2.4
Workshops (day or night)	2.20	0.8 to 1.6	1.6 to 3.2	3.2 to 6.4

Notes
1. 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
2. Daytime is 7am to 10pm and night-time is 10pm to 7am

3.3.2 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 DIN 4150-3. Currently there is no existing Australian Standard for assessment of structural building damage caused by vibration energy.

It is noted that vibration levels required to cause minor cosmetic damage are typically 10 times higher than levels that will cause disturbance to building occupants. Many building occupants assume that building damage is occurring when they feel vibration or observe rattling of loose objects, however the level of vibration at which people perceive vibration or at which loose objects may rattle is far lower than vibration levels that can cause damage to structures.

Within British Standard 7385 Part 1, 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 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 DIN 4150-3, damage is defined as "any permanent consequence of an action that reduces the serviceability of a structure or one of its components" (p.4). The Standard also outlines:

> *"For buildings as in lines 2 and 3 of Tables 1, 4 or B.1, the serviceability is considered to have been reduced if, for example*
>
> - *cracks form in plastered or rendered surfaces of walls;*
> - *existing cracks in a structure are enlarged;*
> - *partitions become detached from load-bearing walls or floor slabs.*
>
> *These effects are deemed 'minor damage. " (DIN 4150.3:2016, p.6)*

While the DIN Standard defines the above damage as 'minor', based on the definitions provided in BS 7385, the DIN standard is considered to deal with cosmetic issues rather than major structural failures.

3.3.2.1 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. BS 7385 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.

BS 7385 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 3-5 sets out the BS 7385 criteria for cosmetic, minor and major damage.

Regarding heritage buildings, BS 7385 Part 2 (1993) notes that "*a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive*" (p.5).

Table 3-5: BS 7385 structural damage criteria

Group	Type of structure	Damage level	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	Cosmetic	50		
		Minor*	100		
		Major*	200		
2	Un-reinforced or light framed structures Residential or light commercial type buildings	Cosmetic	15 to 20	20 to 50	50
		Minor*	30 to 40	40 to 100	100
		Major*	60 to 80	80 to 200	200

Notes: 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.

* Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2

3.3.2.2 German Standard

German Standard DIN 4150 - Part 3 (2016) '*Vibration in buildings - Effects on Structures*' (DIN 4150-3:2016), 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 4150-3:2016 presents the recommended maximum limits over a range of frequencies (Hz), measured at the foundations, in the plane of the uppermost floor of a building or structure or vertically on floor slabs. The vibration limits at the foundations increase as the frequency content of the vibration increases. The criteria are presented in Table 3-6.

Table 3-6: DIN 4150-3:2016 structural damage criteria

Group	Type of structure	Vibration velocity, mm/s				
		At foundation in all directions at frequency of			Plane of floor uppermost storey in horizontal direction	Floor slabs, vertical direction
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	All frequencies	All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40	20
2	Residential buildings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15	20
3	Structures that because of their particular sensitivity to vibration, cannot be classified under Groups 1 and 2 and are of great intrinsic value (eg listed buildings)	3	3 to 8	8 to 10	8	20

4 Construction noise assessment

4.1 Construction traffic

The construction works 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:
  - o Delivery vehicles bring raw materials, plant and equipment to the site
  - o Concrete trucks

Noise emission from the vehicle movements on site is included as part of the construction noise assessment. When the construction-related traffic is on the public road network, a different noise assessment methodology is appropriate as it would be regarded as additional traffic generated on the public road network rather than a part of activities on the construction site.

Access to the site will be from Talavera Road. We are advised that due to Council feedback on the CTMP, there will be minimal deliveries through peak periods (8:00am – 9:30am and 4:30pm – 6:00pm). The only exemption to this will be for large concrete pours which will have up to three to four concrete trucks accessing the site per hour. This volume of heavy vehicles is not expected to significantly alter existing traffic noise and for the majority of construction works, will be significantly lower. Furthermore, there are no noise-sensitive residential receiver located along Talavera Road.

The generation of additional traffic on the public road network by the construction works is not expected to give rise to any significant noise impacts and is not further addressed in this report.

4.2 Construction noise sources

The schedule of plant and equipment items likely to be used during the construction phases of the Project is presented in Table 4-1 below.

Table 4-1: Typical construction equipment & sound power levels, dB(A) re 1pW

Plant item	Plant description	Estimated number of items	Sound power levels $L_{Aeq(15min)}$
Stage 1 - Site establishment			
1	Delivery trucks	1-2	108
2	Mobile cranes	2	105
3	Excavator (10T)	2	103
Stage 2 – Minor demolition works			
4	Truck & dog	1-2	108
5	Bobcat	1	102

Plant item	Plant description	Estimated number of items	Sound power levels $L_{Aeq(15min)}$
6	Excavator (8-35T)	3	103
7	Watercart	1	104
Stage 3 – Earthworks and substructure			
8	Dump trucks	1-2	108
9	Tower crane	2	105
10	Bobcat	1	102
11	Excavator (15-35T)	2	103
12	Watercart	1	104
13	Pilling rig – bored	1-2	108
14	Grader	1	109
15	Vibratory roller	1	113[1]
Stage 4 – Structure and facade			
16	Delivery trucks	1-2	108
17	Tower crane	2	105
18	Concrete pump	2	102
19	Concrete trucks	2	108
20	Non-powered hand tools	Various	98
21	Concrete vibrator	4	99
22	Hand tools	Various	107
Stage 5 – Services and finishes			
23	Delivery trucks	1-2	108
24	Non-powered hand tools	Various	98
25	Bobcat	1	102
26	Hand tools	Various	107
27	Scissor lift (internal)	12	95

Notes 6. A 5 dB(A) penalty has been factored into the sound power level to allow for particularly annoying activities

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

4.3 Noise prediction methodology

A noise model was developed for the Project using the CadnaA computer modelling program and noise levels were predicted using the noise propagation algorithm ISO 9613-2 (1996).

The noise prediction model considers:

- Location of noise sources and sensitive receiver building locations

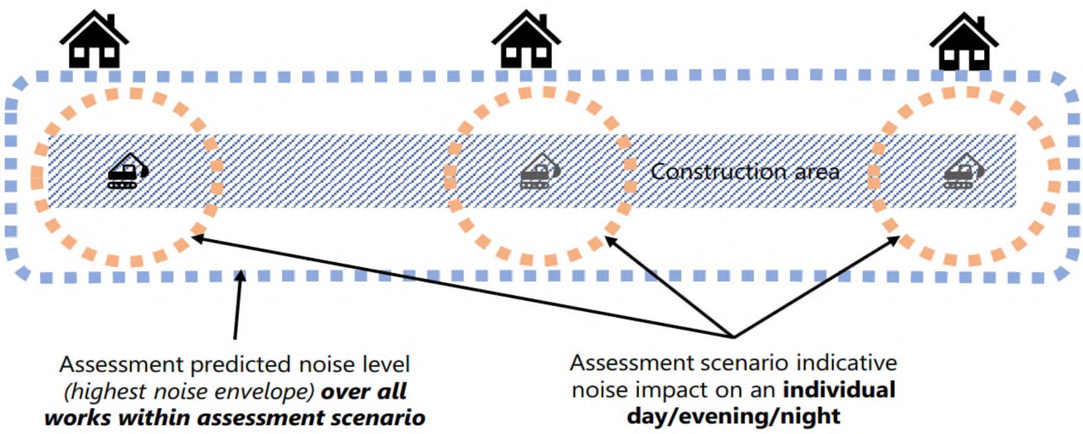
- Height of sources and receivers referenced to digital ground contours for the site and surrounding area
- Sound Power Levels (Lw) of plant and equipment likely to be used during the various construction activities
- Separation distances between sources and receivers
- Acoustic shielding, potential reflections and attenuation from intervening structures, barriers and topography (natural and purpose built)
- Ground absorption between the source and receiver

The predicted levels are conservative and represent the equipment / plant operating simultaneously in any 15-minute period. Where plant items are not operating simultaneously, or for reduced times in a 15-minute period, noise impacts could be lower than predicted.

A 5 dB(A) penalty in accordance with the ICNG has been factored into the noise modelling levels where applicable to allow for particularly annoying activities, such as the operation of the vibratory roller.

For the predicted noise levels in Section 4.4 that are the upper end of the range, these noise levels assume that the assessed activities could occur at the closest point to each receiver. While in practice, high noise generating construction works would occur at different locations throughout the work area, resulting in differing noise levels at each receiver. This means that predicted noise levels are only likely to occur when works are at the closest point to each receiver. The noise impacts may be lower than predicted as the construction activities move around or progress around the construction site, as shown by the lower end of the range in Section 4.4. This concept is demonstrated in Figure 3 and should be considered when reviewing the predicted noise levels in this assessment.

Figure 3: Predicted noise level range over works area



4.4 Predicted noise levels

Noise levels at any receiver location 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.

Construction noise levels were predicted by modelling the noise sources, receiver locations, and operating activities.

Table 4-2 presents noise levels likely to be experienced at the nearby affected receivers based on the construction activities, and plant / equipment associated with the Project, where the range represents the plant items operating at a location furthest away and a location closest to each receiver. Noise levels were calculated taking into consideration attenuation due to distance between the construction works and the receiver locations and any intervening structures. The noise predictions are conservative and do not incorporate acoustic shielding provided by hoarding. For the internal building fit-out works, the predictions include a modest 20dB(A) loss from inside-to-outside through the building fabric.

The worst affected receivers are typically the receivers with direct line-of-sight to the construction work area. Receivers located without direct line-of-sight to the construction area would typically be exposed to construction noise levels 5 to 10 dB(A) lower than the levels predicted for the worst affected receivers.

Table 4-2: Predicted $L_{Aeq(15min)}$ noise levels for construction plant and activities, dB(A)

Receiver ID	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17	R18	R19	R20	R21	R22	R23	R24	R25	R26	R27	R28	R29	R30	R31	R32
NCA	NCA1a	NCA1b	NCA1c	1	1	1	2	2	2	3	1	1	2	2	2	2	2	1	1	2	1	1	1	1	1	1	1	2	1	2	2	1
Receiver type[2]	RES	RES	RES	RES	RES	RES	RES	RES	RES	RES	OSR_CHC	OSR_CHC	OSR_CHC	OSR_CHC	OSR_CHC	OSR_EDU	OSR_EDU	OSR_HOT	OSR_HOT	OSR_HOT	OSR_MED	OSR_COM	OSR_COM	OSR_COM	OSR_COM	OSR_COM	OSR_COM	OSR_COM	OSR_COM	OSR_COM	OSR_COM	OSR_COM
NML dB(A)	55	55	55	55	55	55	62	62	62	52	65	65	65	65	65	65	65	70	70	70	65	70	70	70	70	70	70	70	70	70	70	70
Stage 1 - Site establishment																																
1. Delivery trucks	<20	<20	23	28	31	30	29	23	24	23	37	34	29	26	<20	52	33	27	<20	<20	<20	46	40	54	50	50	45	54	46	36	38	<20
2. Mobile crane	<20-22	<20-23	<20-26	23-27	34-35	34-41	26-40	25-32	<20-32	29-30	25-47	36-44	21-38	24-33	<20-26	49-62	35-36	22-24	<20	<20-25	25-27	26-40	41-49	32-42	32-37	55-57	48-54	53-60	47-54	24-43	41-44	22-27
3. Excavator (10T)	<20-22	<20-25	<20-31	<20-27	21-40	27-42	21-38	<20-35	<20-33	<20-29	22-47	30-48	<20-36	21-27	<20-26	45-59	<20-35	<20-29	<20-31	<20-29	22-25	23-51	38-52	28-48	26-42	52-57	45-53	49-63	34-54	<20-42	31-44	<20-26
Up to 3 noisiest plant operating concurrently + vehicle movements on site	**21-27**	**22-30**	**25-35**	**29-33**	**36-44**	**37-47**	**31-44**	**28-39**	**26-38**	**30-34**	**38-52**	**39-52**	**30-42**	**30-35**	**21-31**	**55-65**	**37-41**	**29-34**	**20-34**	**22-33**	**29-31**	**46-55**	**46-56**	**54-56**	**50-51**	**59-62**	**52-58**	**58-67**	**49-59**	**37-47**	**43-49**	**26-31**
Stage 2 - Minor demolition works																																
4. Truck & dog	<20	<20	23	28	31	30	29	23	24	23	37	34	29	26	<20	52	33	27	<20	<20	<20	46	40	54	50	50	45	54	46	36	38	<20
5. Bobcat	<20-21	<20-24	<20-30	<20-26	<20-39	26-41	<20-37	<20-34	<20-32	<20-28	21-46	29-47	<20-35	20-26	<20-25	44-58	<20-34	<20-28	<20-30	<20-28	21-24	22-50	37-51	27-47	25-41	51-56	44-52	48-62	33-53	<20-41	30-43	<20-25
6. Excavator (8-35T)	<20-22	<20-25	<20-31	<20-27	21-40	27-42	21-38	<20-35	<20-33	<20-29	22-47	30-48	<20-36	21-27	<20-26	45-59	<20-35	<20-29	<20-31	<20-29	22-25	23-51	38-52	28-48	26-42	52-57	45-53	49-63	34-54	<20-42	31-44	<20-26
7. Watercart	<20-23	<20-26	<20-32	<20-28	22-41	28-43	22-39	21-36	<20-34	<20-30	23-48	31-49	<20-37	22-28	<20-27	46-60	<20-36	<20-30	<20-32	<20-30	23-26	24-52	39-53	29-49	27-43	53-58	46-54	50-64	35-55	20-43	32-45	21-27
Up to 3 noisiest plant operating concurrently + vehicle movements on site	**20-27**	**22-31**	**25-36**	**28-33**	**32-46**	**34-48**	**31-43**	**27-40**	**25-38**	**24-35**	**38-52**	**37-53**	**30-42**	**29-33**	**21-32**	**54-64**	**33-41**	**28-35**	**20-36**	**21-34**	**28-31**	**46-56**	**45-57**	**54-57**	**50-52**	**58-63**	**51-58**	**57-68**	**46-60**	**36-47**	**40-49**	**26-31**
Stage 3 - Earthworks and substrate																																
8. Dump truck	<20	<20	23	28	31	30	29	23	24	23	37	34	29	26	<20	52	33	27	<20	<20	<20	46	40	54	50	50	45	54	46	36	38	<20
9. Tower crane	34-35	34-37	36-39	36-37	36-39	38-42	38-38	36-38	27-36	29-32	40-47	40-46	32-42	31-35	31-37	52-60	35-37	40-41	29-30	34-36	28-30	44-49	46-51	42-52	47-52	54-56	48-54	53-60	46-53	33-48	42-45	25-27
10. Bobcat	<20-21	<20-24	<20-30	<20-26	<20-39	26-41	<20-37	<20-34	<20-32	<20-28	21-46	29-47	<20-35	20-26	<20-25	44-58	<20-34	<20-28	<20-30	<20-28	21-24	22-50	37-51	27-47	25-41	51-56	44-52	48-62	33-53	<20-41	30-43	<20-25
11. Excavator (15-35T)	<20-22	<20-25	<20-31	<20-27	21-40	27-42	21-38	<20-35	<20-33	<20-29	22-47	30-48	<20-36	21-27	<20-26	45-59	<20-35	<20-29	<20-31	<20-29	22-25	23-51	38-52	28-48	26-42	52-57	45-53	49-63	34-54	<20-42	31-44	<20-26
12. Watercart	<20-23	<20-26	<20-32	<20-28	22-41	28-43	22-39	21-36	<20-34	<20-30	23-48	31-49	<20-37	22-28	<20-27	46-60	<20-36	<20-30	<20-32	<20-30	23-26	24-52	39-53	29-49	27-43	53-58	46-54	50-64	35-55	20-43	32-45	21-27
13. Piling rig - bored	<20-27	<20-30	<20-36	20-32	26-45	32-47	26-43	25-40	<20-38	<20-34	27-52	35-53	22-41	26-32	<20-31	50-64	<20-40	22-34	<20-36	<20-34	27-30	28-56	43-57	33-53	31-47	57-62	50-58	54-68	39-59	24-47	36-49	25-31
14. Grader	<20-28	<20-31	<20-37	21-33	27-46	33-48	27-44	26-41	<20-39	<20-35	28-53	36-54	23-42	27-33	20-32	51-65	21-41	23-35	<20-37	<20-35	28-31	29-57	44-58	34-54	32-48	58-63	51-59	55-69	40-60	25-48	37-50	26-32
15. Vibratory roller	23-32	23-35	24-41	25-37	31-50	37-52	31-48	30-45	23-43	21-39	32-57	40-58	27-46	31-37	24-36	55-69	25-45	27-39	22-41	24-39	32-35	33-61	48-62	38-58	36-52	62-67	55-63	59-73	44-64	29-52	41-54	30-36
Up to 3 noisiest plant operating concurrently + vehicle movements on site	**34-37**	**35-40**	**37-44**	**37-41**	**38-52**	**42-54**	**39-50**	**37-47**	**30-45**	**31-41**	**42-58**	**44-60**	**35-49**	**36-40**	**32-40**	**58-71**	**37-47**	**41-44**	**30-42**	**35-42**	**34-37**	**48-63**	**52-63**	**54-61**	**52-57**	**64-69**	**57-64**	**62-75**	**50-66**	**39-54**	**46-56**	**32-38**
Stage 4 - Structure and façade																																
16. Delivery trucks	<20	<20	23	28	31	30	29	23	24	23	37	34	29	26	<20	52	33	27	<20	<20	<20	46	40	54	50	50	45	54	46	36	38	<20
17. Tower crane	34-35	34-37	36-39	36-37	36-39	38-42	38-38	36-38	27-36	29-32	40-47	40-46	32-42	31-35	31-37	52-60	35-37	40-41	29-30	34-36	28-30	44-49	46-51	42-52	47-52	54-56	48-54	53-60	46-53	33-48	42-45	25-27
18. Concrete pump	<20	<20-20	<20-24	<20-22	28-33	31-39	22-26	29-30	<20-27	27-28	28-31	34-38	<20-24	21-23	<20-25	51-55	<20-33	<20	<20	22-26	22-23	32-36	39-42	29-38	26-28	53-54	46-49	54-58	47-50	22-34	40-41	<20-22
19. Concrete trucks	<20-24	<20-28	21-31	25-36	36-39	37-44	28-37	31-36	23-33	31-33	36-45	40-44	26-37	28-34	23-31	59-61	38-41	22-35	<20-25	25-30	28-28	41-54	45-48	35-62	32-58	58-59	52-53	62-64	53-54	31-44	46-47	26-28
20. Non-powered hand tools	<20	<20-20	<20-26	<20-22	<20-35	22-37	<20-33	<20-30	<20-28	<20-24	<20-42	25-43	<20-31	<20-22	<20-21	40-54	<20-30	<20-24	<20-26	<20-24	<20-20	<20-46	33-47	23-43	21-37	47-52	40-48	44-58	29-49	<20-37	26-39	<20-21
21. Concrete vibrator	<20	<20-21	<20-27	<20-23	<20-36	23-38	<20-34	<20-31	<20-29	<20-25	<20-43	26-44	<20-32	<20-23	<20-22	41-55	<20-31	<20-25	<20-27	<20-25	<20-21	<20-47	34-48	24-44	22-38	48-53	41-49	45-59	30-50	<20-38	27-40	<20-22
22. Hand tools	<20-26	<20-29	<20-35	<20-31	25-44	31-46	25-42	24-39	<20-37	<20-33	26-51	34-52	21-40	25-31	<20-30	49-63	<20-39	21-33	<20-35	<20-33	26-29	27-55	42-56	32-52	30-46	56-61	49-57	53-67	38-58	23-46	35-48	24-30
Up to 3 noisiest plant operating concurrently + vehicle movements on site	**34-36**	**34-38**	**37-41**	**37-38**	**39-46**	**41-49**	**39-44**	**39-42**	**30-40**	**35-38**	**43-52**	**44-53**	**34-44**	**34-37**	**31-38**	**59-66**	**37-43**	**41-42**	**30-36**	**35-39**	**32-34**	**49-56**	**50-58**	**54-58**	**52-55**	**62-64**	**55-60**	**62-69**	**55-61**	**39-50**	**48-52**	**30-33**
Stage 5 - Services and finishes (external works or works prior to building fabric completion)																																
23. Delivery trucks	<20	<20	23	28	31	30	29	23	24	23	37	34	29	26	<20	52	33	27	<20	<20	<20	46	40	54	50	50	45	54	46	36	38	<20
24. Scissor lift	<20	<20	<20-23	<20	<20-32	<20-34	<20-30	<20-27	<20-25	<20-21	<20-39	22-40	<20-28	<20	<20	37-51	<20-27	<20-21	<20-23	<20-21	<20	<20-43	30-44	20-40	<20-34	44-49	37-45	41-55	26-46	<20-34	23-36	<20
25. Non-powered hand tools	<20	<20-20	<20-26	<20-22	<20-35	22-37	<20-33	<20-30	<20-28	<20-24	<20-42	25-43	<20-31	<20-22	<20-21	40-54	<20-30	<20-24	<20-26	<20-24	<20-20	<20-46	33-47	23-43	21-37	47-52	40-48	44-58	29-49	<20-37	26-39	<20-21
26. Bobcat	<20-21	<20-24	<20-30	<20-26	<20-39	26-41	<20-37	<20-34	<20-32	<20-28	21-46	29-47	<20-35	20-26	<20-25	44-58	<20-34	<20-28	<20-30	<20-28	21-24	22-50	37-51	27-47	25-41	51-56	44-52	48-62	33-53	<20-41	30-43	<20-25
27. Hand tools	<20-26	<20-29	<20-35	<20-31	25-44	31-46	25-42	24-39	<20-37	<20-33	26-51	34-52	21-40	25-31	<20-30	49-63	<20-39	21-33	<20-35	<20-33	26-29	27-55	42-56	32-52	30-46	56-61	49-57	53-67	38-58	23-46	35-48	24-30
Up to 3 noisiest plant operating concurrently + vehicle movements on site	**21-28**	**22-31**	**25-37**	**28-34**	**32-46**	**35-48**	**31-44**	**27-40**	**25-39**	**24-35**	**38-52**	**38-54**	**30-42**	**30-34**	**21-32**	**54-65**	**33-41**	**28-35**	**20-36**	**21-35**	**28-31**	**46-57**	**46-57**	**54-57**	**50-52**	**59-63**	**51-58**	**57-69**	**46-60**	**36-47**	**40-50**	**26-31**
Stage 5 - Services and finishes (external works or works prior to building fabric completion)																																
24. Scissor lift	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	31	<20	<20	<20	<20	<20	23	24	20	<20	29	25	35	26	<20	<20	<20
25. Non-powered hand tools	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	22	23	<20	<20	<20	34	<20	<20	<20	<20	<20	26	27	23	<20	32	28	38	29	<20	<20	<20
27. Hand tools	<20	<20	<20	<20	24	26	22	<20	<20	<20	31	32	20	<20	<20	43	<20	<20	<20	<20	<20	35	36	32	26	41	37	47	38	26	28	<20

Notes:

1. Predicted level not presented if less than 20dB(A)

2. RES = Residential, IND = Industrial, COM = Commercial, CHC = Childcare, EDU = Educational, MED = Medical

4.5 Discussion of construction noise results

The predicted noise levels presented above indicate that the noise levels during the phases of construction are likely to achieve the NML at most of the nearby sensitive receivers and at all residential locations. No receivers are predicted to be highly noise affected (i.e., exposed to noise levels greater than 75 dB(A).

The predictions identify Receivers R16 (Excelsia College at 63-71 Waterloo Road, Macquarie Park) and R28 (commercial premises at 1-5 Khartoum Road, Macquarie Park) located adjacent to the Project site are most likely to be impacted by construction noise. At these receivers, there may be times when the use of loud equipment such as a vibratory roller or a number of concurrent construction activities may result in construction noise levels being over the NML, particularly when these activities are operating in close proximity to these receiver locations.

Noise emissions are predicted to be highest when high noise generating equipment such as piling rigs, graders and vibratory rollers operate close to receivers. For works where high noise generating equipment is not operating, and where the works are occurring within the site further away from receivers, the predicted noise levels are generally below the NMLs.

Considering the predicted noise levels above, it is recommended that a feasible and reasonable approach towards noise mitigation measures be applied to reduce construction noise levels towards achieving the NMLs. Further details on construction noise mitigation and management measures are provided in Section 4.6.

4.6 Construction noise mitigation measures

4.6.1 Noise management measures

The following recommendations provide feasible and reasonable noise control solutions to reduce noise impacts to sensitive receivers. These should be considered and implemented where feasible and reasonable where there is potential for the noise management levels presented in Section 3.2 to be exceeded by the construction works either individually or cumulatively.

Considering the predicted noise levels set out in Section 4.4, the following noise management are recommended for consideration by the contractor and implemented where feasible and reasonable. 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.

Table 4-3 summarises actions that can be applied to manage the potential for noise to impact on sensitive receivers near the Project construction works, which are to be applied where reasonable and feasible.

Table 4-3: Noise mitigation and management measures

Action	Applies to	Details	Estimated noise benefit
At-source mitigation measures			
Equipment selection	Airborne noise Vibration	Use quieter and less noise/vibration emitting construction methods where feasible and reasonable. Where loud plant and/or equipment are being used in construction works, where feasible and reasonable the selection of alternative quieter plant and/or equipment should be considered for tasks.	Variable. Minimise noise impact and reduce risk of annoyance.
Equipment noise and vibration levels	Airborne noise Vibration	Plant and equipment must 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.	Variable. Minimise noise impact and reduce risk of annoyance.
Rental plant and equipment	Airborne noise	The noise levels of plant and equipment items are to be considered in rental decisions, with quieter and less noise/vibration emitting construction methods where feasible and reasonable.	Variable. Minimise noise impact and reduce risk of annoyance.
Use and siting of plant	Airborne noise Vibration	• Simultaneous operation of noisy plant within discernible range of a sensitive receiver is to be avoided. • The offset distance between noisy plant and adjacent sensitive receivers is to be maximised. • Plant used intermittently to be throttled down or shut down. • Noise-emitting plant to be directed away from sensitive receivers. • Any equipment not in use for extended periods during construction work must be switched off.	Up to 20 dB reduction + reduce vibration
Silencers on mobile plant	Airborne noise	Where possible reduce noise from mobile plant through additional fittings including: - Residential grade mufflers - Air parking brake engagement is silenced. Ensure plant including the silencer is well maintained.	0-20 dB reduction Reduce annoyance
Prefabrication of materials off-site	Airborne noise	Where practicable, pre-fabricate and/or prepare materials off-site to reduce noise with special audible characteristics occurring on site. Materials can then be delivered to site for installation.	5-20 dB reduction Reduce noise/vibration impact + risk of annoyance
Engine compression brakes	Airborne noise	Limit the use of engine compression brakes in residential areas. Ensure vehicles are fitted with a maintained original equipment manufacturer exhaust silencer or a silencer that complies with the National Transport Commission's 'In-service test procedure' and standard.	5-20 dB reduction
Reversing alarms	Airborne noise	Use of broadband "quacker" type of reverse/movement alarms instead of the tonal 'beeping" type.	Minimise noise impact and reduce risk of annoyance.
Path mitigation measures			
Site sheds	Airborne noise	The site establishment plan identifies temporary construction offices and amenities to be double-stacked along the eastern and southern facades which provide acoustic shielding to nearby receivers.	Receiver with line of site of the works area: 5-10 dB reduction

Action	Applies to	Details	Estimated noise benefit
Laydown and stockpiling	Airborne noise	The site establishment plan identifies material handling and staging areas that are located along to the southern site boundary. The stockpiling of material at these locations will act as noise mounds and provide acoustic shielding to nearby receivers.	Variable. Minimise noise impact and reduce risk of annoyance.
Management measures			
Implement stakeholder consultation measures	Airborne noise	Letterbox drop detailing all upcoming construction activities delivered to sensitive receivers at least 7 days prior to commencement of relevant works. In particular it is recommended that notification be provided to Excelsia College (R16) to assist with minimising high noise generating construction activities during sensitive periods for these receiver buildings (ie. exam periods) where feasible and reasonable.	Keeps stakeholders informed of the likely impact. Community may identify solution to assist in managing impacts.
Site inductions	Airborne noise Vibration	All employees, contractors and subcontractors are to receive an environmental induction. The induction must at least include: • All relevant project specific and standard noise and vibration mitigation measures • Permissible hours of work • Any limitations on noise generating activities with special audible characteristics • Location of nearest sensitive receivers • Construction employee parking areas • Designated loading/unloading areas and procedures • Site opening/closing times (including deliveries) • Environmental incident procedures.	Keeps construction workforce informed of actions required to minimise noise and vibration impact.
Behavioural practices	Airborne noise	No swearing or unnecessary shouting or loud stereos/radios on site. No dropping of materials from height, throwing of metal items and slamming of doors. No excessive revving of plant and vehicle engines. Controlled release of compressed air.	0-20 dB reduction Reduce annoyance.
Verification monitoring	Airborne noise	In response to noise complaints, a noise monitoring program should be carried out for the duration of works in accordance with the Construction Noise and Vibration Management Plan (CNVMP) or CEMP and any approval conditions.	Minimises noise impacts
Complaints management	Airborne noise Vibration	See Section 6.3 for further details. In addition to the noise mitigation measures outlined above, a management procedure will need to be put in place to deal with noise complaints that may arise from construction activities. Each complaint will 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.	Minimise noise impact and reduce risk of annoyance.

Additionally, 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. Australian Standard 2436-2010, Appendix C, Table C1 suggests possible remedies and alternatives to reduce noise emission levels from typical construction equipment.

4.6.2 Highly noise affected receivers

Where construction noise is likely to be above the 'highly noise affected' level, respite periods should be considered where feasible and reasonable. There are no highly noise affected residential receivers therefore respite periods are not required as a management measure for this project.

4.6.3 Noise monitoring

The following approach could be adopted regarding noise monitoring procedures during the construction works. Details of the procedures for noise monitoring are presented in APPENDIX B.

- In the event of a sustained complaint, noise monitoring may be carried out to examine noise impacts.
  - Reasonable and feasible noise reduction measures must be investigated, where necessary.
  - Typically, short term (attended) noise monitoring would be undertaken to investigate a complaint as opposed to ongoing noise logging as this will enable a faster response time.
  - Where short term attended noise measurements cannot produce a suitable outcome, long term noise monitoring will be considered. Typically, long term monitoring is useful primarily to check if start/finish times or respite periods have been adhered to. Given this limitation, that are not typically proposed in first instance.

5 Construction vibration assessment

5.1 Minimum working 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. Potential vibration generated at receivers for this project will be dependent on separation distances, the intervening soil and rock strata, dominant frequencies of vibration and the receiver building's construction and structure.

The recommended minimum working distances for vibration intensive plant are presented in Table 5-1.

Table 5-1: Recommended minimum working distances for vibration intensive equipment

Plant item	Minimum working distance, m				
	Cosmetic damage			Human disturbance	
	Commercial and industrial buildings[1]	Dwellings and similar structures[1]	Sensitive structures (e.g. heritage)[1]	Residences Day[2]	Offices
Truck traffic (over irregular surfaces)	5	5	10	15	10
Excavator 35T (travelling / digging)	5	5	10	20	10
Piling Rig (bored)	5	5	10	15	10
Grader	5	5	10	20	10
Vibratory Roller 6T	5	15	20	40	20

Notes: 1. Vibration limits referenced from DIN 4150 Structural Damage - Safe Limits for Short-term Building Vibration.
2. Daytime is 7 am to 10 pm;

Site specific buffer distances for vibration significant plant items must be measured on site where plant and equipment are likely to operate close to or within the minimum working distances for cosmetic damage.

As previously identified, unlike noise, vibration cannot be 'predicted' due to many variables from site to site, for example soil type and conditions; sub surface rock; building types and foundations; and actual plant on site. The data relied upon in this assessment (tabulated above) is taken from a database of vibration levels measured at various sites or obtained from other sources (eg. BS 5228-2:2009). They are not specific to this project 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.

5.2 Potential vibration impacts

Based on the proposed plant items presented, vibration generated by construction plant was estimated and potential vibration impacts are summarised in Table 5-2 below.

The assessment is relevant to the identified residential buildings and other similar type structures in the project area and has been assessed against the vibration limits DIN 4150-3:2016 (see Section 3.3.2.2). Receivers R1 to R15, R17 to R23 and R30 to R32 are located greater than 100m from the works and considered to have a low to negligible risk of vibration impact.

Table 5-2: Potential vibration for residential and commercial properties

Receiver location[1]	Approx. distance to nearest buildings from works (m)	Group classification in accordance with Table 3-6	Assessment on potential vibration impacts		
			Structural damage risk	Human disturbance	Vibration monitoring
R16	55 m	Group 1 (commercial /industrial)	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R24	80 m	Group 1 (commercial /industrial)	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R25	95 m	Group 1 (commercial /industrial)	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R26	65 m	Group 1 (commercial /industrial)	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R27	85 m	Group 1 (commercial /industrial)	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R28	45 m	Group 1 (commercial /industrial)	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required
R29	100 m	Group 1 (commercial /industrial)	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works	Vibration monitoring not required

Note: 3. The sources of vibration levels is the vibratory roller 6T. If alternative equipment with higher vibration levels are used, there is an additional risk.

Based on the above assessment for the receivers surrounding the site, there is a low risk of vibration impact. Nevertheless, potential vibration impacts should be reviewed during construction considering site specific buffer distances for vibration significant plant items where plant and equipment is likely to operate close to or within the minimum working distances for cosmetic damage at nearby vibration sensitive receivers, and recommendations for reducing or managing potential vibration impacts are provided in the following section.

5.3 Vibration mitigation 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. A management procedure should be implemented to deal with vibration complaints. Each complaint should be investigated and where vibration levels are established as exceeding the set limits, appropriate amelioration measures should be put in place to mitigate future occurrences.

2. Where vibration is found to be excessive, management measures should be implemented to ensure vibration compliance is achieved. Management measures may include modification of construction methods such as using smaller equipment, establishment of safe buffer zones as mentioned above, and if necessary, time restrictions for the most excessive vibration activities. Time restrictions are to be negotiated with affected receivers.

3. Where construction activity occurs in close proximity to sensitive receivers (i.e. within the minimum working distances within Table 5-1), vibration testing of actual equipment on site should be carried out prior to their commencement of site operation to determine site-specific acceptable buffer distances to the nearest affected receiver locations.

6 Compliance management

6.1 Roles and responsibilities

Specific responsibilities for the implementation of environmental controls, including noise and vibration mitigation and management measures are the responsibility of the Contractor (FDC).

6.2 Training

All employees, contractors, sub-contractors and utility staff working on site will undergo site induction training that includes construction noise and vibration management issues. The induction training will address elements related to noise and vibration management including:

- Existence and requirements of this sub-plan
- Relevant legislation
- Approved construction hours
- Location of noise sensitive areas
- Complaints reporting
- General noise and vibration management measures
- Specific responsibilities to minimise impacts on the community and built environment from noise and vibration associated with the works.

6.3 Community consultation and complaints management

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

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 must be adequately trained and experienced in such matters.

The contractor is responsible for ensuring that all reasonable and feasible mitigation and management measures are implemented such as the provision of a *Community and Stakeholder Engagement Strategy* developed specifically for the Project, 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 are to be informed by direct mail of a direct telephone line and contact person to either make a noise and/or vibration complaint or request information.

Nearby development should be notified of the proposed works.

The notification should outline:

- Detail of a site point of contact.
- The anticipated duration of the project works.
- Identify what stages will have greatest potential impact on each property. This will provide much clearer information for each party about how the site work will impact them specifically (the duration over which the greatest noise impact will occur).

All noise and/or vibration complaints associated with the construction works shall be investigated in accordance with the Noise / Vibration Complaint Management Procedure identified in APPENDIX D.

Excelsia College

We note that GIDDIS Project Management (on behalf of Macquarie Telecom) has initialised contact with Excelsia College in December 2023 to advise on the potential noise impacts and mitigation / management measures for:

- Early drainage works starting around January 2024 and continuing until around June 2024 which involves realignment of stormwater and sewer pipes near the shared boundary; and
- The main construction works which are expected to commence around June 2024.

FDC are to continue consulting with Excelsia College to assist with the development of noise mitigation strategies for high noise generating works specific to the proposed stages of the construction works and satisfy the requirements of Condition B4(d) and B4(e) (eg. establishing when student / staff are on site or any particularly noise-sensitive time periods where high noise generating works should be avoided).

7 Conclusion

A Construction Noise and Vibration Management Plan has been prepared for the construction of the expansion to the existing data centre at 17-23 Talavera Road, Macquarie Park (State Significant Development SSD-24299707). Specifically, this report has been prepared to address the relevant consent conditions in SSD-24229707 which are summarised in Table 1-1.

The noise and vibration impacts from the construction equipment / machinery that will be used at the IC3 West project site have been predicted and presented in Sections 4.4 and 5.2.

Where the assessment has found potential exceedances of the noise objectives, noise mitigation and management measures have been presented in Section 4.6 to aid in providing additional noise reduction benefits.

The assessment of vibration levels from the construction works provides recommended buffer distances for vibration compliance. The assessment revealed the construction works to have a low risk of impacting the surrounding receivers as they are outside of the recommended buffer distances. However, buffer distances should be confirmed prior to the start of the construction works through on-site measurements of vibration.

Procedures to manage complaints are also provided in Section 6.3 and APPENDIX D to ensure complaints are dealt with accordingly.

References

[1] NSW Department of Climate Change and Water (2011), *Road Noise Policy* (RNP)

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

[3] NSW Environment Protection Authority (2017), *Noise Policy for Industry* (NPfI)

[4] NSW Department of Environment and Conservation, *Assessing Vibration – a technical guideline* (AVTG), 2006

[5] British Standard BS 6472-2008, *Evaluation of human exposure to vibration in buildings (1-80Hz)*

[6] British Standard 7385: Part 2-1993 *Evaluation and measurement of vibration in buildings*

[7] German Standard DIN4150-2016 *Structural vibration Part 3: Effects of vibration on Structures*

[8] Standards Australia (2016), *Guide to Noise Control on Construction, Demolition and Maintenance Sites*, AS 2436:2010 (R2016)

[9] Standards Australia (2018), *Acoustics—Description and measurement of environmental noise,* AS1055:2018

[10] AS IEC 61672.1-2004 Electroacoustic - Sound Level Meters - Specifications

APPENDIX A Glossary of terminology

A.1 Glossary of terminology - Noise

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

Absorption Coefficient α	The absorption coefficient of a material, usually measured for each octave or third-octave band and ranging between zero and one. For example, a value of 0.85 for an octave band means that 85% of the sound energy within that octave band is absorbed on coming into contact with the material. Conversely, a low value below about 0.1 means the material is acoustically reflective.
Adverse weather	Weather effects that enhance noise (particularly wind and temperature inversions) occurring at a site for a significant period of time. In the NSW INP this occurs when wind occurs for more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of nights in winter.
Air-borne noise	Noise which is fundamentally transmitted by way of the air and can be attenuated by the use of barriers and walls placed physically between the noise source and receiver.
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.
Amenity	A desirable or useful feature or facility of a building or place.
AS	Australian Standard
Assessment period	The time period in which an assessment is made. e.g. Day 7am-10pm & Night 10pm-7am.
Assessment Point	A location at which a noise or vibration measurement is taken or estimated.
Attenuation	The reduction in the level of sound or vibration.
Audible Range	The limits of frequency which are audible or heard as sound. The normal hearing in young adults detects ranges from 20 Hz to 20 kHz, although some people can detect sound with frequencies outside these limits.
A-weighting	A filter applied to the sound recording made by a microphone to approximate the response of the human ear.
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. 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 LA90 noise level if measured as an overall level or an L90 noise level when measured in octave or third-octave bands.
Barrier (Noise)	A natural or constructed physical barrier which impedes the propagation of sound and includes fences, walls, earth mounds or berms and buildings.
Berm	Earth or overburden mound.
Buffer	An area of land between a source and a noise-sensitive receiver and may be an open space or a noise-tolerant land use.
Bund	A bund is an embankment or wall of brick, stone, concrete or other impervious material, which may form part or all of the perimeter of a compound.
BS	British Standard
CoRTN	United Kingdom Department of Environment entitled “Calculation of Road Traffic Noise (1988)”
Decibel [dB]	The units that sound is measured in. The following are examples of the decibel readings of common sounds in our environment:

	threshold of hearing	0 dB	The faintest sound we can hear, defined as 20 micro Pascal
		10 dB	Human breathing
	almost silent	20 dB	
		30 dB	Quiet bedroom or in a quiet national park location
	generally quiet	40 dB	Library
		50 dB	Typical office space or ambience in the city at night
	moderately loud	60 dB	CBD mall at lunch time
		70 dB	The sound of a car passing on the street
	loud	80 dB	Loud music played at home
		90 dB	The sound of a truck passing on the street
	very loud	100 dB	Indoor rock band concert
		110 dB	Operating a chainsaw or jackhammer
	extremely loud	120 dB	Jet plane take-off at 100m away
	threshold of pain	130 dB	
		140 dB	Military jet take-off at 25m away
dB(A)	A-weighted decibel. 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 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. The dB(C) level is not widely used but has some applications.		
Deemed-to-Satisfy Provisions	The Deemed-to-Satisfy Provisions are an optional means of achieving compliance with the mandatory Performance Requirements of the National Construction Code. (also see Alternate Solution)		
Diffraction	The distortion of sound waves caused when passing tangentially around solid objects.		
DIN	German Standard		
Discontinuous Construction	A wall system having a minimum 20mm cavity between two separate leaves, where, for other than masonry there is no mechanical linkage between leaves except at the periphery.		
DnT,w	Weighted Standardised Field Level Difference A measure of sound insulation performance of a building element. It is characterised by the difference in noise level on each side of a wall or floor. It is measured in-situ. It is a field measurement that relates to the Rw laboratory measured value but is not equal to it because an in-situ space is not of the same quality as a laboratory space. The value is indicative of the level of speech privacy between spaces. The higher its value the better the insulation performance.		
ECRTN	Environmental Criteria for Road Traffic Noise, NSW, 1999		
ENMM	Environmental Noise Management Manual, Roads and Maritime Services (Transport for NSW)		
EPA	Environment Protection Authority		
Field Test	A test of the sound insulation performance in-situ. See also 'Laboratory Test' The sound insulation performance between building spaces can be measured by conducting a field test, for example, early during the construction stage or on completion. A field test is conducted in a non-ideal acoustic environment. It is generally not possible to measure the performance of an individual building element accurately as the results can be affected by numerous field conditions.		

FIIC	Field Impact Isolation Class. A measure of the noise impact performance of a floor. The value indicates the resistance of the floor to the transmission of impact sound and is measured using a standard tapping machine. It is measured in-situ and is therefore subject to the inherent accuracies involved in such a measurement. The term is defined in ASTM E492 and E1007. It is a field measure of the level of impact sound transmitted to a space via a floor. The equivalent measurement in a laboratory is termed the IIC. The higher the value the better the performance.
Flanking	Flanking is the transfer of sound through paths around a building element rather than through the building element material directly. For example, sound travelling through a gap underneath a door or a gap at the top of a wall.
Fluctuating Noise	Noise that varies continuously to an appreciable extent over the period of observation.
Free-field	An environment in which there are no acoustic reflective surfaces. Free field noise measurements are carried out outdoors at least 3.5m from any acoustic reflecting structures other than the ground.
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.
FSTC	Field Sound Transmission Class A measure of the sound insulation performance of a building element. It is characterised by the difference in noise level on each side of a wall or floor. It is measured in the field and is therefore subject to the inherent inaccuracies involved in such a measurement. The term was referred to in older superseded versions of the Building Code of Australia and has now been replaced with the term DnT,w.
Ground-borne noise	Vibration propagated through the ground and then radiated as noise by vibrating building elements such as wall and floor surfaces. This noise is more noticeable in rooms that are well insulated from other airborne noise. An example would be vibration transmitted from an underground rail line radiating as sound in a bedroom of a building located above.
Habitable Area	Includes a bedroom, living room, lounge room, music room, television room, kitchen, dining room, sewing room, study, playroom, family room, home theatre and sunroom. Excludes a bathroom, laundry, water closet, pantry, walk-in wardrobe, corridor, hallway, lobby, photographic darkroom, clothes drying room, and other spaces of a specialised nature occupied neither frequently nor for extended periods.
Heavy Vehicle	A truck, transporter or other vehicle with a gross weight above a specified level (for example: over 8 tonnes).
IGANRIP	Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects, NSW DEC 2007
IIC	Impact Isolation Class A measure of the noise impact performance of a floor. It is measured in very controlled conditions in a laboratory and is characterised by how much sound reaches the receiving room from the operation a standard tapping machine placed on the floor. The term is defined in ASTM E492 and E1007. The higher the number the better the performance.
Impact Noise	The noise in a room, caused by impact or collision of an object onto the walls or the floor. Typical sources of impact noise are footsteps on the floor above a tenancy and the slamming of doors on cupboards mounted on the common wall between tenancies.
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.
INP	NSW Industrial Noise Policy, EPA 1999
Intermittent noise	The level suddenly drops to that of the background noise several times during the period of observation.
Intertenancy wall	Walls that separate buildings or units within a building. They may provide sound resistance or serve as a fire wall. Synonymous with 'party wall'.
Intrusive noise	Refers to noise that intrudes above the background level by more than 5 dB(A).

ISEPP	State Environmental Planning Policy (Infrastructure), NSW, 2007
ISEPP Guideline	Development Near Rail Corridors and Busy Roads - Interim Guideline, NSW Department of Planning, December 2008
L1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L10	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
L10(1hr)	The L10 level measured over a 1 hour period.
L10(18hr)	The arithmetic average of the L10(1hr) levels for the 18 hour period between 6am and 12 midnight on a normal working day.
L90	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).
LAeq or Leq	The “equivalent noise level” is the summation of noise events and integrated over a selected period of time, which would produce the same energy as a fluctuating sound level. When A-weighted, this is written as the LAeq.
LAeq(1hr)	The LAeq noise level for a one-hour period. In the context of the NSW EPA’s Road Noise Policy it represents the highest tenth percentile hourly A-weighted Leq during the period 7am to 10pm, or 10pm to 7am (whichever is relevant).
LAeq(8hr)	The LAeq noise level for the period 10pm to 6am.
LAeq(9hr)	The LAeq noise level for the period 10pm to 7am.
LAeq(15hr)	The LAeq noise level for the period 7am to 10pm.
LAeq (24hr)	The LAeq noise level during a 24 hour period, usually from midnight to midnight.
Lmax	The maximum sound pressure level measured over a given period. When A-weighted, this is usually written as the LAmax.
Lmin	The minimum sound pressure level measured over a given period. When A-weighted, this is usually written as the LAmin.
Ln,w	Weighted Normalised Impact Sound Pressure Level A measure of the sound level transmitted from impacts on a floor to a tenancy below. It is measured in very controlled conditions in a laboratory and is characterised by how much sound reaches the receiving room from a standard tapping machine. A lower value indicates a better performing floor.
LnT,w	Weighted Standardised Field Impact Sound Pressure Level As for Ln,w but measured in-situ and therefore subject to the inherent accuracies involved in such a measurement. The equivalent measurement in a laboratory is the Ln,w. A lower value indicates a better performing floor.
Laboratory Test	The performance of a building element when measured in a laboratory. The sound insulation performance of a building element installed in a building however can differ from its laboratory performance for many reasons including the quality of workmanship, the size and shape of the space in which the measurement is conducted, flanking paths and the specific characteristics of the material used which may vary from batch to batch.
Loudness	A rise of 10 dB in sound level corresponds approximately to a doubling of subjective loudness. That is, a sound of 85 dB is twice as loud as a sound of 75 dB which is twice as loud as a sound of 65 dB and so on. That is, the sound of 85 dB is four times or 400% the loudness of a sound of 65 dB.
Microphone	An electro-acoustic transducer which receives an acoustic signal and delivers a corresponding electric signal.
NCA	Noise Catchment Area. An area of study within which the noise environment is substantially similar.
NCG	Noise Criteria Guideline, Roads and Maritime Services (Transport for NSW)

NMG	Noise Mitigation Guideline, Roads and Maritime Services (Transport for NSW)
Noise	Unwanted sound
Normalised	A method of adjusting the measured noise indices in a laboratory so that they are independent of the measuring space. The noise level in a room is affected by reverberation in the room. For example, the Ln,w impact sound pressure level measured in a laboratory is dependent upon the amount of absorptive material in the receiving room. The value is adjusted to what would be measured if the sound absorption in the receiving room is set at 10m2. This enables all laboratories to report the same value when measured under slightly different conditions. See also 'Standardised'.
NRC	Noise Reduction Coefficient. A measure of the ability of a material to absorb sound. The NRC is generally a number between 0 and 1 but in some circumstances can be slightly greater than 1 because of absorption at the edges of the material. A material with an NRC rating of 1 absorbs 100% of incoming sound, that is, no sound is reflected back from the material. The NRS is the average of the absorption coefficient measured in the octave bands 250Hz, 500Hz, 1kHz & 2kHz which correspond to the predominant frequencies associated with the human voice.
Partition wall	A wall dividing two rooms.
Party wall	A wall dividing two tenancies. Synonymous with 'Intertenancy Wall'.
Pre-construction	Work in respect of the proposed project that includes design, survey, acquisitions, fencing, investigative drilling or excavation, building/road dilapidation surveys, minor clearing (except where threatened species, populations or ecological communities would be affected), establishing ancillary facilities such as site compounds, or other relevant activities determined to have minimal environmental impact (e.g. minor access roads).
RBL	Rating Background Level is the representative LA90 background noise level for a period, as defined in the NSW EPA's noise policies.
Reflection	Sound wave reflected from a solid object obscuring its path.
RING	Rail Infrastructure Noise Guideline, NSW, May 2013
RMS	Root Mean Square value representing the average value of a signal.
Rw	Weighted Sound Reduction Index A measure of the sound insulation performance of a building element. It is measured in very controlled conditions in a laboratory. The term supersedes the value STC which was used in older versions of the Building Code of Australia. Rw is measured and calculated using the procedure in ISO 717-1. The related field measurement is the DnT,w. The higher the value the better the acoustic performance of the building element.
R'w	Weighted Apparent Sound Reduction Index. As for Rw but measured in-situ and therefore subject to the inherent accuracies involved in such a measurement. The higher the value the better the acoustic performance of the building element.
RNP	Road Noise Policy, NSW, March 2011
Sabine	A measure of the total acoustic absorption provided by a material. It is the product of the Absorption Coefficient (alpha) and the surface area of the material (m2). For example, a material with alpha = 0.65 and a surface area of 8.2m2 would have 0.65 x 8.2 = 5.33 Sabine. Sabine is usually calculated for each individual octave band (or third-octave).
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.
Sole-occupancy Unit	An area within a building for the exclusive use of the owner or occupier.
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 by conversion to thermal energy.
Sound Insulation	Sound insulation refers to the ability of a construction or building element to limit noise transmission through the building element. The sound insulation of a material can be described by the Rw and the sound insulation between two rooms can be described by the DnT,w.
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 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 of 1 pico watt.
Sound pressure level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone referenced to 20 micro Pascal.
Spoil	Soil or materials arising from excavation activities.
Standardised	A method of adjusting the measured noise indices in-situ so that they are independent of the measuring space. The noise level in a room is affected by reverberation in the room. For example, the L'n,w impact sound pressure level measured in a room is dependent upon the amount of absorptive material in the receiving room. The value is adjusted to what would be measured if the reverberation time in the receiving room is set at 0.5 seconds. This enables the same value to be reported independent of whether the room contains carpet and furnishings and the like. See also 'Normalised'.
STC	Sound Transmission Class A measure of the sound insulation performance of a building element. It is measured in controlled conditions in a laboratory. The term has been superseded by Rw.
Structure-borne Noise	Audible noise generated by vibration induced in the ground and/or a structure. Vibration can be generated by impact or by solid contact with a vibrating machine. Structure-borne noise cannot be attenuated by barriers or walls but requires the isolation of the vibration source itself. This can be achieved using a resilient element placed between the vibration source and its support such as rubber, neoprene or springs or by physical separation (using an air gap for example). Examples of structure-borne noise include the noise of trains in underground tunnels heard to a listener above the ground, the sound of footsteps on the floor above a listener and the sound of a lift car passing in a shaft. See also 'Impact Noise'.
Tonal Noise	Sound containing a prominent frequency and characterised by a definite pitch.
Transmission Loss	The sound level difference between one room or area and another, usually of sound transmitted through an intervening partition or wall. Also the vibration level difference between one point and another. For example, if the sound level on one side of a wall is 100dB and 65dB on the other side, it is said that the transmission loss of the wall is 35dB. If the transmission loss is normalised or standardised, it then becomes the Rw or R'w or DnT,w.

A.2 Glossary of terminology - Vibration

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

Acceleration	The rate of change of velocity, often measured in m/s2 or g's. 1 g = 9.81 m/s2. Commonly used to assess human response to vibration and for machine condition monitoring.
Accelerometer	A vibration transducer sensor that is used to measure acceleration.
ANC	The Association of Noise Consultants, UK.
Ambient vibration	The all-encompassing vibration occurring at a given location, at a given time, composed of all vibration sources near and far.

Amplification	Vibration amplification refers to an increase in vibration. Amplification may occur due to resonance, when an object or structure is excited at its natural frequency.
Attenuation	Attenuation refers to a reduction in vibration. This may occur due to damping of a vibration system, the inclusion of attenuating devices or, in the case of ground vibration, during propagation through the ground. Ground attenuation is determined by the dynamic properties of the site's soil and rock.
AVTG	Assessing Vibration: A Technical Guideline. NSW Department of Environment and Conservation's (DEC) 2006 guideline for assessing human responses to vibration. Based on BS 6472–1992.
Axis	A fixed reference line for the measurement for the measurement of vibration in a particular direction. Vibration is commonly measured in transverse (T), longitudinal (L) and vertical (V) axes (or X, Y and Z).
Background vibration	The underlying level of vibration present in the ambient environment, measured in the absence of the vibration sources of interest.
Blasting	Excavation or demolition using explosives.
Borehole transducer	A geophone transducer rigidly mounted at the bottom of a borehole (either permanently or temporarily) to measure underground vibration.
Broadband vibration	The overall vibration level which encompasses a wide range of frequencies. As opposed to vibration levels for specific frequency bands (see Octave) or narrowband vibration levels as produced by FFT.
BS	British Standard.
Continuous vibration	Vibration that continues uninterrupted over a defined period.
Cosmetic damage	Damage to a structure due to vibration that only affects the appearance of the structure and can be easily repaired, e.g. hairline cracks in mortar joints of brick or concrete constructions, or cracks in plasterwork.
Coupling loss	The change in vibration level when vibration is transmitted from the ground to a building's foundations.
Crest factor	The ratio of the peak value of a vibration event to the RMS value of a vibration event.
Damping	Reduction of vibrational energy due to friction or other forces.
DEC	NSW Department of Environment and Conservation, now the Department of Planning, Industry and Environment.
Decibel [dB]	The logarithmic unit used to represent sound and vibration levels. A vibration level in dB equals 20 times the logarithm to the base 10 of the ratio of the vibration level relative to the reference level. For vibration velocity, the reference level is commonly 1 nm/s. For vibration acceleration, the reference level is commonly 1 $\mu m/s^2$. Other reference values are commonly used. The reference value should always be stated.
DIN	German Standard.
Displacement	Change in position of a body from a reference point. Usually measured in m or mm.
EPA	Environment Protection Authority.
eVDV	Estimated Vibration Dose Value. See also VDV.
Filter	An electrical circuit that allows signals of certain frequency ranges to pass through, and blocks all other frequencies. Types of filters include low pass filters, high pass filters, and band pass filters.
FFT	Fast Fourier Transform. An algorithm that converts a signal from the time domain to the frequency domain.
Frequency	In the case of vibration, frequency is the number of oscillations that occurs per second. Frequency is measured in units of Hertz (Hz).
Geophone	A vibration transducer sensor that is used to measure velocity.

Ground-borne noise	Vibration propagated through the ground and then radiated as noise by vibrating building elements such as wall and floor surfaces. This noise is more noticeable in rooms that are well insulated from other airborne noise. An example would be vibration transmitted from an underground rail line radiating as sound in a bedroom of a building located above.
Ground spike	A metal stake with a flat top that is driven into the ground and used to mount a vibration transducer to measure vibration levels.
Habitable Area	Includes a bedroom, living room, lounge room, music room, television room, kitchen, dining room, sewing room, study, playroom, family room, home theatre and sunroom. Excludes a bathroom, laundry, water closet, pantry, walk-in wardrobe, corridor, hallway, lobby, photographic darkroom, clothes drying room, and other spaces of a specialised nature occupied neither frequently nor for extended periods.
Intermittent vibration	Either interrupted periods of continuous vibration or repeated periods of impulsive vibration.
Impulsive vibration	Vibration that rapidly builds up to a peak followed by a damped decay. May consist of multiple impulsive events, typically less then 2 seconds in duration.
Isolation	The process of reducing the vibrational energy transmitted to an object, such as a piece of equipment or building, from the source of vibrations.
Minor damage	Damage to a structure due to vibration that affects the serviceability of residential style buildings or other sensitive structures but does not affect the structural elements. E.g. cracks in plastered or rendered surfaces, existing cracks enlarged or partitions detached.
Mode	A mode of vibration is a characteristic pattern or shape in which a mechanical system will vibrate. The actual vibration of a structure is a combination of all the vibration modes, but to varying degrees, depending on the vibration source.
Natural frequency	The frequency at which a system tends to oscillate in the absence of any driving or damping force.
Noise floor	The residual level of unwanted signal measured by an instrumentation system. The signal of interest must be above the noise floor to be measured accurately. See also Signal to noise ratio.
Octave	An octave represents a doubling or halving in frequency. Noise or vibration levels across a frequency spectrum are commonly given in octave or one-third octave frequency bands.
Peak-to-peak	The difference between the highest positive peak level and the lowest negative peak of a vibration event.
Peak vibration velocity	The absolute maximum value of the vibration velocity signal measured in the X, Y or Z axis during a given time interval. Also referred to as the peak component particle velocity.
PPV	Peak Particle Velocity. The absolute maximum value of the vibration velocity signal measured in any axis during a given time interval.
PVS	Peak Vector Sum. The vector sum of the peak vibration velocities measured in the three orthogonal axes.
Resonance	The phenomenon of increased amplitude that occurs when the frequency of an applied force is equal or close to the natural frequency of the system.
RMS	Root Mean Square value representing the average value of a signal.
Sampling rate	The number of samples per second taken from a continuous signal to make a discrete or digital signal. Measured in Hertz. To accurately record the signal and determine the spectrum, the sampling rate must two or more times the maximum frequency of interest.
Settlement	The movement of soil due to vibration or other forces, often in relation to a building's foundations. The indirect effect of settlement and ground movement may cause building damage, separately from the direct of effect of building vibration.
Signal to noise ratio	A ratio of the level of a desired signal to the level of the background, often expressed in decibels.
Source vibration	A source that generates vibration. Can be quantified by the amplitude, frequency content and duration of the vibration. Common sources of vibration include rail and road traffic, construction and demolition activities and blasting.
Spectrum	The result of transforming a signal from the time domain to the frequency domain.

Structural damage	Damage to a structure due to vibration that may affect its serviceability due to damage to structural elements. May result in the reduced stability of the building and/or reduction in load-bearing capacities.
Structural fatigue	The weakening of a material caused by cyclic loading that results in progressive and localised structural damage and the growth of cracks.
Structure-borne Noise	Audible noise generated by vibration induced in the ground and/or a structure. Vibration can be generated by impact or by solid contact with a vibrating machine. Structure-borne noise cannot be attenuated by barriers or walls but requires the isolation of the vibration source itself. This can be achieved using a resilient element placed between the vibration source and its support such as rubber, neoprene or springs or by physical separation (using an air gap for example). Examples of structure-borne noise include the noise of trains in underground tunnels heard to a listener above the ground, the sound of footsteps on the floor above a listener and the sound of a lift car passing in a shaft.
Tactile vibration	Vibration of a level that can be felt by humans, dependant on the amplitude and frequency of the source. Note that vibration may also be perceived through indirect effects such as ground-borne noise or the shaking of building elements.
Transducer	A device that converts energy from one form to another. Vibration transducers convert either acceleration, velocity or displacement to an electrical signal that is processed by the monitoring system.
Triaxial	Three axes. Measurement systems often consist of three vibration transducers arranged triaxially – oriented at 90° from each other.
VDV	Vibration Dose Value. A measure of tactile vibration levels used to assess intermittent vibration.
Velocity	The rate of change of vibration displacement, usually measured in mm/s.
Vibration	A mechanical phenomenon whereby oscillations occur about an equilibrium point; a periodic back-and-forth motion of an elastic body or medium, commonly resulting when almost any physical system is displaced from its equilibrium condition.
Vrms	Root mean square (RMS) vibration level for the train passby, typically expressed in mm/s
Waveform	A graphical representation of a vibration event in the time domain, showing the measured vibration levels for each sample.

APPENDIX B Specification for Construction Noise Monitoring

B.1 Scope

This document specifies methods for undertaking noise monitoring during the construction phase of the project. This is for measurement of receivers construction noise levels, for either at-receiver measurement or intermediate locations.

B.2 Referenced standards and guidelines

- Standards Australia (2019), *Electroacoustics - Sound Level Meters - Specifications*, AS IEC 61672.1:2019 or Standards Australia (2013), Electroacoustics - Sound Level Meters - Specifications, IEC 61672.1:2013
- Standards Australia (2018), *Acoustics—Description and measurement of environmental noise*, AS 1055:2018
- NSW Department of Environment and Climate Change (2009), *Interim Construction Noise Guideline* (ICNG)
- NSW Environment Protection Authority (2017), *Noise Policy for Industry* (NPfI)

B.3 Monitoring 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 Class 2 instruments as described in IEC 61672.1:2013 and calibrated to standards that are traceable to *NATA General Accreditation Guidance: General Equipment Table* (July 2019), and consistent with the requirements of AS 1055:2018. 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).

B.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).

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.

B.5 Short-term (attended) monitoring

Where noise complaints or requests from relevant authorities are received or as required by project approvals or this management plan, attended short-term noise monitoring shall also be conducted at the requested location and at any other relevant noise receiver location with closest proximity to the construction activities.

The noise verification monitoring locations will take into consideration the nature of construction activities being undertaken by the Project. The identification of monitoring locations will consider the following:

- Most affected noise sensitive receiver location in proximity to the assessed activities,
- Location of previous monitoring sites,
- Proximity of the receiver to a Project worksite,
- Sensitivity of the receiver to noise,
- Background noise levels, and

- Safety of personnel undertaking the measurements,
- Expected duration of the impact.

Noise monitoring should, where practicable, be in positions with unobstructed views of general site activities, whilst shielded as much as possible from non-construction site noise (e.g. road traffic, rail noise and other surrounding noise).

In accordance with Australian Standard AS1055, outdoor noise monitoring is to be undertaken at least 3.5m from any reflecting structure other than the ground. Outdoor noise monitoring is to be undertaken with the microphone at a height of 1.2 to 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 1 m from the walls or other major reflecting surfaces, 1.2 m to 1.5m above the floor, and 1.5m from windows. Where the noise monitors are placed within 3.5 metres of building facades, walls or cliffs, then a reflection correction of up to -2.5 dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

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. 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}.

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;
- Name of person(s) undertaking the measurements;
- Qualifications and/or competency/suitability of the person carrying out the monitoring;
- 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);
- Measurement location details, measurement microphone height, and number of measurements at each location;

- Sketch map of area with critical measurement elements [ie. monitoring location, distance to operating plant/equipment, the location of noise/vibration generating items (construction activities and other environmental noise sources), the location and type of mitigation measures, the location of other acoustically relevant items (e.g. walls/barriers) along with relevant distances to the monitoring location];
- Photographs clearly identifying the monitoring location, setup, and critical measurement elements;
- Weather conditions during measurements, including wind velocity, wind direction, temperature, relative humidity and cloud cover;
- Description of operation and load conditions of the noise sources under investigation;
- Any adjustment made for presence or absence of nearby reflecting surfaces;
- Measured noise levels including the minimum descriptors required;
- Estimated noise level from construction activities only;
- Estimated noise levels from environmental noise sources other than construction; and
- Details of any extraneous noise due to other sources that influenced the measurement (eg traffic, aircraft, trains, dogs barking, insects, other construction equipment etc).

APPENDIX C Specification for Construction Vibration Monitoring

C.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.

C.1.1 Requirements for vibration monitoring

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

- At any locations identified within the projects Conditions of Approval / Consent Condition.
- 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 **($a=\Delta v/\Delta t$)** 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).

C.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 4150-2016 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.

C.3 Vibration minimum working distances

Where the contractor is unsure of the minimum working distance for any item of plant, these can be established through measurements to provide 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.

C.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 checked for accuracy (to manufacturer's specification) at least every two years against a reference vibration transducer that is calibrated at least every three years [ref: NATA General Accreditation Guidance: General Equipment Table (July 2019)].

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 4150-2016 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 4150-2016 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.

C.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;
- Name of person(s) undertaking the measurements;
- Qualifications and/or competency/suitability of the person carrying out the monitoring;
- 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 with critical measurement elements [ie. monitoring location, distance to operating plant/equipment, the location of noise/vibration generating items (construction activities and other environmental noise sources), the location and type of mitigation measures, the location of other acoustically relevant items (e.g. walls/barriers) along with relevant distances to the monitoring location];
- Photographs clearly identifying the monitoring location, and critical measurement elements;
- 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).

C.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.

C.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 checked for accuracy (to manufacturer's specification) at least every two years against a reference vibration transducer that is calibrated at least every three years [ref: NATA General Accreditation Guidance - General Equipment - Calibration and Checks, General Equipment Table (January 2018)].

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.

C.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.

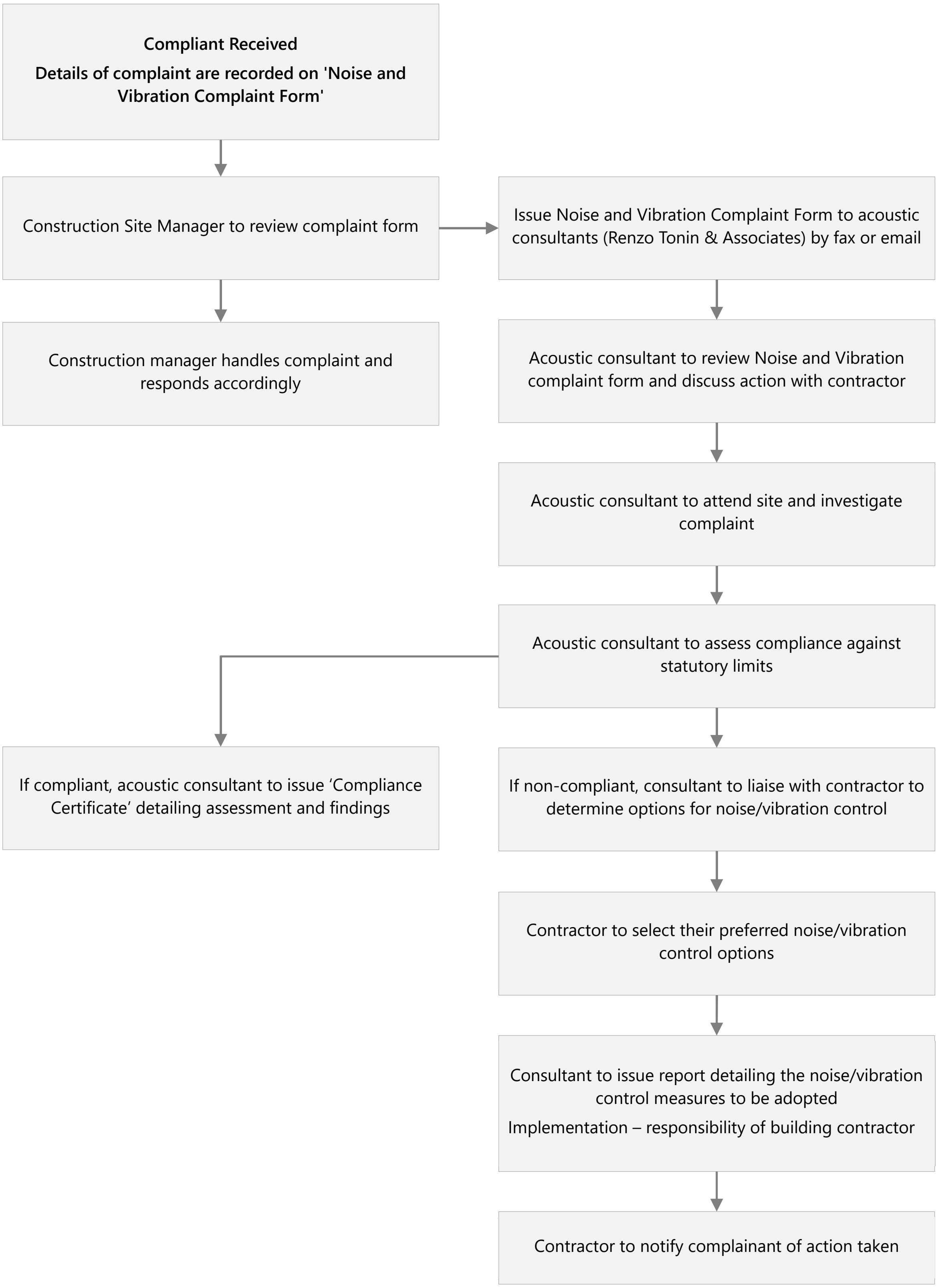
- Where a suitable mounting surface is unavailable, a metal stake (at least 300mm in length) with a mounting plate should be driven into solid ground adjacent to the building of interest. The vibration sensor or transducer shall be fixed to the mounting plate.

C.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 C.4.

APPENDIX D Noise / vibration complaint management procedure



NOISE/ 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/vibration:

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