AGNSW

Art Gallery of NSW Expansion - Sydney Modern Project

Environmental Impact Statement – Acoustics Report

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Job number 246695-00

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Executive Summary

This report has been produced in response to the Secretary's Environmental Assessment Requirements as amended 8 June 2016 in support of the State Significant Development Application Number SSD 6471 on behalf of The Art Gallery of NSW (AGNSW).

This report addresses Key Issues required for a SSD and specifically responds to the SEARs Key Issue numbers 3 and 11 as these relate to noise and vibration. These Key Issues state:

(3) Address and outline design principles incorporated into the development in terms of sunlight/overshadowing, natural ventilation, wind impacts, visual and acoustic privacy, and safety and security;

(11) Address potential air quality, noise and odour impacts, in particular during the construction and operation of the development and appropriate mitigation measures.

Undertake a quantitate assessment of potential construction and operational noise and vibration impacts of the proposals, including potential impacts on nearby sensitive receivers

Detail noise and vibration management and monitoring measures to mitigate impacts on sensitive receivers.

This report sets out the criteria that relate to noise and vibration from the development affecting the environment both during construction and in operation. Also included are recommendations for noise intrusion limits to enable the internal environment to comply with the requirements for various noise policies.

The table below summaries the key revision of this report.

Table 1: Key revisions of this report

Key revision	Summary of updates
E	SSDA lodgement
I	Updates to response to submissions received and concerns raised during the public exhibition of SSD 6471. These concerns included the plant noise emission, noise from the usage of the loading dock and noise emission from the outdoor café.
J	Acoustic assessment update for the replacement of the seawater heat exchange with cooling towers.

Conclusion

This report has addressed the SEARs Issues 3 and 11, EPA response (Doc17/561514-02), and issues raised during the public exhibition of SSD 6471 and demonstrates that the issues in SEARs that relate to noise and vibration can be appropriately resolved. In particular:

- Criteria based on site measurements have been developed for noise from plant affecting the environment. These criteria comply with the *NSW Industrial Noise Policy (EPA 2000)*.
- Noise from the proposed cooling towers has been assessed in Section 5.2. Acoustic mitigation measures have been proposed to meet the noise emission criteria. With acoustic mitigation measures, no acoustic impact to the residences or Botanic Garden/Domain is anticipated.
- The impact of road and rail noise and vibration on the development has been assessed in relation to *NSW Road Noise Policy (DECCW 2011), Development Near Rail Corridors and Busy Roads (DoPI), SEPP (Infrastructure) 2007 (relating to the frontage to a classified road)*. The proposed internal noise level criteria are consistent with these criteria and the provisions to control noise intrusion through the envelope of the building will enable these requirements to be met.
- The noise impact from the loading dock usage has been assessed in the section 5.3. Noise generated from the vehicles during the night and early morning (including the shoulder period) is unlikely to exceed the sleep disturbance noise criterion.
- The noise impact of the outdoor café has been assessed in the section 5.4.1. Calculations show that the activities at the outdoor café are unlikely to exceed the noise limits at the residence. No amplified music, or activities listed in the in Section 90(2) of the Protection of Environment Operations (General) Regulation 2009, are proposed. The outdoor areas would not be used after 2200h.
- Vibration measurements have shown that the levels of ground vibration is such that appropriate criteria (based on *Assessing Vibration: A Technical Guideline 2006* and other requirements relating to the protection of precious artefacts) can be achieved.
- Noise during construction will be assessed based on the requirements set out in the *Interim Construction Noise Guideline 2009 (EPA)*. The control of noise and vibration during construction will be a strict requirement for the future contractor. The requirements to achieve acceptable construction noise and vibration levels in the gallery are likely to be more onerous than those to achieve acceptable conditions at the nearest noise sensitive receiver.

1 Introduction

The Art Gallery of NSW proposes to undertake a major expansion of the existing art gallery in the eastern part of the Royal Botanic Gardens and Domain. The expansion is located north of the existing gallery, partly extending over the Eastern Distributor land bridge and includes a disused Navy fuel bunker located to the north east of this land bridge.

The new expansion, known as the Sydney Modern Building, comprises a new entry plaza, new exhibition spaces, shop, food and beverage facilities, visitor amenities, art research and education spaces, new roof terraces and landscaping and associated site works and infrastructure, including loading and service areas, services infrastructure and cooling tower plant.

Development consent is sought for:

- Site preparation works, including:
  - Site clearing, including: demolition of former substation, part of road surfaces, kerbs and traffic islands, pedestrian crossings, foot paths, retaining walls, stairs, and part of disused underground former Navy fuel bunkers;
  - Tree removal;
- Excavation and site earthworks;
- Remediation works;
- Construction of the Sydney Modern Building comprising:
  - Covered public plaza;
  - Entry pavilion and five building levels following the site topography down to Lincoln Crescent;
  - Retention of part of existing disused underground former Navy fuel bunker for use as gallery space and support spaces;
  - Art gallery spaces;
  - Outdoor terraces;
  - Shop, café and restaurant;
  - Multipurpose space;
  - Education spaces;
  - Ground level loading dock (accessed via Lincoln Crescent) with associated workshops, service parking, plant, and storage areas.
- New open staff and administration visitor carpark to rear of art gallery building;
- Landscaping and public domain improvements including:

  - Continuation of the east-west pedestrian link between the Domain and Woolloomooloo Bay, including dedicated lift structure for disability access;
  - Hard and soft landscaping to roof terraces;
  - Planter beds and new pathways;
  - Increased landscaped area to forecourt of existing Art Gallery building;
  - Relocation of selected trees to the south-eastern corner of the site.
- Upgrade works to part of Art Gallery Road, Cowper Wharf Road, Mrs Macquaries Road, and Lincoln Crescent, including new pedestrian crossings;
- Provision of vehicle drop off points including a taxi stand, private vehicle drop-off and bus/coach drop off, at Art Gallery Road;
- Diversion, extension and augmentation of physical infrastructure and utilities as required.

2 SEARs Issues Addressed

This report addresses the following Key Issues for SEARs (as amended 8 June 2016) issued for the project identified within Application Number SSD 6471.

(3) Address and outline design principles incorporated into the development in terms of sunlight/overshadowing, natural ventilation, wind impacts, visual and acoustic privacy, and safety and security;

The design principles incorporated into the development must also ensure that The Royal Botanic Garden and Domain's (RBGD) high level of environmental amenity is preserved.

(*11) Address potential air quality, noise and odour impacts, in particular during the construction and operation of the development and appropriate mitigation measures.*

Relevant Policies and Guidelines

- *NSW Industrial Noise Policy (EPA)*
- *Interim Construction Noise Guideline 2009 (EPA)*
- *Assessing Vibration: A Technical Guideline 2006*
- *NSW Road Noise Policy (DECCW 2011)*
- *Development Near Rail Corridors and Busy Roads (DoPI)*
- *Protection of Environment Operations (General) Regulation 2009*

In addition to the above, noise has been assessed in relation to

- *SEPP (Infrastructure) 2007 (relating to the frontage to a classified road)*

Note that this report only considers noise and vibration impacts. Issues associated with air quality and odour are dealt with in separate documents.

2.1 Response to Concerns Raised During the Notification Period

This report clarifies and provides additional information the following key issues raised during the exhibition period.

- Potential noise impact from the general building services noise
- Potential noise impact from heat rejection equipment (updated in this report from seawater heat exchange to cooling towers)
- Potential noise impact from the outdoor café
- Potential noise impact from occasional usage of loading dock during night and morning period.

3 Existing Environment

The NSW Industrial Noise Policy (INP)[1] sets out a methodology to derive appropriate criteria for noise from plant affecting the environment. This is based on the levels of existing noise around the site which in turn are derived from an extensive survey of existing noise levels, details of which are given below. The derivation of the noise criteria from this data is given in Section 4.1 below.

3.1 Description of Site

The Sydney Modern Project is located on the north eastern side of the existing Art Gallery of New South Wales.

The site is situated within the Domain and connected to the Botanic Garden to its north.

There are two major roads and a railway line close to the site. The Eastern Distributor Motorway and Cahill Expressway are going through the site (under land bridge) from south to the north west of the site. The railway is located on the south west of the existing Art Gallery of New South Wales.

There are residential buildings adjacent to the site on Lincoln Crescent. The figure below shows the proximity of the residential building to the proposed development.

[1] NSW Industrial Noise Policy. Environment Protection Authority. January 2000

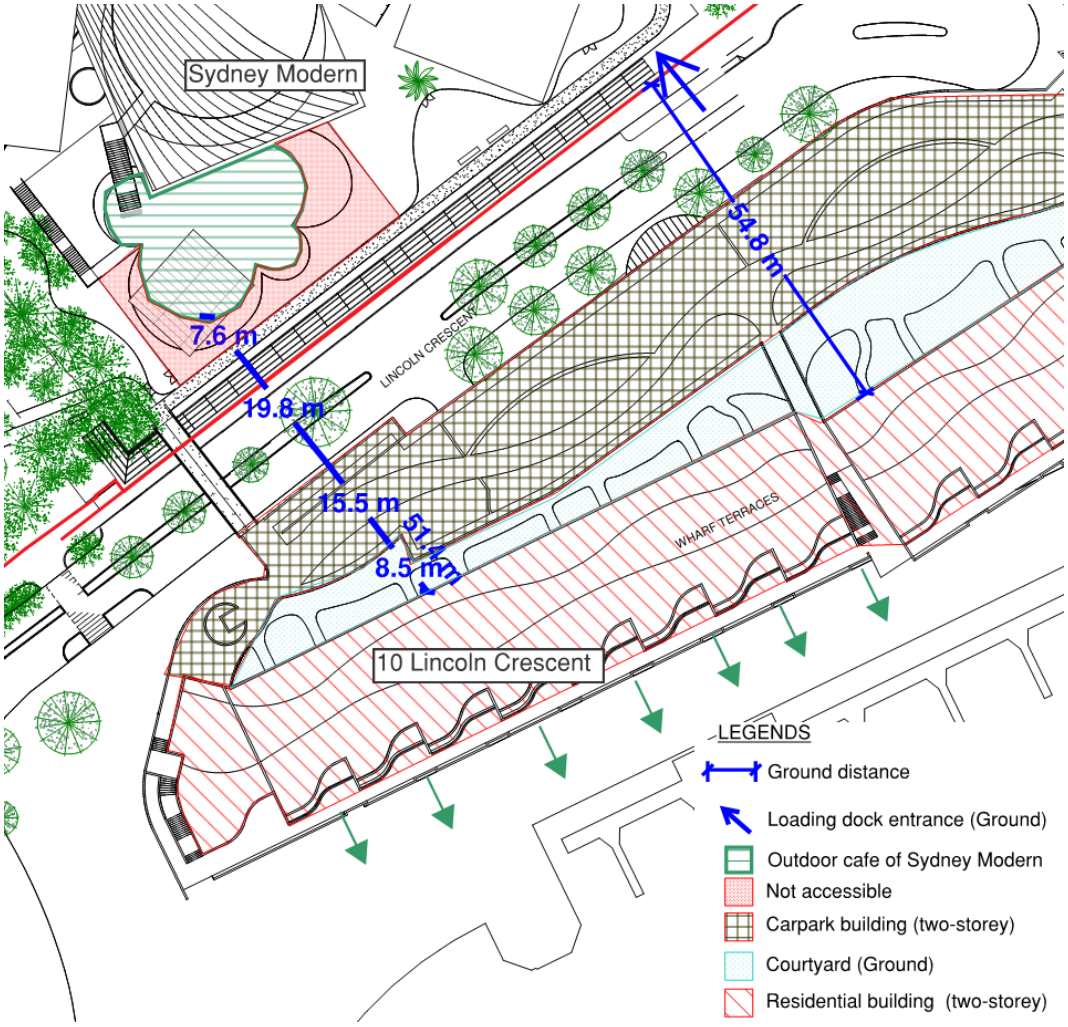


Figure 1: Proximity to the closest residence

Noise sensitive receivers close to site are summarised in the Table 2 below.

Table 2: Summary of Noise Sensitive Receivers

Noise Sensitive Receiver	**Classification**
10 Lincoln Crescent	Residential
9-31 Lincoln Crescent	Residential
Botanic Garden	Passive recreation
Domain	Active recreation

3.2 Measurement of existing noise levels

3.2.1 Methodology

Unattended Long-Term Noise Measurements

Unattended noise monitoring equipment was used to gain an understanding of typical noise levels at the subject site. Noise monitoring devices were installed on 10 March to 24 March 2016 at two locations (see Noise Logger Locations 1 and 2 on Figure 2).

Additional noise monitoring was conducted from 30 January 2018 to 9 February 2018 on top of the residence at 10 Lincoln Crescent (see Noise Logger Location 2A on Figure 2). This additional noise monitoring was conducted in response to concerns raised during the exhibition period.

Long-term noise measurements were made in 15-minute intervals, with a 'fast' time weighting. Broadband and octave band L_{Aeq}, L_{A10} and L_{A90} measurements were made.

Meteorological conditions were monitored during the survey period. Measured data was removed as required to account for the influence of any adverse weather conditions and extraneous noise events.

Attended Short Term Noise Measurements

Attended short term noise measurements were undertaken by Harvey Yang on 10 March 2016 (Location 1, 2 and 3), by Jonothan Holmes on 24 March 2016 (Location 1 and 2).

Additional attended measurements at Attended Location 2A and 2B were undertaken by Chris Nugroho on 31 Jan 2018. This additional noise measurement is located adjacent to the entrance to the Wharf Apartments and was conducted in response to concerns raised during the exhibition period. The noise levels measured are presented in Appendix B, which notes that there was some construction work going on nearby that may have affected the results of the L_{eq} measurements but the L_{90} results are considered representative.

Broadband and octave band L_{Aeq}, L_{A10} and L_{A90} measurements were made. The locations of the attended short-term noise measurements are shown in Figure 2.

The attended measurement at Location 3 was conducted at 5.2 m above the ground, as shown in Figure 3.

Figure 2 Locations of noise loggers and attended measurements

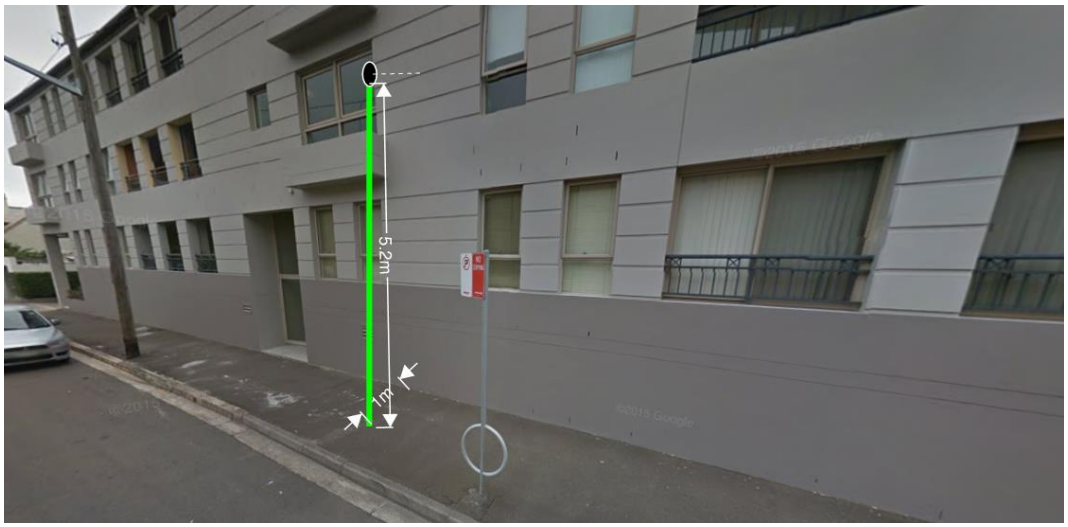


Figure 3 Microphone position at Location 3

3.2.2 Equipment

Equipment used to measure the baseline noise levels is detailed in Table 3. All equipment was checked for calibration before and after measurements with no

significant drift in calibration being recorded. All equipment held a current NATA calibration certificate at the time of the survey.

Table 3: Noise Survey Equipment

Equipment manufacturer and type	Description of Equipment	Serial No.
ARL Ngara – Type 1	Sound logging meter	878061
ARL Ngara – Type 1	Sound logging meter	87807F
Brüel and Kjær 2270	Type 1 sound level meter	2754328
Brüel and Kjær 4231	Sound level meter calibrator	2445716

3.2.3 Noise Logger Results

Results are presented under Day, Evening and Night time periods as defined in the NSW Industrial Noise Policy. Refer to Appendix B for complete noise survey results and details of the derivation of noise criteria.

Long term noise measurements were checked and validated against short-term attended measurements.

Note that the results of Location 3 are developed based on the attended measurement and noise logging results at Location 1, due to the accessibility and safety issues associated with long period logging at Location 3. The attended measurements at Location 3 were synchronized with the noise logging at Location 1, which allows direct comparisons to be made between the two locations. The Rating Background Level (RBL) at Location 3 was then developed by applying the offset to the results at Location 1.

Table 4: Summary of measured noise indices

Location	Time Period	Rating Background Level (RBL) – dB(A)	dB $L_{Aeq, period}$
Location 1	Day (7:00 – 18:00)	59	65
	Evening (18:00 – 22:00)	58	63
	Night (22:00 – 7:00)	47	60
Location 2	Day (7:00 – 18:00)	49	60
	Evening (18:00 – 22:00)	49	62
	Night (22:00 – 7:00)	44	54
Location 3	Day (7:00 – 18:00)	54	60
	Evening (18:00 – 22:00)	53	58
	Night (22:00 – 7:00)	42	55
Location 2A	Day (7:00 – 18:00)	50	56
	Evening (18:00 – 22:00)	50	54
	Night (22:00 – 7:00)	44	51

4 Acoustic Criteria

4.1 NSW Industrial Noise Policy (INP)

This section outlines applicable external noise limiting criteria. Noise criteria are provided to maintain on site acoustic amenity and avoid adverse acoustic impacts to the surrounding environment.

The INP covers noise emissions from the proposed operation of a facility and from other plant and equipment affecting the proposed facility. Noise from traffic movement on a site (i.e. not on public roads) is assessed as being operational noise under the INP.

The objective of the INP is to protect sensitive receivers, such as residences, from noise generated by commercial, industrial or trade premises. In this context, 'industrial' refers to the source of the noise (e.g. plant) rather than the nature of the premises.

Noise limits are set based on land use in the area and existing background noise levels. Compliance is achieved if the adjusted L_{Aeq} noise level at any sensitive receivers affected by noise from the facility is below the noise limit. The adjusted L_{Aeq} is determined by applying corrections for such noise characteristics as duration, intermittency, tonality, and impulsiveness.

The assessment of noise emission under the INP is based on the calculation of a noise limit at a receiver position, taking into account the land-use in the surrounding area and the existing background noise level.

The INP separates the 24-hour day into three different time periods – day, evening and night. These time periods are detailed below in Table 5.

Table 5: Standard INP time periods.

Period	Day of Week	Time period
Day	Monday-Saturday Sunday, Public Holidays	7:00 am-6:00 pm 8:00 am-6:00 pm
Evening	Monday-Sunday	6:00 pm -10:00 pm
Night	Monday-Saturday Sunday, Public Holidays	10:00 pm -7:00 am 10:00 pm -8:00 am

The INP states that background noise levels should be determined over the "days and times of operation of the project". When setting criteria, only the measured data from the hours of operation of the project should be included.

The INP provides guidance on acceptable noise levels from the introduction of new industrial noise sources to an area. The assessment procedure for industrial noise sources has two components:

- Controlling intrusive noise impacts in the short term for residences; and
- Protecting noise level amenity for particular land uses such as residences, recreation areas and commercial offices etc.

Both of these components result in noise criteria that should not be exceeded in order to avoid any adverse noise impacts on the affected areas. Both criteria have been taken into account when assessing the noise impact of building services noise source(s) associated with the project, and where the intrusiveness and the amenity criterion differ, the most stringent of the noise criteria has been adopted as the 'project-specific' noise criterion. In most cases, the project-specific criterion has been determined by the more-stringent amenity criterion.

A summary of the environmental noise criteria is presented in Table 6 below. Refer to Appendix B for complete noise survey results and derivation.

Table 6: Project Specific Noise Levels at Noise Sensitive Receivers.

Noise Sensitive Receiver	**Classification**	**Time Period**	**Project Specific Criterion for Industrial Noise Emission**
10 Lincoln Crescent (Location 2A)	Residential	Day	55 dB $L_{Aeq, 15mins}$
		Evening	44 dB $L_{Aeq, Evening}$
		Night	41 dB $L_{Aeq, Night}$
9-31 Lincoln Crescent (Location 3)	Residential	Day	54 dB $L_{Aeq, Day}$
		Evening	48 dB $L_{Aeq, Evening}$
		Night	45 dB $L_{Aeq, Night}$
Botanic Garden* (Location 2)	Passive recreation	When in use	50 dB $L_{Aeq, peroid}$
Domain* (Location 2)	Active recreation	When in use	50 dB $L_{Aeq, peroid}$

All levels noted for the residential buildings in Table 6 above are applicable at the most-affected point on or within the residential property boundary.

The Botanic Garden to the north of the site is considered to be for passive recreation and is characterised by contemplative activities that generate little noise. The background noise level at Location 2 is considered to be representative for the Botanic Garden, as the location is closer to the Botanic Garden and the amenity is similar.

The Domain and the Domain Pitches are considered to be active recreation areas since sporting activities and public events (e.g. concerts, festivals) often take place within the area. It is also because it serves as a main walking corridor from the city to the Eastern suburbs and is surrounded by major roads and a railway. The background noise level at Location 2 is considered to be representative for the Domain areas because of the similarity of the amenity. Note that the background noise level at Location 1 is not considered to be representative as it is very close to the Eastern Distributor Motorway and Cahill Expressway.

* For both criteria noted for the Botanic Garden and the Domain it is appropriate that the noise criteria in Table 6 above is considered applicable when measured at the most-affected point located at least 15 m from the nearest road barrier, road boundary or AGNSW and new building facades. This deviation from the typical INP parkland assessment distances is recommended because each of them are

large land areas adjacent to major roads and they are exposed to high levels of traffic noise at their boundaries, but the proposed criteria have been derived based on quieter background noise levels more typical of the parkland amenity found when located away from the boundaries.

Assessment of building services noise mitigation requirements to meet these criteria are discussed in Section 5.1 below.

4.2 Sleep Disturbance Criteria

Noise emanating from project has also been assessed for its potential to disturb sleep, for which criteria apply for operations between 10 pm and 7 am.

In accordance with current NSW EPA policy (https://www.epa.nsw.gov.au/your-environment/noise/industrial-noise/nsw-industrial-noise-policy/applying-industrial-noise-policy), the sleep disturbance criteria of $L_{A1(1min)} \leq L_{A90(15min)} + 15$ dB(A) is to be used for initial assessment. The L_{Amax} may be used as an alternative to the $L_{A1(1min)}$. It is noted that the background $L_{A90(15minute)}$ noise level used for establishing the sleep disturbance criteria includes all background noise including noise from the project.

The NSW Road Noise Policy, while relating more specifically to traffic on the road network, outlines that research on sleep disturbance to date concludes:

- L_{Amax} (the maximum A-weighted noise level) internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep (corresponding to approximately 60-65 dB(A) external); and,
- One or two noise events per night, with maximum internal noise levels of 65–70 dB(A) (corresponding to approximately 75-80 dB(A) external), are not likely to affect health and wellbeing significantly.

The sleep disturbance criteria for the project are presented in Table 7.

Table 7: Sleep disturbance criteria

Location	Time period	Rated background noise levels, dBL_{A90}	Sleep disturbance criteria, $dBL_{A1,1min}$ measured at 1m from the outside of the façade of the affected bedroom (L_{A90}+15 dB)
10 Lincoln Crescent	10pm to 5am	44	59
	5am to 7am	47	62

4.3 NSW Road Noise Policy (RNP)

The *NSW Road Noise Policy (DECCW 2011)* provides noise criteria for both residential and other non-residential noise sensitive receivers. The RNP provides both absolute noise level limits, dependent upon road category, and limits to control the relative increase in road traffic noise.

The RNP includes assessment criteria for various types of building but does not specifically include art galleries. Of the types of spaces noted in the RNP, the most relevant is the criterion for School Classrooms. A noise level of 40 dBL_{Aeq} is recommended for traffic noise within classrooms and noise levels from traffic will be designed to meet this criterion for the gallery spaces. Other spaces have more onerous requirements (see below).

4.4 Limits on Noise Local to The Development

As well as controlling noise affecting nearby residences and the nearby recreation spaces, it is appropriate to control noise local to the development in order to protect amenity of the outdoor areas.

Based on the site noise survey, it is proposed that normally operating external plant noise egress is limited to 50 dB(A) when measured at any publicly accessible location at least 1m from a grille or the façade of the building.

4.5 Noise from Traffic

Reference in the SEARs has been made to "NSW Road Noise Policy"[2]. It is considered that there are no specific requirements for the proposed development as a result of this policy and that the maintenance of acceptable noise levels as defined in AS/NZS 2107:2016 "Acoustics - Recommended design sound levels and reverberation times for building interiors" will ensure that noise intrusion from road noise sources will be kept to acceptable levels.

4.6 Noise and Vibration from Rail

The site is sufficiently far away from the rail corridor (approximately 180 m) that noise and vibration impacts from rail are not significant. Reference has been made to "Development Near Rail Corridors and Busy Roads – Interim Guideline"[3] in this regard.

Noise and vibration measurements on site have shown that rail sources are not significant for the new development, because of the distances involved and the inherent acoustic screening afforded by the existing Gallery.

Comparison with Figures 3.1 and 3.2 in Reference 2 provides further confirmation that rail noise and vibration is unlikely to be problematic.

[2] New South Wales Road Noise Policy. DECCW, March 2011.
[3] Development Near Rail Corridors and Busy Roads – Interim Guideline. NSW Government Department of Planning. December 2008

5 Noise Impacts to the Community

5.1 Noise Sensitive Receivers in the Community

Noise sensitive receivers in the community are summarised in Table 2 including residential buildings on Lincoln Crescent, the Domain and the Botanic Garden.

5.2 Plant Noise

5.2.1 General Plant Noise

Plant noise will be limited to the criteria listed in Section 4.1 above. The plant noise will also be controlled to meet the noise limits in the Royal Botanic Garden and Domain, as well as appropriate noise limits local to the building (see section 4.4 above). This will help to maintain the existing amenity of the areas.

At this stage in the project, details of the plant selections are not known and therefore detailed selections of noise control devices cannot be made. Space for appropriate noise and vibration control treatments will be allowed for during the early stages of the plant design and detailed noise modelling undertaken when specific plant noise data is available. The project documentation will define the maximum sound power levels for all items of plant.

These treatments are likely to include:

- Rectangular and circular attenuators to control fan noise
- Acoustic louvres to control noise from plantroom ventilation openings
- Cooling air and flue gas attenuators on the generator set
- Vibration isolators to reduce vibration input to the building structure
- Acoustic screens around any external plant
- Incorporation of sound absorptive treatments in plantroom spaces where needed.
- Provision of vibration isolation devices to rotating and reciprocating plant.

5.2.2 Cooling Towers

Cooling towers will be included in a plantroom buried into the landscape adjacent to Gallery 2. The location of the cooling towers respective to the to the closest residence at 10 Lincoln Crescent is shown in Figure 4.

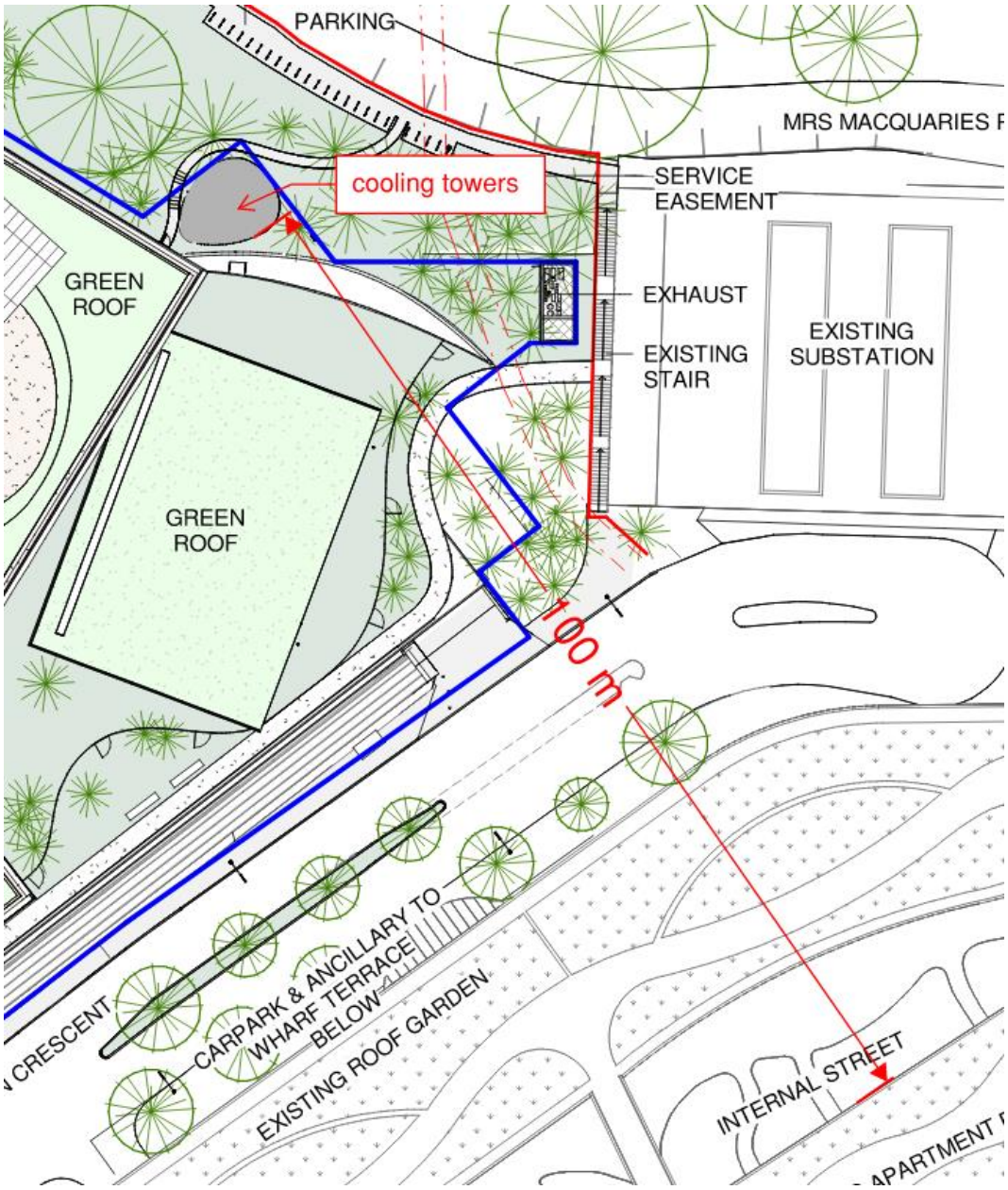


Figure 4: Proposed location of the cooling towers and distance to the nearest residence.

The cooling towers will be located internally within a plantroom and appropriate noise mitigation measures will be employed to ensure that noise from the cooling towers is adequately controlled to ensure that noise from the operation of all plant meets the INP limits.

Based on the preliminary design and equipment selections, an acoustic assessment has been conducted. Acoustic mitigation measures are recommended to meet the noise limits specified in the Section 4.1, including:

- Minimum 600 mm long attenuators to the air intake under grille;

- Minimum 600 mm long attenuators installed to the discharge plenum/duct;
- The building envelope designed to meet airborne sound insulation ratings to adequately control noise break-in from the cooling towers;
- Provision of appropriate vibration isolation mounting for the cooling towers.

The predicted noise level based on the preliminary design and equipment selections is summarised in Table 8 below.

Based on the predictions, the compliance to the acoustic criteria can be achieved with the proposed acoustic measures.

Table 8: Cooling towers predicted noise level emissions.

Receiver	**Predicted cumulative noise level, dB $L_{Aeq,15min}$**	**Compliance to the criteria**
The closest residence at 10 Lincoln Crescent (approximately 100 m away from the louvre)	43	YES
Botanic Garden/Domain (at the closest site boundary)	48	YES

5.3 Noise from loading dock

The loading dock is proposed to be located on the Lincoln Crescent opposite to the carpark building of 10 Lincoln Crescent. This section provides a detailed acoustic analysis undertaken in response to the concerns raised by the residents during the public exhibition period.

Based on the traffic impact assessment report, only very limited vehicle movements are expected in the loading dock during the night time (2200-0700h). The only movements are night would be cars or light vans, except for three delivery trucks (MRV with occasional HRV) in early morning period (0500-0700h). The delivery trucks events are in the shoulder period. All loading and unloading activities will take place within the enclosed loading dock.

Noise data from Arup library have been utilised for the assessment and is summarised in Table 9 below.

The closest noise sensitive receiver is the residential units at 10 Lincoln Crescent behind the carpark building. Acoustic shielding provided by the carpark building has been included in the assessment. The height of the carpark building is at the same height of the residential building. Assessment assumes light vehicular at 0.5 m above ground and 1m above ground for trucks.

The predicted noise level is summarised in Table 9 below.

Table 9: Loading dock noise assumption and prediction

Type of vehicle	Movement	Sound power level		Predicted noise level at the closet receiver at 10 Lincoln Crescent		Compliance to the criteria
		$dBL_{A1,1min}$	$dBL_{Aeq,15min}$	$dBL_{A1,1min}$	$dBL_{Aeq,15min}$	
Car	Accelerating into the loading dock (up ramp)	89	68	48	27	YES
Delivery Truck (HRV)	Accelerating into the loading dock (up ramp)	96	75	55	34	YES

The prediction shows that the proposed loading dock activities during night and early morning period is unlikely to cause sleep disturbance, and that there is a low risk of noise impacts.

To further minimise the potential for noise disturbance, the following are recommended:

- Loading activities must be conducted in the loading dock with the entrance door shut
- Reversing with alarm is not allowed outside the loading dock during the night time (2200-0700)
- Alarm for the loading dock gate is not allowed during the night time (2200-0700)
- Horn is not allowed
- Management plan should be prepared, including the recommendations outlined above, to minimise the noise generation from use of the loading dock.

5.4 Event Noise

5.4.1 Outdoor café event

Outdoor café is proposed to accommodate 100 people under the normal operation, and up to 500 people during functions. Functions will not include any external amplified music.

To assess the noise from the outdoor café, following conservative assumptions are made:

- All 500 people are speaking at the same time on the café terrace
- 500 people are divided in several groups distributed on the café terrace.
- People would interact at normal conversation levels.
- None of the activities listed in the in Section 90(2) of the Protection of Environment Operations (General) Regulation 2009 is allowed on the café terrace.

Section 90 (2) In this clause, outdoor entertainment activities means any of the following activities, but only if the activity is carried on outdoors (including if it is carried on under or within a tent, marquee or similar structure) and sound amplification equipment is used as part of the activity:

(a) concerts, (b) festivals, (c) cinematic and theatrical events, (d) sporting events, (e) a rehearsal, sound check or other preparation for an activity listed in paragraphs (a)–(d).

Noise levels from crowds can be estimated using empirical methods described in a paper by Hayne and others[4].

With distance loss and acoustic barrier effects provided by the building and terrace, the noise level is estimated to be less than 43 dBL_{Aeq} at the closest noise sensitive receiver, 10 Lincoln Crescent (the evening RBL at this location is 50 dB(A)). Noise from an external event is unlikely to be noticeable during the day and evening. No attendees or activities will be permitted outside after 2200h.

The predicted noise level is summarised in Table 10 below.

Table 10: Outdoor café noise assumption and prediction

Number of people	**Sound power level, $dBL_{Aeq,15min}$**	**Contingency allowed for occasional speeches, dB**	**Predicted noise level at the closet receiver at 10 Lincoln Crescent, $dBL_{Aeq,15min}$**	**Compliance to the criteria for day and evening**
500 Distributed in the outdoor café area	105	5	43	YES

As noted above, foreground amplified music will not be allowed on the external terrace. Noise from light background music or occasional speeches is unlikely to be excessive at the noise sensitive receivers. The management of the Gallery will assess all proposed events to ensure that noise levels generated by activities will not exceed 50 $dBL_{Aeq,15mins}$ when measured at the closest noise sensitive receiver.

Activities listed in the in Section 90(2) of the Protection of Environment Operations (General) Regulation 2009 will not be allowed on the café terrace unless the activity is approved by relevant authorities in a separate application.

[4] Prediction of Noise from Small to Medium Sized Crowds. M.J. Hayne (1), J.C. Taylor (1), R.H. Rumble (1) and D.J. Mee (2), (1) Ron Rumble Renzo Tonin, 96 Petrie Terrace, Petrie Terrace QLD Australia 4000, (2) School of Mechanical and Mining Engineering, The University of Queensland, Brisbane, Australia 4072

5.4.2 Entry Plaza

There will be potentially informal crowds gathering for some exhibitions in the Entry Plaza. Noise from these crowds is not expected to be significant with noise at normal conversation levels.

With the large distances to the receivers (approx. 100m), and acoustic barrier effects provided by the gallery buildings, noise levels from crowds are not expected to be excessive. Using Haynes' methodology, the noise level at the nearest residential receiver from a crowd of 1000 people at the Entry Plaza is estimated conservatively to be less than 40 dBL_{Aeq} at the nearest residential properties in 10 Lincoln Crescent. Noise from the Entry Plaza at this level is unlikely to be noticeable.

5.5 Construction Noise and Vibration Levels

5.5.1 Effect on the Community

The importance of the noise and vibration that will be generated by the project construction is recognised. As noted below, noise and vibration will be critical for the operation of the gallery and in some cases, noise control treatments necessary to achieve appropriate noise levels at the existing Gallery will help to reduce noise affecting the nearest residential properties.

The control of noise affecting the community will be given a high priority and form a critical part of the eventual Contractor's scope of work. There will be a specific requirement for the Contractor to prepare a detailed Construction Noise and Vibration Management Plan as part of their appointment.

The project falls *outside* the area where the "Construction Hours / Noise within the Central Business District"[5] document applies and therefore only the requirements given in the "Interim Construction Noise Guideline[6]" will apply (this is also in accordance with the relevant policies as listed in the SEARs). This defines noise limits and work periods based on the Rating Background Level (RBL) as defined in the NSW Industrial Noise Policy.

Table 11: Management Levels at residences at different working hours

Working Hours	**Location**	**Management Level, dB $L_{Aeq,15min}$**
Standard hours:		
Monday to Friday 7am to 6pm and Saturday 8am to 1pm No work on Sunday or Public Holiday	10 Lincoln Crescent (Location 2)	59
	9-31 Lincoln Crescent (Location 3)	64

[5] Construction Hours / Noise within the Central Business District. City of Sydney Code of Practice 1992
[6] Interim Construction Noise Guideline, Department of Environment & Climate Change, NSW, July 2009

Working Hours	Location	Management Level, dB $L_{Aeq,15min}$
Outside Standard hours:		
Day (Sunday or Public Holiday 7am – 6pm, Saturday 7am - 8am and 1pm – 6pm)	10 Lincoln Crescent (Location 2)	54
	9-31 Lincoln Crescent (Location 3)	59
Evening (6pm – 10pm)	10 Lincoln Crescent (Location 2)	54
	9-31 Lincoln Crescent (Location 3)	58
Night (10pm – 7am)	10 Lincoln Crescent (Location 2)	49
	9-31 Lincoln Crescent (Location 3)	47

5.5.2 Effect on The Royal Botanic Garden and Domain

Guidance is also given in the Interim Construction Noise Guidelines on the level of construction noise for recreation areas, which will be applied to the central open areas of the Domain and Botanic Garden (i.e. at a distance away from the road boundaries). At these locations, noise management levels of 65 $dBL_{Aeq,15\ min}$ for active recreation (Domain) and 60 $dBL_{Aeq,15\ min}$ (Botanic Gardens – passive recreation) is recommended.

Good practice to limit construction noise and solid hoardings, as well as the natural screening of the domain by the hillside, is expected to limit general construction noise from the site to the noise management levels or below. Construction traffic using Art Gallery Road will be noticeable at particularly busy times.

5.5.3 Effect on the Existing Gallery

The existing gallery is likely to be the most sensitive of the noise receivers. Given the nature of the space and the sensitivity of some of the artefacts, control of construction noise and vibration will be a critical part of the construction process. The project team will be reviewing construction methodologies and the programme from which a detailed construction noise and vibration management plan will be developed along with the contractor.

The eventual contractor will have a key role in managing the noise and vibration levels during the works and this will include:

- Appointing a named member of the site staff who will act as the Responsible Person with respect to noise and vibration.
- Ensuring that the Responsible Person keeps the Gallery (and local community) advised on expected activities.
- Ensuring that the Responsible Person checks the conditions of the powered equipment used on site daily to ensure plant is properly maintained and that noise is kept as low as practicable.

- Managing and monitoring the noise and vibration logging equipment installed around the site.
- Ensuring that the Responsible Person controls the working hours on site to ensure that work is only done during the acceptable periods as defined in the Interim Construction Noise Guideline for NSW (7am to 6pm on weekdays and 8am to 1pm on Saturdays. No work on Sundays).
- The impact of noise from construction activity on the Gallery may be mitigated by working outside Gallery opening hours, provided there is no adverse impacts on residential receivers nearby.
- Ensuring that noise levels are kept as low as is reasonably practicable and providing appropriate and safe noise mitigation methods following the guidance in *AS2436-1981: Guide to noise control on construction, maintenance and demolition sites*.
- Ensuring that noise levels do not exceed the limits specified in the Interim Construction Noise Guideline for NSW.
- Maintaining appropriate records of complaints.

5.5.4 Construction Noise Levels

The noise levels predicted in this section are indicative based on the preliminary construction plan (i.e. Construction Management Plan Rev11) and assumed noise levels of appliances. The actual noise levels will depend on the appliances finally selected for the works. This will be assessed in detail at a later stage as the construction methodology is fully developed and specific plant is identified.

As noted above, some works may need to be conducted outside of gallery opening hours in order to limit noise affecting the gallery itself. Any such works would comply with the requirements in the Interim Construction Noise Guidelines to avoid disturbing local residents.

Construction Equipment and Staging

The sound power levels of the proposed appliances have been derived with reference to the AS 2436:2010 and DEFRA documents. Where an appliance is shown in both documents, the highest sound power level has been used for the purpose of this assessment. The sound power levels for the proposed appliances are summarized in Table 12.

Table 12: Source levels of proposed appliances.

Appliances	**Sound Power Level, dB(A)**
Demolition	
Excavator	115
Loader	105
Truck	117

Appliances	Sound Power Level, dB(A)
Construction	
Quick Cut Saw	117
Excavator	115
Air Compressor	101
Generator	99
Concrete Pump	108
Crane	105
Piling	111

Mitigation Measures

Noise mitigation measures and indicative noise reductions have been obtained from the guidance of AS2436 and BS5228.1. Mitigation measures relevant to this study are summarised below in Table 13.

Table 13: Indicative Noise Reduction Provided by Noise Mitigation Measures.

Appliance	Mitigation Measures	A-Weighted Sound Reduction (dB)
Excavator with Pneumatic concrete breaker, rock drills and tools	Erection of acoustic screening	Up to 10
	Fit Suitably designed muffler	Up to 10
Compressors and generators	Acoustically dampen metal casing	Up to 10
Piling	Enclose hammer head and top of pile in acoustic screen	5 - 10
Earth-moving plant (crane, dump truck, excavator and loader)	Fit more efficient exhaust sound reduction equipment	5 - 10
Pumps	Use machine inside acoustic enclosure	Up to 20

Predicted Noise Levels

The level on noise impact will vary depending on the specific location of each piece of equipment in relation to the nearest noise sensitive receivers. When an item of equipment is closer to the receiver location, the noise impacts will be higher.

Locations and volume of trucks are based on the Construction Management Plan Rev11 Appendix 1 Preliminary Site Management Plan. It is understood that, during the construction phase, the truck route is designed to be Art Gallery Road.

The predictions below are based on the peak volume of trucks and is therefore the worst case.

The predicted noise levels for residential noise sensitive receivers are summarised in Table 14 below.

Table 14: Preliminary Construction Noise Prediction with/without Mitigation Measures.

Noise Sensitive Receiver	Phase	Predicted Unmitigated Noise Levels, dB $L_{Aeq,15min}$	Compliance with the Criteria?	Predicted Mitigated Noise Levels, dB $L_{Aeq,15min}$	Compliance with the Criteria?
10 Lincoln Crescent	Demolition	64	NO	54	YES [2]
	Construction	64	NO	55	YES [2]
9-31 Lincoln Crescent	Demolition	59	YES [1]	49	YES [2]
	Construction	64	YES [3]	56	YES [2]

Notes:

[1] Non-compliance during Evening (6pm – 10pm) and Night (10pm – 7am).

[2] Non-compliance during Night (10pm – 7am).

[3] Non-compliance during Day (Sunday or Public Holiday 7am – 6pm, Saturday 7am - 8am and 1pm – 6pm), Evening (6pm – 10pm) and Night (10pm – 7am).

Note that the predictions are preliminary and indicative. It should be checked and updated when the construction plan is finalised.

5.5.5 Construction Vibration

The main vibration sensitive receivers around the site are the existing AGNSW facilities and the nearby residential units in Lincoln Crescent. The other possible vibration sensitive receivers of note are the Sydney Eye Hospital and the Parliament of New South Wales. However, these are some 400m from the development and unlikely to be significantly affected by vibration from construction of the Sydney Modern development.

The most sensitive location with respect to vibration will be the existing facilities within the AGNSW. Vibration during construction will need to be carefully controlled to protect artefacts and to avoid disturbing visitors and staff working within the building.

The Contractor will be required to enact a detailed vibration monitoring protocol to ensure that vibration levels are kept within acceptable levels. This will form a part of their contractual obligations and will define where vibration levels are to be monitored, how the monitoring is to take place and the reporting and recording process.

The Contractor will also be required to monitor vibration at the residential receivers around in Lincoln Crescent. They will be obliged to install vibration logging devices at a defined location and monitor the outcomes. The precise location in Lincoln Crescent will be determined as part of the contract documentation process as more details of the expected construction methodologies are defined.

The vibration criteria stipulated for artefacts will refer to the recommendations in Reference 7 and will be developed at the latest responsible moment when details of the specific artefacts in the building are known.

Criteria for general comfort will be as shown below in Table 15. These criteria are taken from the recommendations in *Assessing Vibration: A Technical Guideline 2006.*

Audible vibration (eg groundborne noise) will be assessed against airborne noise criteria as part of the noise assessment process.

Table 15: Vibration Limit Values (m/s^2 from 1 to 80 Hz).

Location	Z axis vibration	X and Y axis vibration	Z axis vibration	X and Y axis vibration
	Preferred values		Maximum Values	
Continuous vibration				
Residential Daytime	0.010	0.0071	0.020	0.014
Residential Nighttime	0.007	0.005	0.014	0.010
Office Anytime	0.020	0.014	0.040	0.028
Gallery Areas Anytime	To be determined based on items in collection at the time			
Impulsive Vibration				
Residential Daytime	0.3	0.21	0.60	0.42
Residential Nighttime	0.1	0.071	0.2	0.14
Office Anytime	0.64	0.46	1.28	0.92
Gallery Areas Anytime	To be determined based on items in collection at the time			

5.6 Construction Noise and Vibration Management

It will be a specific requirement of the Contractor's scope that he effectively deals with construction noise and vibration by planning, mitigation and consultation and implement all "feasible and reasonable" work practices to minimise noise. They will be required to comply with the requirements of the appropriate codes – particularly Interim Construction Noise Guideline for NSW.

This will include:

- Appointing a named member of the site staff who will act as the Responsible Person with respect to noise and vibration
- Ensuring that the Responsible Person keeps the local community advised on expected activities.
- Ensuring that the Responsible Person checks the conditions of the powered equipment used on site daily to ensure plant is properly maintained and that noise is kept as low as practicable.

- Ensuring that the Responsible Person controls the working hours on site to ensure that work is only done during the acceptable periods as defined in the Interim Construction Noise Guideline for NSW (7am to 6pm on weekdays and 8am to 1pm on Saturdays. No work on Sundays) unless prior approval from the consent authority is arranged.
- Ensuring that noise levels are kept as low as is reasonably practicable and providing appropriate and safe noise mitigation methods following the guidance in AS2436-1981: Guide to noise control on construction, maintenance and demolition sites.
- Maintaining appropriate records of complaints.

Universal Work Practices

- Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways to minimise noise.
- Ensure site managers 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
- Ensure all doors/hatches are shut

Demolition

- Demolition works are to be conducted during standard construction hours only (i.e. no works on Sunday or Saturday after 1:00 pm)
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.
- Use non-“beeper” reversing/movement alarms such as broadband (non-tonal) alarms or ambient noise-sensing alarms.
- Avoid dropping materials from height.
- Provide resilient damping material on bin trucks to minimise impact noise from materials loaded on truck
- Avoid metal-to-metal contact on equipment wherever possible
- Conduct work behind temporary hoardings/screens wherever possible. Site hoardings shall be located as close to the noise source as possible, and will be as high as feasible considering the structural support of the hoarding. Site hoardings may not be effective at screening noise to upper floors of residential receivers, but can be an effective noise mitigation measure for receivers located on lower floors.
- Keep blade of saws sharp; use a damped blade wherever possible

- Fit mufflers/silencers to pneumatic tools (e.g. breakers)
- Use residential-grade mufflers on plant
- Use dampened bits on impulsive tools such as jackhammers to avoid "ringing" noise.

If mitigated noise levels from demolition are predicted or measured to exceed 75 dBA $L_{Aeq,15minute}$, provide respite periods (e.g. breaks of 1-2 hours) during the day when demolition does not occur.

Excavation

- Excavation works are to be conducted during standard construction hours only (i.e. no works on Saturday after 1:00 pm)
- Use residential-grade mufflers on major items of plant
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.
- Use non-"beeper" reversing/movement alarms such as broadband (non-tonal) alarms or ambient noise-sensing alarms.
- Avoid dropping materials from height.
- Provide resilient damping material on bin trucks to minimise impact noise from materials loaded on truck
- Avoid metal-to-metal contact on equipment wherever possible
- Conduct work behind temporary hoardings/screens wherever possible. Site hoardings shall be located as close to the noise source as possible, and will be as high as feasible considering the structural support of the hoarding. Site hoardings may not be effective at screening noise to upper floors of residential receivers, but can be an effective noise mitigation measure for receivers located on lower floors.
- If mitigated noise levels from excavation are predicted or measured to exceed 75 dBA $L_{Aeq,15minute}$, provide respite periods (e.g. breaks of 1-2 hours) during the day when excavation does not occur.

Construction

- Construction is to occur during standard construction hours only (i.e. no works on Saturday after 1:00 pm)
- Use residential-grade mufflers on major items of plant
- Regularly inspect and maintain plant to avoid increased noise levels from rattling hatches, loose fittings etc.
- Check hatches/enclosures regularly to ensure that seals are in good working order and doors close properly against seals.
- Use non-"beeper" reversing/movement alarms such as broadband (non-tonal) alarms or ambient noise-sensing alarms.
- Avoid dropping materials from height.

- Provide resilient damping material on bin trucks to minimise impact noise from materials loaded on truck
- Avoid metal-to-metal contact on equipment wherever possible
- Conduct work behind temporary hoardings/screens wherever possible. Site hoardings shall be located as close to the noise source as possible, and will be as high as feasible considering the structural support of the hoarding. Site hoardings may not be effective at screening noise to upper floors of residential receivers, but can be an effective noise mitigation measure for receivers located on lower floors.
- If mitigated noise levels from installation are predicted or measured to exceed 75 dBA $L_{Aeq,15minute}$, provide respite periods (e.g. breaks of 1-2 hours) during the day when Installation works do not occur.

Deliveries

- Keep truck drivers informed of designated vehicle routes, parking locations and acceptable delivery hours for the site.
- Avoid deliveries at night/evenings
- No idling of delivery trucks
- Receive/unload all deliveries behind a site hoarding/temporary acoustic screen, wherever possible

Stockpiling

- Stockpile materials behind a site hoarding/temporary acoustic screen
- Use residential-grade mufflers on major items of plant

Landscaping

- Use residential-grade mufflers on major items of plant

Work Outside of Standard Working Hours

Work outside standard hours will only be conducted in the following circumstances:

- Works required to prevent any threat to pedestrian safety or a threat of environmental harm if work was to occur during standard construction hours (e.g. emergency works, incomplete works that need to continue out-of-hours in order to maintain safe passage, works requiring closure of Main Avenue entrance).
  In these situations the person who becomes aware of the situation will notify the Site Foreman (SF) or Project Engineer (PE) who will in turn notify the General Foreman (GF) or Project Manager (PM) who will be responsible for recording the details of the additional working hours. Attended monitoring of noise levels by the Acoustic Consultant (AC) may be required at the discretion of the PM. Clear and concise notification of the community will occur as discussed below.
- The delivery of plant, equipment and materials which is required outside Standard Working Hours as requested by police or other authorities for safety reasons and with clear and concise notification to the community as agreed by the Site Environmental Representative
- All "feasible and reasonable" noise mitigation measures discussed in this chapter must be implemented for out-of-hours' work.

If the resulting mitigated noise levels for the activity exceed the Highly Noise Affected Level (75 dB L_{Aeq}), and works cannot be conducted during standard construction hours, the works may still occur subject to the consent authority's approval, however affected residents must be informed of the likely time, duration and extent of the noise impacts.

Noise and Vibration Monitoring

Attended environmental noise and vibration monitoring will take place at locations determined prior to the beginning of the construction works. This would include a suitable location in Lincoln Crescent.

The locations for noise monitoring shall be representative of the worst affected locations in order to effectively address community concerns in regards to noise and to respond to concerns about vibration affecting the existing AGNSW. Vibration monitoring for the residential premises will be implemented if vibration is expected to be significant.

Additional attended noise monitoring at other locations and plant and equipment monitoring on-site will take place as and when necessary.

The GF will issue a detailed construction programme as required. An acoustic consultant will review the programme and arrange monitoring to coincide with potentially noisy activities.

Reporting

Reports covering the attended monitoring will be prepared after each monitoring session by the Acoustic Consultant. The reports will summarise and interpret the results of each session of noise monitoring. Noise monitoring reports will be prepared within 1 week of completed monitoring and issued in a format suitable for presentation to the consent authority.

Community Notification

Community notification via letter box drops must occur at least five (5) days in advance of any planned out-of-hours work. Notification will occur regardless of whether the planned work is expected to cause adverse noise impacts to residents.

The notification will:

- Provide a clear and concise description of the planned works
- Provide details of the timing and expected duration of the works
- Provide details of the timing and expected duration of "loud" activities
- Inform residents of the noise mitigation measures being implemented for the proposed works, and that all "feasible and reasonable" measures have been implemented to reduce noise impacts.
- Provide a readily accessible contact point (eg mobile phone number and name, 24-hour toll-free information line)

Letter box drops will also be used to manage noise sensitive receiver expectations by notifying residents that increased noise levels may be experienced by upper-floor receivers due to these receivers overlooking the site.

6 Internal Design Criteria

6.1 Australian Standard AS2107

Design levels for steady-state internal noise levels within the building are given in *Australian Standard AS 2107:2000 Acoustics – Recommended design sound levels and reverberation times for building interiors.*

These recommended noise levels apply to all steady-state noise sources within the development. Accordingly, the internal noise levels from the following sources should be controlled to meet the AS 2107 noise levels:

- Noise from the ventilation system (expected to be present in all areas of the development);
- Break-in noise from mechanical plant within the development;
- Traffic noise break-in through the façade; and

AS2107 recommends maximum design noise levels for generic spaces within building interiors, although many of the gallery spaces are not specifically mentioned in the standard. The following criteria for traffic noise intrusion are proposed which are based on the requirements for similar spaces called up in AS 2107 along with specific experience of noise level requirements from other international projects undertaken by Arup. The criteria are outlined in Table 16. These are considered appropriate for the Sydney Modern project and are consistent with, or more onerous than, the generic recommendations in AS 2107.

The criteria for external noise intrusion are expressed in terms of the L_{Aeq} level. This is an overall 'average' of noise levels and as such excludes occasional and sporadic events such as extreme weather or particularly noisy vehicles.

Table 16: Design sound levels for Typical Spaces within the Development.

Space	**Maximum External Noise Intrusion Level, dB $L_{Aeq, 15min}$**
Café	45
Gallery Exhibition Spaces	40
Multipurpose	35
Shop	45

6.2 Internal Acoustic Privacy

The nature of the development means that there are only limited requirements to control acoustic privacy.

In practice, acoustic privacy will depend on the sound insulation of the partitions selected and the overall levels of ambient noise within the spaces. The noise control design and specification of partitions will be undertaken by the project acoustic specialist.

Other spaces will need to be provided with high standards of sound insulation in order to protect them from incoming noise that might affect events or noise from events affecting other internal spaces (e.g. multipurpose and cafe).

7 Impact of Environmental Noise and Vibration on the Development

7.1 Noise and Acoustic Privacy

A detailed assessment of noise intrusion is being conducted as part of the acoustic design of the project and will achieve appropriate acoustic privacy between the inside and outside of the building.

This process is ongoing and includes detailed calculations of noise intrusion through the key elements (facades, openings and roofs) and the development of architectural and acoustic designs. These factor in all the acoustical parameters that influence the resulting internal noise levels, recognising that there are many non-acoustic parameters that will also influence the constructions that will eventually be installed.

The preliminary calculations show that controlling internal noise levels to appropriate criteria is unlikely to be problematic. Noise measurements taken on the landbridge at different heights above local ground level show that there is a significant degree of natural acoustic screening by the landbridge parapet, and the low-rise nature of the development will help to maximise the benefits of the screening effects of the parapet.

Further acoustic modelling of the external environment will be undertaken to ensure that the overall internal noise levels resulting from all sources are acceptable.

7.2 Vibration

Measurements have been made of vibration levels on the landbridge and adjoining the highway. This data has formed the basis of an assessment of vibration as it could affect the new development. This assessment has looked at the potential implication of vibration on the building in terms of audible groundborne noise. Calculations show that groundborne noise is unlikely to have any significant impact on noise levels within the development.

The impact of vibration on artefacts has also been reviewed against criteria proposed by the British Museum[7]. Again, the measured levels of vibration are unlikely to be problematic and damage to artefacts from operational vibration is considered very low risk.

Reference has also been made to *Assessing Vibration: A Technical Guideline 2006.* This document primarily refers to human comfort requirements and the criteria in reference 7 are considered more appropriate for assessing vibration affecting art objects.

[7] British Museum, Conservation Research Group. Report No 1999/6 Assessment of Vibration Damage Levels. D. Thickett

Lower levels of vibration can impact items housed on shelving because of the tendency of shelving to amplify vibration where there are long spans. The levels of vibration that will cause items to move on shelving are not well understood - being a complex interaction between the shelf construction and the friction between the shelf and the artefact. This issue is best considered as and when shelving is being procured.

Vibration generating audible noise will be assessed against the internal noise criteria for the development.

The issue of vibration during construction is considered separately in Section 5.5.3.

8 Conclusion

This report has addressed the SEARs Key Issue Nos 3 and 11 regarding the impact of the noise and vibration from development during its construction and operation. This report has been updated to provide clarifications and further information for the acoustic issues raised during the exhibition period.

In addition to the assessment of the nearby residential premises, the potential noise impacts to the existing Art Gallery, The Royal Botanic Garden and Domain have been assessed. Relevant noise limits and potential noise mitigation measures have been proposed. It also addresses the impact of the existing noise and vibration climate on the development itself.

Reference has been made to relevant NSW and Australian guidance as well as international experience in art gallery design from within Arup. On the basis of the noise and vibration measurements made on site and the information currently available for the development, we see no impediment to approval.

Appendix A

Glossary of Acoustic Terminology

Decibel

The decibel scale is a logarithmic scale which is used to measure sound and vibration levels. Human hearing is not linear, which allows hearing over a large range of sound pressure levels. Therefore a logarithmic scale, the decibel (dB) scale, is used to describe sound levels.

dB(A)

dB(A) is a single number to describe a sound pressure level and includes a frequency weighting to reflect the subjective loudness level.

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

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. Some typical dB(A) levels are shown below.

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

dBL_1

The dBL_1 statistical level is often used to represent the maximum level of a sound level that varies with time.

Mathematically, the dBL_1 level is the sound level exceeded for 1% of the measurement duration. As an example, 87 $dBL_{A1,15min}$ is a sound level of 87 dB(A) or higher for 1% of the 15 minute measurement period.

dBL_{10}

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

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

dBL_{90}

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

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

dBL_{eq}

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

dBL_{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. When the dB(A) weighting is applied, the level is denoted $dBL_{Aeq.}$ Often the measurement duration is quoted, thus $dBL_{Aeq,15\ min}$ represents the dB(A) weighted energy-average level of a 15 minute measurement.

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" and sounds with a higher frequency are perceived as "high pitched".

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. 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. Either metric units (such as mm, mm/s and mm/s2) or using a decibel scale are used to describe vibration.

Appendix B

Environmental Noise Survey Results

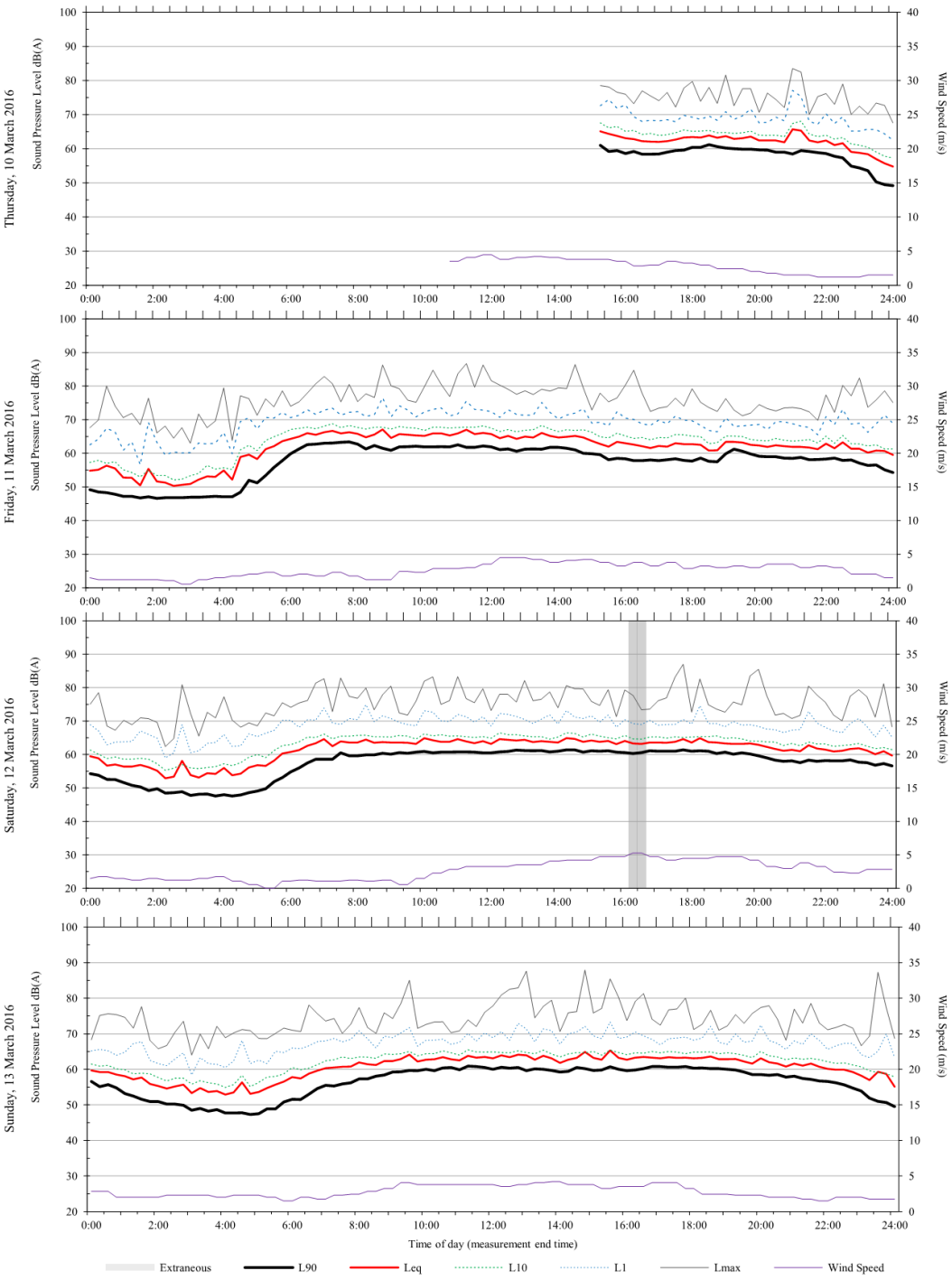
B1 Long Term Unattended Noise Logging Results

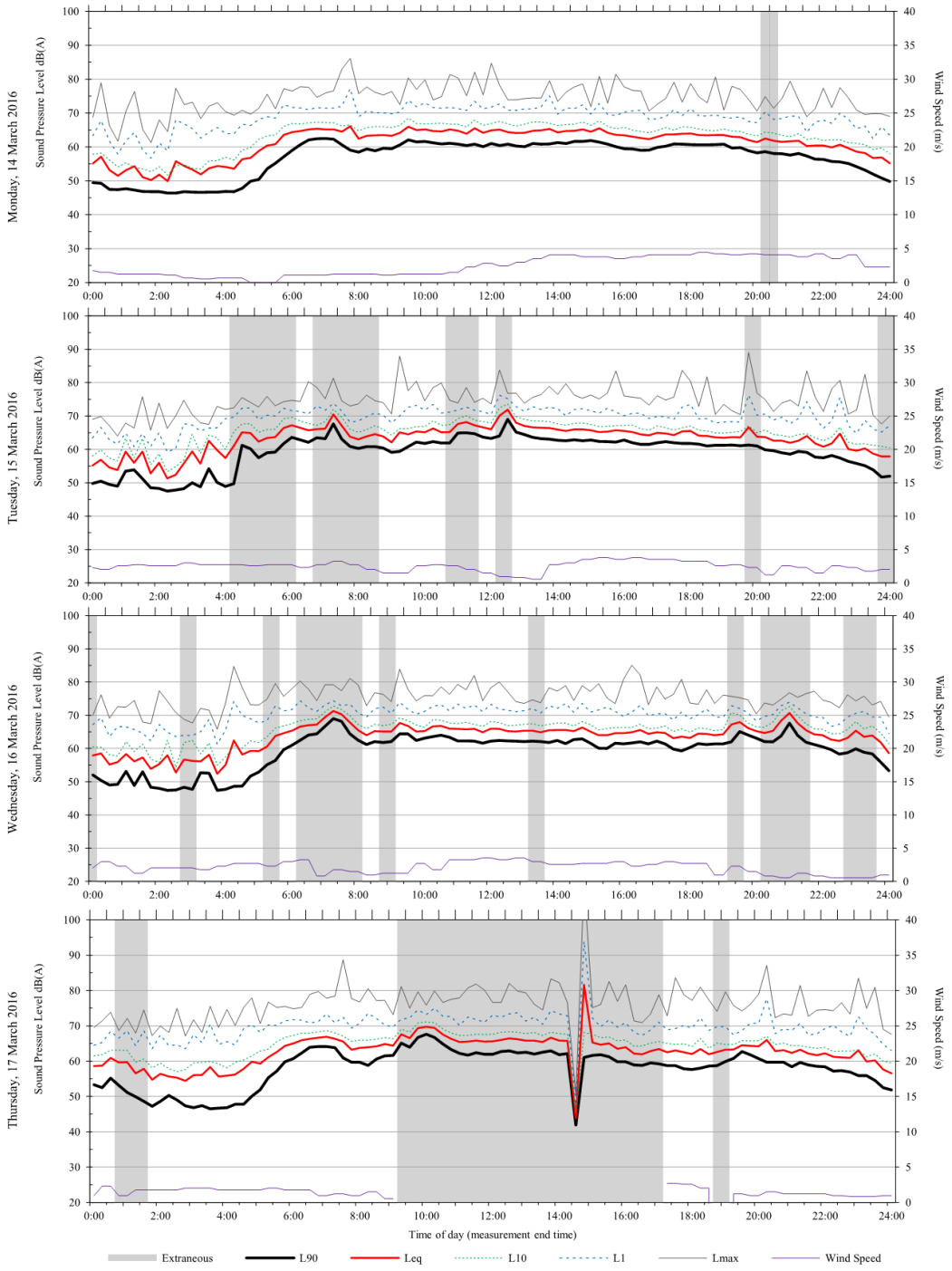
Results are presented under Day, Evening and Night time periods as defined in the NSW Industrial Noise Policy.

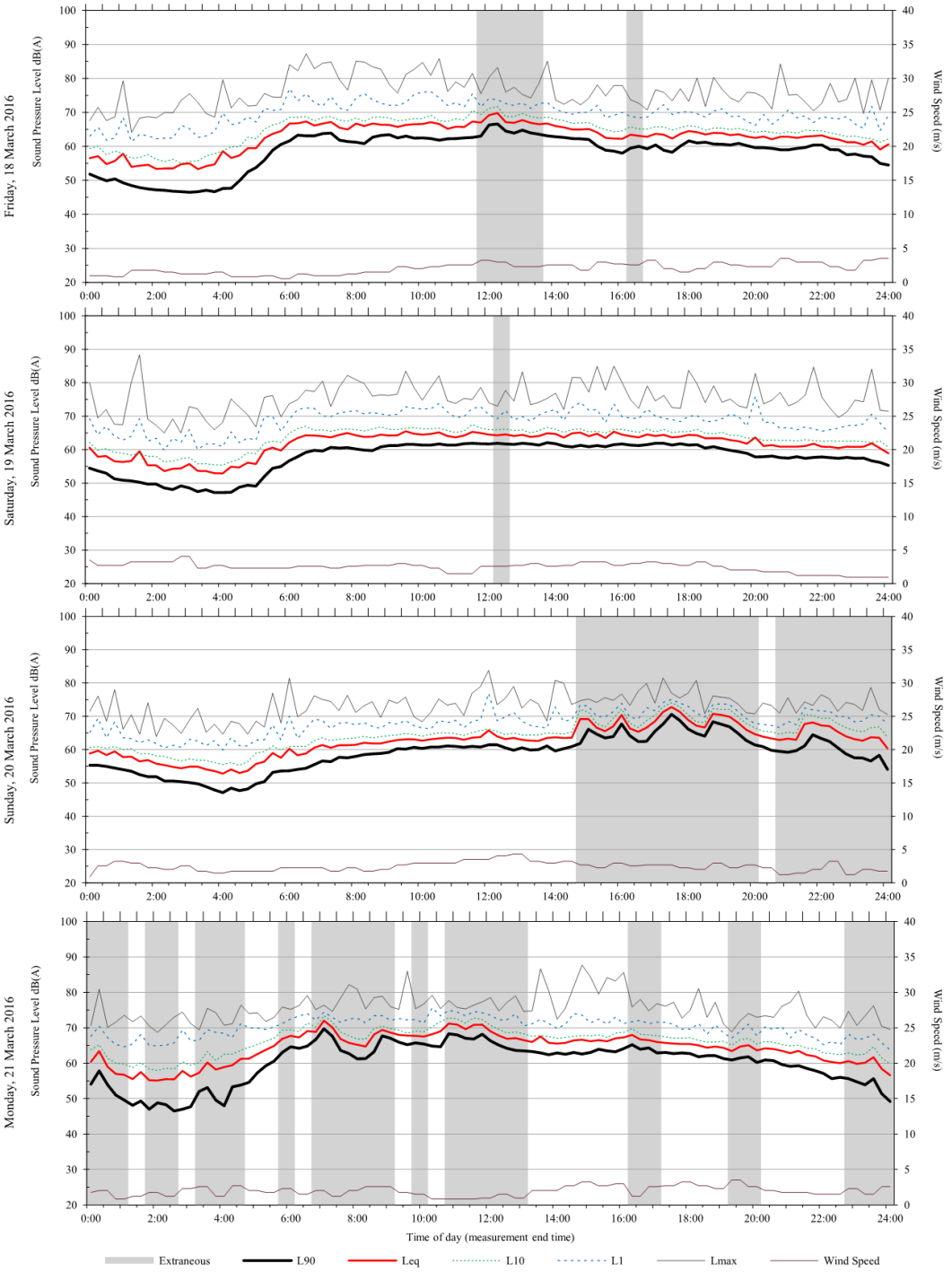
Long term noise measurements were checked and validated against short-term attended measurements. Section B1.1 and Section B1.2 summarised the results in Graphs.

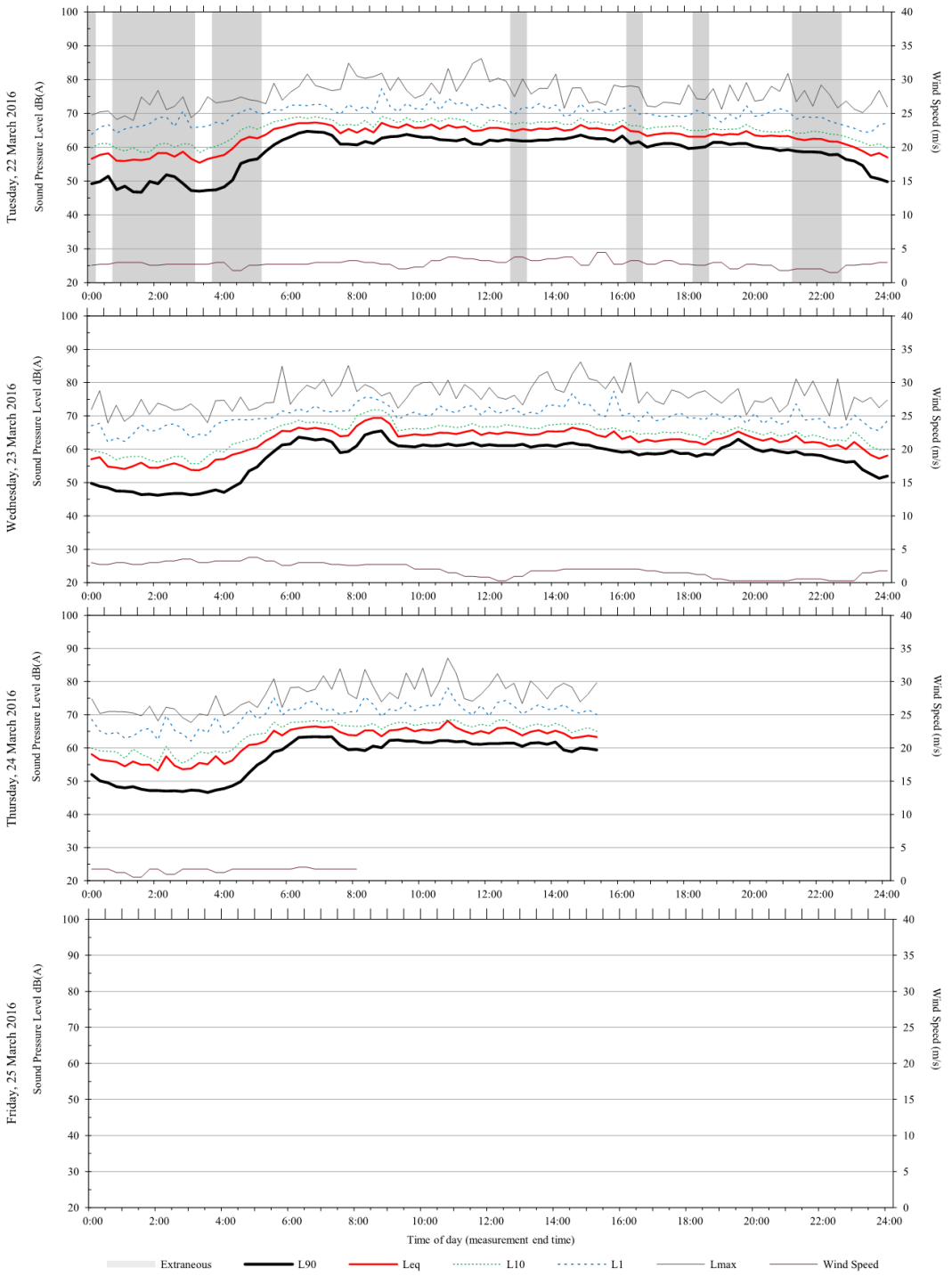
Location	Time Period	Rating Background Level (RBL) – dB(A)	$L_{Aeq\ (period)}$, dB
Location 1	Day (7:00 – 18:00)	59	65
	Evening (18:00 – 22:00)	58	63
	Night (22:00 – 7:00)	47	60
Location 2	Day (7:00 – 18:00)	49	60
	Evening (18:00 – 22:00)	49	62
	Night (22:00 – 7:00)	44	54
Location 2A	Day (7:00 – 18:00)	50	56
	Evening (18:00 – 22:00)	50	54
	Night (22:00 – 7:00)	44	51

B1.1 Location 1

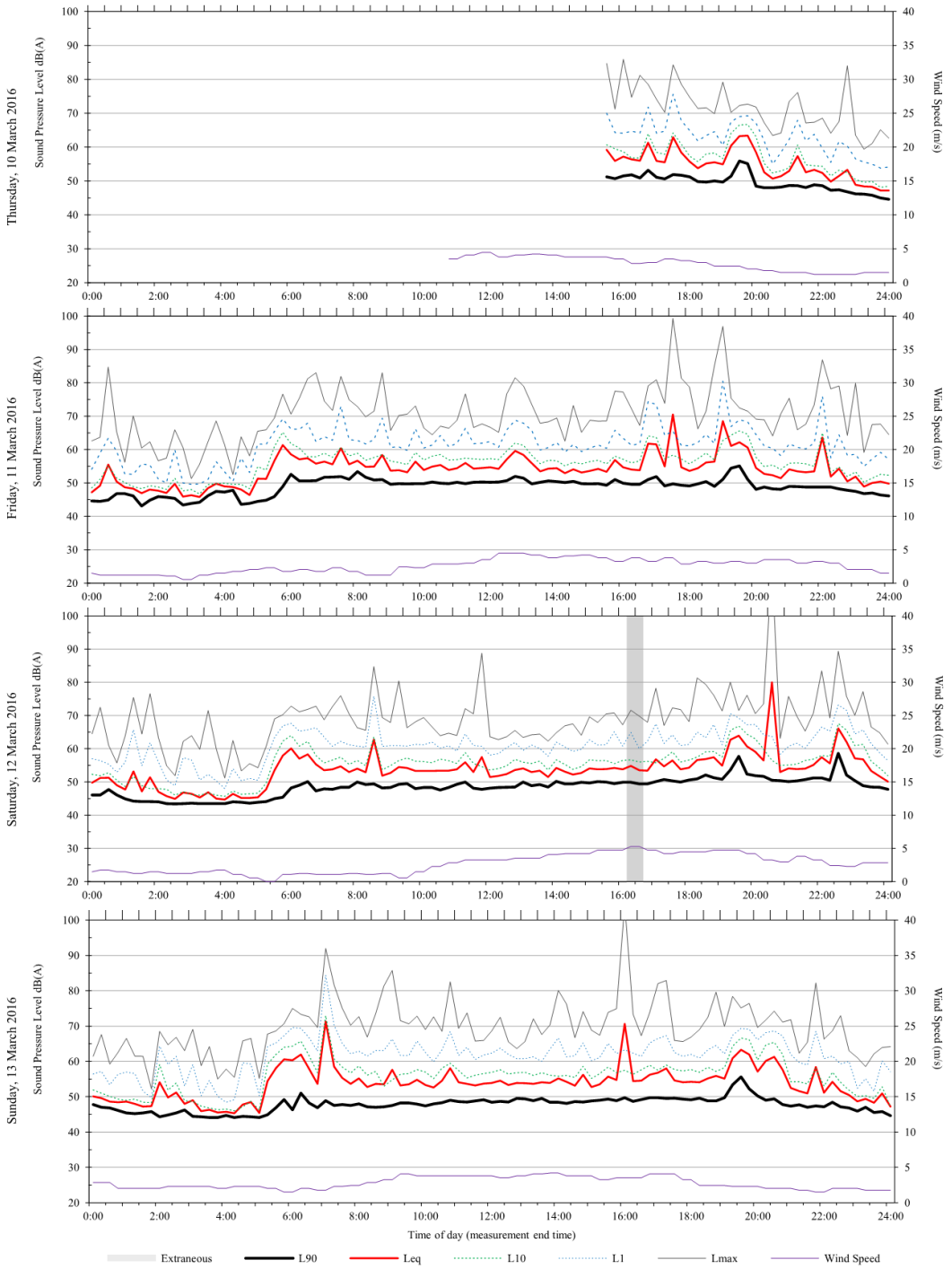


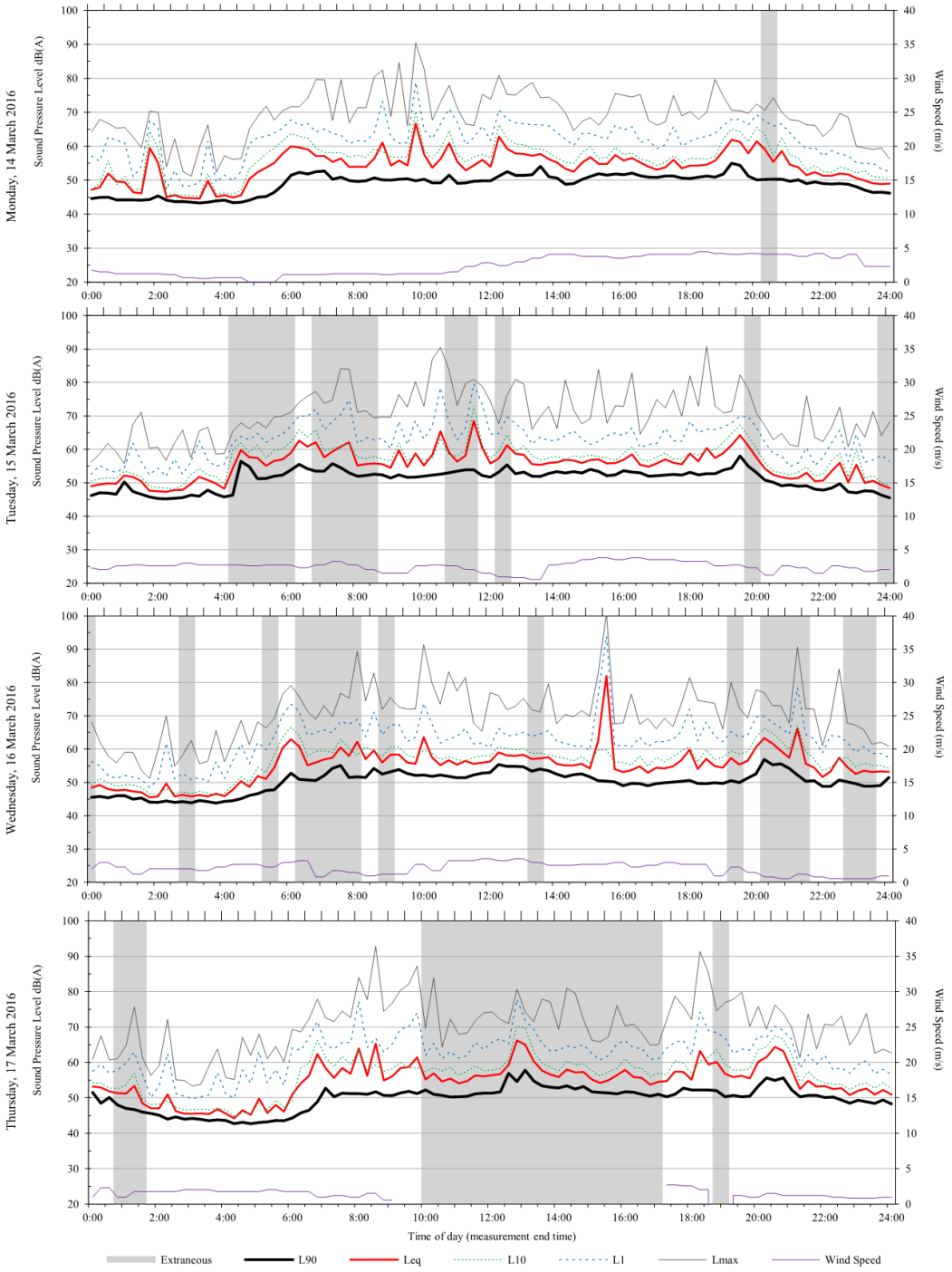

Monday, 14 March 2016
Tuesday, 15 March 2016
Wednesday, 16 March 2016
Thursday, 17 March 2016
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of day (measurement end time)
Extraneous
L90
Leq
L10
L1
Lmax
Wind Speed

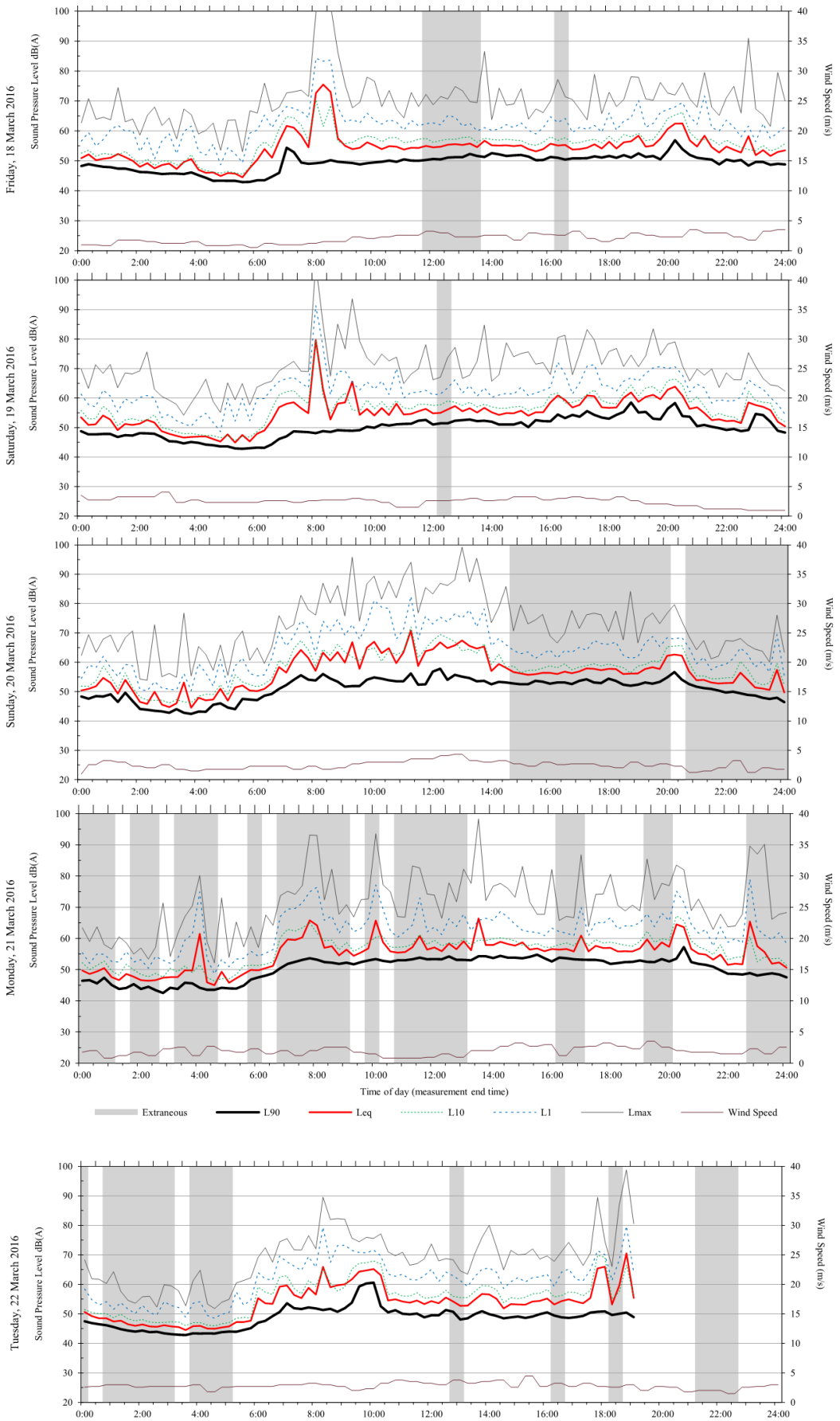

Friday, 18 March 2016
Saturday, 19 March 2016
Sunday, 20 March 2016
Monday, 21 March 2016
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of day (measurement end time)
Extraneous
L90
Leq
L10
L1
Lmax
Wind Speed


Tuesday, 22 March 2016
Wednesday, 23 March 2016
Thursday, 24 March 2016
Friday, 25 March 2016
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of day (measurement end time)
Extraneous
L90
Leq
L10
L1
Lmax
Wind Speed

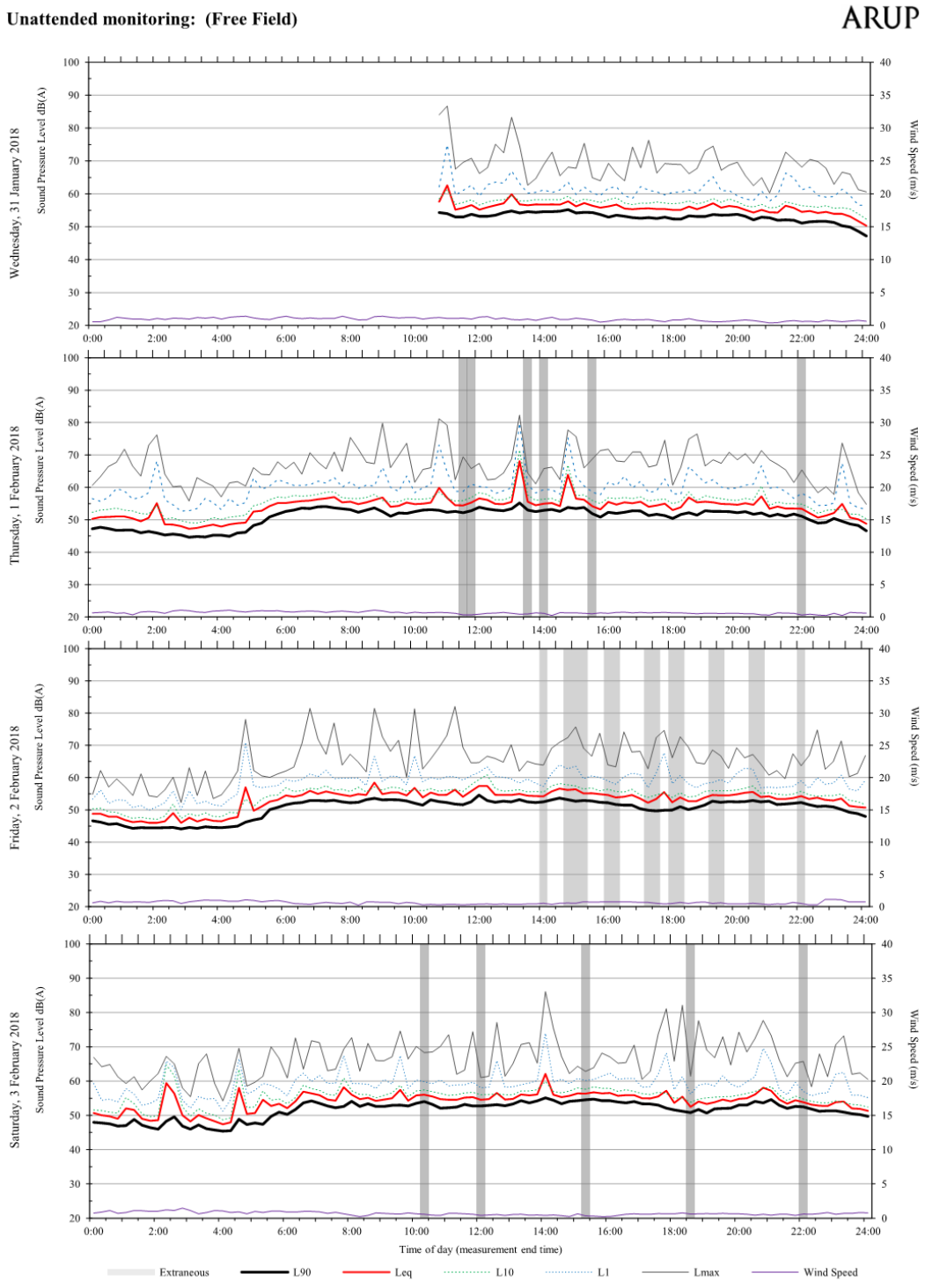
B1.2 Location 2




Monday, 14 March 2016
Tuesday, 15 March 2016
Wednesday, 16 March 2016
Thursday, 17 March 2016
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of day (measurement end time)
Extraneous
L90
Leq
L10
L1
Lmax
Wind Speed

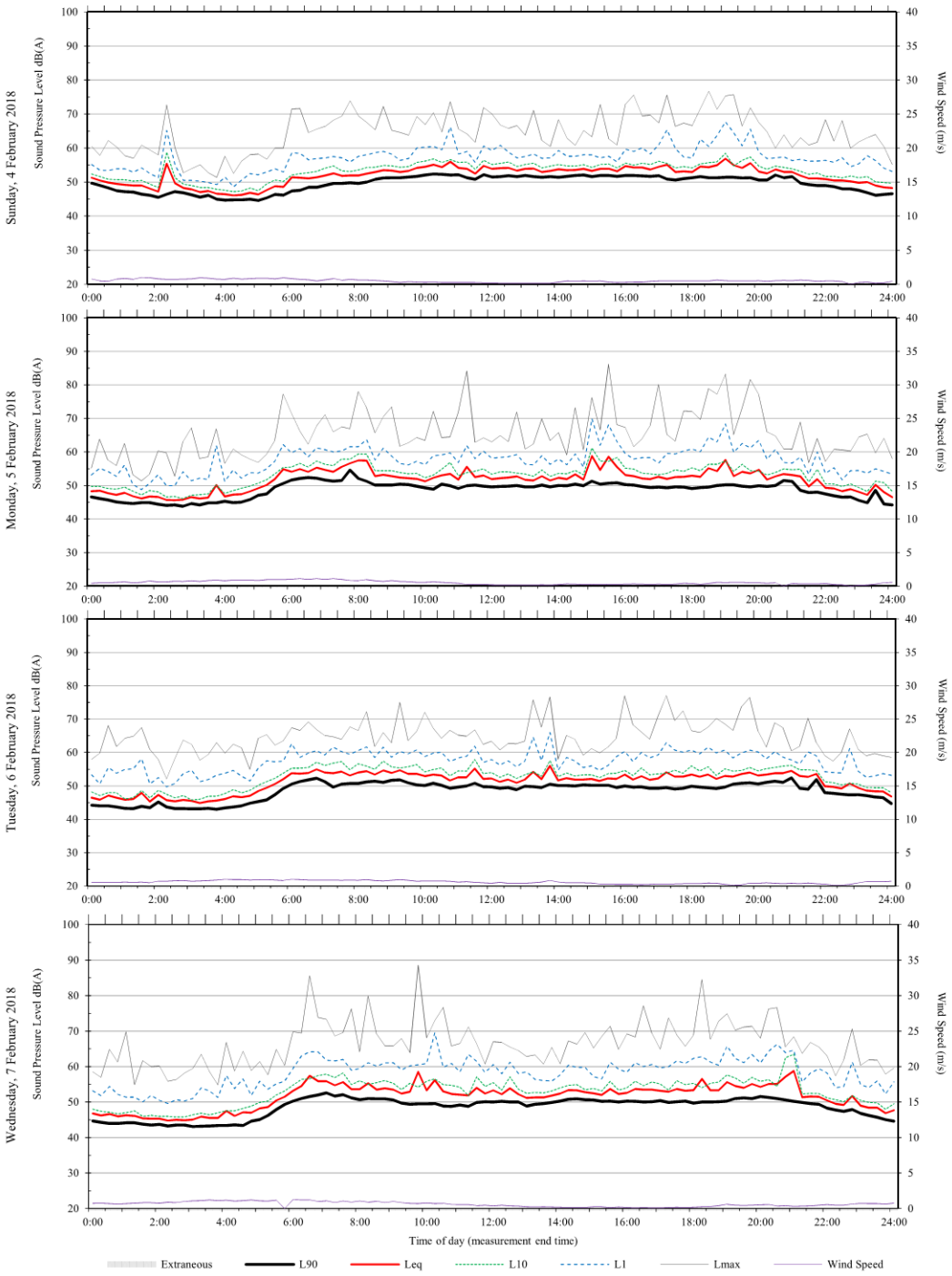

Friday, 18 March 2016
Saturday, 19 March 2016
Sunday, 20 March 2016
Monday, 21 March 2016
Tuesday, 22 March 2016
Sound Pressure Level dB(A)
Wind Speed (m/s)
Time of day (measurement end time)
Extraneous
L90
Leq
L10
L1
Lmax
Wind Speed

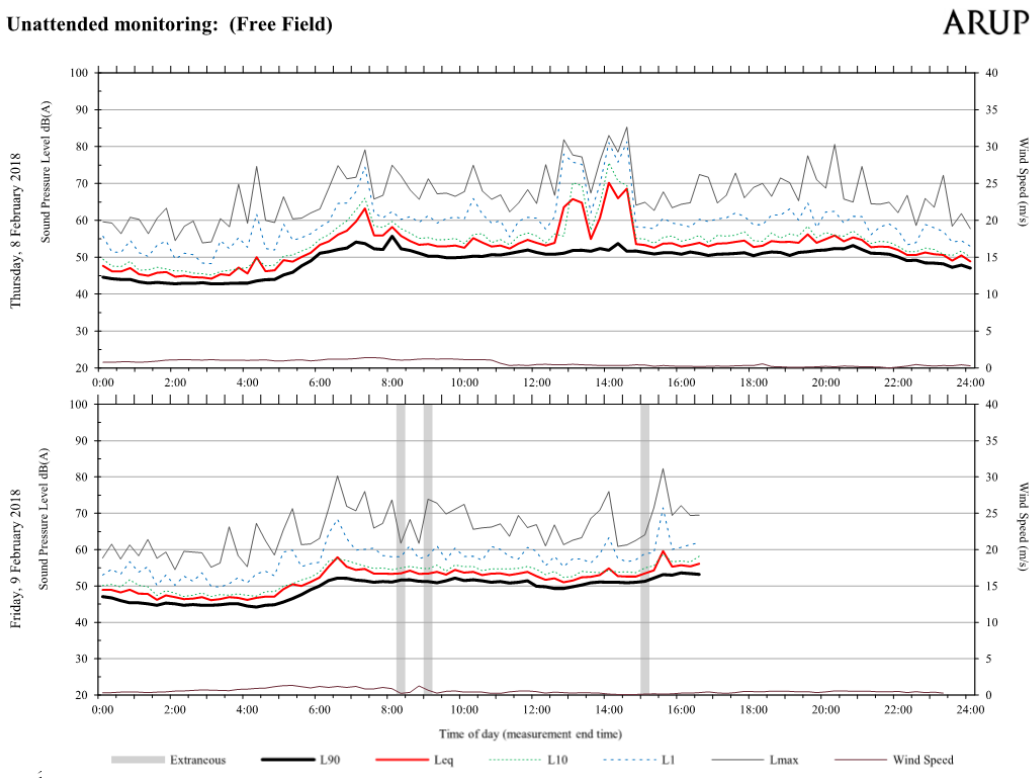
B1.3 Location 2A



Unattended monitoring: (Free Field)

ARUP





B2 Attended Short Term Noise Measurements

B2.1 Location 1

Date	Time	$L_{eq,15min}$, dB(A)	$L_{1,15min}$, dB(A)	$L_{10,15min}$, dB(A)	$L_{90,15min}$, dB(A)
10 March 2016	16:00 – 16:15	63	73	66	59
24 March 2016	15:15 – 15:30	65	73	68	60

B2.2 Location 2

Date	Time	$L_{eq,15min}$, dB(A)	$L_{1,15min}$, dB(A)	$L_{10,15min}$, dB(A)	$L_{90,15min}$, dB(A)
10 March 2016	15:30 – 15:45	59	70	61	51
24 March 2016	15:15 – 15:30	65	73	68	60

B2.3 Location 2A

Date	Time	$L_{eq,15min}$, dB(A)	$L_{1,15min}$, dB(A)	$L_{10,15min}$, dB(A)	$L_{90,15min}$, dB(A)
31 January 2018	11:00 – 11:15	55	60	56	53

B2.4 Location 2B

Date	Time	$L_{eq,15min}$, dB(A)	$L_{1,15min}$, dB(A)	$L_{10,15min}$, dB(A)	$L_{90,15min}$, dB(A)
31 January 2018	11:28 – 11:43	56	64 *	58 *	52

* The $L_{1,15min}$ and $L_{10,15min}$ was slightly affected by occasional road works nearby. Due to short period time of the road work events, L_{90} and $L_{eq,\ 15mins}$ are expected to be unaffected.

B2.5 Location 3

Date	Time	$L_{eq,15min}$, dB(A)	$L_{1,15min}$, dB(A)	$L_{10,15min}$, dB(A)	$L_{90,15min}$, dB(A)
10 March 2016	17:00 – 17:15	58	65	60	55

B2.6 Derivation of the NSW INP Project Specific Criterion

Noise Sensitive Receiver	Classification	Time Period	Intrusiveness Criterion dB$L_{Aeq,15min}$	Amenity Criterion dB$L_{Aeq,period}$	Project Specific Criterion
10 Lincoln Crescent (Location 2A)	Residential	Day	55	58	54 dB $L_{Aeq,\ 15min}$
		Evening	55	44	44 dB $L_{Aeq,\ Evening}$
		Night	49	41	41 dB $L_{Aeq,\ Night}$
9-31 Lincoln Crescent (Location 3)	Residential	Day	59	54	54 dB $L_{Aeq,\ Day}$
		Evening	58	48	48 dB $L_{Aeq,\ Evening}$
		Night	47	45	45 dB $L_{Aeq,\ Night}$
Botanic Garden	Passive recreation	When in use	-	50	50 dB $L_{Aeq,\ period}$
Domain	Active recreation	When in use	-	50	50 dB $L_{Aeq,\ period}$