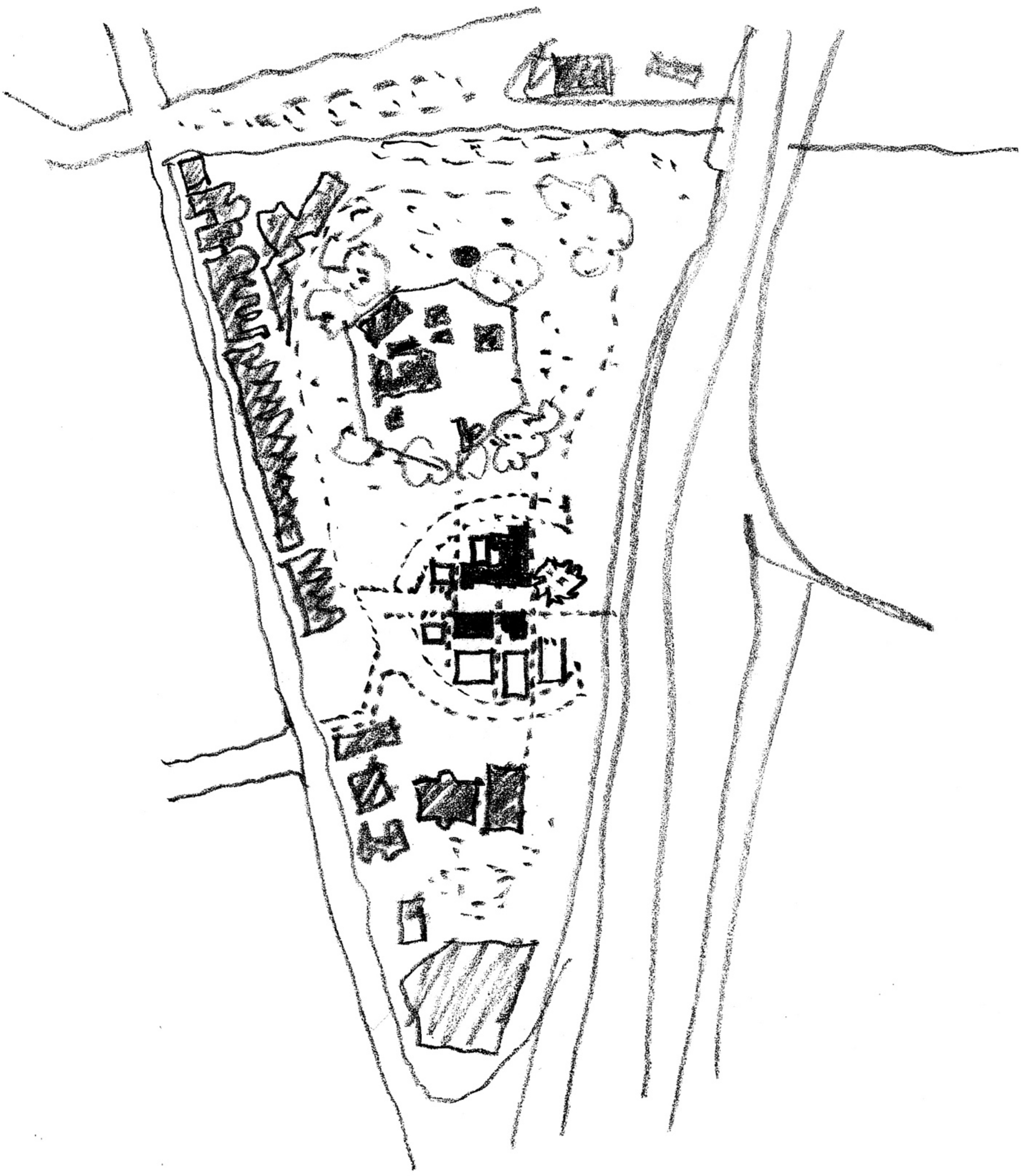
Fort Street Public School
Noise and Vibration Assessment Report

SSD 10340
Prepared by Arup
For School Infrastructure NSW
20 December 2019



NSW Department of Education

Fort Street Public School

SSDA Acoustic Assessment Report

AC03

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Document verification

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Appendices

1 Introduction

Arup has been engaged to prepare a construction and operational acoustic assessment for the development application for the Fort Street Public School Redevelopment.

Approval is sought for the expansion of Fort Street Public School to accommodate a total of 550 primary school students. Specifically:

Site preparation, demolition and excavation

- Site remediation.
- Demolition of the southernmost school building, the garage and storage shed west and east of the Bureau of Meteorology Building (the Met/the Met Building), and the toilet block adjoining the main school building.
- Selective removal of various elements of the main school building, as well as minor and insignificant elements of the Met Building and the Messenger's Cottage to facilitate refurbishment and future use of these buildings.
- Bulk excavation works to facilitate the new southern buildings and onsite detention.
- Tree removal.
- Installation of hydraulic and electrical services.

Land use

- Use of all buildings for the purpose of a school.

Existing buildings

- Retention, refurbishment and extension of the existing Fort Street Public School, including construction of a new roof and rooftop additions.
- Retention and refurbishment of the Met Building and internal alterations and additions.
- Retention and minor alterations and additions to the Messenger's Cottage.

Construction of New buildings

- Construction of one new building on the western part of the site for a staff room.
- Construction of two new, interconnected school buildings on the southern third of the site.
- Construction of a new communal hall and canteen building.

Landscaping

- Retention of the existing large fig tree.
- Landscaping works throughout the site, including construction of a new amphitheatre, new central plaza, and a multi-purpose forecourt.

- Landscaping of roof gardens on top of the new southern buildings and the existing Met Building.

Other works

- Works to the existing entrance road, including alterations to the Bradfield Tunnel Services Building.
- Modifications to existing pick-up / drop-off arrangements.
- Provision of signage zones.
- Installation of on-site detention.

1.1 Acoustic assessment requirements

Key Issue 12 of the SEARs for application SSD 10340 sets out the following requirements with regard to the assessment of noise and vibration:

> *The EIS must address the following specific matters:*
>
> - *Identify and provide a quantitative assessment of the main noise and vibration generating sources during demolition, site preparation, bulk excavation, construction. Outline measures to minimise and mitigate the potential noise impacts on surrounding occupiers of land.*
> - *Identify and assess operational noise, including consideration of any public-address system, school bell, mechanical services (e.g. air conditioning plant), use of any school hall for concerts etc. (both during and outside school hours) and any out of hours community use of school facilities, and outline measures to minimise and mitigate the potential noise impacts on surrounding occupiers of land.*
> - *Provide details of acoustic wall, floor and ceiling finishes for the school campus to ensure appropriate internal noise levels are achieved.*

SSD 10340 also references the following policies relevant to acoustics:

- NSW *Noise Policy for Industry* (NPI) [1]
- NSW *Interim Construction Noise Guideline* [2]
- NSW *Assessing Vibration: A Technical Guideline* [3]
- *Development Near Rail Corridors and Busy Road-Interim Guideline* [4]
- Australian Standard 2363:1999 Acoustics – Measurement of noise from helicopter noise

The above policies and guidelines have been addressed in this report as follows:

Acoustic aspect	Policy or guideline	Report section
Operational noise from site	NSW Industrial Noise Policy	Section 4
Road Traffic and Rail noise and vibration impacts onto site	Development Near Rail Corridors and Busy Road-Interim Guideline	Section 5

Acoustic aspect	Policy or guideline	Report section
	Assessing Vibration: A Technical Guideline	
Construction noise & vibration	Interim Construction Noise Guideline	Section 6
	Assessing Vibration: A Technical Guideline	

1.1.1 Clarifications

The following clarifications are provided with respect to the acoustic assessment requirements and the way in which they are addressed in this report:

- **Item 1**: appropriate detail on the construction methodologies required for quantitative assessment of the project are not yet known. However, construction Noise Management Levels (NMLs) are determined and preliminary construction noise and vibration management strategies are provided.
- **Item 2**: regarding mechanical services equipment, appropriate criteria are determined based on relevant legislation. The assessment focusses on the chillers which will be the most significant mechanical equipment to potentially cause adverse impact to surrounding receivers and for which the mechanical engineers have provided preliminary selections. Other mechanical equipment selections are not available at this time, and therefore in-principle noise mitigation and management measures are included.

  Regarding school events taking place in the Communal Hall it is anticipated that the building envelope will be designed to control external noise intrusion as well as noise egress.

  With respect to PA system and school bell, no substantial changes to the acoustic environment are anticipated due to these as these aspects are not anticipated to change significantly.
- **Item 3:** the required assessment for this clause is not clear, and Arup have interpreted the requirement as follows: *"Provide preliminary acoustic design strategies for the building envelope to mitigate external noise intrusion and ensure appropriate internal noise levels are achieved throughout the school"*.

  The design of internal walls and floors for acoustic separation of internal activities is not typically the subject of the development approvals process. While important to the outcome of the school, these aspects are addressed at future stages of the project in accordance with requirements of NSW Schools Infrastructure.
- **Reference to AS 2363:1999**: the basis for inclusion of this is unclear. Arup has requested further information from the Department of Planning, Industry and Environment (DPIE) regarding specific helicopter noise concerns. Based on noise monitoring conducted on site, helicopter noise has not been identified as a particular issue for the school, therefore this is not included in this report.

1.2 Scope of assessment

The following outlines the scope of assessment with respect to the above acoustic aspects and relevant policies and guidelines:

- Examine the proposed development plans to identify acoustic aspects of the construction and operation of the developments.
- Identify the development surrounding the site, which are to be assessed with regard to construction and operational activities.
- Conduct noise level monitoring to quantify the existing acoustic environment at relevant surrounding receiver locations to set project targets in accordance with relevant policy.
- Conduct noise level monitoring to quantify the school site exposure to environmental noise.
- Where appropriate, carry out a quantitative acoustic assessment of potential impacts and compare against the relevant noise and vibration targets.
- Identify where further design development is required and identify in-principle mitigation or management methods for the control of noise and vibration where required.
- Outline the processes to be adopted for the continued design development of acoustic aspects for the project.

A glossary of the acoustic terminology used in this document is presented in Appendix A.

2 Surrounding land uses

Fort Street Public School (FSPS) is located on a prominent site adjacent to significant NSW Government land holdings (Sydney Observatory and Park, the National Trust building site and Kent Street Tennis Courts).

The nearest noise sensitive development surrounding the site were identified as the residential premises (units and houses) located on Kent Street to the west and along the Agar Steps to the southwest. The residences on Kent Street back onto a cutting, which provides a degree of 'acoustic shielding' from the FSPS site.

The Cahill Expressway cut surrounds the site almost in its entirety, and the Sydney Harbour Bridge approach (Bradfield Highway and Western Distributor) is located at the east site boundary. Due to this, the site is exposed to reasonably high levels of road traffic noise.

Sydney train lines T1 (North Shore and Western Line) and T9 (Northern Line) run under the Bradfield Highway and Western Distributor to the east of site.

Figure 1 below shows the site location and it immediate surroundings.

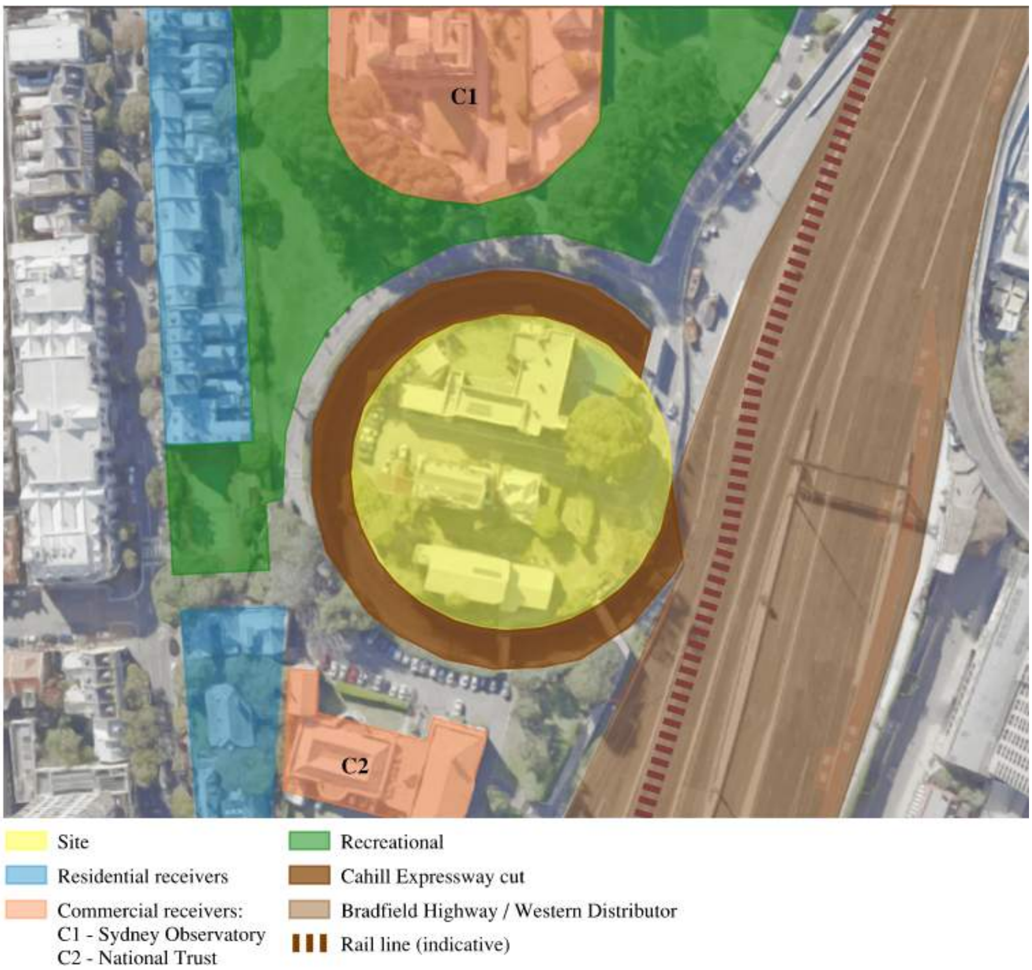


Figure 1: Fort Street Public School and surrounding land uses

3 Existing acoustic environment

3.1 Noise survey

A noise survey has been conducted to establish criteria for the assessment of operational and construction noise from the school as well as to establish the levels of environmental noise the site is exposed to.

The noise survey included both long-term and short-term noise monitoring throughout the school as well as short-term noise measurements in two locations outside the school.

3.1.1 Noise measurement locations

Noise measurements are ideally carried out at the nearest or most potentially affected locations surrounding a development. An alternative, representative location should be established in the case of access restrictions or a safe and secure location cannot be identified. Furthermore, representative locations may be established in the case of multiple receivers as it is usually impractical to carry out measurements at all locations surrounding a site.

The long-term and short-term measurement locations are outlined in Table 1 and Table 2, and shown in Figure 2.

Table 1: On-site noise monitoring locations

ID	Description
L1	School entrance east of reception, 1.5m above ground, free-field measurement
L2	Western boundary, 1m above ground, free-field measurement
S1	School yard, 1.5m above ground, free-field measurement
S2	Eastern boundary, 1.5m above ground, free-field measurement
S3	Northern boundary, 1.5m above ground, free-field measurement
S4	Southern boundary, 1.5m above ground, free-field measurement
S5	Noise Logger Location 1, 1.5m above ground, free-field measurement
S6	Main school road – front of reception, 1.5m above ground, free-field measurement
S7	Main school road – front of heritage building, 1.5m above ground, free-field measurement
S8	Noise Logger Location 2, 1.5m above ground, free-field measurement
S9	School garden, 1.5m above ground, free-field measurement

Table 2: Off-site noise monitoring locations

ID	Description
S10	Observatory Hill west adjacent to residences on Kent St, 1.5m above ground, free-field measurement. **Representative of nearest residential receiver.**
S11	Kent St – Street Level, 1.5m above ground, facade measurement

Figure 2: Noise measurement locations

3.1.2 Long-term noise measurement results

Long-term noise monitoring was carried out from Thursday, 30 May 2019 to Friday, 14 June 2019. The long-term noise monitoring methodology as well as noise level-vs-time graphs of the data are included in Appendix B.

Table 3 presents the overall single Rating Background Levels (RBL) and representative ambient L_{eq} noise levels for each assessment period, determined in accordance with the NPI.

Table 3: Long-term noise monitoring results, dB(A)

Location	Time period	Rating background noise levels, dBL_{A90}	Ambient dBL_{Aeq} noise levels
L1 – School entrance	Day	58	62
	Evening	56	60

Location	Time period	Rating background noise levels, dBL_{A90}	Ambient dBL_{Aeq} noise levels
	Night	47	57
L2 – Western boundary	Day	59	67
	Evening	56	65
	Night	46	61
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 As required by the NPI, the external ambient noise levels presented are free-field noise levels. [i.e.. no façade reflection]			

Table 4 presents the representative weekday L_{eq} noise levels for assessment against road traffic noise intrusion criteria (refer to Section 5)

Table 4: Daily representative $L_{eq\ (15hr,\ 9hr\ and\ 1hr)}$

Location	L_{Aeq} Noise Levels		$L_{Aeq\ 1hr}$ Noise levels	
	Day[1]	Night[2]	Day	Night
L1 – School entrance	**62**	**58**	**64**	**62**
L2 – Western boundary	**66**	**62**	**68**	**66**
1. Day is 7:00am to 10:00pm 2. Night is 10:00pm – 7:00am				

3.1.3 Short-term noise measurement results

Short-term noise measurements were undertaken during the daytime of Thursday, 30 May 2019, Friday 14 June 2019 and Thursday 20 June 2019 in order to supplement the long-term noise monitoring / and provide greater detail of the surrounding noise environment.

A summary of the short-term measurement results is presented in Table 5.

Table 5: Short-term noise monitoring results

Location	Date & Time	dB $L_{A90(15mins)}$	dB $L_{Aeq(15mins)}$	Observations
S1	30 May 2019 – 12:45pm to 1:00pm	57	61	Relatively lower noise levels than the boundaries – major source of noise (Western Distributor) is shielded by the main school building
S2	30 May 2019 – 1:02pm to 1:17pm	65	67	Measured at wooden deck. Primarily traffic noise from Western Distributor.
S3	30 May 2019 – 12:45pm to 1:00pm	62	66	Significant traffic noise reflected from the Cahill Express cutaway

Location	Date & Time	dB $L_{A90(15mins)}$	dB $L_{Aeq(15mins)}$	Observations
S4	30 May 2019 – 1:04pm to 1:19pm	65	69	Highest point of Cahill Expressway cutaway
S5	14 June 2019 – 12:40pm to 12:55pm	62	64	For noise logger calibration purposes, mainly affected by Western Distributor
S6	14 June 2019 – 12:59pm to 1:14pm	57	61	Closer to Western Distributor and has direct line of sight.
S7	14 June 2019 – 12:59pm to 1:14pm	57	61	Affected by both Cahill Expressway cutaway and has direct line of sight to Western Distributor.
S8	14 June 2019 – 1:15pm to 1:30pm	60	67	For noise logger calibration purposes. Mainly affected by Cahill Expressway cutaway
S9	14 June 2019 – 1:31pm to 1:46pm	59	64	Affected by both Cahill Expressway cutaway and has direct line of sight to Western Distributor. Children playing while measurement was taken.
S10	20 June 2019 – 9:32am to 9:47am	57	60	Affected by construction noise from Crown Casino at Barangaroo
S11	20 June 2019 – 9:51am to 10:06am	57	69	Busy road with frequent trucks and buses passing by

3.2 Vibration monitoring

Vibration monitoring was also conducted to assess rail vibration exposure onto the school from the train lines T1 (North Shore and Western Line) and T9 (Northern Line) than run under the Bradfield Highway and Western Distributor to the east of site.

3.2.1 Measurement location

The vibration measurement location was selected, as potentially being the most affected location for a new building based on the design options considered for the project. The vibration monitoring location is shown in Figure 3 below.

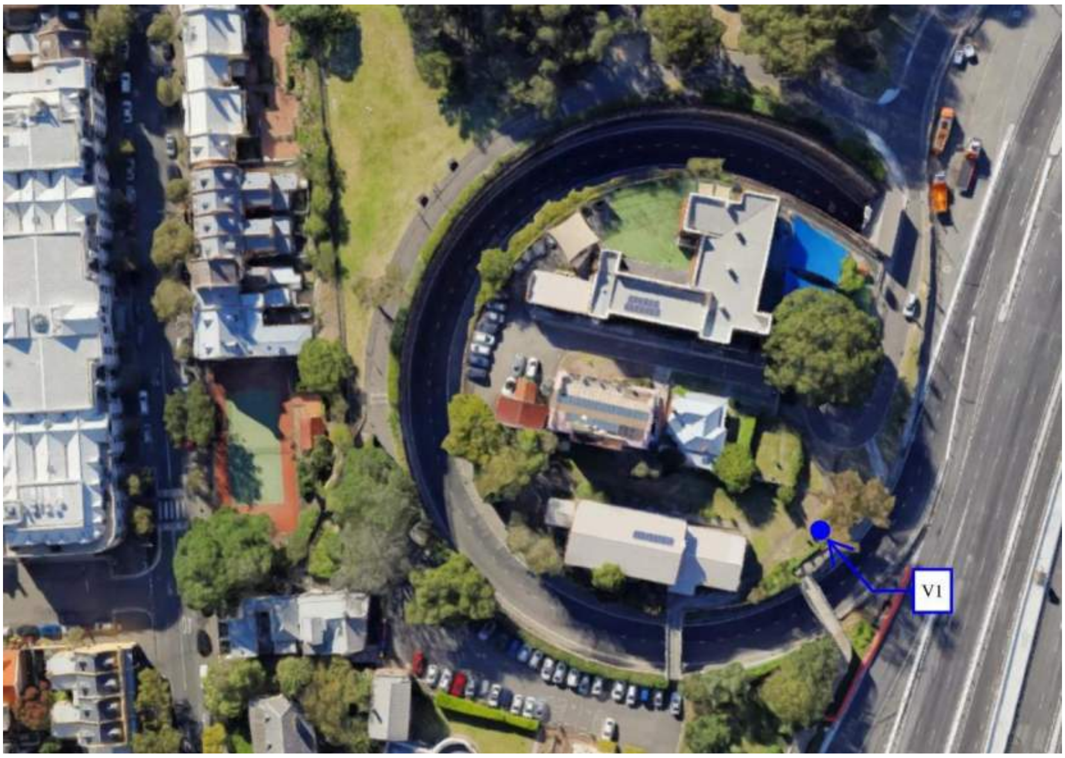


Figure 3: Vibration measurement location

3.2.2 Results

Vibration measurement were conducted on Friday 10 June 2019 for 1 hour between 8:00 am and 9:00 am.

Vibration measurement results are presented in Figure 4 below. **It is noted that no train pass bys were measurable**. The results are for the average continuous vibration levels during the measurement period.

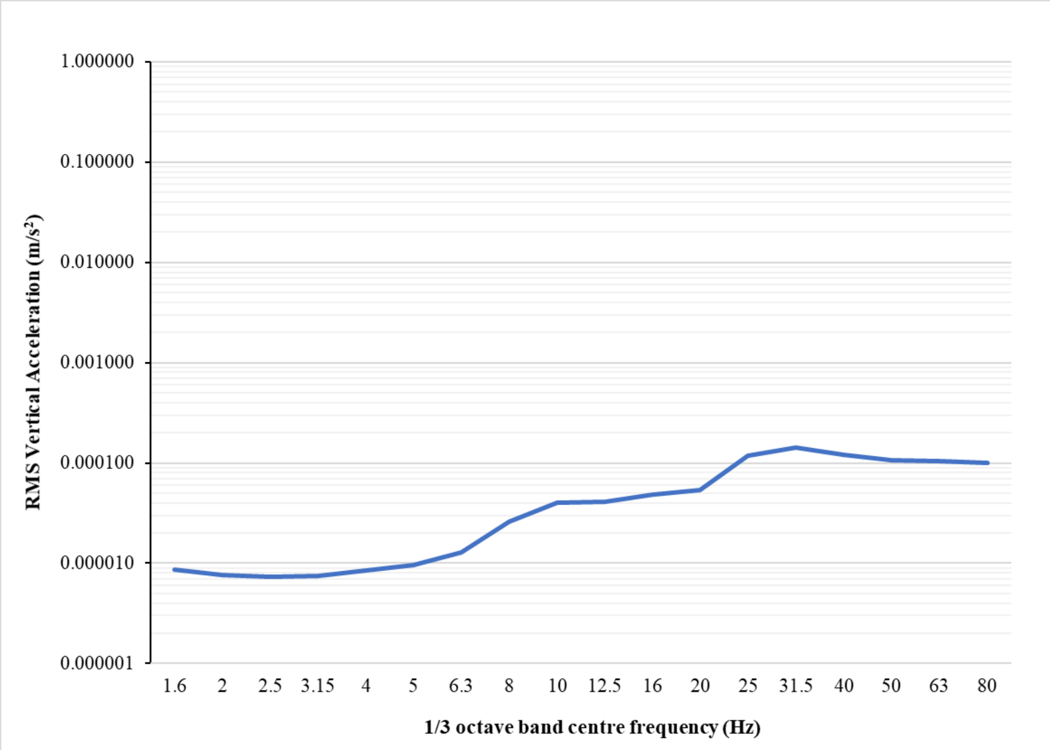


Figure 4: Measured vibration levels

4 Operational noise

4.1 Overview

The primary operational noise sources from the site, with the potential to impact upon surrounding noise sensitive uses include:

- New mechanical plant and equipment.
- School events taking place in the Hall.
- School PA system announcements and school bell, although these are not expected to change from current operational situation at the school.

4.2 Criteria

4.2.1 NSW Noise Policy for Industry

Building services and equipment noise will be assessed in accordance with the NSW Noise Policy for Industry (NPI) [1].

The NPI is primarily concerned with controlling intrusive noise impacts in the short-term for residences and maintaining long-term noise level amenity for residences and other land uses.

The NPI sets out the procedure to determine the project noise trigger levels relevant to an industrial development. The project noise trigger level is a level that, if exceeded would indicate a potential noise impact on the community and so ‘trigger’ a management response.

4.2.1.1 Intrusive noise trigger level

The intrusiveness noise trigger level is applicable to residential premises only and is summarised as follows:

- $L_{Aeq,15minute} \leq$ Rating Background Level (RBL) plus 5 dB

  (where $L_{Aeq,15minute}$ represent the equivalent continuous noise level of the source)

Note that as the Intrusive Noise Trigger Level is established from the prevailing background noise levels at the residential receiver location, the existing background noise level is to be measured.

4.2.1.2 Recommended and project amenity noise level

To limit continuing increases in noise levels from application of the intrusiveness level alone, the ambient noise level within an area from **all** industrial noise sources combined should remain below the recommended amenity noise levels specified in Table 2.2 of the NPI where feasible and reasonable. An extract from the policy is given below in Table 6.

Table 6: NPI Recommended Amenity Noise Levels (RANLs)

Receiver	Noise amenity area	Time of Day	Recommended amenity noise levels (RANLs) dB L_{Aeq}
Residential *Kent St and Agar Steps residences*	Urban	Day	60
		Evening	50
		Night	45
Active recreation area (e.g. school playground, golf course) *Observatory park* *School outdoor areas*	All	When in use	55
Commercial premises *Sydney Observatory* *National Trust building*	All	When in use	65

Notes:

1. The recommended amenity noise levels (RANLs) refer only to noise from industrial sources. However, they refer to noise from all such sources at the receiver location, and not only noise due to a specific project under consideration. The levels represent outdoor levels except where otherwise stated.
2. The NPI defines day, evening and night time periods as:
   - Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays.
   - Evening: the period from 6 pm to 10 pm.
   - Night: the remaining period

The recommended amenity noise levels (RANLs) represent the objective for **total** industrial noise at a receiver location, whereas the **project amenity noise level (PANL)** represents the objective for noise from a **single** industrial development at a receiver location.

To ensure that any new industrial source of noise is within the RANLs for an area, the PANL applies for each new source of industrial noise as follows:

- *Project Amenity Noise Level (PANL) = Recommended Amenity Noise Level (RANL) minus 5 dB(A)*

The NPI also provides the following exceptions to the above method for deriving the project amenity noise level:

1. *In areas with high traffic noise levels.*
2. *In proposed developments in major industrial clusters.*
3. *Where the resultant project amenity noise level is 10 dB or more lower than the existing industrial noise level. In this case the project amenity noise levels can be set at 10 dB below existing industrial noise levels if it can be demonstrated that existing industrial noise levels are unlikely to reduce over time.*
4. *Where cumulative industrial noise is not a necessary consideration because no other industries are present in the area, or likely to be*

introduced into the area in the future. In such cases the relevant amenity noise level is assigned as the project amenity noise level for the development.

As per item 4, there are no other significant sources of industrial noise in the areas and it is not expected that these be introduced in the future, therefore the PANLs have been set to be the same as the RANLs.

4.2.1.3 Sleep disturbance

The NSW NPI also recommends criteria for the assessment of potential sleep disturbance, for the period between 10 pm and 7 am. The school is not expected to operate during this time period, therefore potential sleep disturbance is not being considered.

4.2.1.4 NPI Project specific noise levels

Based on the background and ambient noise monitoring, Table 7 summarises the derived project specific noise levels based on the NPI.

Table 7: NPI Project specific noise levels.

Receiver	Time Period	Project Noise Trigger Levels		
		Intrusive Noise Trigger Levels $L_{Aeq,15min}$[1]	Project Amenity Noise Level (PANL) $L_{Aeq,period}$[2]	Project Noise Trigger Level $L_{Aeq,\ 15min}$
Nearest residential receivers on Kent St and Agar Steps	Day	62[3]	60	60
	Evening	61[3]	50	50
	Night	51[3]	45	45
Observatory park	When in use	-	55	55
Sydney Observatory and National Trust	When in use	-	65	65

Notes

1. Only applies to residential receivers
2. Cumulative industrial noise is not a necessary consideration. Therefore, PANL is the same as the RANL.
3. Derived based on attended measurement location S10 as representative of the nearest residential receivers and normalised to the change in level recorded at long-term monitoring location L2.

4.2.2 Emergency equipment

Concessions are proposed for emergency equipment such as backup generators and smoke exhaust systems. Specifically, an allowance of +10 dB above the normal operations criteria is proposed.

4.2.3 School activities

There are no specific regulatory policies or guidelines for noise associated with school activity and it is expected that noise emissions due to this are not likely to change significantly as a result of the development.

Specifically, noise emission from internal areas, such as music rooms, auditoria or sports halls are often required to achieve the same criteria as building services.

Regarding school PA system and bell, these two relate to specific current operational aspects of the school and should not result in any significant changes to the acoustic environment.

4.3 Operational noise review

4.3.1 Mechanical services

The primary operational noise associated with the school relates to building services equipment, such as air-conditioning and ventilation systems.

Currently the mechanical strategy for the project is to provide a chilled and heating hot water system which will include the following equipment:

- Two (2) air cooled chillers at an outdoor plant area.
- Outside air fans located in separate rooms throughout the building facades.
- Pumps located in an enclosed plantroom.
- Fan coil units located in the ceiling space throughout internal areas.
- Air Handling Units (AHU) located in an enclosed plantroom.
- Exhaust fans located on roof.

During ongoing design of the development, equipment will be selected and provided with noise and vibration attenuation measures as required to meet the Project goals. Noise mitigation treatment will likely be required, including:

- Specification of maximum sound power levels for all items of plant as part of the project documentation.
- Use of attenuators to control fan noise.
- Acoustic louvres to control noise from plantroom ventilation openings.
- Vibration isolators to reduce vibration input to the building structure.
- Acoustic screens around external plant, where required.
- Incorporation of sound absorptive treatments in plantroom spaces.

Acoustic design and certification of building services equipment is typically recommended to be provided at the construction certificate stage.

4.3.1.1 Preliminary assessment of chiller noise

Chillers typically emit high levels of noise and as mentioned above two (2) chillers have been proposed to be located on the roof of Building J. Therefore, they have the potential to cause adverse noise impacts to surrounding receivers.

The mechanical engineers have provided preliminary chiller selections to allow a preliminary acoustic assessment to determine noise mitigation measures. These will need to be developed further and coordinated with the mechanical engineers as the design progresses. Other external noise sources such as outside air and exhaust fans will also need to be assessed once equipment has been selected.

Location of chillers

Figure 5 below shows the location of the chillers in relation to the nearest residential receiver located along the Agar Steps to the southwest of the site at approximately 42 m from the chillers.

Figure 5: Location of chillers and residential receiver on Agar Steps

Operational assumptions

It is assumed that the school may operate during the evening period. Night time use is not expected. Therefore, the assessment has been conducted to assess compliance with the day time and evening periods noise criteria.

As advised by the mechanical engineers, the two chillers may operate concurrently.

Unmitigated noise levels

Sound power levels for the selected chillers are listed in Table 8 below.

Table 8: Chiller sound power levels

Equipment	Sound Power Level, dB re 1 pW Octave Band Centre Frequency, Hz							
	63	125	250	500	1 k	2 k	4 k	8 k
Chiller - unmitigated	86	86	87	90	92	85	83	83

Based on the sound power levels listed above, noise levels have been predicted at the residential receiver on Agar Steps. Results are presented in Table 9

Table 9: Predicted chiller noise levels at residential receiver on Agar Steps - unmitigated

Receiver	Predicted $L_{Aeq,15min}$ dB(A)	Operational criteria		Meets criteria?
		Period	$L_{Aeq,15min}$ dB(A)	
Residential – Agar Steps	60	Day	60	Yes
		Evening	50	No (+10 dB. Requires mitigation)

Mitigation measures

Based on the preliminary equipment selection and proposed location, mitigation and management measures are deemed to be required to address potential impacts to surrounding development. Further consideration will also need to be given to noise exposure on the school site, which may warrant mitigation beyond that required to satisfy the environmental assessment requirements.

To address emissions to surrounding development a 3 m high acoustic screen around the chillers has been included in the design. Further detailed acoustic design as well as coordination with the mechanical engineers will be required to finalise the mitigation specifications.

Figure 6 below shows the acoustic screen (in red) as currently documented in the architectural SSDA package.

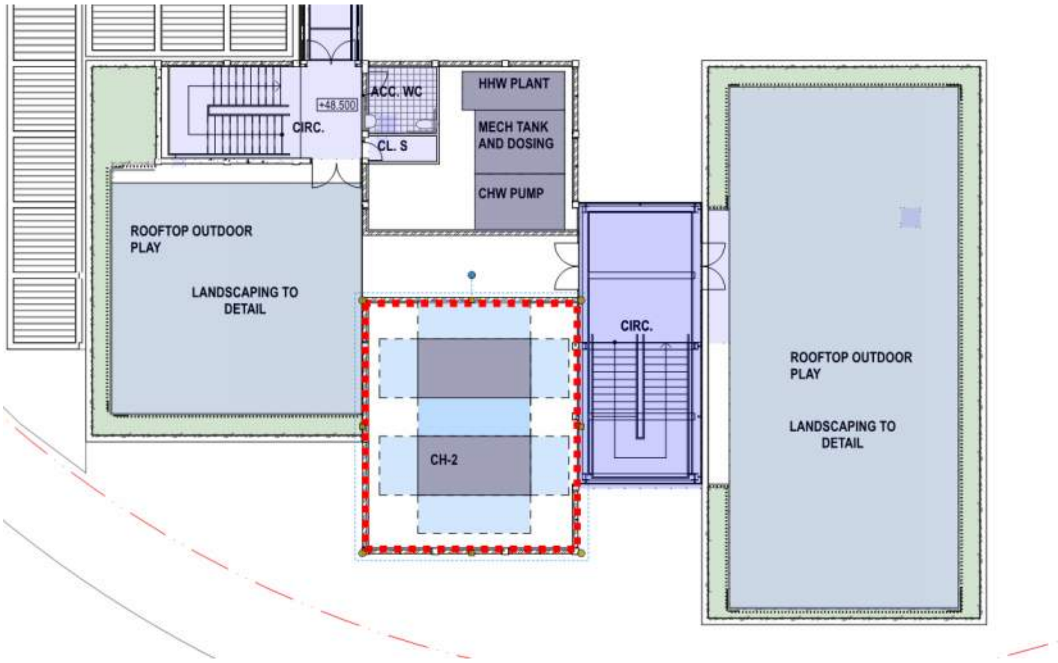


Figure 6: Acoustic screen around chillers

Predicted noise levels with the 3 m high acoustic screen are presented in Table 10.

Table 10: Predicted chiller noise levels at residential receiver on Agar Steps - mitigated

Receiver	Predicted $L_{Aeq,15min}$ dB(A)	Operational criteria		Meets criteria?
		Period	$L_{Aeq,15min}$ dB(A)	
Residential – Agar Steps	50	Day	60	Yes
		Evening	50	Yes

4.3.2 Communal Hall events

The building envelope will be designed to control external noise intrusion and ensure appropriate internal noise levels are meet. Due to the high ambient noise levels in the area it is anticipated that the building envelope will need to achieve a high acoustic performance (refer to Section 5.2.2). Therefore, it is anticipated that noise egress from the hall will also be controlled to cause minimal impact on surrounding receivers. This will be reviewed as design progresses.

5 Impacts upon development

5.1 Criteria

Development near rail corridors and busy roads must address the *State Environmental Planning Policy (Infrastructure) 2007* (ISEPP) [5], which is supported by the *Development Near Rail Corridors and Busy Roads – Interim Guideline* [4] , which cover airborne noise, ground borne noise and vibration. The policy is a requirement for educational establishments.

5.1.1 Airborne and ground-borne noise

Table 11 presents the ISEPP requirement for educational spaces. This is considered the minimum requirements for educational institutions.

Table 11: ISEPP internal noise criteria for airborne and ground borne noise

Receiver type	**Time**	**Airborne noise daytime $L_{Aeq,15h}$**	**Airborne noise night-time $L_{Aeq,9h}$**	**Groundborne noise $L_{Amax(slow)}$ for 95% of rail pass-by events**
Educational Institutions including child care centres	When in use	40	40	40

The NSW Department of Education, *Educational Facilities Standards and Guidelines* (EFSGs) [6] also stipulates that road noise shall be assessed in accordance with the ISEPP requirements. However, the EFSGs sets lower internal noise levels for some spaces depending on their use and sensitivity.

Table 12 summarises the internal noise levels for the project in line with the EFSGs, which include contribution from steady-state noise sources such as road traffic and mechanical noise.

Table 12: Internal noise criteria for the project

	Maximum internal background noise levels for normal operations: includes building services and steady-state external noise sources	
Spaces	**EFSG equivalent category**	**Design sound level ($L_{Aeq,1\ hour}$)[1]**
Canteen	Dining rooms	45
Canteen office	Office areas	40
Clerical	Office areas	40
Comms room[4]	-	-
Communal Hall	Assembly halls	35
Circulation	Corridors and lobbies	45
Deputy principal	Professional and administrative offices	35
Homebase	Open plan teaching area	40

Spaces	Maximum internal background noise levels for normal operations: includes building services and steady-state external noise sources	
	EFSG equivalent category	Design sound level ($L_{Aeq,1\ hour}$)[1]
Interview room	Interview/ counselling rooms	35
Library – general areas	Library – general areas	40
Library – reading areas	Library – reading areas	35
Library – stack areas	Library – stack areas	45
Plantroom	-	75
Practical Activities Area (PAA)	Open plan teaching area	40
Principal's office	Professional and administrative offices	35
Security	Office areas	40
Shared office / workroom	Office areas	40
Sick bay	Medical rooms (first aid)	40
Special Programs Rooms	Teaching spaces – primary schools	35
Staff room	Staff common rooms	40
Storage	-	55
Toilets	Toilet/change/showers	50
Withdrawal room	Teaching spaces – primary schools	35
Notes 1. 1-hour is proposed as the EFSGs do not specify a period.		

Regarding ground-borne noise impacts, as presented in Section 3.2, no train passbys were measurable, and therefore ground-borne noise from rail operations has not been considered further in this assessment.

5.1.1.1 Natural ventilation

The internal airborne noise criteria are generally achieved through a sealed building. Ideally where natural ventilation is to be provided, the same criteria would also be achieved, particularly for critical spaces, where higher ambient noise levels may otherwise impact on speech intelligibility or unduly impact concentration. However, for some uses, research has indicated that occupants are willing to accept trade-offs in the ambient noise levels where natural ventilation is provided.

The ISEPP guideline allows for a + 10 dB concession for the open windows condition, and while this could be applied to educational uses, it is considered that such a decision should be made by the end users and/or relevant development stakeholders. The desire for natural ventilation may be an important feature of the design but will leave the teaching areas vulnerable to noise intrusion, potentially exacerbating the listening issues associated with open plan classrooms.

5.1.2 Vibration

In accordance with the ISEPP guideline, potential vibration disturbance to human occupants of buildings is made in accordance with the NSW DEC '*Assessing Vibration; a technical guideline*' [3]. The criteria outlined in the guideline is based on the British Standard BS 6472-1992 '*Evaluation of human exposure to vibration in buildings (1-80Hz)*'. Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent', with rail projects typically being defined as intermittent as described in Table X below.

Table 13: Types of vibration – Definition

Type of vibration	**Definition**	**Examples**
Continuous vibration	Continues uninterrupted for a defined period (usually throughout the day-time and/or night-time)	Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).
Impulsive vibration	A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading.
Intermittent vibration	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer, this would be assessed against impulsive vibration criteria.

Table 14 is a reproduction of the 'Preferred' and 'Maximum' values for continuous vibration at Schools from Table 2.2 of the Guideline which represent the most stringent criteria for the project

Table 14: Preferred and maximum vibration acceleration levels for human comfort, m/s^2

Location	**Assessment period1**	**Preferred values**		**Maximum values**	
		z-axis	**x- and y-axes**	**z-axis**	**x- and y-axes**
Continuous vibration (weighted RMS acceleration, m/s2, 1-80Hz)					
Offices, schools, educational institutions and places of worship	Day- or night-time	0.020	0.014	0.040	0.028
1 - Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am 2 - Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specified above. Alternative criteria is outside the scope of the policy and other guidance documents should be referred to.					

As presented in Section 3.2 vibration levels are well below the preferred value for continuous vibration at schools.

5.2 Assessment of road traffic noise intrusion

5.2.1 Road traffic noise model

To be able to predict road traffic noise levels throughout the site with the proposed upgrades to the school as well as new buildings, a road traffic noise model has been built in SoundPLAN 8.0. This noise model is constructed from the following inputs:

- Terrain mesh extracted from building model, supplied by FJMT.
- Surrounding road network strings, digitized from geolocated satellite imagery
- Existing building structures, digitized from supplied drawings by FJMT.
- Proposed building structures, digitized from supplied drawings by FJMT.

The noise model was calibrated against the noise logger and attended noise measurements documented in Section 3.1.

5.2.2 Preliminary recommendations

Façade noise levels have been extracted from the noise model to determine preliminary façade acoustic performance requirements and indicative build-ups to address the internal noise criteria for the project.

The advice focusses on the glazed elements of the façade at this stage.

The advice provided herein is indicative and shall not be used for construction. Detailed assessment of the whole building shall be carried out during the detailed design phase to confirm the acoustic performance requirements of the façade as well as suitable build-ups. Furthermore, the final acoustic performance specification shall give appropriate regarding to the installed performance of the system.

It is noted that natural ventilation has not been considered in the design and it is recommended that this is not enabled for teaching and learning spaces. It may be considered for office and back of house areas as the design progresses.

Table 15: Façade assessment, $L_{Aeq,\ 1hr}$

Building	Level	Area	External Noise Level $L_{Aeq,\ 1hr}$	Façade glazing		Predicted InternalNoise Level LAeq, 1hr (traffic noise only)	Compliance?
				Recommended Sound Insulation Performance Rw + Ctr	Indicative Construction		
A	GF	PAA - North	69	33	10 mm float glass / 12 mm cavity / 6 mm float glass	38	YES
		Open learning - East	67	33	10 mm float glass / 12 mm cavity / 6 mm float glass	36	YES
		Withdrawal Room 3	67	45	10 mm float glass / 200 mm cavity / 6 mm float glass	30	YES
		Withdrawal Room 4	67	40	6 mm float glass / 150 mm cavity / 4 mm float glass	30	YES
		Withdrawal Room 5	59	33	10 mm float glass / 12 mm cavity / 6 mm float glass	30	YES
		Withdrawal Room 6	59	33	10 mm float glass / 12 mm cavity / 6 mm float glass	30	YES
		Teachers area	66	27	6 mm float glass / 12 mm cavity / 6 mm float glass	38	YES
		Presentation space - East	67	37	10 mm float glass / 12 mm cavity / 17. 5 mm laminated glass	31	YES
		Presentation space - South	60	27	6 mm float glass / 12 mm cavity / 6 mm float glass	31	YES
		PAA – Central	66	33	10 mm float glass / 12 mm cavity / 6 mm float glass	36	YES
		Open learning - South	59	27	6 mm float glass / 12 mm cavity / 6 mm float glass	37	YES
	L1	PAA - North	69	33	10 mm float glass / 12 mm cavity / 6 mm float glass	38	YES
		Withdrawal Room 10	70	45	10 mm float glass / 200 mm cavity / 6 mm float glass	30	YES
		Withdrawal Room 11	70	45	10 mm float glass / 200 mm cavity / 6 mm float glass	30	YES
		Open learning - East	70	35	10 mm float glass / 12 mm cavity / 6.38 mm laminated glass	38	YES
		Circulation – South east	65	27	6 mm float glass / 12 mm cavity / 6 mm float glass	41	YES
		Learning Studio	67	37	10 mm float glass / 12 mm cavity / 17,5 mm laminated glass	37	YES
	L2	Presentation space	65	40	6 mm float glass / 150 mm cavity / 4 mm float glass	31	YES

Building	Level	Area	External Noise Level $L_{Aeq, 1hr}$	Façade glazing		Predicted InternalNoise Level $L_{Aeq, 1hr}$ (traffic noise only)	Compliance?
				Recommended Sound Insulation Performance Rw + Ctr	Indicative Construction		
		Open learning - Central	65	33	10 mm float glass / 12 mm cavity / 6 mm float glass	35	YES
		Withdrawal Room 24	66	52	21.5 mm laminated glass / 200 mm cavity / 17.5 mm laminated glass	32	YES
		Withdrawal Room 25	66	52	21.5 mm laminated glass / 200 mm cavity / 17.5 mm laminated glass	32	YES
		PAA - North	69	37	10 mm float glass / 12 mm cavity / 17. 5 mm laminated glass	37	YES
		Withdrawal Room 22	69	45	10 mm float glass / 200 mm cavity / 6 mm float glass	32	YES
		Open learning – North east	69	40	6 mm float glass / 150 mm cavity / 4 mm float glass	36	YES
		PAA – South east	65	37	10 mm float glass / 12 mm cavity / 17. 5 mm laminated glass	37	YES
C	GF	Deputy Principal Type 1	62	35	10 mm float glass / 12 mm cavity / 6.38 mm laminated glass	33	YES
		Principal	63	33	10 mm float glass / 12 mm cavity / 6 mm float glass	32	YES
		Interview	63	33	10 mm float glass / 12 mm cavity / 6 mm float glass	32	YES
		Entry	63	27	6 mm float glass / 12 mm cavity / 6 mm float glass	39	YES
F	GF	Staff Room	60	27	6 mm float glass / 12 mm cavity / 6 mm float glass	38	YES
G	GF	Community Hall - North	64	39	10 mm float glass / 16 mm cavity / 12.5 mm acoustic laminate	32	YES
		Community Hall - South	72	52	21.5 mm laminated glass / 200 mm cavity / 17.5 mm laminated glass	32	YES
H	GF	Clerical	56	39	8.5 mm acoustic laminated / 16 mm cavity / 12.5 mm acoustic laminate	37	YES

Building	Level	Area	External Noise Level $L_{Aeq, 1hr}$	Façade glazing		Predicted InternalNoise Level $L_{Aeq, 1hr}$ (traffic noise only)	Compliance?
				Recommended Sound Insulation Performance Rw + Ctr	Indicative Construction		
		Clerical entry	56	27	6 mm float glass / 12 mm cavity / 6 mm float glass	42	YES
		Main circulation	59	27	6 mm float glass / 12 mm cavity / 6 mm float glass	43	YES
	L1	PAA	71	45	10 mm float glass / 200 mm cavity / 6 mm float glass	38	YES
		Presentation space - South	67	40	6 mm float glass / 150 mm cavity / 4 mm float glass	33	YES
		Withdrawal rooms	60	40	6 mm float glass / 150 mm cavity / 4 mm float glass	31	YES
		Teachers area	64	40	6 mm float glass / 150 mm cavity / 4 mm float glass	36	YES
J	GF	Open learning	67	39	10 mm float glass / 16 mm cavity / 12.5 mm acoustic laminate	37	YES
		Withdrawal room 7	64	45	10 mm float glass / 200 mm cavity / 6 mm float glass	29	YES
		PAA	57	27	6 mm float glass / 12 mm cavity / 6 mm float glass	38	YES
		Circulation - North	59	27	6 mm float glass / 12 mm cavity / 6 mm float glass	43	YES
	L1	Open learning	65	35	10 mm float glass / 12 mm cavity / 6.38 mm laminated glass	38	YES
		Withdrawal room 17	60	39	8.5 mm acoustic laminated / 16 mm cavity / 12.5 mm acoustic laminate	31	YES
		PAA	60	39	8.5 mm acoustic laminated / 16 mm cavity / 12.5 mm acoustic laminate	37	YES
M	GF	Office	59	27	6 mm float glass / 12 mm cavity / 6 mm float glass	33	YES
		Library - West	62	33	10 mm float glass / 12 mm cavity / 6 mm float glass	33	YES
		Library – North East	60	27	6 mm float glass / 12 mm cavity / 6 mm float glass	36	YES
	L1	Library – reading area	64	33	10 mm float glass / 12 mm cavity / 6 mm float glass	33	YES
		Library – stack area	62	27	6 mm float glass / 12 mm cavity / 6 mm float glass	35	YES

Building	Level	Area	External Noise Level $L_{Aeq, 1hr}$	Façade glazing		Predicted InternalNoise Level $L_{Aeq, 1hr}$ (traffic noise only)	Compliance?
				Recommended Sound Insulation Performance Rw + Ctr	Indicative Construction		
		KLA resource	65	33	10 mm float glass / 12 mm cavity / 6 mm float glass	32	YES

6 Construction

6.1 Construction noise criteria

The NSW *Interim Construction Noise Guideline* [2] (ICNG or Guideline) provides recommended noise levels for airborne construction noise at sensitive land uses. The guideline provides construction noise management levels above which all feasible and reasonable work practices should be applied to minimise the construction noise impact. The ICNG works on the principle of a 'screening' criterion – if predicted or measured construction noise exceeds the ICNG levels then the construction activity must implement all 'feasible and reasonable' work practices to reduce noise levels.

The ICNG provides two methods for assessing construction noise, varying typically on the basis of the project duration, being either a quantitative or a qualitative assessment. A quantitative assessment is recommended for major construction projects of significant duration, and involves the measurement of background noise levels for determination of noise management levels and prediction of construction noise levels. 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.

This development is expected to warrant a quantitative assessment.

The ICNG sets out management levels for noise at noise sensitive receivers, and how they are to be applied. These noise management levels (NMLs) for residential receivers and other sensitive receivers are reproduced in Table 16 and in Table 17 respectively.

The following construction hours are sought, being consistent with the City of Sydney Code of Practice 1992 *Construction Hours/Noise within the Central Business District*

- Monday to Friday (inclusive): 7:00am – 7:00pm
- Saturday: 7:00am – 5:00pm

Table 16: Construction noise management levels (NMLs) at residential receivers

Time of day	NML [1] $L_{Aeq\ (15\ min)}$	How to apply
Standard hours:[2] Monday to Friday 7am to 7pm Saturday 7am to 5pm 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 $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. The proponent should also inform all potentially impacted residents of the nature of works to be

Time of day	NML [1] $L_{Aeq\ (15\ min)}$	How to apply
		carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: • times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences • if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 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.*

1 – 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.

2 – Modified standard hours in line with City of Sydney Code of Practice 1992 *Construction Hours/Noise within the Central Business District*

Table 17: Construction noise management levels (NMLs) at other noise sensitive land uses

Land use	Where objective applies	Management level $L_{Aeq(15\ min)}$[1]
Classrooms at schools and other educational institutions	Internal noise level	45 dB(A)
Hospital wards and operating theatres	Internal noise level	45 dB(A)
Places of worship	Internal noise level	45 dB(A)
Active recreation areas	External noise level	65 dB(A)
Passive recreation areas	External noise level	60 dB(A)

Land use	Where objective applies	Management level $L_{Aeq(15 min)}$[1]
Community centres	Depends on the intended use of the centre.	Refer to the 'maximum' internal levels in AS2107 for specific uses.
Commercial premises	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)

1 - Noise management levels apply when receiver areas are in use only.

6.1.1 Project construction noise targets

Construction noise criteria are set based the residential receiver areas identified in Section 2. Measured noise data obtained at the logger location most representative of each noise catchment area has been used to derive appropriate noise management levels for the project. These are summarised in Table 18.

Table 18: Construction Noise Management Criteria for Residential Premises

Time Period	NML Description	NML Criteria $L_{Aeq (15 min)}$
During recommended standard hours	Noise affected	67
	Highly noise affected	75
Outside recommended standard hours	Noise affected	51

1 - 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.

6.2 Construction vibration criteria

6.2.1 Disturbance to buildings occupants

Concerns regarding impacts on human occupants to buildings would generally be assessed in accordance with the 'intermittent' vibration criteria outlined in the DEC Guideline [3], however reference would typically be made to the Maximum levels. However due to the intermittent and low intensity works proposed, focus for management purposes is on structural damage, as outlined below.

6.2.2 Structural damage

6.2.2.1 Definition

Potential structural or cosmetic damage to buildings as a result of vibration is typically assessed in accordance with British Standard 7385 Part 2 [7] and/or German Standard DIN4150-3 [8]. British Standard 7385 Part 1: 1990, defines different levels of structural damage as:

- *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.*

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

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

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

> *"that for structures as in lines 2 and 3 of Table 1, the serviceability is considered to have been reduced if*
>
> - *cracks form in plastered surfaces of walls;*
> - *existing cracks in the building are enlarged;*
> - *partitions become detached from loadbearing walls or floors.*
>
> *These effects are deemed 'minor damage." (DIN4150.3, 1990, p.3)*

While the DIN Standard defines the above damage as 'minor', the description aligns with BS7385 cosmetic damage, rather than referring to structural failures.

6.2.2.2 British Standard BS7835-2

BS7385-2 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4–250 Hz, and a maximum displacement value below 4 Hz is recommended. Table 19 sets out the BS7385 criteria for cosmetic, minor and major damage. Regarding heritage buildings, British Standard 7385

Part 2 [7, p. 5] notes that "*a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive*".

Table 19: BS 7385-2 structural damage criteria

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

1 - Peak Component Particle Velocity is the maximum Peak particle velocity in any one direction (x, y, z) as measured by a tri-axial vibration transducer.

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

All levels relate to transient vibrations in low-rise buildings. Continuous vibration can give rise to dynamic magnifications that may require levels to be reduced by up to 50%.

6.2.2.3 German Standard

German Standard DIN 4150 - Part 3 '*Structural vibration in buildings - Effects on Structure*' [8] are generally recognised to be conservative and is often referred to for the purpose of assessing structurally sensitive buildings. For the subject site, surrounding buildings are not deemed structurally sensitive and therefore the British Standard is considered appropriate for vibration management.

6.2.3 Buried services

It is not expected that the proposed works will impact upon buried services, however the following is nonetheless provided for guidance.

DIN 4150-2:1999 sets out guideline values for vibration effects on buried pipework and reproduced in Table 20 below.

Table 20: Guideline values for short-term vibration impacts on buried pipework

	Pipe material	Guideline values for vibration velocity measured on the pipe, mm/s
1	Steel (including welded pipes)	100
2	Clay, concrete, reinforced concrete, pre-stressed concrete, metal (with or without flange)	80
3	Masonry, plastic	50

Note: For gas and water supply pipes within 2m of buildings, the levels given in DIN4150-3 [8] should be applied. Consideration must also be given to pipe junctions with the building structure as potential significant changes in mechanical loads on the pipe must be considered.

In addition, specific limits for vibration affecting high-pressure gas pipelines is provided in the UK National Grid's *Specification for Safe Working in the Vicinity* *of National Grid High Pressure Gas Pipelines and Associated Installations – Requirements for Third Parties* (report T/SP/SSW/22, UK National Grid, Rev 10/06, October 2006). This specification states that no piling is allowed within 15 meters of a pipeline without an assessment of the vibration levels at the pipeline. The PPV at the pipeline is limited to a maximum level of 75 mm/s, and where PPV is predicted to exceed 50 mm/sec the ground vibration is required to be monitored.

Other services that maybe encountered include electrical cables and telecommunication services such as fibre optic cables. While these may sustain vibration velocity levels from between 50 mm/s and 100 mm/s, the connected services such as transformers and switchgear, may not. Where encountered, site specific vibration assessment in consultation with the utility provider should be carried out.

6.3 Construction noise and vibration management

Appropriate detail on the construction methodologies required for quantitative assessment of the project are not yet known. However, given the distance from the site to the nearest sensitive receiver locations, it is expected that activities would comply with the Highly Affected Noise Targets, however may result in exceedance of the Noise Affected Levels. Accordingly, application of all reasonable and feasible mitigation measures should be adopted for the project. The following discusses in-principle management measures.

6.3.1 Construction noise and vibration management plan

For all construction works, the contractor would be expected to prepare a detailed Construction Noise and Vibration Management Plan (CNVMP). This plan should include but not be limited to the following:

- Roles and responsibilities
- Noise sensitive receiver locations
- Areas of potential impact
- Mitigation strategy
- Monitoring methodology
- Community engagement strategy.

General guidance on the control of construction noise and vibration impacts relevant to this study are discussed in the following sections.

6.3.2 General

In general, practices to reduce construction noise impacts will be required, and may include;

- Adherence to the standard approved working hours as outlined in the Project Approval.

- Manage noise from construction work that might be undertaken outside the recommended standard hours
- The location of stationary plant (concrete pumps, air-compressors, generators, etc.) as far away as possible from sensitive receivers
- Using site sheds and other temporary structures or screens to limit noise exposure where possible.
- The appropriate choice of low-noise construction equipment and/or methods
- Modifications to construction equipment or the construction methodology or programme. This may entail programming activities to occur concurrently where a noisy activity will mask a less noisy activity, or, at different times where more than one noisy activity will significantly increase the noise. The programming should also consider the location of the activities due to occur concurrently.
- Carry out consultation with the community and surrounding building owners/occupants during construction including, but not limited to; advance notification of planned activities and expected disruption/effects, construction noise complaints handling procedures.

6.3.3 Universal work practices

The following noise mitigation work practices are recommended to be adopted at all times on site:

- Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways to minimise noise.
- Site managers to periodically check the site and nearby residences for noise problems so that solutions can be quickly applied.
- Avoid the use of radios or stereos outdoors.
- Avoid the overuse of public address systems.
- Avoid shouting, and minimise talking loudly and slamming vehicle doors.
- Turn off all plant and equipment when not in use.

6.3.4 Vibration – minimum working distances

Recommended minimum working distances for vibration intensive plant, which are based on international standards and guidance and reproduced in Table 21 below for reference. With regard to the proposed development works, vibration is not expected to impact upon surrounding development.

Table 21: Recommended minimum working distances for vibration intensive plant

Plant Item	Rating / Description	Minimum working distance	
		Cosmetic damage (BS 7385)	Human response (OH&E Vibration Guideline)
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m

Plant Item	Rating / Description	Minimum working distance	
		Cosmetic damage (BS 7385)	**Human response (OH&E Vibration Guideline)**
	< 100 kN (Typically 2-4 tonnes)	6 m	20 m
	< 200 kN (Typically 4-6 tonnes)	12 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	100 m
	> 300 kN (> 18 tonnes)	25 m	100 m
Small Hydraulic Hammer	(300 kg - 5 to 12t excavator)	2 m	7 m
Medium Hydraulic Hammer	(900 kg – 12 to 18t excavator)	7 m	23 m
Large Hydraulic Hammer	(1600 kg – 18 to 34t excavator)	22 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2 m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

Note: More stringent conditions may apply to heritage or other sensitive structures

7 Conclusion

Arup has completed an acoustic assessment for the Fort Street Public School Redevelopment to address the SEARs which relate to construction and operational noise and vibration emission to surrounding development and potential impact upon the development site.

Regarding the proposed operations, the assessment concludes that the proposed development is capable of satisfying the standard NSW EPA noise policy requirements. Notwithstanding, further detailed acoustic assessment is warranted during the design development, particularly with regard to building services noise control, and noise control from school events.

Regarding construction noise and vibration, the proposed development may result in some exceedances of the relevant noise management levels and, accordingly, mitigation and management procedures will need to be considered for the works. It is expected that a detailed Construction Noise and Vibration Management Plan would be prepared by the contractor prior to the commencement of works.

References

[1] NSW Environmental Protection Authority (EPA), “Noise Policy for Industry,” 2017.

[2] Department of Environment and Climate Change NSW, “Interim Construction Noise Guideline,” Department of Environment and Climate Change NSW, Sydney, 2009.

[3] Department of Environment and Conservation (NSW), “Assessing Vibration: A technical guideline,” Department of Environment and Conservation (NSW), Sydney, 2006.

[4] NSW Department of Planning, Development Near Rail Corridors and Busy Roads - Interim Guideline, July 2009.

[5] N. Government, State Environmental Planning Policy (Infrastructure) 2007, 2007.

[6] N. D. o. Education, Educational Facilities Standards and Guidelines.

[7] Bristish Standard Institution, “BS 7385-2: 1993 Evaluation and measurement for vibration in buildings - Pt 2: Guide to damage levels from groundborne vibration,” Bristish Standard Institution, London, 1993.

[8] Deutsches Institut fur Normung, “DIN 4150-3 (1999) Structural vibration - Effects of vibration on structures,” Deutsches Institut fur Normung, Berlin, 1999.

Appendix A

Glossary

Absorption Coefficient, α

The amount of sound absorbed by a sample is characterised by the absorption coefficient, α. A perfect absorber (e.g. a sufficiently large opening in a room) from which no sound is reflected has an absorption coefficient of 1.00. There are two common methods for measuring sound absorption coefficients of a material.

One, the impedance tube method, is useful for readily obtaining results and only requires a small sample to be tested, but is limited in that it can only measure the *normal-incidence absorption coefficient* – i.e. the absorption coefficient for a single angle with sound propagating perpendicular to the material.

The other method, the reverberation chamber method, requires more extensive tests and a larger (~10 m²) sample size, but obtains the *random-incidence absorption coefficient*- i.e. the effective absorption coefficient of the material averaged over all angles. The random-incidence absorption coefficient is required for detailed room acoustic calculations.
Note that the reverberation chamber method can legitimately measure coefficients greater than 1.0 due to "edge effects" such as diffraction or scattering from the edges of the sample. These edge effects are reduced by using a barrier around the sample or by using a larger sample.

Weighted absorption coefficient (α_w)

The weighted absorption coefficient, defined in ISO 11654 is a frequency-weighted single number absorption coefficient used to categorise the overall absorption effectiveness of a material.
Descriptors are used to indicate if the material absorbs strongly at high ("H"), mid ("M") and/or low ("L") frequencies – e.g. a material may be rated as α_w 0.85(LH), which indicates that it strongly absorbs at both low and high frequencies.
The weighted-absorption coefficient is also used to assign materials into five absorption classes (materials with very low absorption are not assigned a class): Class A has the highest absorption, with Class E having the lowest absorption.

Noise-reduction Coefficient (NRC)

The noise reduction coefficient (NRC) is the (arithmetical) average of the sound-absorption coefficients of a material at 250Hz, 500Hz, 1kHz and 2kHz. It is intended for use a single-number index of the sound absorbing efficiency of a material.

Ambient Noise Level

The ambient noise level is the overall noise level measured at a location from multiple noise sources. When assessing noise from a particular development, the ambient noise level is defined as the remaining noise level in the absence of the specific noise source being investigated. For example, if a fan located on a city building is being investigated, the ambient noise level is the noise level from all other sources without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans on other buildings.

Background Noise Level

The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects.

Assessment Background Level (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background L_{A90} noise levels – i.e. the measured background noise is above the ABL 90% of the time.

Rating Background Level (RBL / $minL_{A90,1hour}$)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey. This parameter is denoted RBL in NSW, and $minL_{A90,1hour}$ in QLD.

Clarity Index (C_{80})

The clarity index, expressed in dB, is used to objectively evaluate orchestral or vocal (musical, not speech) clarity. Measured in decibels, it is 10 times the logarithm of the ratio of the total sound energy received in the first 80 ms following (and including) the direct sound energy to the sound energy received after 80 ms – i.e. the ratio of “early” to “late” sound. The higher the value of C_{80}, the greater the expected subjective clarity.

Comb Filtering

Comb filtering is an acoustic defect that leads to acoustic colouration. Comb filtering occurs from coherent interference between a sound and its reflection from a large smooth surface, and is most prominent in small rooms. Comb filtering imparts a “ragged” harshness to the sound.

Comb filtering may be treated by adding absorption (which reduces the amplitude of the reflected sound and reduces the strength of the interference) or by adding diffusion (which breaks up the reflection so that the sound waves do not interfere coherently).

Colouration

Colouration refers to an acoustic defect within a room where particular frequencies are either enhanced or reduced so that the frequency balance of the room is distorted, adding an acoustic “tinge” to the sound quality (analogous to particular colours in a visual image being either enhanced or reduced and skewing the colour balance of the image). Colouration most commonly occurs from strong individual sound reflections that are not distinct enough to be perceived as a separate sound (an echo) but are nevertheless strong enough to be heard by the ear.

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear and involves hearing over a large range of sound pressure levels, which would be unwieldy if presented on a linear scale. Therefore a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

An increase of approximately 10 dB corresponds to a subjective doubling of the loudness of a noise. The minimum increase or decrease in noise level that can be noticed is typically 2 to 3 dB.

dB(A)

dB(A) denotes a single-number sound pressure level that includes a frequency weighting (“A-weighting”) to reflect the subjective loudness of the sound level.

The frequency of a sound affects its perceived loudness. Human hearing is less sensitive at low and very high frequencies, and so the A-weighting is used to account for this effect. An A-weighted decibel level is written as dB(A).

Some typical dB(A) levels are shown below.

Sound Pressure Level dB(A)	**Example**
130	Human threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud stereo in living room
60	Office or restaurant with people present

Sound Pressure Level dB(A)	Example
50	Domestic fan heater at 1m
40	Living room (without TV, stereo, etc)
30	Background noise in a theatre
20	Remote rural area on still night
10	Acoustic laboratory test chamber
0	Threshold of hearing

L_1

The L_1 statistical level is often used to represent the maximum level of a sound level that varies with time.

Mathematically, the L_1 level is the sound level exceeded for 1% of the measurement duration. As an example, 87 dB $L_{A1,15min}$ is a sound level of 87 dB(A) or higher for 1% of the 15 minute measurement period.

L_{10}

The L_{10} statistical level is often used as the "average maximum" level of a sound level that varies with time.

Mathematically, the L_{10} level is the sound level exceeded for 10% of the measurement duration. L_{10} is often used for road traffic noise assessment. As an example, 63 dB $L_{A10,18hr}$ is a sound level of 63 dB(A) or higher for 10% of the 18 hour measurement period.

L_{90}

The L_{90} statistical level is often used as the "average minimum" or "background" level of a sound level that varies with time.

Mathematically, L_{90} is the sound level exceeded for 90% of the measurement duration. As an example, 45 dB $L_{A90,15min}$ is a sound level of 45 dB(A) or higher for 90% of the 15 minute measurement period.

L_{eq}

The 'equivalent continuous sound level', L_{eq}, is used to describe the level of a time-varying sound or vibration measurement.

L_{eq} is often used as the "average" level for a measurement where the level is fluctuating over time. Mathematically, it is the energy-average level over a period of time (i.e. the constant sound level that contains the same sound energy as the measured level). When the dB(A) weighting is applied, the level is denoted dB $L_{Aeq.}$ Often the measurement duration is quoted, thus $L_{Aeq,15\ min}$ represents the dB(A) weighted energy-average level of a 15 minute measurement.

L_{max}

The L_{max} statistical level can be used to describe the "absolute maximum" level of a sound or vibration level that varies with time.

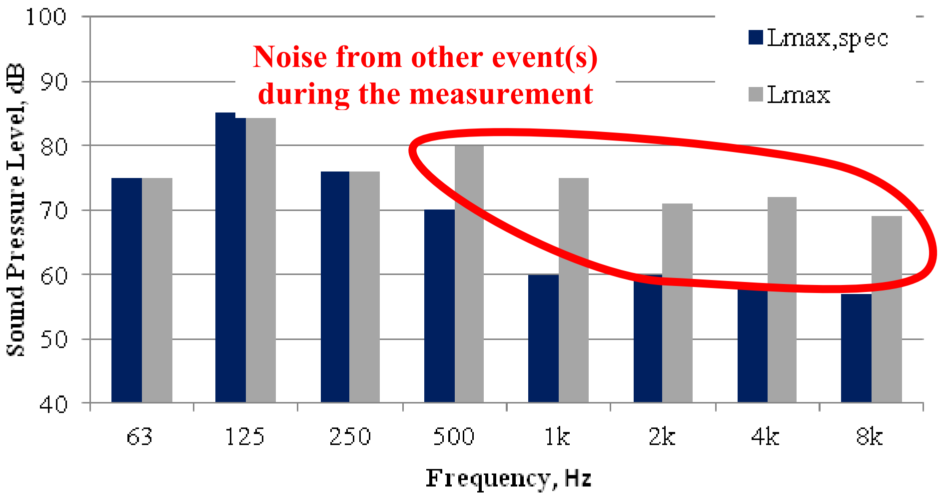
Mathematically, L_{max} is the highest value recorded during the measurement period. As an example, 94 dB L_{Amax} is a highest value of 94 dB(A) during the measurement period.

Since L_{max} is often caused by an instantaneous event, L_{max} levels often vary significantly between measurements.

$L_{max\ spec}$

$L_{max\ spec}$ is another representation of the highest noise or vibration levels during the measurement period.

$L_{max\ spec}$ is the spectrum of the event that caused the highest overall sound or vibration level during the measurement period is denoted by dB $L_{max\ spec}$. An example of the relationship between dB L_{max} and dB $L_{max\ spec}$ is shown below.



L_{max} (see definition above), when measured on an octave band or 1/3 octave band meter, is the spectrum obtained by recording the highest measured value in each band. However, the highest measured values in each band may occur at different times.

Hence, $L_{max\ spec}$ represents a real event, while L_{max} is often the mathematical addition of frequency band values from different times and often does not represent a real-world event.

Since $L_{max\ spec}$ is caused by an instantaneous event, $L_{max\ spec}$ levels often vary significantly between measurements.

Frequency

Frequency is the number of cycles per second of a sound or vibration wave. In musical terms, frequency is described as "pitch". Sounds towards the lower end of the human hearing frequency range are perceived as "bass" or "low-pitched" and sounds with a higher frequency are perceived as "treble" or "high pitched".

Impact Sound Pressure Level

The technical parameter used to determine impact sound isolation of floors is the impact sound pressure level, L_i.

In the laboratory, the weighted normalised impact sound pressure level, $L_{n,w}$, is used to represent the impact sound isolation as a single figure.

On site, the weighted normalised apparent impact sound pressure level, $L'_{n,w,}$ and the weighted standardised apparent impact sound pressure level, $L'_{n,Tw}$, are used to represent the impact sound isolation of a floor as a single figure.

These single weighted values are determined by comparing the spectral impact sound pressure levels (as defined in ISO 140-6 & ISO 140-7) with reference values outlined in AS/NZS ISO 717.2.

Peak Particle Velocity (PPV)

Peak Particle Velocity (PPV) is the highest velocity of a particle (such as part of a building structure) as it vibrates. Most sound level meters measure *root mean squared* (RMS) values; it is common to approximate the PPV based on an RMS measurement.

PPV is commonly used as a vibration criteria, and is often interpreted as a PPV based on the L_{max} or $L_{max,spec}$ index.

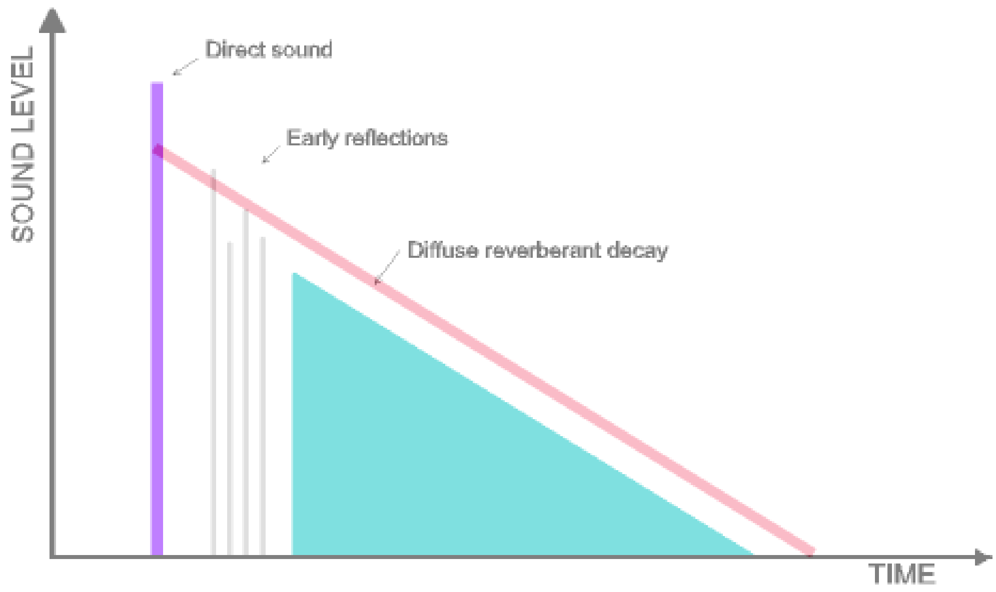
Reverberation Time (T_{60})

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

Examples of typical design reverberation times are provided below:

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

Mid-frequency Reverberation Time, s	Example
1.0 – 1.2	Music studios
1.2 – 1.5	Chamber music venues
1.5 – 2.0	Orchestral music venues
2.0 – 3.0	Church
3.0 – 8.0	Cathedral



Sound Exposure Level (SEL)

The Sound Exposure Level or Single Event Noise Exposure Level, denoted SEL or L_{AE}, is a measure of the total amount of acoustic energy contained in an acoustic event. The SEL is the constant sound pressure level that would produce in a period of one second the same amount of acoustic energy contained in the acoustic event. SEL is commonly used to quantify the total acoustic energy contained in transient events such as a vehicle pass-by.

Sound Level Difference (D)

Sound level difference is used to quantify the sound insulation between two spaces, and is equal to the difference in sound level between the two rooms at a particular frequency (e.g. if the sound level in the source room is 100 dB and the sound level in the adjacent room is 75 dB, the sound level difference is 25 dB). The weighted sound level difference, D_w, (as defined in AS/NZS ISO 717.1) is commonly used to provide a single-number descriptor to describe the overall performance of a partition across a wider frequency range.

The terms used to describe the airborne sound insulation rating of a building element when tested on-site are the weighted normalised level difference ($D_{n,w}$), which corrects the measured sound level difference to a reference absorption area in the receiving room, or the weighted standardized level difference ($D_{nT,w}$), which corrects the measurements to a reference reverberation time in the receiving room. These single numbers are determined by comparing the spectral sound insulation test results (as defined in ISO 140-4) with reference values, as outlined in AS/NZS ISO 717.1.

Sound Power and Sound Pressure

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

Sound Reduction Index (R)

The sound reduction index (or transmission loss) of a building element is a measure of the loss of sound through the material, i.e. its sound attenuation properties. It is a property of the component, unlike the sound level difference, which is affected by the common area between the rooms and the acoustics of the receiving room. R is the ratio (expressed in decibels) of the sound energy transmitted through the building element to the sound energy incident on the building element for a particular frequency.

The weighted sound reduction index, R_w, is a single figure description of sound reduction index across a wider frequency range and is defined in BS EN ISO 717-1: 1997. R_w values are calculated from measurements in an acoustic laboratory. Sound insulation ratings derived from site measurements (which are invariably lower than the laboratory figures) are referred to as apparent sound reduction index (R'_w) ratings.

Strength (also called Loudness) (G)

This parameter is used to compare the loudness of halls. It is the ratio of the measured sound pressure level at a location to the free-field (open air) sound pressure level from the same source, measured at 10m from the source – i.e. how much the hall “amplifies” or “reduces” the loudness of a source. An omni-directional source is used and the parameter unit is dB.

Speech Transmission Index (STI)

STI is a technical index, predictable and measurable using specialised equipment, for assessing speech and vocal intelligibility. STI takes into account the signal/noise ratio of the speech signal and the reverberation of the receiving environment. The higher the value of STI, the higher the expected speech intelligibility.

STI ratings are assigned subjective categories, as follows:

STI Range	Subjective Category
< 0.3	Bad
0.3 – 0.45	Poor
0.45 – 0.6	Fair
0.6 – 0.75	Good
0.8 – 1.0	Excellent

Spectrum Adaptation Terms (C and C_{tr})

The terms C and C_{tr} are spectrum adaptation terms (in dB) that are added to the R_w or D_w value of a partition in order to determine the overall sound insulation rating of a partition for various conditions. The overall performance of the partition is quoted as the sum of the Rw value and the spectrum adaptation terms, e.g. D_w + C 55 dB; R_w + C_{tr} 60 dB.

C is a spectrum adaptation term used to measure the performance of a partition for medium to high-frequency noise sources, such as speech.

C_{tr} is a spectrum adaptation term used to measure the performance of a partition for low-frequency noise sources such as traffic noise.

The values of C and C_{tr} are dependent on the construction of the partition. Because C and C_{tr} are (usually) negative quantities, they typically increase the Rw requirement of a partition (eg if C_{tr} is -6 dB, an R_w of 56 dB is required to achieve a rating of R_w + C_{tr} 50 dB).

Structureborne Noise

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

Room Criteria (RC) Mark II Curves

Room criteria Mark II (RC-II) curves were developed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), as an improved method of assessing mechanical services noise. RC curves are shaped so as to achieve a bland, neutral sound spectrum, and extend to lower frequencies than NC or NR curves. The RC curves allow the spectral balance of the noise spectrum to be assessed as Neutral (N), Rumble (LF), Roar (MF) or Hiss (HF).

The RC value of a noise spectrum is obtained by averaging the octave band spectra values in the 500 Hz, 1 kHz and 2 kHz octave bands. This number gives the RC-II curve rating of the spectrum.

Vibration

Waves in a solid material are called “vibration”, as opposed to similar waves in air, which are called “sound” or “noise”. If vibration levels are high enough, they can be felt; usually vibration levels must be much higher to cause structural damage.

A vibrating structure (eg a wall) can cause airborne noise to be radiated, even if the vibration itself is too low to be felt. Structureborne vibration limits are sometimes set to control the noise level in a space.

Vibration levels can be described using measurements of displacement, velocity and acceleration. Velocity and acceleration are commonly used for structureborne noise and human comfort. Vibration is described using either metric units (such as mm, mm/s and mm/s^2) or else using a decibel scale.

Appendix B

Unattended Monitoring Results

B1 Noise monitoring equipment

Long-term and short-term noise monitoring was carried out using the following equipment:

Table 22: Noise monitoring equipment.

Equipment/model	Description of Equipment	Serial No.
Brüel and Kjær 2250	Type 1 sound level meter	2449851
Brüel and Kjær 2270	Type 1 sound level meter	2754328
ARL Ngara	Environmental noise logger	8780FB 8780F0

Note

All meters comply with AS IEC 61672.1 2013 "Electroacoustics - Sound Level Meters" and designated either Class 1 as per table, and are suitable for field use.

The equipment was calibrated prior and subsequent to the measurement period using a Bruel & Kjaer Type 4231 calibrator. No significant drift in calibration was observed.

B2 Extraneous/weather affected data

Measurement samples affected by extraneous noise, wind (greater than 5m/s) or rain were excluded from the recorded data in accordance with the procedures outlined in Fact Sheet A of the NSW Noise Policy for Industry (NPI).

Data provided by the Bureau of Meteorology (BOM), for the nearest representative weather station to noise monitoring location(s). Wind speed data was adjusted to account for the difference in measurement height and surrounding environment between the BOM weather station (measured 10 m above ground) and the microphone location based on Table C.1 of ISO 4354:2009 '*Wind actions on structures*'.

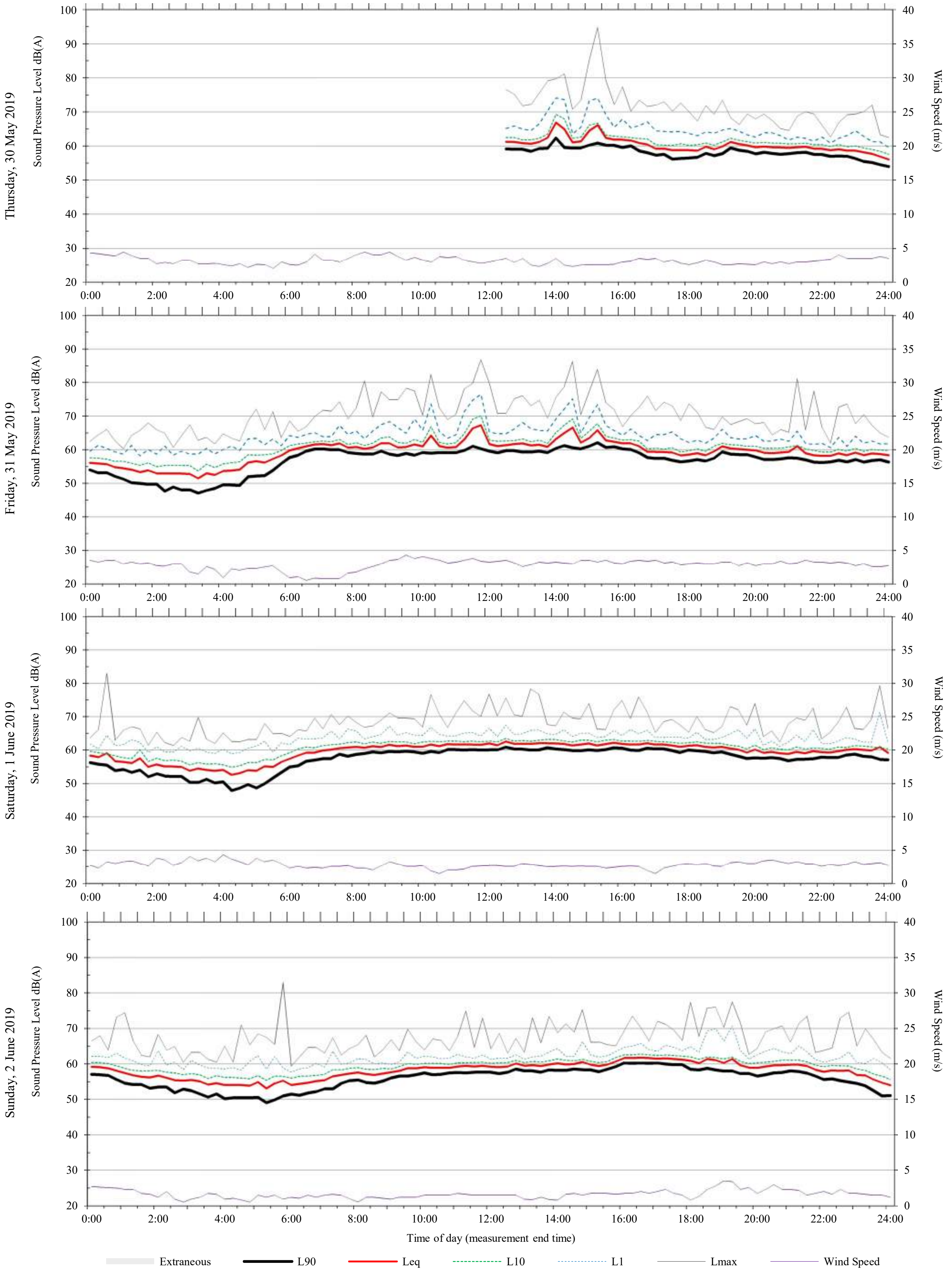
B3 Logger graphs

The following noise level vs time graphs present overall dB(A) levels recorded by the unattended logger(s) for a range of noise descriptors, including L_{Aeq}, L_{A90}, L_{A10} and L_{Amax}, While line graphs are presented, sampling is at 15 minute intervals.

Wind speeds are also show where relevant, and periods of excluded data are shaded grey.

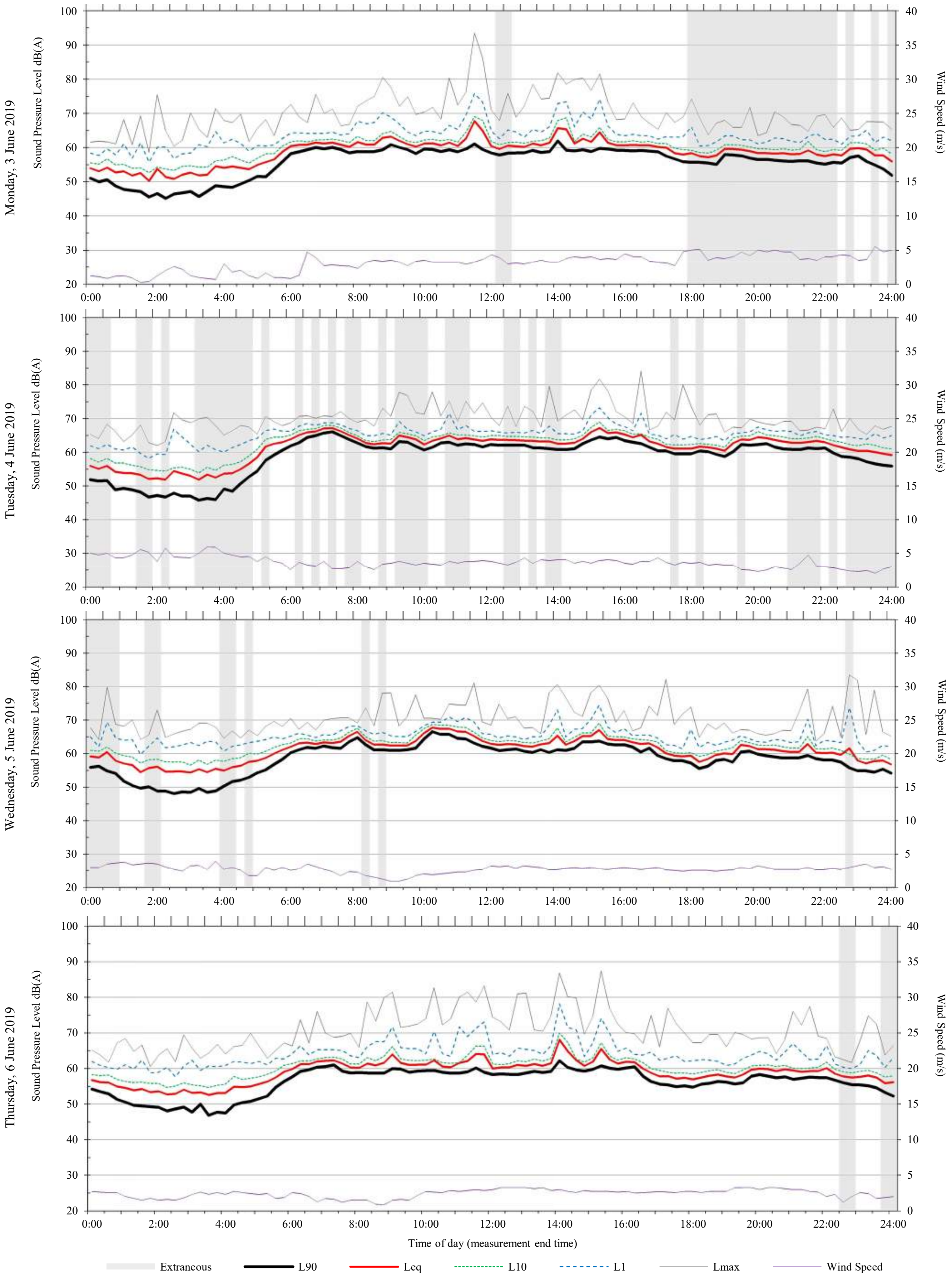
Unattended monitoring: (Free Field)

ARUP



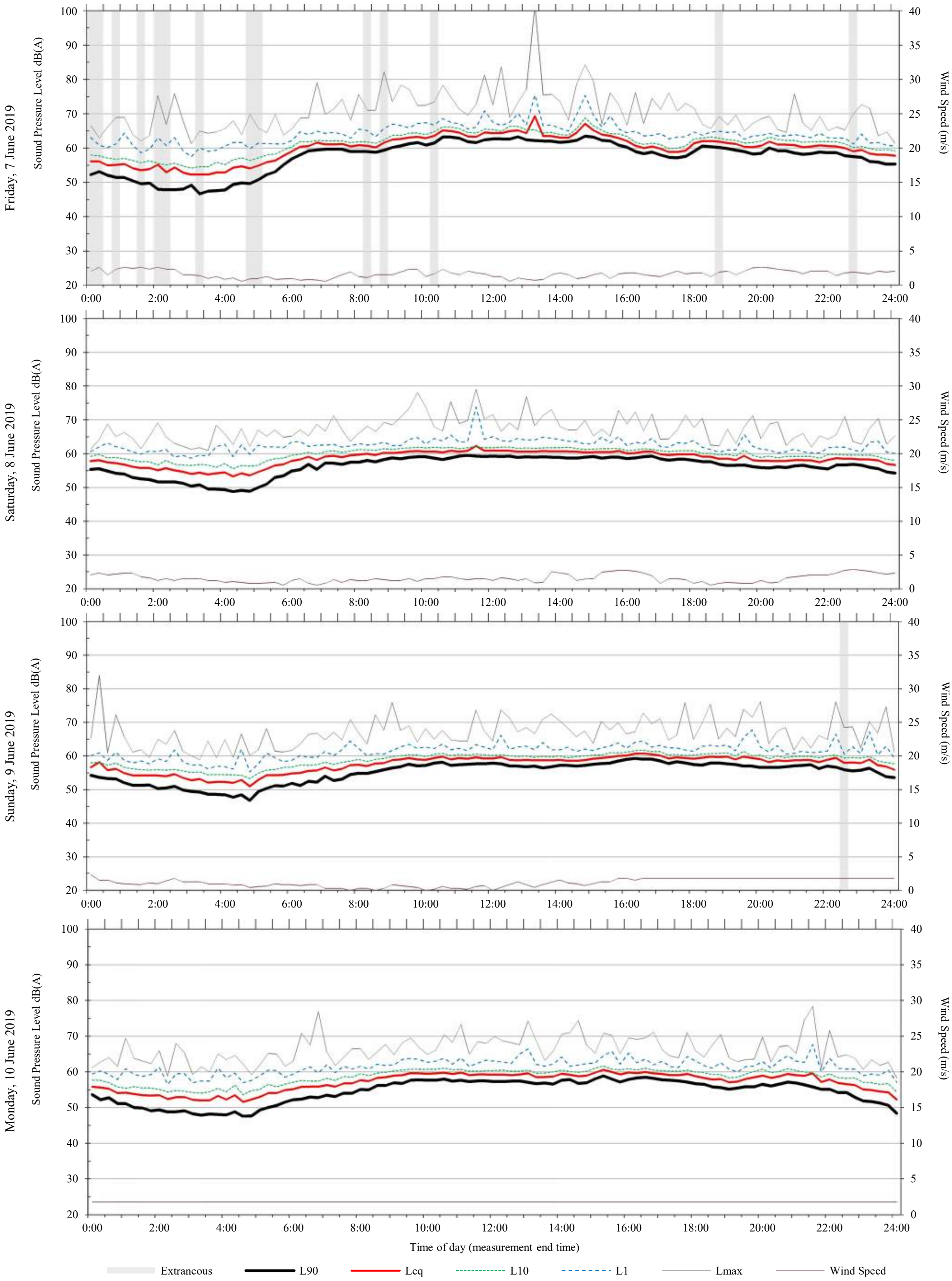
Unattended monitoring: (Free Field)

ARUP

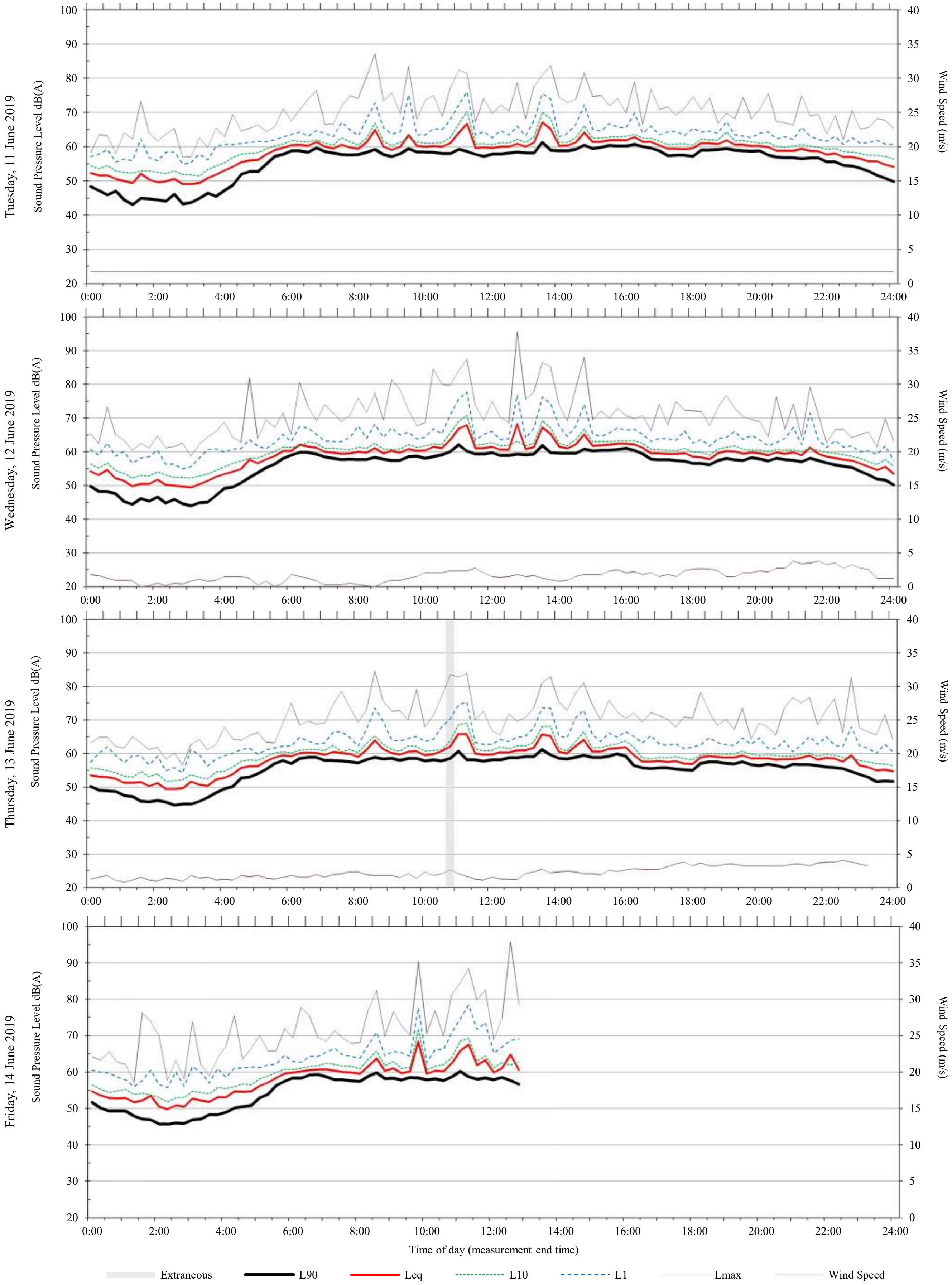


Unattended monitoring: (Free Field)

ARUP

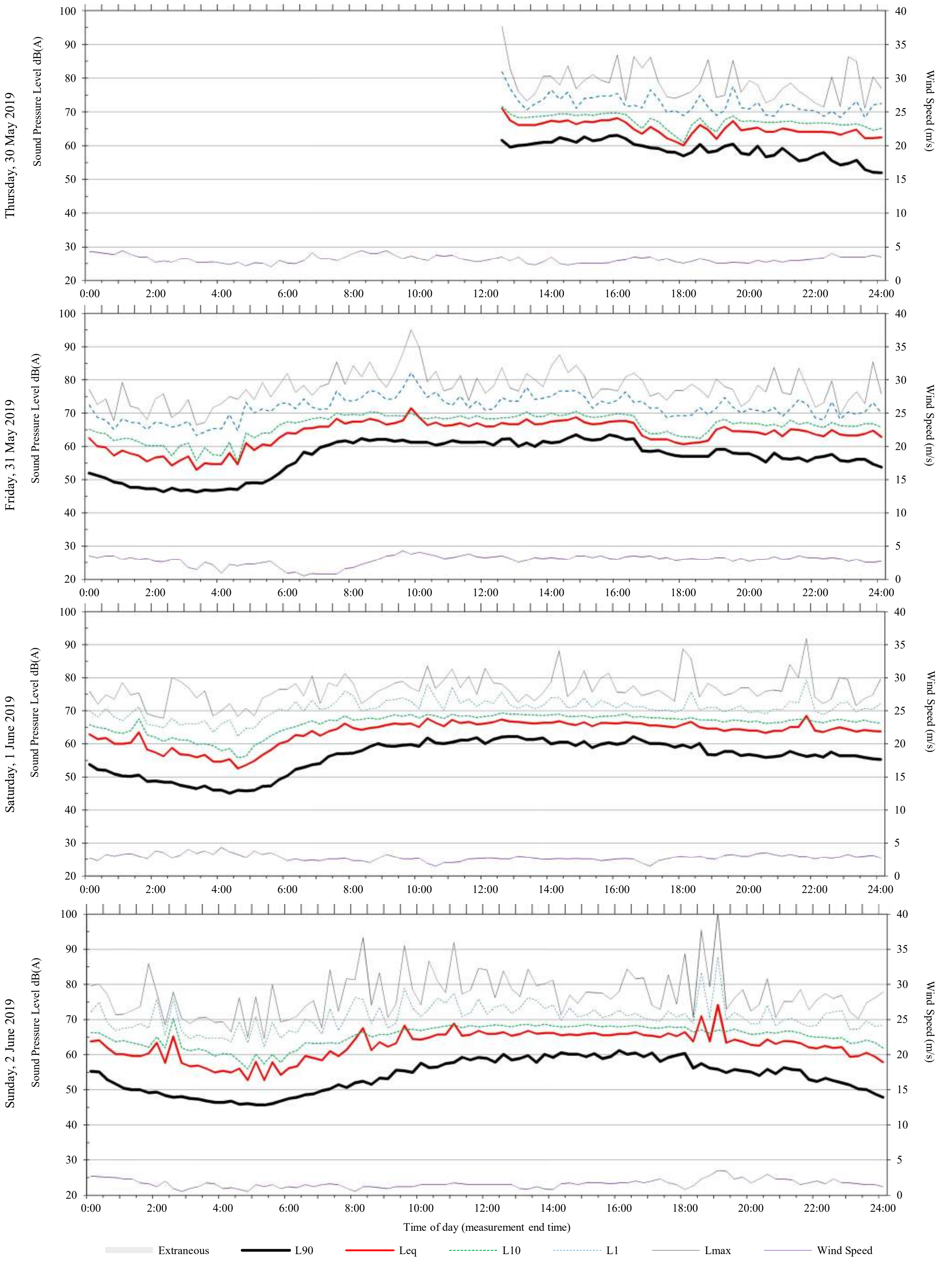


Unattended monitoring: (Free Field) ARUP



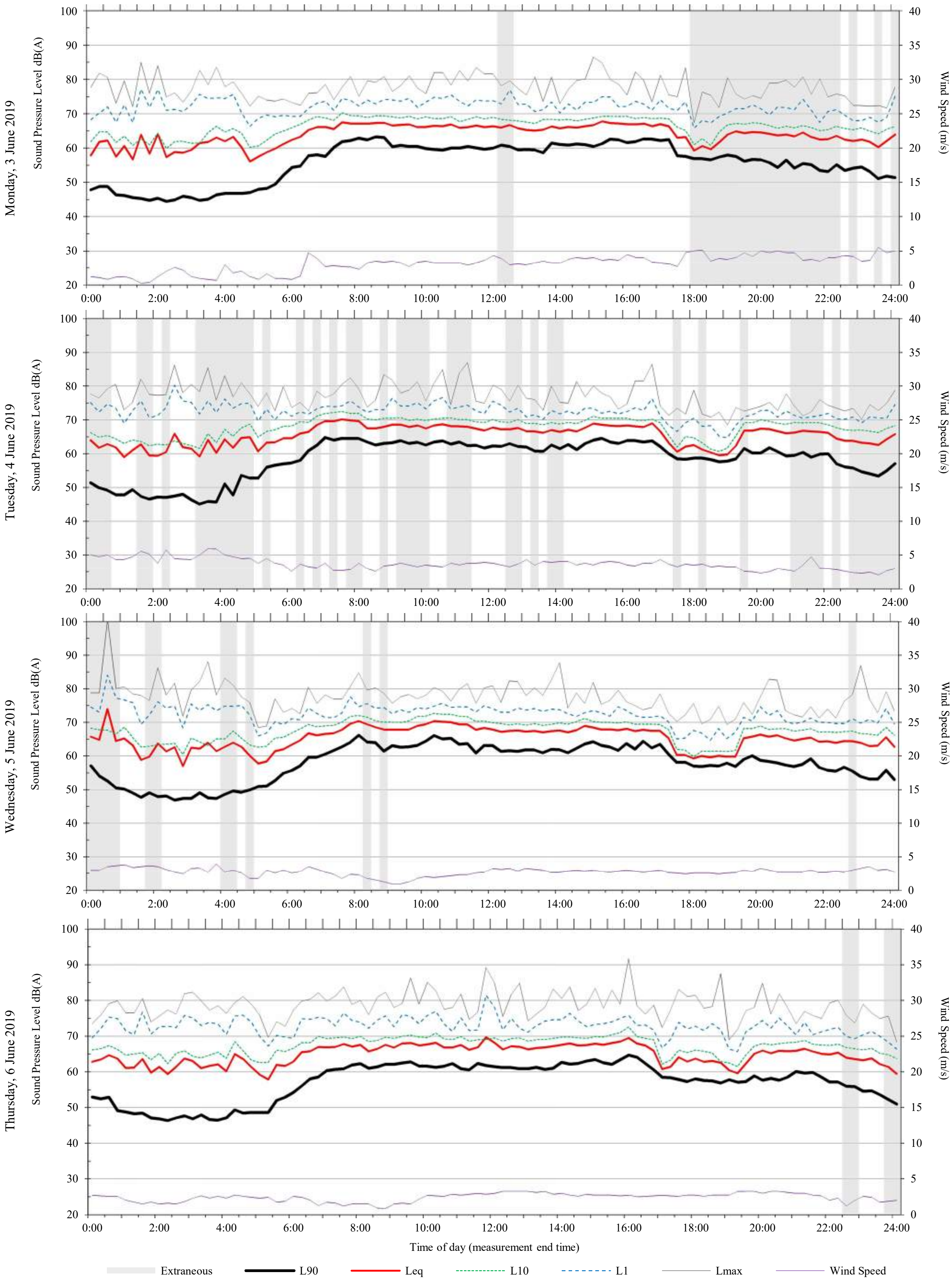
Unattended monitoring: (Free Field)

ARUP



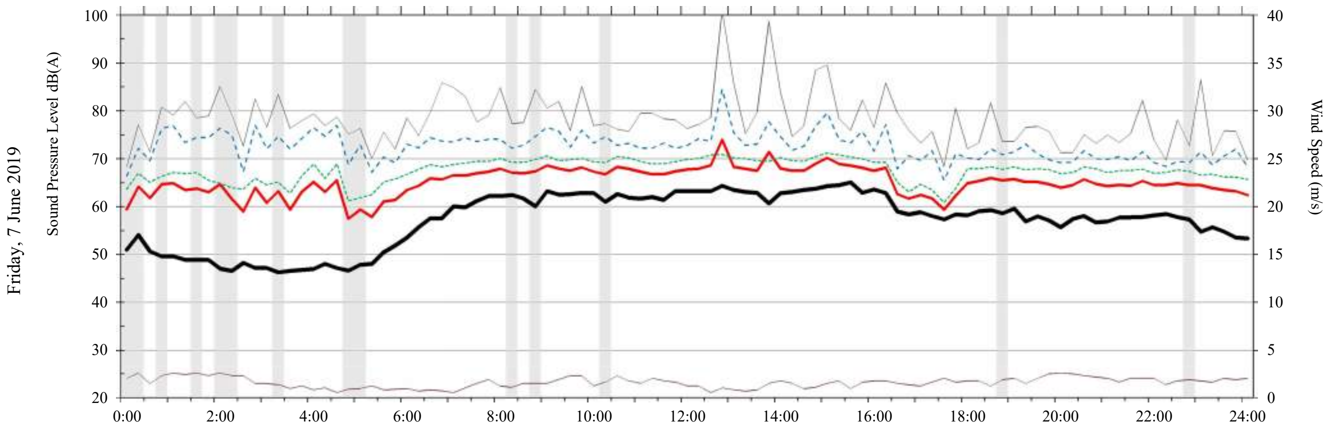
Unattended monitoring: (Free Field)

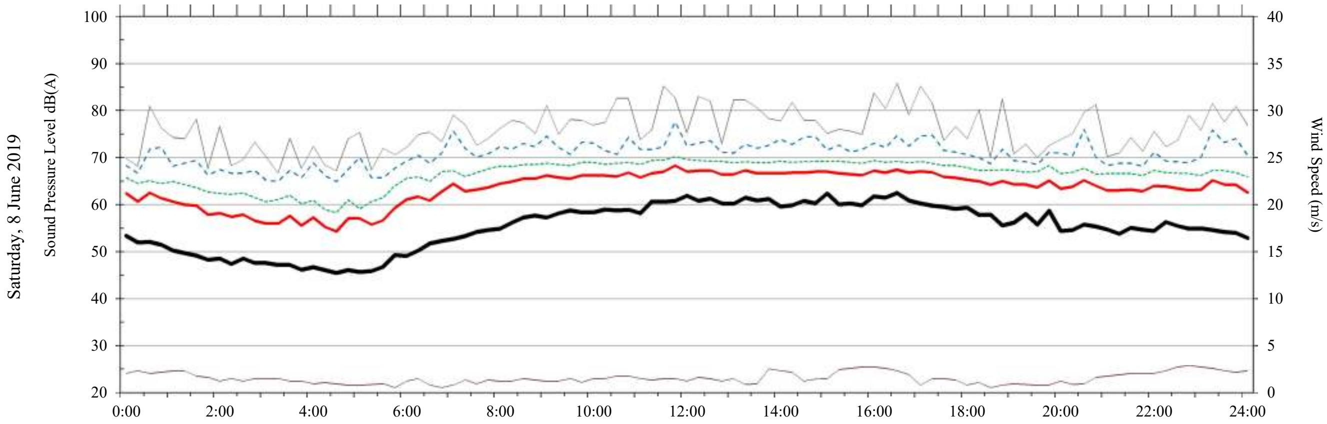
ARUP

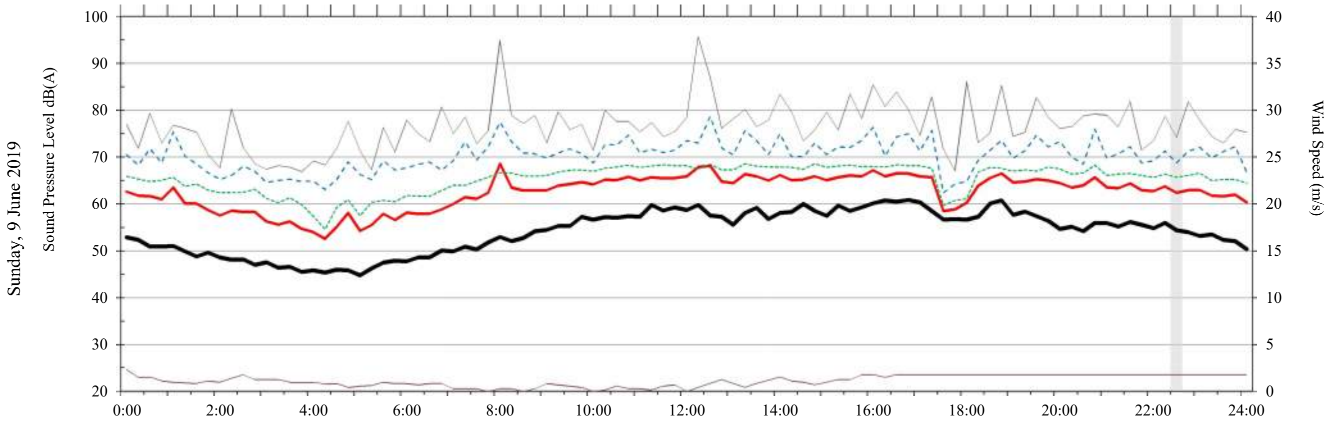


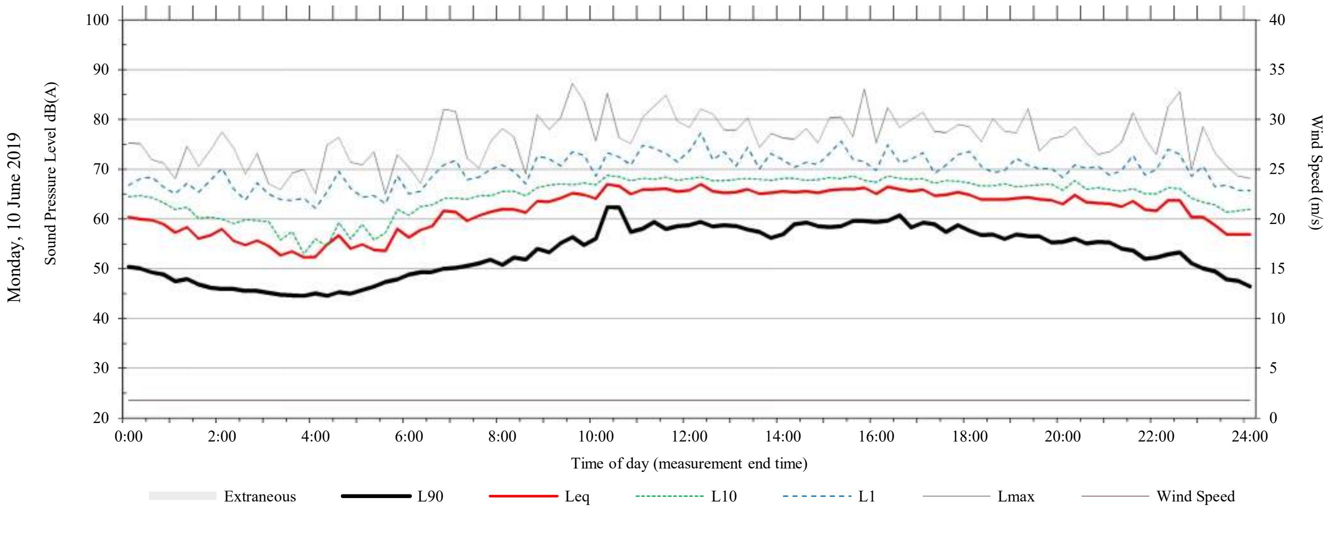
Unattended monitoring: (Free Field)

ARUP









Unattended monitoring: (Free Field)

ARUP