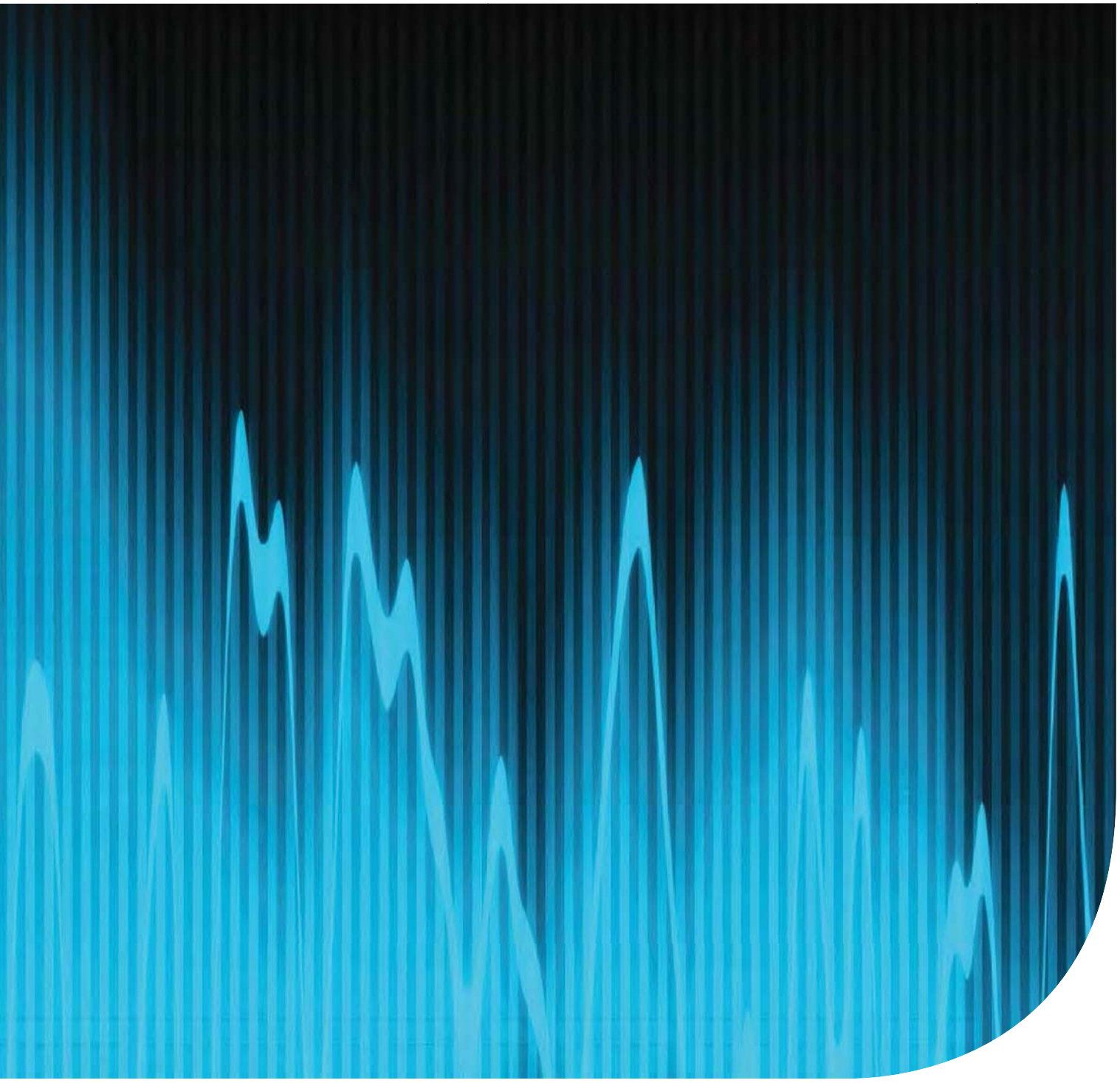
Noise and vibration impact assessment

Lot 23 & 24 Hollinsworth Road Masterplan, Marsden Park

Prepared for Logos Property Pty Ltd | 8 December 2017



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Noise and vibration impact assessment

Final

Report J17164RP1 | Prepared for Logos Property Pty Ltd | 8 December 2017

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1 Introduction

1.1 Overview

EMM consulting Pty Ltd (EMM) has been engaged by Logos Property Group (Logos) to prepare a noise and vibration impact assessment (NVIA) to accompany a development application for the proposed industrial warehouse estate (the project) at Lot 23 and Lot 24 on Hollinsworth Road, Marsden Park, NSW.

A development application for the project is being prepared to be lodged with Blacktown City Council (council). The following key issues are addressed as part of the assessment for the development application:

- existing acoustic environment at nearest sensitive receivers;
- potential operational noise impacts at nearest sensitive receivers;
- review of construction noise and vibration emissions; and
- road noise impacts associated with the project.

The NVIA has been prepared with reference to the following noise policies, plans, guidelines and standards:

- Blacktown Development Control Plan 2015;
- NSW Environment Protection Authority (EPA), Industrial Noise Policy (EPA 2000);
- NSW Environment Protection Authority (EPA), Road Noise Policy (EPA 2011);
- NSW Department of Environment and Climate Change (DECC), Interim Construction Noise Guideline (DECC 2009); and
- Australia Standard AS 1055-1997 *Acoustics - Description and Measurement of Environmental Noise*.

The NVIA was prepared in accordance with the requirements of the NSW Department of Planning and Environment (DPE). These were set out in the Secretary's Environmental Assessment Requirements (SEARs) for the project, issued on 4 August 2017. Table 1.1 lists the individual requirements relevant to this NVIA as identified in the SEARs, and shows where they are addressed in this report.

Table 1.1 Relevant SEARs

DPE requirement	Section of the report
• a description of the existing environment, using sufficient baseline data	Section 3.2
• a description of all potential noise and vibration sources during the construction and operational phases of the development, including on and off-site traffic noise and external mechanical plant;	Section 5.2 to Section 5.7
• a quantitative noise impact assessment, including a cumulative noise impact assessment in accordance with relevant Environment Protection Authority guidelines; and	Section 5.4, Section 5.6
• details of noise mitigation, management and monitoring measures.	Section 5.4, Section 5.5, Section 6.1 and Section 6.2
• The report should address noise attenuation for 24 hour truck operations on the sleep disturbance criteria of the residents between 10 pm and 7 am.	Section 5.5 and Section 6.1

To inform preparation of the SEARs, DPE invited other government agencies to recommend matters to be addressed in the EIS. These matters were taken into account by the Secretary for DPE when preparing the SEARs. Copies of the government agencies' advice to DPE were attached to the SEARs. However, no additional matters were recommended in regards to noise and vibration.

Several technical terms are required for the discussion of noise and vibration. These are explained in Appendix A.

2 Project overview

2.1 Site description

The project site is located off Hollinsworth Road in Marsden Park, on Lot 23 and Lot 24 of DP262886 which covers an area of 203,844 m^2 (or 21.12 ha).

The site is currently vacant and was previously used for rural/agricultural land.

The project site is located within the Marsden Park Industrial Precinct which is an Industrial zone as per the Blacktown City Council Growth Centre Precincts Development Control Plan. Several industrial and commercial developments surround the site. To the immediate north of the project site is a caravan accommodation facility on industrial zoned land. Further north is a landfill operation. To the north-east and east of the site are bulky goods, retail and other commercial and light industrial land uses, with some still in construction. Immediately south of the site is a road corridor (proposed Castlereagh Freeway) which provides a buffer zone of approximately 120 m between the site and residences of Bidwill and Hassall Grove.

2.2 Project description

The project will primarily comprise warehouses with loading dock facilities, hardstand areas, internal access roads, car parking spaces, office spaces, and landscaped garden areas. Site access will be via Hollinsworth Road along the north of the site. A westward extension of the current Hollinsworth Road is also proposed for site access to the western buildings. The project will include the construction and operation of nine warehouses, carpark spaces and offices within the following areas:

- Building 1A - 11,761 m^2;
- Building 1B - 11,761 m^2;
- Building 2A - 17,277 m^2;
- Building 2B - 16,363 m^2;
- Building 3 - 62,453 m^2;
- Building 4 - 7,878 m^2;
- Building 5 - 13,069 m^2;
- Building 6 - 25,560 m^2; and
- Building 7 - 23,795 m^2.

The project will operate 24 hours a day seven days a week. General operations on site would include pallet handling and truck movements. Noise emissions from patrons' traffic movements and mechanical plant (eg air conditioning units) are also considered in the assessment. It is anticipated that on-site trucking activities will be the dominant noise source from operation of the site.

The masterplan layout for the project is provided in Appendix B.

The project is proposed to be completed in four stages with construction activities expected to commence in April 2018 and continue until early 2020. Operation (lease) is expected to start as early as late 2018. The project staging masterplan is provided in Appendix C and described as follows:

- Stage 1 - Building 5 and Building 7: Construction commence April 2018, lease commence October 2018;
- Stage 2 - Building 4 and Building 6: Construction commence October 2018, lease commence May 2019;
- Stage 3 - Building 3: Construction commence April 2019, lease commence January 2020; and
- Stage 4 - Building 1 and Building 2: Construction commence October 2019, lease commence June 2020.

3 Existing acoustic environment

3.1 Assessment locations

Several assessment locations surrounding the project have the potential to be impacted by future site noise. Table 3.1 presents the nearest representative assessment locations to the project site.

Table 3.1 Assessment locations and coordinates (MGA 56)

Assessment location	Address	Easting	Northing
R1 – Caravan park	140 Hollinsworth Road, Marsden Park	299031	6266579
R2 – Residence	105 Stockholm Avenue, Hassall Grove	299397	6266074
R3 – Residence	85 Stockholm Avenue, Hassall Grove	299233	6266093
R4 – Residence	67B Stockholm Avenue, Hassall Grove	299065	6266115
R5 – Residence	9 Amelia Way, Bidwill	298963	6266091
R6 – Residence	11 Pine Crescent, Bidwill	298772	6266116
R7 – Residence	5 Ramosus Way, Bidwill	298540	6266145
R8 – Baitul Huda Mosque	45 Hollinsworth Road, Marsden Park	300120	6266158

Assessment location R1 (caravan park) is located within an industrial zone as per the Blacktown City Council Growth Centre Precincts Development Control Plan. Therefore, this location will be assessed as 'isolated residences' within an industrial zone in accordance with the INP.

Where compliance is demonstrated at assessment locations listed in Table 3.1, compliance is expected at all other surrounding receivers.

3.2 Ambient noise survey

3.2.1 Unattended noise monitoring

To establish the existing ambient noise environment of the area, unattended noise monitoring was conducted at one location representative of residential receivers surrounding the project, as described in Table 3.2. The unattended monitoring locations along with the assessment locations are shown in Figure 3.1.

Table 3.2 Noise logging location

Location ID	Address	Easting	Northing
Location 1 (L1)	Amelia Way, Bidwill	298996	6266092

Noise monitoring was conducted in general accordance with the procedures described in Australian Standard AS 1055-1997 *Acoustics - Description and Measurement of Environmental Noise*.

The unattended logging was carried out using one Type 1 environmental noise logger EL-215 (S/N 194447) from 11 to 21 August 2017. Calibration of instrumentation was checked prior to and following the logging. All equipment carried appropriate and current NATA (or manufacturer) calibration certificates.

Data affected by adverse meteorological conditions has been excluded from the results in accordance with methodologies provided in the INP. The Rating Background noise Levels (RBL) and ambient noise levels (L_{Aeq}) derived from long term noise monitoring are summarised in Table 3.3. Daily noise data and charts are provided in Appendix D. The measurement data was analysed in accordance with the INP, using weather data from the Bureau of Meteorology's (BoM) Horsley Park station (ID 067119).

Table 3.3 Summary of measured background and ambient noise levels

Location ID	RBL, dB(A)			Ambient (L_{Aeq}) noise level, dB		
	Day	Evening	Night	Day	Evening	Night
L1	37	35	31	57	45	43

Notes: 1. Measured noise levels exclude data affected by adverse weather as per the INP.

2. Day is from 7 am to 6 pm Monday to Saturday, and from 8 am to 6 pm on Sundays and public holidays; Evening is from 6 pm to 10 pm; Night is the remaining periods.

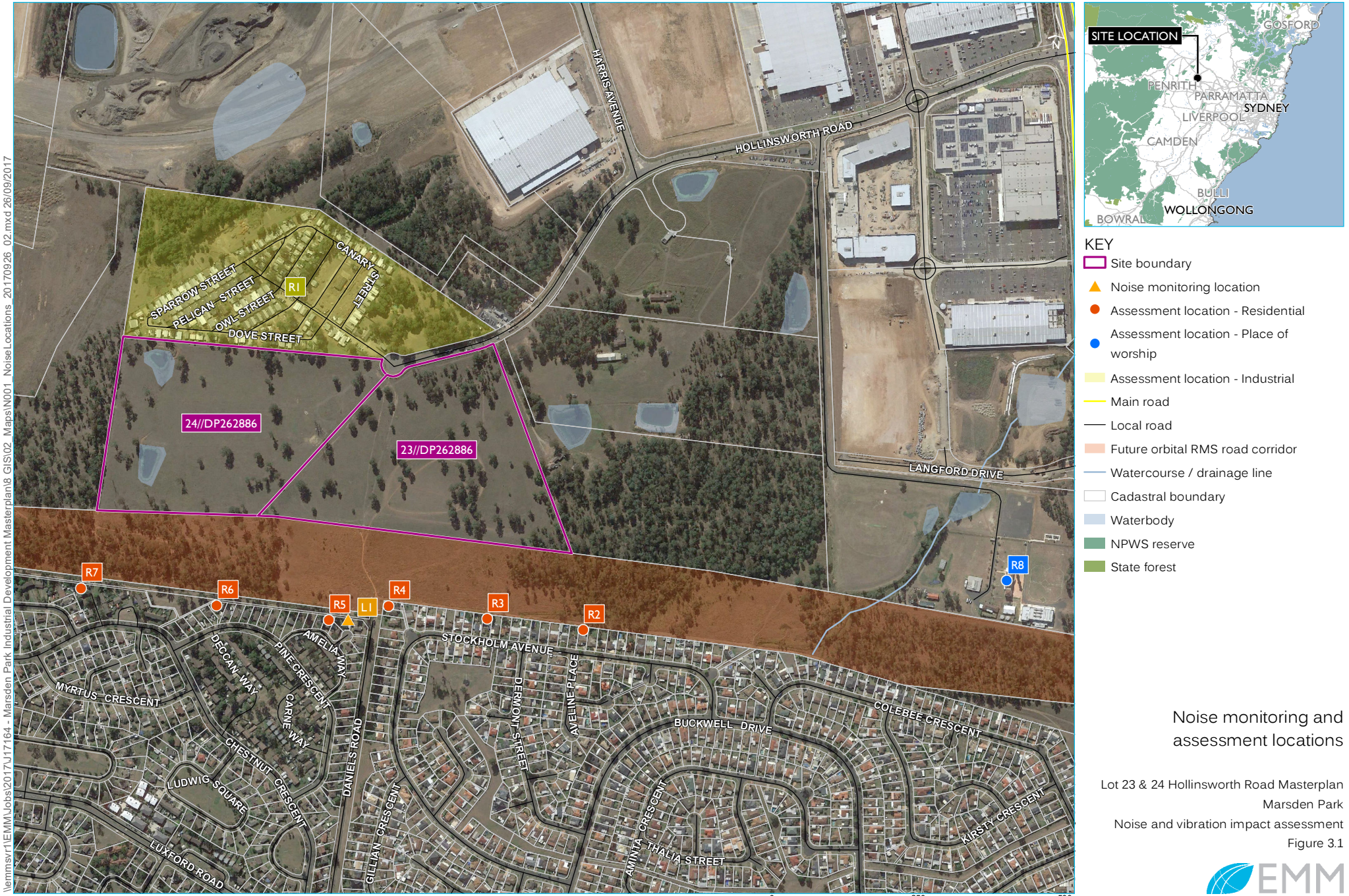
3.2.2 Attended noise measurements

To qualify the unattended monitoring results, a 15-minute operator-attended noise measurement was completed at the logger location. The attended monitoring results are presented in Table 3.4.

The attended monitoring results indicate that the noise environment at L1 was dominated by noise sources typical to suburban areas, including human activity. Industrial noise sources were not discernible during the measurement at L1.

Table 3.4 Attended noise monitoring results

Location	Start time	Measured noise levels, dB			Comments
		$L_{Aeq(15min)}$	L_{A90}	L_{Amax}	
L1	15:27	61	38	81	Noise environment dominated by suburban sources (eg barking dogs, music and human activity).



KEY

- Site boundary
- Noise monitoring location
- Assessment location - Residential
- Assessment location - Place of worship
- Assessment location - Industrial
- Main road
- Local road
- Future orbital RMS road corridor
- Watercourse / drainage line
- Cadastral boundary
- Waterbody
- NPWS reserve
- State forest

Source: EMM (2017); DFSI (2017); LPI (2015); GA (2015); Google Earth (2016)

0 250 500 m

GDA 1994 MGA Zone 56

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Noise monitoring and assessment locations

Lot 23 & 24 Hollinsworth Road Masterplan
Marsden Park
Noise and vibration impact assessment
Figure 3.1

EMM

3.3 Prevailing weather conditions

Noise propagation over distance can be significantly affected by weather conditions. Of most interest are source to receiver winds, the presence of temperature inversions and drainage flow effects, as these conditions can enhance received noise levels. To account for these phenomena, the INP specifies meteorological analysis procedures to determine the prevalent weather conditions.

3.3.1 Prevailing winds

The INP recommends consideration of wind effects if they are a “feature” of the area. The INP defines “feature” as the presence of source-to-receiver winds at speeds up to 3 m/s (measured at 10 m above ground level) and occurring for 30% of the time or more in any assessment period and season.

This is further clarified by defining source-to-receiver wind direction as being the directional component of wind. The INP states that where wind is identified to be a feature of the area then assessment of noise impacts should consider the highest wind speed below 3 m/s, which is considered to prevail for at least 30% of the time.

A thorough review of the vector components of the 15-minute wind data was undertaken using 5 years of data (2012-2017) from the BoM's Horsley Park Station (ID 067119). The analysis shows that the frequency of occurrence of winds up to 3 m/s triggered the 30% INP assessment requirement for all assessment periods (ie day, evening and night). Prevailing winds adopted for the noise modelling are discussed later in this report. Results of the prevailing weather analysis are provided is Appendix E.

3.3.2 Temperature inversions

Temperature inversions (ie where atmospheric temperature increases with altitude) typically occur during the night-time period in the winter months and can also increase (ie focus) noise levels at surrounding assessment locations. As per the INP, temperature inversions are to be assessed when they are found to occur for 30% of the time (about two nights per week) or greater during the winter months. The INP also states that the assessment of the impact of temperature inversions be confined to the night-time noise assessment period where temperature inversions generally occur.

The frequency of temperature inversions was determined based on sigma-theta data obtained from the BoM’s Horsley Park Station. Analysis of the data found that temperature inversion conditions may occur for 30% or more during the night-time period and, as such, have been considered in the modelling and assessment of noise emissions for the night-time period.

3.3.3 Drainage flow winds

The INP states that a default wind drainage value should be applied where sources are at a higher altitude than the assessment location with no intervening topography. All assessment locations are at a similar or higher elevation than the subject site. Therefore, drainage flow winds are not relevant and have not been adopted in this assessment.

3.3.4 Assessed meteorological conditions

The noise modelling has adopted the meteorological conditions shown in Table 3.5.

Table 3.5 Meteorological conditions adopted for the noise modelling

Assessment period	Meteorological condition	Air temperature	Relative humidity	Wind speed[1]	Wind direction[2]	Stability category
Day	Calm	20°C	70%	0 m/s	n/a	D class
	Winds	20°C	70%	1.9 m/s	292.5° to 315°	D class
Evening	Calm	10°C	90%	0 m/s	n/a	D class
	Winds	10°C	90%	2.4 m/s	67.5° to 292.5°	D class
Night	Calm	10°C	90%	0 m/s	n/a	D class
	Winds	10°C	90%	2.5 m/s	157.5° to 315°	D class
	Temperature inversion	10°C	90%	0 m/s	n/a	F class

Notes: 1. Based on the 10th percentile wind speed of all winds present for 30% of the time during the relevant period.

2. Wind direction is in degrees from North (0°).

4 Criteria

4.1 Blacktown City Council Growth Centre Precincts Development Control Plan

Schedule 3 of the Blacktown City Council Growth Centre Precincts Development Control Plan (BCC Growth Centre DCP) provides general guidance for all development proposed adjacent to the existing caravan park (referred as assessment location R1 in this report) to ensure that the boundary between industrial development and the Caravan Park is not dominated by noise generating activities. Section 5.1.3 of the BCC Growth Centre DCP provides the following objectives and control measures:

> **Objectives**
>
> To minimise impacts from industrial development on the existing Caravan Park.
>
> To provide for a landscaped buffer between industrial development and the existing Caravan Park.
>
> To ensure the boundary between industrial development and the Caravan Park is not dominated by over-shadowing or noise generating activities.
>
> **Control**
>
> 1. In addition other provisions that may apply to development contained in this DCP, the following provisions apply to all development adjacent to the existing Caravan Park.
>
> 2. A minimum 20 metre buffer zone is to be provided between the Caravan Park boundary and any industrial development.
>
> 3. The buffer zone is to include high quality landscaping.
>
> 4. Employee car parking, storage and other non-intrusive uses are permitted within the buffer zone. Noise generating activities are not permitted within the buffer zone.
>
> 5. If the Caravan Park ceases to continuing operating as a business, Clause 5.1.3 will no longer apply.

4.2 Industrial noise criteria

The NSW EPA's Industrial Noise Policy (INP) stipulates guidelines for the assessment of noise from the operation of industrial facilities. The main objectives of the policy are to protect the community from excessive intrusive noise, and to preserve the amenity for specific land uses. In order to do so the INP provides two criteria to assess industrial noise sources, namely, the intrusiveness criteria and the amenity criteria.

4.2.1 Intrusive criteria

The intrusiveness criterion requires that the $L_{Aeq(15min)}$ noise levels from the newly-introduced source during each of the day, evening and night time periods do not exceed the existing rating background noise levels (RBL) by more than 5 dB at noise sensitive receivers. Table 4.1 shows the derived intrusive criteria for the project. Intrusive criteria do not apply at isolated receivers located within an industrial zone as defined in an LEP (R1), or at places of worship (R8) in accordance with Section 2 the INP (EPA 2000).

Table 4.1 Intrusiveness criteria

Assessment location	Address	$L_{Aeq(15min)}$ noise level criteria, dB		
		Day	Evening	Night
R1 - Caravan park[2]	140 Hollinsworth Road, Marsden Park	N/A	N/A	N/A
R2	105 Stockholm Avenue, Hassall Grove	42	40	36
R3	85 Stockholm Avenue, Hassall Grove	42	40	36
R4	67B Stockholm Avenue, Hassall Grove	42	40	36
R5	9 Amelia Way, Bidwill	42	40	36
R6	11 Pine Crescent, Bidwill	42	40	36
R7	5 Ramosus Way, Bidwill	42	40	36
R8 - Baitul Huda Mosque[3]	45 Hollinsworth Road, Marsden Park	N/A	N/A	N/A

Notes: 1. Day is from 7 am to 6 pm Monday to Saturday, and from 8 am to 6 pm on Sundays and public holidays; Evening is from 6 pm to 10 pm; Night is the remaining periods.

2. Within an industrial zone as per the BCC Growth Centre DCP, therefore intrusive criteria are not applicable in accordance with Section 2 of the INP (EPA 2000).

3. Places of worship are assessed against the amenity criteria, therefore intrusive criteria are not applicable.

4.2.2 Amenity criteria

The INP stipulates acceptable and maximum noise levels from all industry consistent with maintaining amenity for specific land uses. The acceptable target noise levels are presented in Table 4.2 for each assessment period and for specific surrounding land uses. Assessment location R1 (caravan park) is located within the Marsden Park Industrial Precinct which is listed as an Industrial zone as per the BCC Growth Centre DCP, and therefore the industrial amenity criteria apply at this location in accordance with Section 2 of the INP (EPA 2000). For the receivers located to the south of the project site (R2-R7), the 'suburban' amenity category has been conservatively adopted. Noise goals for places of worship apply to R8 (Baitul Huda Mosque).

Table 4.2 Noise amenity goals for specific land uses

Land use	Acceptable amenity $L_{Aeq(period)}$ noise levels, dB		
	Day	Evening	Night
Industrial (R1 - Caravan park)[2]	70	70	70
Suburban (R2-R7)	55	45	40
Places of worship - internal (R8)	40 (when in use)		

Notes: 1. Day is from 7 am to 6 pm Monday to Saturday, and from 8 am to 6 pm on Sundays and public holidays; Evening is from 6 pm to 10 pm; Night is the remaining periods.

2. Within an industrial zone as per the BCC Growth Centre DCP, therefore industrial noise criteria are applicable in accordance with Section 2 of the INP (EPA 2000).

4.2.3 Project specific noise levels

Table 4.3 summarises the project specific noise levels (PSNLs) derived from the more stringent of the intrusive and amenity criteria. As existing industrial noise for the site is minimal, no adjustment to the amenity target is required as per the INP. The difference between internal and external noise levels is typically 10 dB with windows open. For assessment location R8, this corresponds to an external level of 50 dB.

Table 4.3 Project specific noise levels

Assessment location	Period	RBL, dB	Intrusiveness $L_{Aeq(15min)}$, dB	Amenity $L_{Aeq(period)}$, dB	PSNL, dB
R1	Day	N/A	N/A	70	70 $L_{Aeq(period)}$
	Evening	N/A	N/A		
	Night	N/A	N/A		
R2-R7	Day	37	42	55	42 $L_{Aeq(15min)}$
	Evening	35	40	45	40 $L_{Aeq(15min)}$
	Night	31	36	40	36 $L_{Aeq(15min)}$
R8	Day	N/A	N/A	40 (internal) [2]	50 $L_{Aeq(period)}$ [3]
	Evening	N/A	N/A		
	Night	N/A	N/A		

Notes: 1. Day is from 7 am to 6 pm Monday to Saturday, and from 8 am to 6 pm on Sundays and public holidays; Evening is from 6 pm to 10 pm; Night is the remaining periods.

2. Criteria applicable when in use.

3. The difference between internal and external noise levels is 10 dB with windows open.

4.3 Sleep disturbance

The INP criteria described in Section 4.2, which consider the average noise emission of a source over 15 minutes, are appropriate for assessing noise from continuous and intermittent sources, such as engine noise from road trucks, mobile plant and other equipment. Noise from transient (impact) sources (eg reversing beepers or heavy items being dropped) is also required to be assessed, however the L_{Aeq} noise level from transient sources would not be representative since the noise in question may not be present for much of the time. Hence, the above INP criteria are not appropriate to assess the potential impact from this type of noise. The most important effect of transient noise is the potential to cause sleep disturbance at sensitive receivers. The INP Application Notes indicate that to prevent sleep disturbance, the $L_{A1(1min)}$ noise level from an intrusive source should not exceed the background noise level by more than 15 dB.

It is noted that this criterion does not take account of more recent research of the effects on sleep of road traffic noise. The EPA's Road Noise Policy (RNP) (2011) indicates that maximum noise levels below 50 to 55 dB(A) inside residences from road traffic sources are unlikely to cause awakening reactions. The difference between internal and external noise levels is 10 dB with windows open, and hence this corresponds to an external maximum noise level of approximately 60 to 65 dB(A). In our experience, adopting the former more stringent criterion (ie RBL + 15 dB) would be desirable in the first instance, however if exceedances are predicted, consideration should be given to the frequency of such events and the more recent research above.

On this basis, the maximum ($L_{A1(1min)}$) noise level from site related operations should not exceed the levels shown in Table 4.4 during the night period.

Table 4.4 Sleep disturbance noise criteria (night period)

Assessment location	Sleep disturbance $L_{A1(1min)}$ criteria [1], dB
R2-R7	46

Notes: 1. Criteria are assessable at the façade of the most affected sleeping area.

4.4 Construction noise criteria

The Interim Construction Noise Guideline (ICNG) provides guidelines for the assessment and management of noise from construction works. The ICNG recommends a quantitative approach for projects where construction is anticipated to occur for greater than three weeks in duration. The ICNG suggests the following time restriction for construction activities where noise is audible at residential premises:

- Monday to Friday 7 am - 6 pm;
- Saturday 8 am - 1 pm; and
- No construction work is to take place on Sundays or public holidays.

Table 4.5 has been reproduced from Table 2 of the ICNG and provides noise management levels for residential receivers for standard hours and out of hours (OOH) periods.

Table 4.5 ICNG residential criteria

Time of day	Management level $L_{Aeq(15min)}$ [1]	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm. No work on Sundays or public holidays	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured LAeq(15min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dB	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: i) 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; and ii) if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours (OOH)	Noise affected RBL + 5 dB	• 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.

Table 4.5 ICNG residential criteria

Time of day	Management level $L_{Aeq(15min)}$ [1]	How to apply
		• Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2.

Notes: 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.

In summary, the ICNG noise management levels for construction activities during standard hours are 10 dB above the existing background levels. For OOH activities, the noise management levels should be no more than 5 dB above the existing background levels.

Table 4.6 presents ICNG noise management levels for other land uses.

Table 4.6 ICNG noise management levels at other land uses

Land use	Management level, $L_{Aeq(15\text{-}min)}$
Industrial premises	External noise level 75 dB (when in use)[1]
Place of worship	Internal noise level 45 dB (when in use)[2]

Notes: 1. Apply at the most affected point occupied point of the premises.

2. Apply at the most affected point within 50 m of the area boundary.

The noise management levels (NMLs) for residential assessment locations have been developed using the noise monitoring data provided in Section 3. For other land uses, the NMLs were determined in accordance with the ICNG. It is assumed that construction hours for the project will be limited to standard hours as defined in Table 4.5. Adopted NMLs for all assessment locations are provided in Table 4.7. The difference between internal and external noise levels is 10 dB with windows open. For assessment location R8, this corresponds to an external level of 55 dB.

Table 4.7 Adopted NMLs (standard hours)

Assessment location	NML, $L_{Aeq(15min)}$, dB
R1	75[1]
R2-R7	47
R8	55[2]

Notes: 1. Industrial criteria have been applied to isolated receivers within an industrial zone.

2. The difference between internal and external noise levels is 10 dB with windows open.

4.5 Construction vibration criteria

4.5.1 Human comfort – Assessing vibration a technical guideline

Environmental Noise Management – Assessing Vibration: a technical guideline (DEC 2006) is based on guidelines contained in *BS 6472 – 2008, Evaluation of human exposure to vibration in buildings (1-80Hz).*

The guideline presents preferred and maximum vibration values for use in assessing human responses to vibration and provides recommendations for measurement and evaluation techniques. At vibration values below the preferred values, there is a low probability of adverse comment or disturbance to building occupants. Where all feasible and reasonable mitigation measures have been applied and vibration values are still beyond the maximum value, it is recommended the operator negotiate directly with the affected community.

The guideline defines three vibration types and provides direction for assessing and evaluating the applicable criteria. Table 2.1 of the guideline provides examples of the three vibration types and has been reproduced in Table 4.8.

Table 4.8 Examples of types of vibration

Continuous vibration	Impulsive vibration	Intermittent vibration
Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).	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.	Trains, intermittent nearby 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 these would be assessed against impulsive vibration criteria.

The most relevant to the proposed construction activities are continuous and intermittent vibration and these are discussed further in the following sections.

i Continuous vibration

Appendix B of the guideline outlines acceptable criteria for human exposure to continuous vibration (in the range 1 Hz to 80 Hz). The criteria are dependent on both the time of activity (usually daytime or night-time) and the occupied place being assessed. Table 4.9 reproduces the preferred and maximum criteria relating to measured peak velocity.

Table 4.9 Criteria for exposure to continuous vibration

Place	Time	Peak velocity (mm/s)	
		Preferred	Preferred
Critical working Areas (eg hospital operating theatres, precision laboratories)	Day or night-time	0.14	0.28
Residences	Day	0.28	0.56
	Night-time	0.20	0.40

Table 4.9 Criteria for exposure to continuous vibration

Place	Time	Peak velocity (mm/s)	
		Preferred	Preferred
Offices	Day or night-time	0.56	1.1

Notes: *1. Root mean square velocity (mm/s) and vibration velocity value (dB re 10^{-9} mm/s).*

2. Values given for most critical frequency >8 Hz assuming sinusoidal motion.

ii Intermittent vibration

Intermittent vibration (as defined in Section 2.1 of the guideline) is assessed using the vibration dose concept which relates to vibration magnitude and exposure time.

Intermittent vibration is representative of activities such as impact hammering, rolling or general excavation work (eg an excavator tracking).

Section 2.4 of the guideline provides acceptable values for intermittent vibration in terms of vibration dose values (VDV) which requires the measurement of the overall weighted root mean square (RMS) acceleration levels over the frequency range 1 Hz to 80 Hz. To calculate VDV the following formula (refer *section 2.4.1* of the guideline) was used:

$$VDV = \left[\int_0^T a^4(t)dt\right]^{0.25}$$

Where VDV is the vibration dose value in $m/s^{1.75}$, *a (t)* is the frequency-weighted RMS of acceleration in m/s^2 and *T* is the total period of the day (in seconds) during which vibration may occur.

The acceptable Vibration Dose Values (VDV) for intermittent vibration are reproduced in Table 4.10.

Table 4.10 Acceptable vibration dose values (VDV) for intermittent vibration (m/s 1.75)

Location	Daytime		Night-time	
	Preferred value, $m/s^{1.75}$	Maximum value, $m/s^{1.75}$	Preferred value, $m/s^{1.75}$	Maximum value, $m/s^{1.75}$
Critical Areas	0.10	0.20	0.10	0.20
Residences	0.20	0.4	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

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

2. These criteria are indicative only, and there may be a need to assess intermittent values against continuous or impulsive criteria for critical areas.

There is a low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values. Adverse comment or complaints may be expected if vibration values approach the maximum values. The guideline states that activities should be designed to meet the preferred values where an area is not already exposed to vibration.

4.5.2 Structural vibration criteria

Structural vibration should be assessed at the foundation of a building structure. The German Standard *DIN 4150 - Part 3: 1999* (DIN 4150) provides guideline levels of vibration velocity for evaluating the effects of vibration in structures. The limits presented in this standard are generally recognised to be conservative.

The DIN 4150 values (maximum levels measured in any direction at the foundation, or maximum levels measured in (x) or (y) horizontal directions, in the plane of the uppermost floor), are summarised in Table 4.11 and shown graphically in Figure 4.1 in the case of foundation levels. For residential and commercial type structures, the standard recommends safe limits as low as 5 mm/s and 20 mm/s respectively. These limits increase with frequency values above 10 Hz. The operational frequency of construction plant typically ranges between 10 Hz to 30 Hz, and hence according to DIN 4150, the safe vibration criteria range for dwellings is 5 to 15 mm/s. For reinforced commercial type buildings the limit range is 20 to 40 mm/s.

Table 4.11 Structural damage guideline values of vibration velocity – DIN 4150

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

Notes: 1. "Line" refers to curves in Figure 1 of DIN 4150.

2. For frequencies above 100 Hz the higher values in the 50 Hz to 100 Hz column should be used.

These levels are 'safe limits', for which damage due to vibration effects is unlikely to occur. 'Damage' is defined in DIN 4150 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls.

Should such damage be observed without vibration levels exceeding the safe limits then it is likely to be attributable to other causes. DIN 4150 also states that when vibration levels higher than the safe limits are present, it does not necessarily follow that damage will occur.

As indicated by the criteria in Table 4.11, high frequency vibration has less potential to cause damage than lower frequencies. Furthermore, the 'point source' nature of vibration from plant causes the vibratory disturbances to arrive at different parts of nearby large structures in an out-of-phase manner, thereby reducing its potential to excite in-phase motion of the low order modes of vibration in such structures.

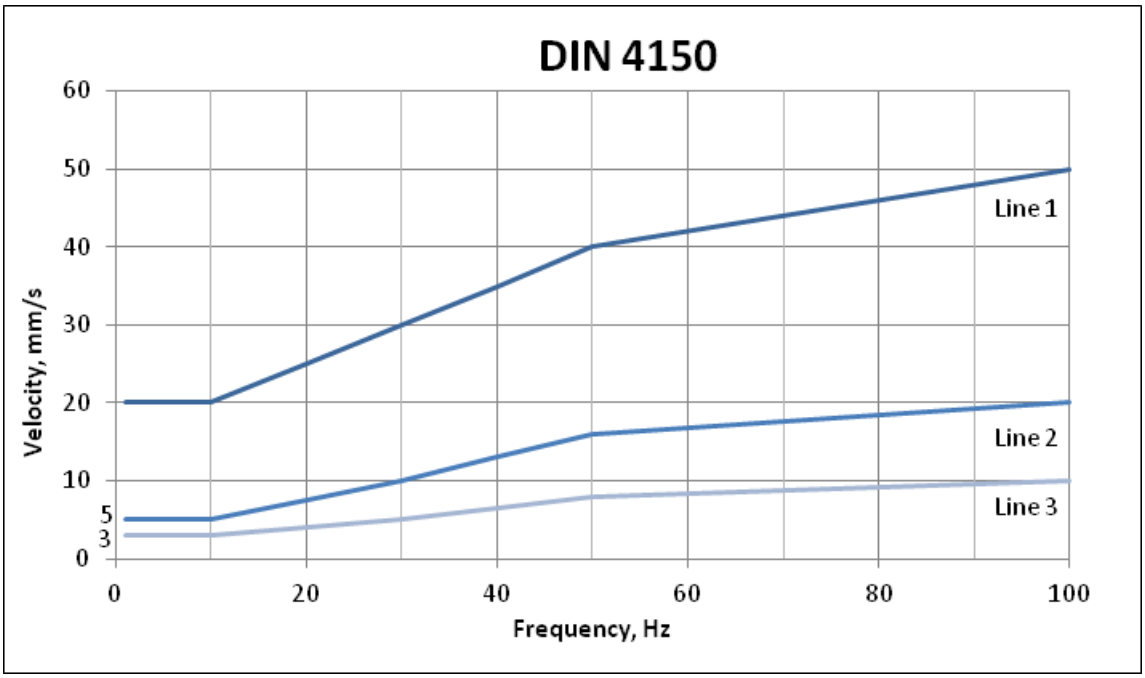


Figure 4.1 DIN 4150 Structural vibration safe limits for buildings

4.5.3 Ground-borne noise

Ground-borne noise is noise generated by vibration transmitted through the ground into a structure. The ICNG provides guidance on the assessment of ground-borne noise and relevant internal noise levels for the evening and night-time periods above which management actions should be implemented.

The proposed construction works are not expected to occur during the evening or night periods, and as such, ground-borne noise impacts are not expected at the nearest assessment locations.

4.6 Road traffic noise

The potential impacts of traffic noise resulting from site related traffic on public roads are assessed against criteria defined in the RNP.

Site related traffic comprising road trucks and light vehicles will use routes that currently experience relatively heavy traffic and part of the broader road network. Access to the project site will be via Hollinsworth Road which does not include residences. Hollinsworth Road is proposed to be extended westward to provide access to warehouse buildings west of the site (refer to Appendix B). Furthermore, Hollingsworth Road is planned to be extended further west to join South Street as part of a future road network servicing the Marsden Park Industrial Precinct, and therefore is considered a public road and not part of the project site.

In accordance with the RNP, this assessment has adopted a sub-arterial road type for Hollinsworth Road and its proposed extension. Table 4.12 presents the road noise assessment criteria reproduced from Table 3 of the RNP (EPA 2011).

Table 4.12 Road traffic noise assessment criteria for residential land uses

Road category	Type of project/development	Assessment criteria, dB	
		Day (7 am to 10 pm)	Night (10 pm to 7 am)
Freeway/arterial/ sub-arterial	Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments.	$L_{Aeq(15hr)}$ 60 (external)	$L_{Aeq(9hr)}$ 55 (external)

Additionally, the RNP states where existing road traffic noise criteria are already exceeded, any additional increase in total traffic noise level should be limited to 2 dB, which is generally accepted as the threshold of perceptibility to a change in noise level.

In addition to meeting the assessment criteria, any significant increase in total traffic noise at assessment locations must be considered. Table 4.13 presents the relative increase assessment criteria reproduced from Table 6 of the RNP (EPA 2011). Assessment locations experiencing increases in total traffic noise levels above those outlined in Table 4.13 should be considered for mitigation.

Table 4.13 Relative increase criteria for residential land uses

Road category	Type of project/development	Total traffic noise level increase, dB	
		Day (7 am to 10 pm)	Night (10 pm to 7 am)
Freeway/arterial/ sub-arterial roads and transitways	New road corridor/redevelopment of existing road/land use development with the potential to generate additional traffic on existing road.	Existing traffic $L_{Aeq(15hr)}$+12 dB (external)	Existing traffic $L_{Aeq(9hr)}$+ 12 dB (external)

5 Assessment

5.1 Noise modelling methodology

This section presents the methods and parameters used to model noise emissions from the project.

Noise modelling was undertaken based on three-dimensional digitised ground contours of the project area and surrounding land. Noise predictions were carried out using Brüel and Kjær Predictor Version 11 (Predictor) noise prediction software. Predictor calculates total noise levels at assessment locations from the concurrent operation of multiple noise sources. The model considers factors such as:

- the lateral and vertical location of noise sources;
- activity to assessment location distances;
- ground effects;
- atmospheric absorption; and
- surrounding topography.

5.2 Construction noise

Construction activity associated with the project will include earthworks and building construction. A list of plant and equipment proposed for use during construction of the project and representative sound power levels adopted in the noise modelling are summarised in Table 5.1. All plant and equipment were assumed to be working simultaneously and at full power, and therefore this assessment should be considered conservative.

Table 5.1 Plant and equipment and sound power levels

Plant and equipment	Sound power level, dB	Quantity
Dump truck	106	5
Dozer	113	2
Scraper	106	1
Excavator (30 tonne)	109	4
Crane	105	2

The predicted noise levels from typical construction activities during calm and prevailing worst case winds are presented in Table 5.2. The results show that construction noise levels will satisfy the relevant NMLs at R1 and R8 during worst case weather conditions. During calm conditions, construction noise levels are also predicted to satisfy the NML at R2. During worst case winds, construction noise levels are predicted to be marginally (up to 2 dB) above the NMLs at R2 and R7, and moderately (3 to 5 dB) above the NMLs at R3, R5 and R6. At R4, construction noise levels are predicted to be higher again (up to 6 dB) above the NML during worst case winds. It is noted that construction is temporary and exceedances are common and are best addressed through management.

Construction noise levels are predicted to remain well below the highly noise affected criterion of 75 dB during worst case weather conditions at all residences.

Table 5.2 Predicted construction noise levels (standard hours)

Assessment location	Predicted $L_{Aeq(15min)}$ construction noise level, dB		NML, dB(A)	Exceedance, dB	
	Calm	Worst case winds		Calm	Worst case winds
R1[1]	57	57	75	Nil	Nil
R2	47	49	47	Nil	**2**
R3	50	52	47	**3**	**5**
R4	51	53	47	**4**	**6**
R5	51	52	47	**4**	**5**
R6	50	51	47	**3**	**4**
R7	48	48	47	**1**	**1**
R8[2]	38	41	45 (internal)	Nil	Nil

Notes: 1. Industrial criteria apply.

2. Place of Worship criteria apply when in use.

The project is proposed to develop westward from the eastern site boundary with construction and operation activities expected to overlap following the completion of Stage 1 construction, through to completion of Stage 4 construction. Hence, construction and operational activities are expected to occur concurrently during this time (refer to Appendix C for the project staging masterplan). A review of site noise levels from concurrent construction and operation activities during standard construction hours was completed. Site noise levels during operation when site is fully operational (refer to Table 5.3) are predicted to be much lower than during construction (refer to Table 5.2). Further, it is anticipated that operational noise levels during the earlier stages of the project (prior to construction being fully completed) will be lower than during full operation (refer to results in Table 5.3). Given these, it is anticipated that site noise levels from daytime operation in the early stages of the project are unlikely to cause in increase in site noise levels during any stage of the construction phase and therefore concurrent noise impacts are unlikely.

Feasible and reasonable management and mitigation measures in relation to construction noise are discussed further in Section 6.2.

5.3 Construction vibration

As a guide, safe working distances for typical items of vibration intensive plant are listed in Table 5.3. The safe working distances are quoted for both “Cosmetic Damage” (refer to British Standard BS 7385) and “Human Comfort” (refer to British Standard BS 6472-1).

Table 5.3 Recommended safe working distances for vibration intensive plant

Plant Item	Rating/Description	Safe working distance	
		Cosmetic damage (BS 7385)	Human response (BS 6472)
Vibratory Roller	<50kN (Typically 1-2 tonnes)	5 m	15 to 20 m
	<100kN (Typically 2-4 tonnes)	6 m	20 m
	<200kN (Typically 4-6 tonnes)	12 m	40 m
	<300kN (Typically 7-13 tonnes)	15 m	100 m
	>300kN (Typically 13-18 tonnes)	20 m	100 m
	>300kN (>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

Source: Transport Infrastructure Development Corporation Construction's Construction Noise Strategy (Rail Projects (November 2007).

The safe working distances presented in Table 5.3 are indicative and will vary depending on the particular item of plant and local geotechnical conditions. They apply to cosmetic damage of typical buildings under typical geotechnical conditions.

In relation to human comfort (response), the safe working distances in Table 5.3 relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions are intermittent in nature and, for this reason, higher vibration levels occurring over shorter periods are allowed, as discussed in BS 6472-1.

The nearest building facades to the site are the residences within the Caravan Park (R1) located at least 25 m north of the site boundary. Therefore, it is envisaged that human response (rather than cosmetic damage to nearby structures) would be the most likely impact. It is difficult at this stage to predict the level of vibration that may occur at during the construction stage of the project. This is due to a number of variables including construction activities, plant location, operator behaviour and local geotechnical conditions. Therefore, in the first instance the guide values presented in Table 5.3 should be followed. Additional construction vibration management measures are presented in Section 6.2.

5.4 Operational noise

The proposed site will be used 24 hours a day 7 days a week. Night-time operating scenarios (eg possible decrease in vehicle movements at night) for each building have not been confirmed at this stage of the project, therefore this assessment has assumed that site operations will be consistent 24 hours a day 7 days a week. However, this is unlikely and therefore predicted operational noise levels are deemed to be conservative for the night period.

Site traffic access will be via Hollinsworth Road. The assessment was based on the masterplan drawings dated 10 October 2017, as provided by Logos (refer to Appendix B).

Operational noise sources from the project will comprise on-site traffic movements (light and heavy), sources within the buildings (eg forklifts) and mechanical plant (eg fans, air conditioning units). All noise sources were considered in the modelling, however it is anticipated that site noise will be dominated by on-site truck movement emissions.

Table 5.4 presents the warehouse floor area for each building and the approximate number of loading docks associated with the project.

Table 5.4 Proposed loading docks per warehouse

Building number and warehouse floor size	Number of loading docks[1]
Building 1A - 6,220 m^2	6
Building 1B - 6,245 m^2	6
Building 2A - 9,440 m^2	8
Building 2B - 9,440 m^2	8
Building 3 - 37,110 m^2	20
Building 4 - 3,235 m^2	4
Building 5 - 5,924 m^2	9
Building 6 - 11,140 m^2	11
Building 7 - 12,075 m^2	9
Total - 100,834 m^2	81

Notes: 1. Operational noise associated with warehouse activities are typically dominated by truck movements.

The noise modelling assumed that 4,652 site related traffic movements would occur throughout the site daily, including 18% of heavy vehicles. These numbers are consistent with the Traffic Impact Assessment prepared for the project. It has also been conservatively assumed that on-site traffic movements per 15-minute period (traffic movement rate) during the night period would be half (50%) of that during the day and evening periods.

It is noted that the project layout will result in on-site truck movements being shielded to surrounding assessment locations by adjoining buildings. Trucks driving to/from loading docks on the southern facade of Building 3 and eastern facade of Building 6 and Building 7 have been identified as acoustically significant sources for the project as they have direct line of site to neighbouring assessment locations to the south. It is noted that this ignores any road side noise barriers for the likely future freeway to the south.

Based on sound power level data in EMM's database for similar operations, noise emission levels from on-site trucking operations were used to predict site noise levels at assessment locations. A sound power level of 102 dB L_{Aeq} was adopted for one truck.

The modelling results are summarised in Table 5.5. The results show that site noise levels during the day and evening periods are predicted to satisfy the relevant criteria at all assessment locations. During the night period, site noise is predicted to satisfy the relevant criteria at most assessment locations. The exceptions were at R4 and R5, where night-time noise levels are predicted to marginally (by 1 to 2 dB) exceed the relevant criteria during F class temperature inversion conditions or during prevailing adverse winds.

Table 5.5 Operational noise modelling results

Assessment location	Period	Predicted $L_{Aeq(15min)}$ noise level, dB			Noise criteria, dB	Exceedance, dB		
		Calm	Winds	F class inversion		Calm	Winds	F class inversion
R1	Day	48	48	N/A	70 $L_{Aeq(Day)}$	Nil	Nil	N/A
	Evening	48	48	N/A	70 $L_{Aeq(Evening)}$	Nil	Nil	N/A
	Night	45	46	46	70 $L_{Aeq(Night)}$	Nil	Nil	Nil
R2	Day	32	34	N/A	42 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Evening	32	34	N/A	40 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Night	31	33	33	36 $L_{Aeq(15min)}$	Nil	Nil	Nil
R3	Day	34	36	N/A	42 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Evening	34	36	N/A	40 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Night	33	35	35	36 $L_{Aeq(15min)}$	Nil	Nil	Nil
R4	Day	38	40	N/A	42 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Evening	38	39	N/A	40 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Night	36	38	38	36 $L_{Aeq(15min)}$	Nil	**2**	**2**
R5	Day	38	39	N/A	42 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Evening	38	38	N/A	40 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Night	35	37	37	36 $L_{Aeq(15min)}$	Nil	**1**	**1**
R6	Day	37	38	N/A	42 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Evening	37	38	N/A	40 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Night	34	35	36	36 $L_{Aeq(15min)}$	Nil	Nil	Nil
R7	Day	33	33	N/A	42 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Evening	33	35	N/A	40 $L_{Aeq(15min)}$	Nil	Nil	N/A
	Night	31	31	33	36 $L_{Aeq(15min)}$	Nil	Nil	Nil
R8	Day	26	29	N/A	50 $L_{Aeq(Day)}$ [1]	Nil	Nil	N/A
	Evening	26	29	N/A	50 $L_{Aeq(Evening)}$ [1]	Nil	Nil	N/A
	Night	25	28	28	50 $L_{Aeq(Night)}$ [1]	Nil	Nil	Nil

Notes: *1. The difference between internal and external noise levels is 10 dB with windows open.*

2. N/A = Not applicable.

Following a review of the noise model, feasible and reasonable noise mitigation measures have been considered for the assessment. A noise barrier (from 2 to 4 m high) along the southern site boundary, adjacent to Building 3, Building 6 and Building 7 (being the dominant contributors due to relatively higher quantity of trucking operations and/or their proximity to the southern receivers), was considered to shield noise to southern residential receivers. However, it was found that site noise levels with the noise barrier did not significantly decrease during worst case meteorological conditions. Given the height and extent of noise barrier required, and the corresponding cost associated with the construction of such a structure, the marginal exceedance (up to 2 dB) during only worst case meteorological conditions during the night period, this mitigation measure was considered to be unreasonable.

Further, the road corridor (proposed Castlereagh Freeway) immediately south of the site will be developed in the future by the NSW Roads and Maritime Services. Given the close proximity to the southern receivers (R2-R7), it is expected that road traffic noise from the future freeway would generally mask site noise at these receivers. Furthermore, noise control measures (ie noise barriers) are expected

to be constructed along the future freeway's boundaries to mitigate road traffic noise and such barriers would also result in site noise levels decreasing further at these receivers.

5.5 Sleep disturbance

The loading/unloading of trucks during the night-time period has been assessed. Typical maximum noise level event activities are likely to include reversing alarms. A typical L_{Amax} sound power level of 110 dB (including a 5 dB tonality correction as per the INP) has been used in the assessment of sleep disturbance.

Table 5.6 presents the results of the INP sleep disturbance screening criteria assessment at residences. Modelling results show that site L_{Amax} noise levels are expected to satisfy the relevant criteria at assessment location R7 during calm meteorological conditions. Site L_{Amax} noise levels are predicted to be above the sleep disturbance screening criteria at all residential assessment locations during calm meteorological conditions and worst case meteorological conditions.

Table 5.6 Predicted maximum noise levels (night-time)

Assessment location	Predicted L_{Amax} noise level, dB		Noise criteria, dB	Exceedance, dB	
	Calm	Worst case conditions		Calm	Worst case conditions
R2	48	50	46	**2**	**4**
R3	50	52	46	**4**	**6**
R4	52	53	46	**6**	**7**
R5	50	51	46	**4**	**5**
R6	50	51	46	**4**	**5**
R7	44	47	46	Nil	**1**

However, as discussed in Section 4.3, the RNP (EPA 2011) concluded from the research on sleep disturbance that 'maximum internal noise levels below 50 to 55 dB(A) are unlikely to awaken people from sleep'. Assuming partially open windows, which would reduce external to internal noise levels by 10 dB, external noise levels in the order of 60 to 65 dB calculated at the facade of a residence are unlikely to cause awakening reactions. The highest predicted external maximum noise level from site at any residential assessment locations (R2-R7) was 53 dB under worst case meteorological conditions. Therefore, it is unlikely that night-time operations from the project will awaken people at any of the assessment locations. Further, work practices during the night period will be appropriately managed to minimise the impact and number of potential events. Recommendations in this regard are provided in Section 6.1.

5.6 Cumulative noise

Potential cumulative noise impacts from existing and successive developments are considered by the INP procedures by ensuring that the appropriate noise criteria are established with a view to maintaining acceptable noise amenity levels. The cumulative impact of the project with approved adjacent industrial developments have the potential to generate noise at residential assessment locations (south of site) assessed as part as this study. It has been conservatively assumed that amenity noise levels are 3 dB below the intrusive noise level. On this basis, the highest predicted amenity noise levels at any residential assessment location are $L_{Aeq(day)}$ 37 dB (based on 40 dB $L_{Aeq(15min)}$ at R4) for the day period, $L_{Aeq(evening)}$ 36 dB (based on 39 dB $L_{Aeq(15min)}$ at R4) for the evening period and $L_{Aeq(night)}$ 35 dB (based on 38 dB $L_{Aeq(15min)}$ at R4) for the night period. These noise levels are at least 5 dB below the relevant acceptable amenity

criteria for a suburban receiver type and therefore are predicted to have a negligible effect on increasing total industrial noise above the relevant criteria.

5.7 Road traffic noise

The nearest assessment locations potentially affected by an increase in road traffic as a result of the proposed development traffic are located in the caravan park (R1). This location is within an industrial zone as per the SEPP and therefore has been treated as such in accordance with the INP (EPA 2000) and RNP (EPA 2011). Given the distance between Hollinsworth Road and the southern residences, as well as shielding provided by the proposed warehouse buildings, road traffic noise associated with the proposed development is not anticipated to have an impact on those residences.

6 Mitigation and management

6.1 Operational noise and sleep disturbance

Operational noise predictions indicated that sensitive receivers have the potential to be exposed to noise levels marginally above the relevant criteria. As discussed in Section 5.4, the construction of a noise barrier along the southern boundary, adjacent to Building 3, Building 6 and Building 7, was considered to reduce site noise levels to below the relevant criteria during the night period, however was deemed to be unreasonable.

Notwithstanding, mitigation measures that may be employed to reduce operational noise impacts include:

- for Building 3, during the night-time period use the eastern loading docks and limit the use of the southern loading docks as far as practicable;
- minimise use of broadband audible reverse alarms on heavy vehicles during the night period;
- use recessed loading docks where possible during the night period to minimise noise from loading/unloading operations; and
- schedule truck movements and loading dock operations such that concurrent operation of vehicles is minimised. This would include limiting onsite vehicle idling while loading.

6.2 Construction noise and vibration

Construction noise levels from the project are predicted to be above the NMLs at most assessment locations. Construction vibration impacts are anticipated to be insignificant. Nonetheless, the proponent will manage construction noise and vibration from the site by adopting universal work practices during construction. These practices will include consideration of the following:

- restrict construction activities during ICNG standard hours only;
- preparation of a construction noise management plan prior to construction to ensure that all employees understand and take responsibility for noise control at site;
- regular reinforcement (such as at toolbox talks) of the need to minimise noise and vibration;
- regular identification of noisy activities and adoption of improvement techniques;
- schedule construction activities such that the concurrent operation of plant is limited;
- properly maintain plant to ensure rated noise emission levels are not exceeded;
- avoid or minimise the use of portable radios, public address systems or other methods of site communication that may unnecessarily impact upon nearby residents except where required for safety reasons;
- develop routes within the site for the delivery of materials and parking of vehicles to minimise noise;

- where possible, avoid the use of equipment that generates impulsive noise;
- minimise the need for vehicle reversing; eg by arranging for one-way site traffic routes;
- minimise use of broadband audible reverse alarms on vehicles used on site;
- minimise the unnecessary movement of materials and plant;
- schedule intensive works outside of respite periods; and
- provide a contact telephone number via which the public may seek information or make a complaint. A log of complaints should be maintained and actioned by the site superintendent in a responsive manner.

7 Conclusion

EMM has completed a noise and vibration impact assessment of the proposed industrial warehouse estate at Lot 23 and Lot 24 on Hollinsworth Road, Marsden Park, NSW.

This assessment considered the potential for noise and vibration impacts during operation and construction and has been prepared in accordance with the methodology outlined in the INP and associated Application Notes, as well as other relevant guidelines and standards as required by the SEARs.

Project Specific Noise Levels have been established based on the results of ambient noise monitoring and methodology provided in the INP.

Findings of the assessment are summarised below:

- a quantitative assessment of construction noise from the project was undertaken. Noise levels from construction are predicted to be above the ICNG noise management levels at most residential assessment locations. Whilst such findings are common during construction, they are limited in duration. Nonetheless, feasible and reasonable measures have been provided in this report.

- the assessment considered potential construction vibration impacts from the project. Construction vibration impacts from the project are considered unlikely. Notwithstanding, recommendations have been provided with regard to safe operating distances for typical construction equipment.

- operational noise levels were assessed for the daytime, evening and night-time periods during calm and prevailing weather conditions. The assessment found that noise from operation of the project is predicted to satisfy INP noise criteria for day, evening and night periods at most assessment locations. At R4 and R5, noise levels are predicted to marginally exceed the criteria during the night period during worst case meteorological conditions. By adopting management measures recommended in this report, these marginal exceedances can be mitigated.

- the potential for sleep disturbance from operation of the project during the night period has been assessed. Internal maximum noise levels from the operations are predicted to be below those likely to wake residents. On this basis, sleep disturbance impacts during the night period are unlikely; however, the proponent will manage noise as described in this report during this period to avoid maximum noise level events.

- an assessment of cumulative industrial noise from the project with other industrial noise sources in the vicinity was conducted. The project is not predicted to increase industrial noise levels above the relevant amenity criteria.

Recommended management and mitigation measures and work practices have been provided to further reduce site noise impacts from construction and operation.

Appendix A

Acoustic terms

A glossary of acoustic and other terms referenced in this report are provided in Table A.1.

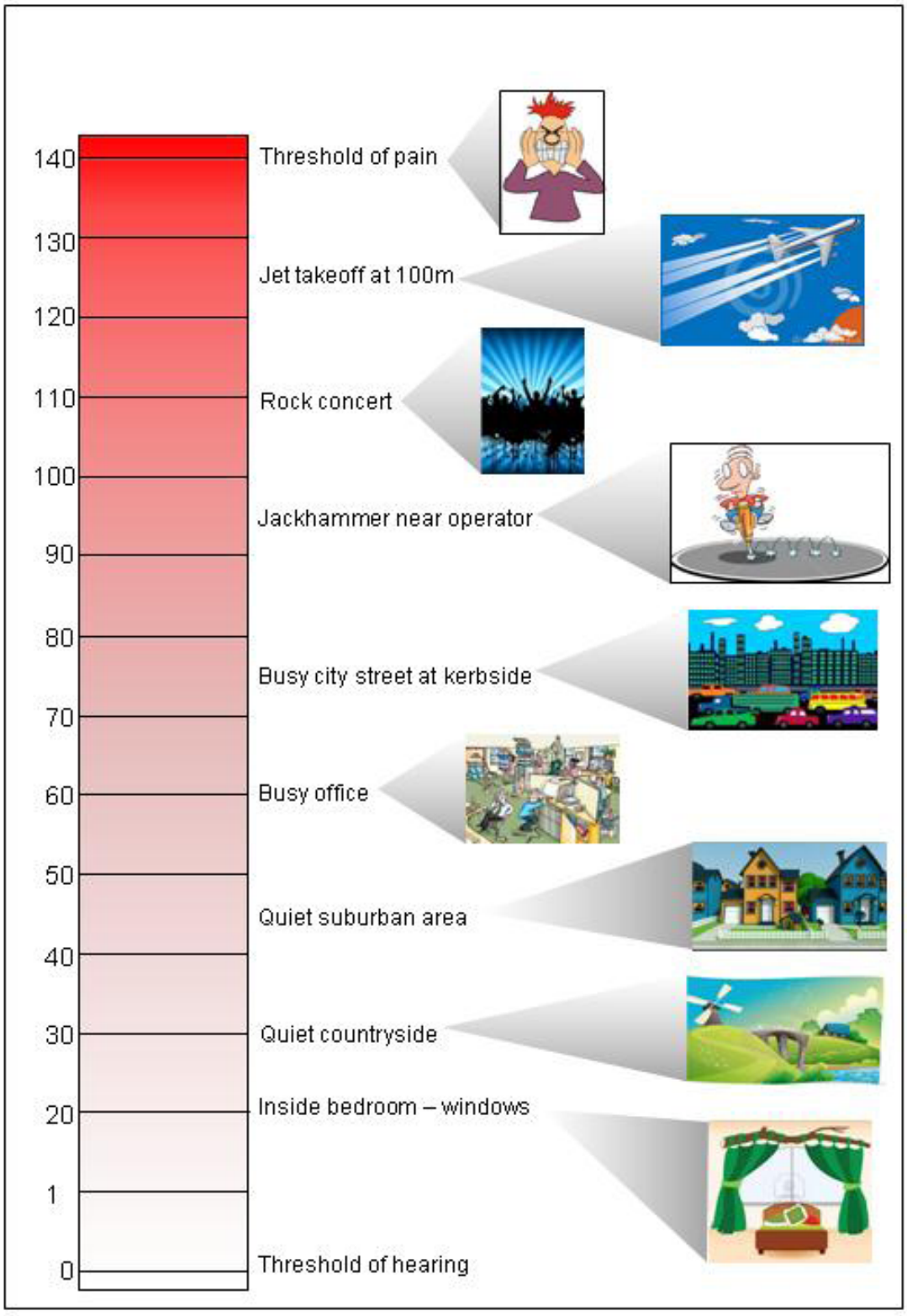
Table A.1 Glossary of terms

Abbreviation or term	Definition
ABL	The assessment background level (ABL) is defined in the INP as a single figure background level for each assessment period (day, evening and night). It is the tenth percentile of the measured L90 statistical noise levels.
Amenity noise criteria	The amenity noise criteria relate to existing industrial noise. Where industrial noise approaches base amenity noise criteria, then noise levels from new industries need to demonstrate that they will not be an additional contributor to existing industrial noise. See Section 3.1.2 for more detail.
Day period	Monday–Saturday: 7 am to 6 pm, on Sundays and public holidays: 8 am to 6 pm.
dB(A)	Noise is measured in units called decibels (dB). There are several scales for describing noise, the most common being the 'A-weighted' scale. This attempts to closely approximate the frequency response of the human ear.
EPA	The NSW Environment Protection Authority (formerly the Environment Protection Authority and the Department of Environment, Climate Change and Water).
Evening period	Monday–Saturday: 6 pm to 10 pm, on Sundays and public holidays:
INP	Industrial Noise Policy (NSW)
Intrusive noise criteria	The intrusive noise criteria refer to noise that intrudes above the background level by more than 5 dB. The intrusiveness criterion is described in detail in Section 3.1.1.
L_{A90}	The A-weighted noise level that is exceeded 90% of the time. Commonly referred to as the background noise level.
L_{Aeq}	The energy average noise from a source. This is the equivalent continuous A-weighted sound pressure level over a given period. The $L_{Aeq(15min)}$ descriptor refers to an L_{Aeq} noise level measured over a 15-minute period.
L_{Amax}	The maximum A-weighted sound pressure level received during a measuring interval.
Night period	Monday–Saturday: 10 pm to 7 am, on Sundays and public holidays: 10 pm to 8 am.
PSNL	The project-noise trigger level (PSNL) is criteria for a particular industrial noise source or industry. The PSNL is the lower of either the intrusive noise criteria or amenity noise criteria.
RBL	The rating background level (RBL) is an overall single value background level representing each assessment period over the monitoring period. The RBL is used to determine the intrusiveness criteria for noise assessment purposes and is the median of the average background levels.
RNP	Road Noise Policy (NSW)
Sound power level (Lw)	A measure of the total power radiated by a source. The sound power of a source is a fundamental property of the source and is independent of the surrounding environment.

Table A.2 gives an indication as to what an average person perceives about changes in noise levels. Examples of common noise levels are provided in Figure A.2.

Table A.2 Perceived change in noise

Change in sound level (dB)	Perceived change in noise
3	just perceptible
5	noticeable difference
10	twice (or half) as loud
15	large change
20	four times (or quarter) as loud

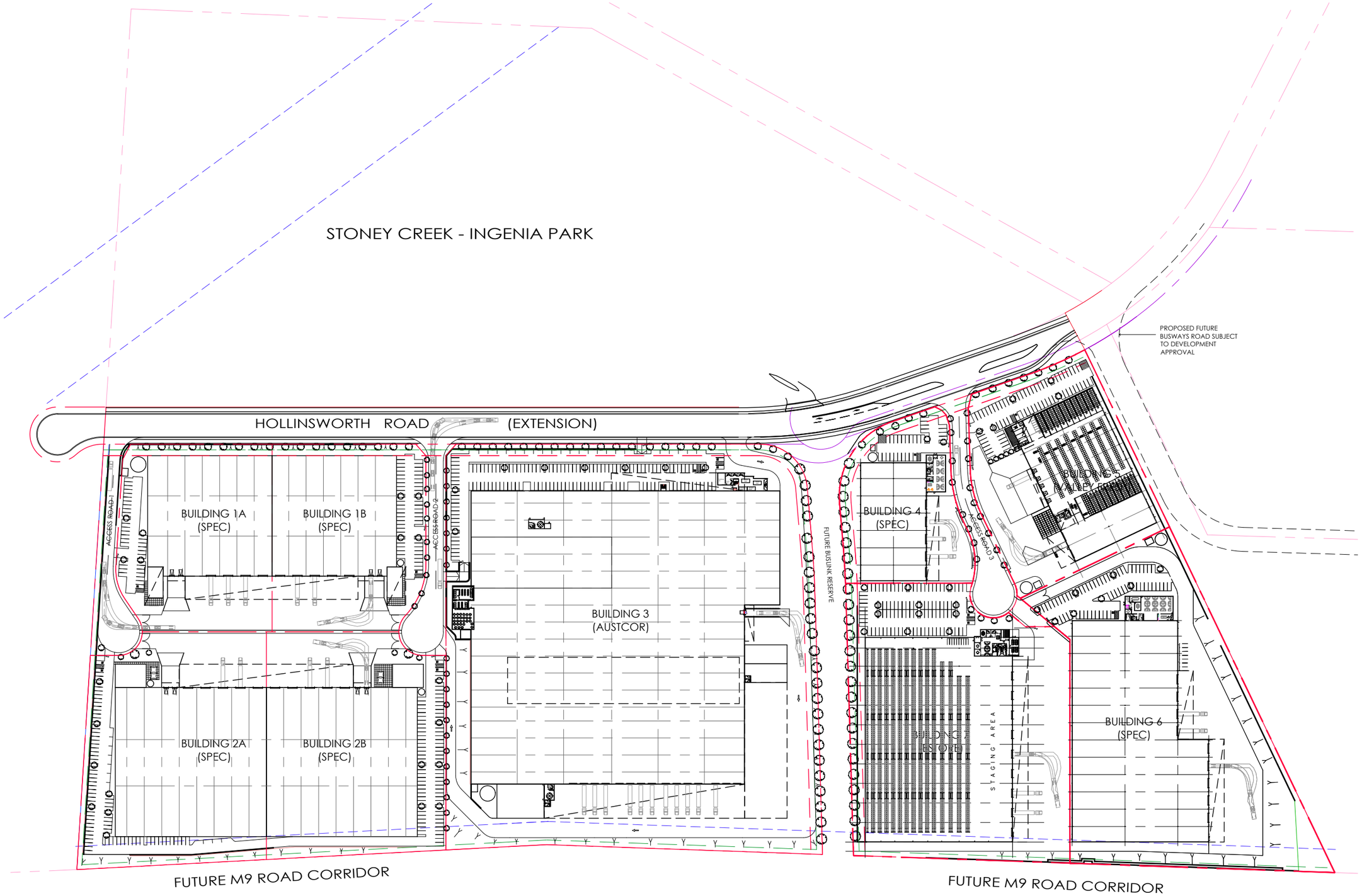


Source: Noise Measurement Manual (Queensland Department of Environment and Heritage Protection 2013).

Figure A.1 Common noise levels

Appendix B

Masterplan layout



1 ESTATE MASTERPLAN PLAN
1:2500

ESTATE MASTERPLAN AREA SCHEDULE

Total Site Area	214,805 sqm
Less:	
Hollinsworth Road Widening	1,120 sqm
Hollinsworth Road Extension	10,641 sqm
Common Access Road 1	2,403 sqm
Common Access Road 2	2,351 sqm
Common Access Road 3	2,617 sqm
Bus Link Reserve Lot	5,734 sqm
Total Developable Area	189,939 sqm
BUILDING 1A (SPEC)	
Site Area	11,761 sqm
Warehouse Area	6,225 sqm
Office (2 Levels) Area	500 sqm
Total Building Area	6,725 sqm
Carparking Provided	34
BUILDING 1B (SPEC)	
Site Area	11,761 sqm
Warehouse Area	6,245 sqm
Office (2 Levels) Area	500 sqm
Total Building Area	6,745 sqm
Carparking Provided	50
BUILDING 2A (SPEC)	
Site Area	17,277 sqm
Warehouse Area	9,440 sqm
Office (2 Levels) Area	625 sqm
Total Building Area	10,065 sqm
Carparking Provided	92
BUILDING 2B (SPEC)	
Site Area	16,363 sqm
Warehouse Area	9,440 sqm
Office (2 Levels) Area	625 sqm
Total Building Area	10,065 sqm
Carparking Provided	72
BUILDING 3 (AUSTCOR)	
Site Area	62,453 sqm
Warehouse Area	37,110 sqm
Office Area	2,333 sqm
Total Building Area	39,443 sqm
Carparking Provided	165
BUILDING 4 (SPEC)	
Site Area	7,815 sqm
Warehouse Area	3,263 sqm
Office (1 Level) Area	300 sqm
Total Building Area	3,563 sqm
Carparking Provided	28
BUILDING 5 (VALLEY FRESH)	
Site Area	13,076 sqm
Warehouse Area	5,924 sqm
Office (2 Levels) Area	300 sqm
Total Building Area	6,224 sqm
Carparking Provided	66
BUILDING 6 (SPEC)	
Site Area	25,560 sqm
Warehouse Area	11,140 sqm
Office (2 Levels) Area	1,000 sqm
Total Building Area	12,140 sqm
Carparking Provided	59
BUILDING 7 (ESTORE)	
Site Area	23,873 sqm
Warehouse Area	12,352 sqm
Office (1 Level) Area	450 sqm
Total Building Area	12,802 sqm
Carparking Provided	97
Total Warehouse Area	101,139 sqm
Total Office Area	6,633 sqm
Total Building Area	107,772 sqm
Site Efficiency	57%

CARPARKING REQUIREMENTS

DCP Council Requirements:

Office (GFA)	1 space/ 40 sqm
Warehouse <7,500sqm (GFA)	1 space/ 75 sqm
Warehouse >7,500sqm (GFA)	1 space/ 200 sqm
Total Carparking Required	1163 sapces

Cars Required:

Based off RMS Rates & Marketing Parking Proposal (Refer Traffic Report)

Office (GFA)	1 space/ 35 sqm
Warehouse (GFA)	1 space/ 300 sqm
Total Carpaking Required	527 spaces
Total Carpaking Provided	663 spaces

[watch this SPACE design]

Architect

WATCH THIS SPACE DESIGN PTY LTD

LEVEL 6, SUITE 66 - 61 MARLBOROUGH STREET, SURRY HILLS, NSW 2010
Email: info@watchthisspacedesign.com
www.watchthisspacedesign.com

Amendments

A	Amended Building 4-7 Lots and Access Rd 3	08.11.17
B	Added future Busways road	10.11.17

LOGOS

Client
LOGOS

Project
Lot 23 & 24 Hollinsworth Road
Marsden Park NSW 2765

Drawn	Checked	Approved
TT	PM	PM
Scale	Date	
1:2500 @ A3	OCT 2017	

Drawing Title
ESTATE MASTERPLAN PLAN

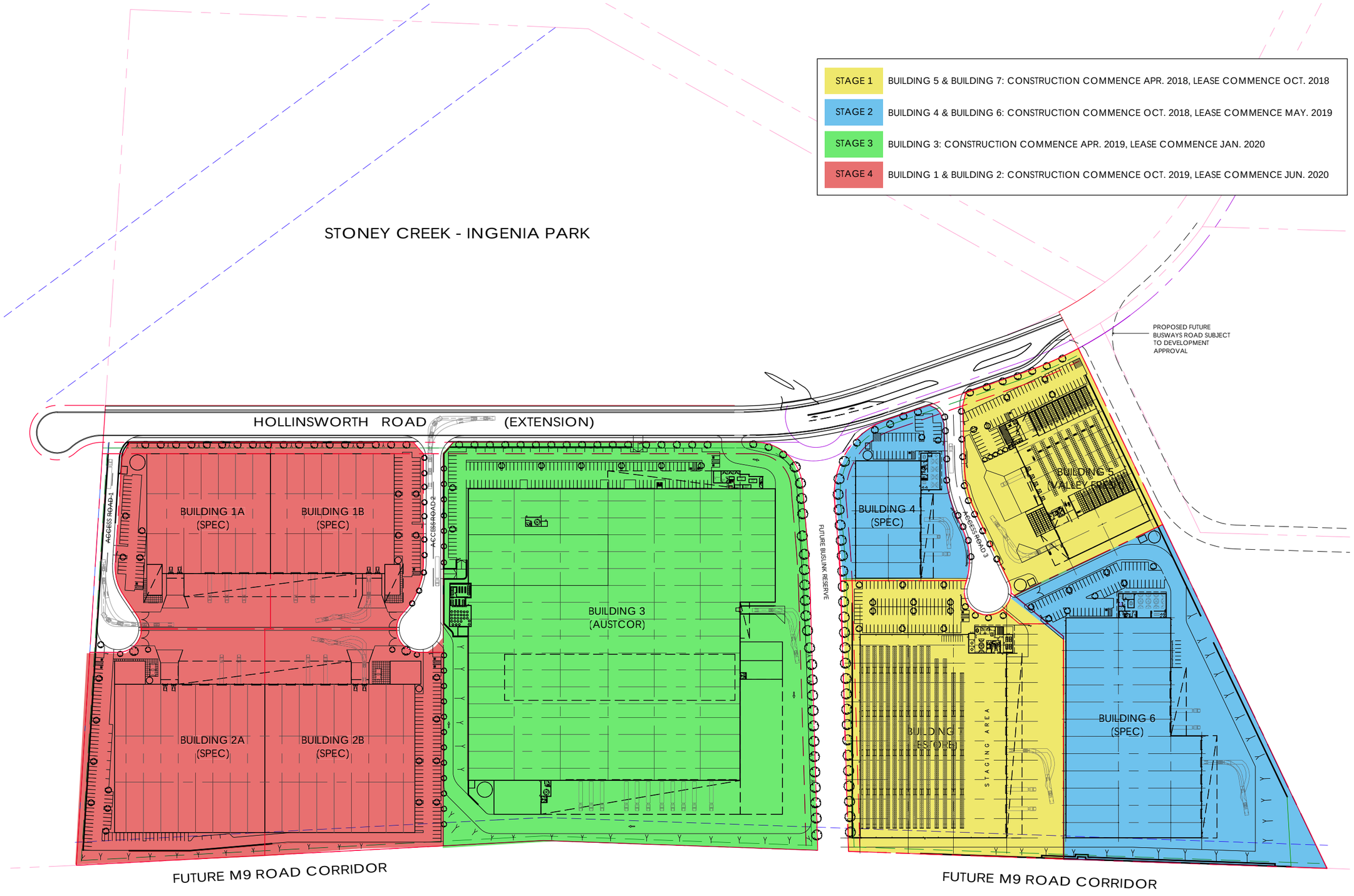
Project Number	Drawing Number	Rev
1706	LG MAR DA01	B

Status
DEVELOPMENT APPLICATION

Appendix C

Project staging masterplan

STAGE 1	BUILDING 5 & BUILDING 7: CONSTRUCTION COMMENCE APR. 2018, LEASE COMMENCE OCT. 2018
STAGE 2	BUILDING 4 & BUILDING 6: CONSTRUCTION COMMENCE OCT. 2018, LEASE COMMENCE MAY. 2019
STAGE 3	BUILDING 3: CONSTRUCTION COMMENCE APR. 2019, LEASE COMMENCE JAN. 2020
STAGE 4	BUILDING 1 & BUILDING 2: CONSTRUCTION COMMENCE OCT. 2019, LEASE COMMENCE JUN. 2020



1 ESTATE MASTERPLAN PLAN
1:2500

ESTATE MASTERPLAN AREA SCHEDULE

Total Site Area	214,805 sqm
Less:	
Hollinsworth Road Widening	1,120 sqm
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Common Access Road 2	2,351 sqm
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Office (2 Levels) Area	500 sqm
Total Building Area	6,745 sqm
Carparking Provided	50
BUILDING 2A (SPEC)	
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Office (2 Levels) Area	625 sqm
Total Building Area	10,065 sqm
Carparking Provided	92
BUILDING 2B (SPEC)	
Site Area	16,363 sqm
Warehouse Area	9,440 sqm
Office (2 Levels) Area	625 sqm
Total Building Area	10,065 sqm
Carparking Provided	72
BUILDING 3 (AUSTCOR)	
Site Area	62,453 sqm
Warehouse Area	37,110 sqm
Office Area	2,333 sqm
Total Building Area	39,443 sqm
Carparking Provided	165
BUILDING 4 (SPEC)	
Site Area	7,815 sqm
Warehouse Area	3,263 sqm
Office (1 Level) Area	300 sqm
Total Building Area	3,563 sqm
Carparking Provided	28
BUILDING 5 (VALLEY FRESH)	
Site Area	13,076 sqm
Warehouse Area	5,924 sqm
Office (2 Levels) Area	300 sqm
Total Building Area	6,224 sqm
Carparking Provided	66
BUILDING 6 (SPEC)	
Site Area	25,560 sqm
Warehouse Area	11,140 sqm
Office (2 Levels) Area	1,000 sqm
Total Building Area	12,140 sqm
Carparking Provided	59
BUILDING 7 (ESTORE)	
Site Area	23,873 sqm
Warehouse Area	12,352 sqm
Office (1 Level) Area	450 sqm
Total Building Area	12,802 sqm
Carparking Provided	97
Total Warehouse Area	101,139 sqm
Total Office Area	6,633 sqm
Total Building Area	107,772 sqm
Site Efficiency	57%

CARPARKING REQUIREMENTS

DCP Council Requirements:

Office (GFA)	1 space/ 40 sqm
Warehouse <7,500sqm (GFA)	1 space/ 75 sqm
Warehouse >7,500sqm (GFA)	1 space/ 200 sqm
Total Carparking Required	1163 sapces
Cars Required:	
Based off RMS Rates & Marketing Parking Proposal (Refer Traffic Report)	
Office (GFA)	1 space/ 35 sqm
Warehouse (GFA)	1 space/ 300 sqm
Total Carpaking Required	527 spaces
Total Carpaking Provided	663 spaces

[watch this SPACE design]

Architect

WATCH THIS SPACE DESIGN PTY LTD

LEVEL 6, SUITE 66 - 61 MARLBOROUGH STREET, SURRY HILLS, NSW 2010
Email: info@watchthisspacedesign.com
www.watchthisspacedesign.com

Amendments

LOGOS

Client
LOGOS

Project
Lot 23 & 24 Hollinsworth Road
Marsden Park NSW 2765

Drawn	Checked	Approved
TT	PM	PM
Scale	Date	
1:2500 @ A3	OCT 2017	

Drawing Tit
STAGING MASTERPLAN

Project Number	Drawing Number	Rev
1706	LG MAR DA02	A

Status
DEVELOPMENT APPLICATION

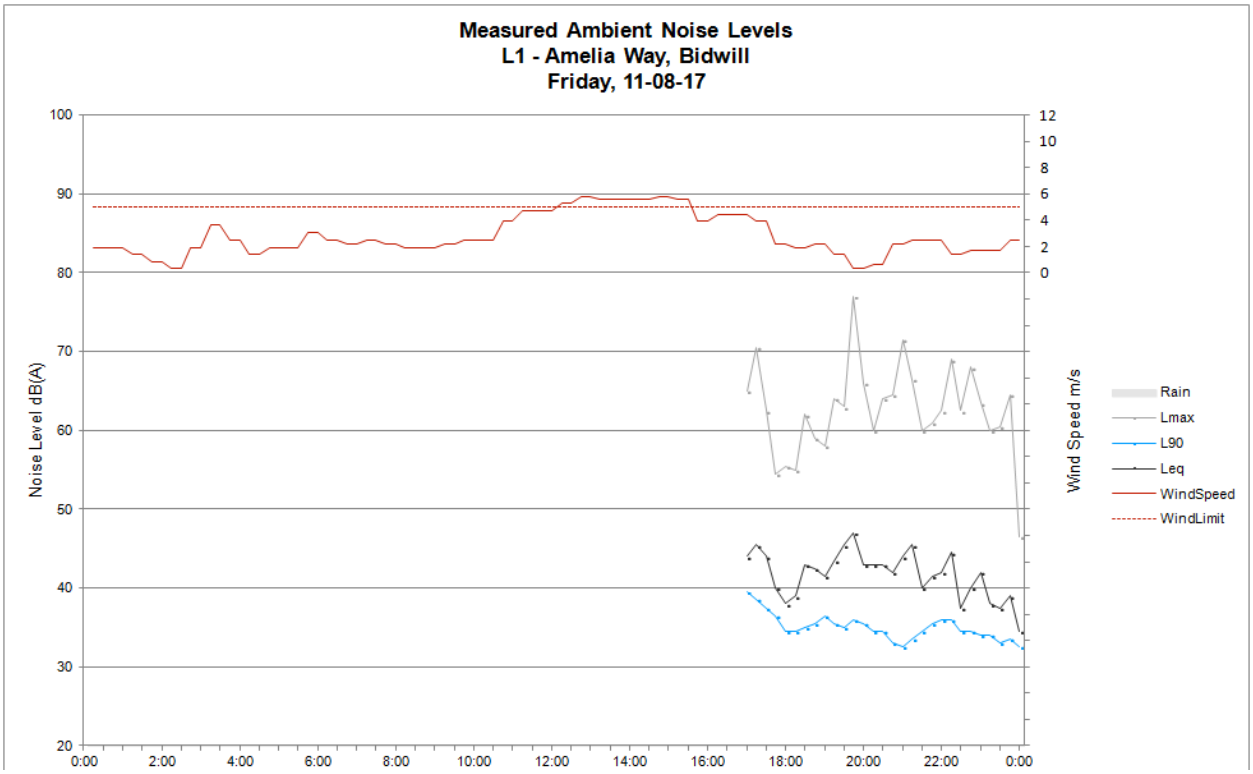
Appendix D

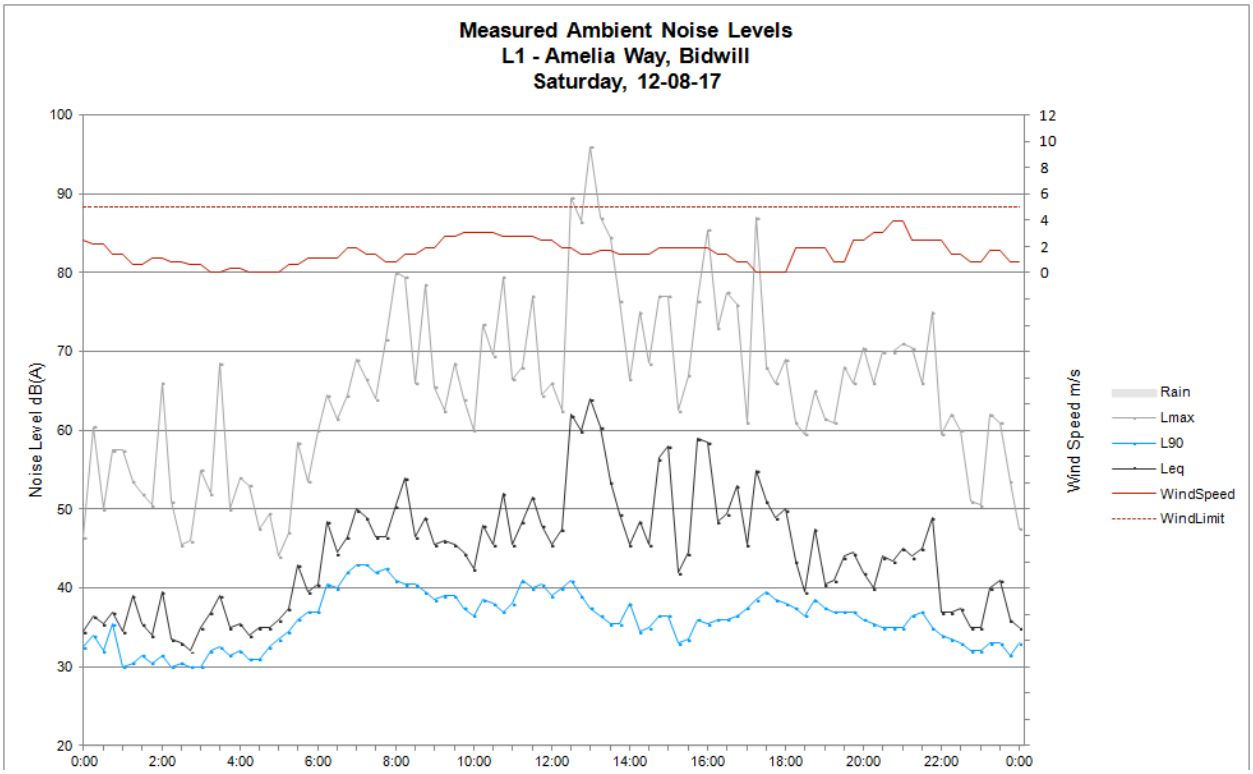
Noise logger results and charts

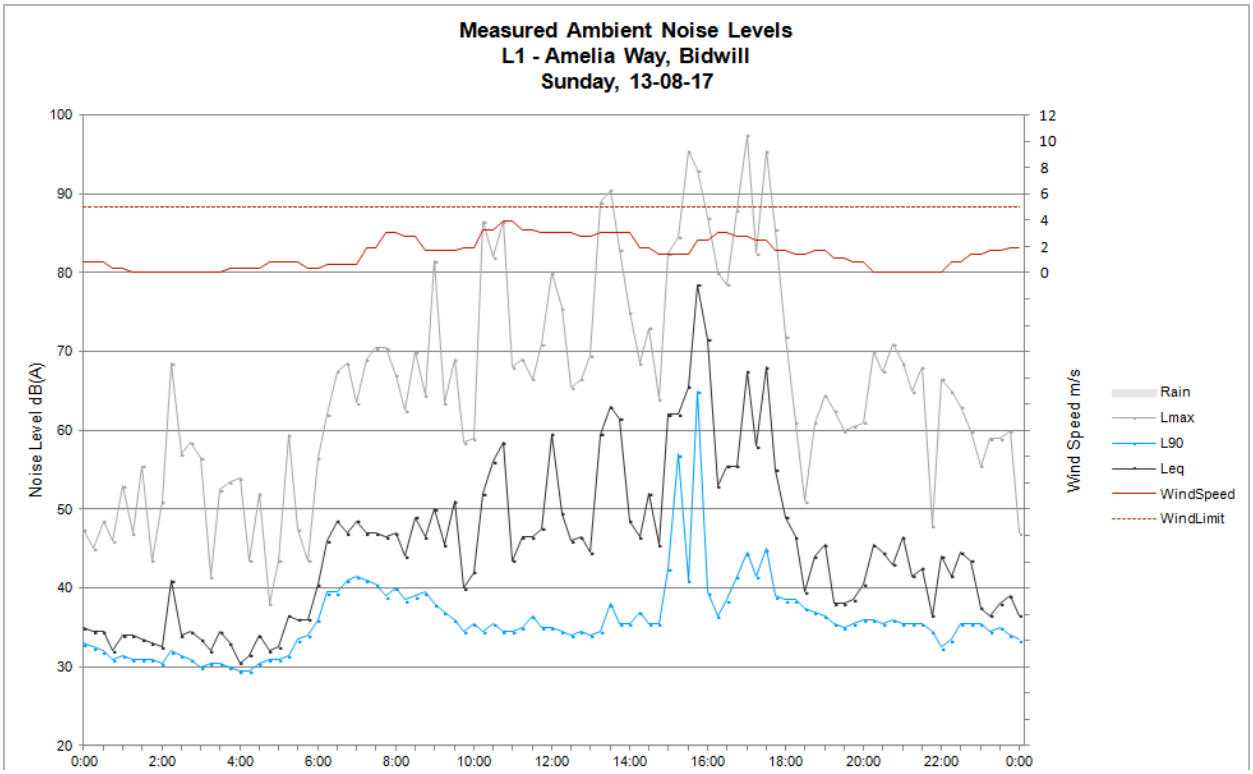
Table D.3 Noise logger results

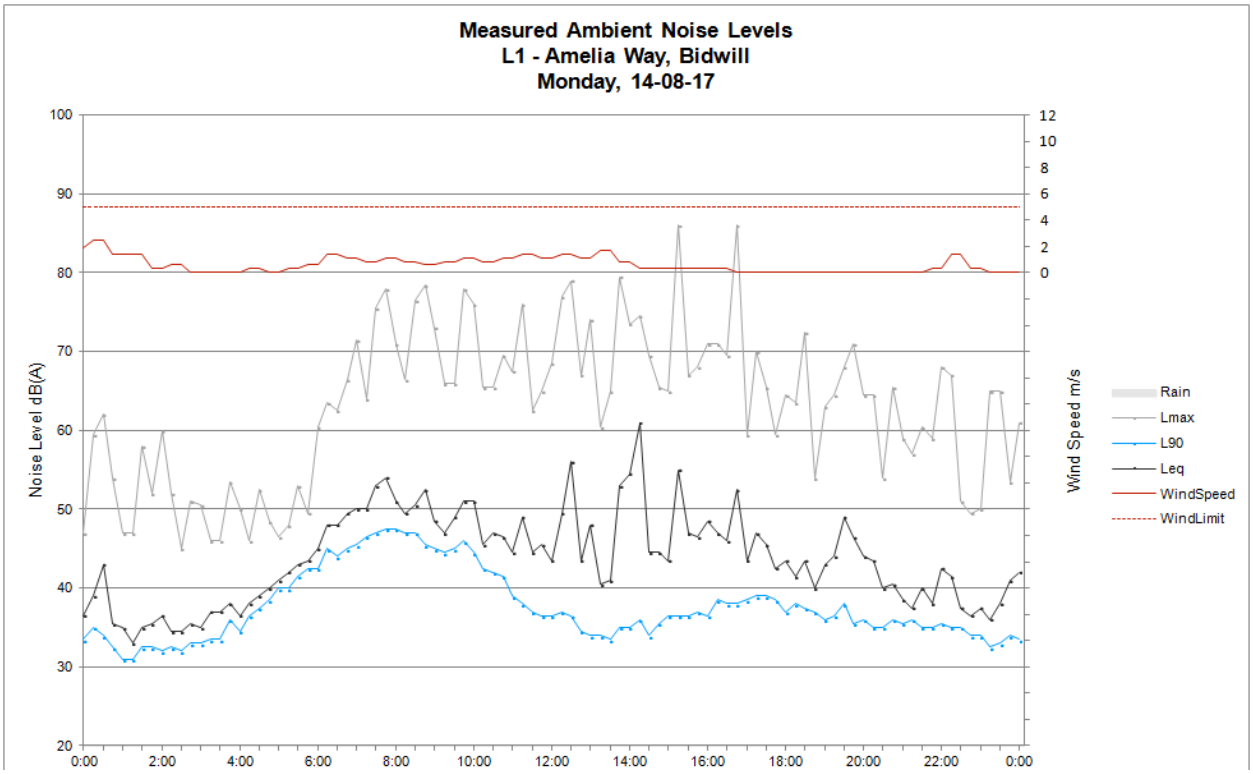
Date	ABL – Day	ABL – Evening	ABL – Night	$L_{Aeq(Day)}$	$L_{Aeq(Evening)}$	$L_{Aeq(Night)}$
Friday, 11-08-17	-	33	30	-	43	41
Saturday, 12-08-17	36	35	30	54	44	40
Sunday, 13-08-17	35	35	32	64	43	42
Monday, 14-08-17	35	35	33	51	43	42
Tuesday, 15-08-17	42	37	36	52	42	45
Wednesday, 16-08-17	44	36	29	55	48	42
Thursday, 17-08-17	37	34	32	50	43	47
Friday, 18-08-17	-	37	29	-	47	41
Saturday, 19-08-17	40	38	31	54	46	39
Sunday, 20-08-17	36	36	31	54	44	42
Monday, 21-08-17	-	-	-	-	-	-
RBL	37	35	31			
Average L_{Aeq}				57	45	43

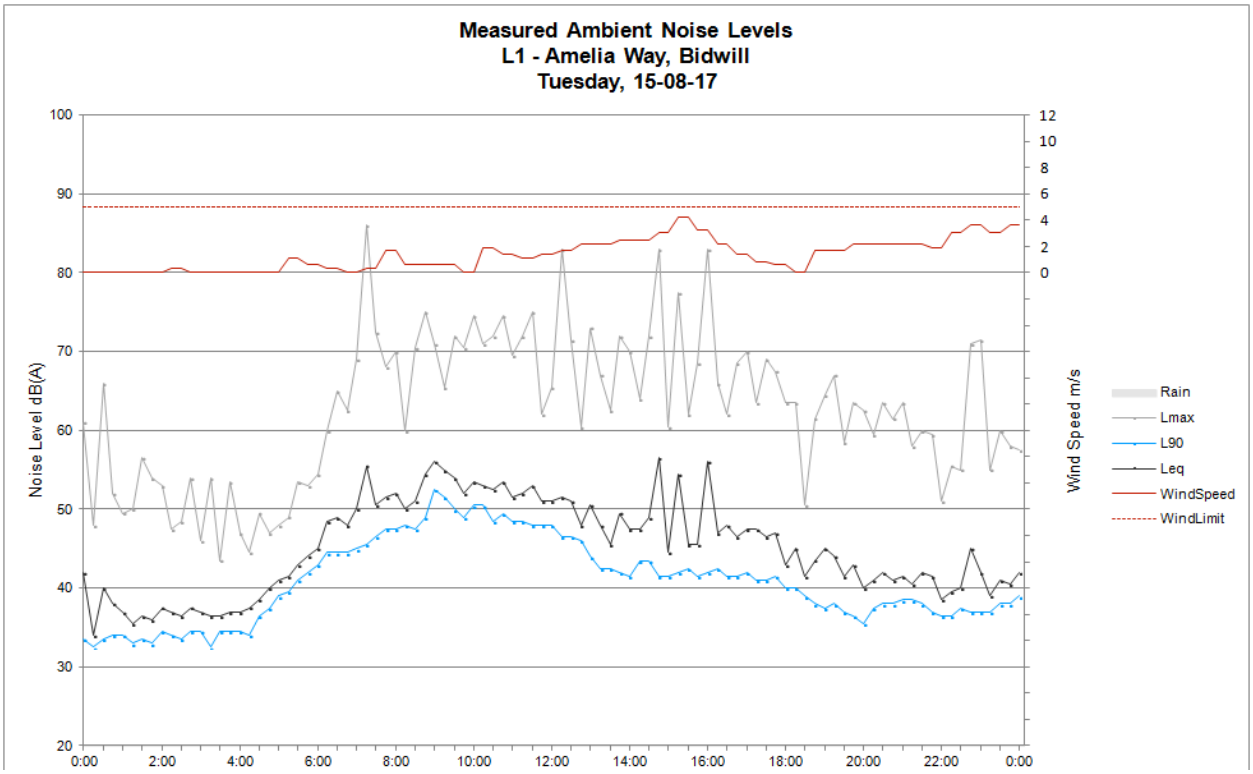
Notes: 1. "-" indicates a period with too few valid samples due to weather or logger operation.

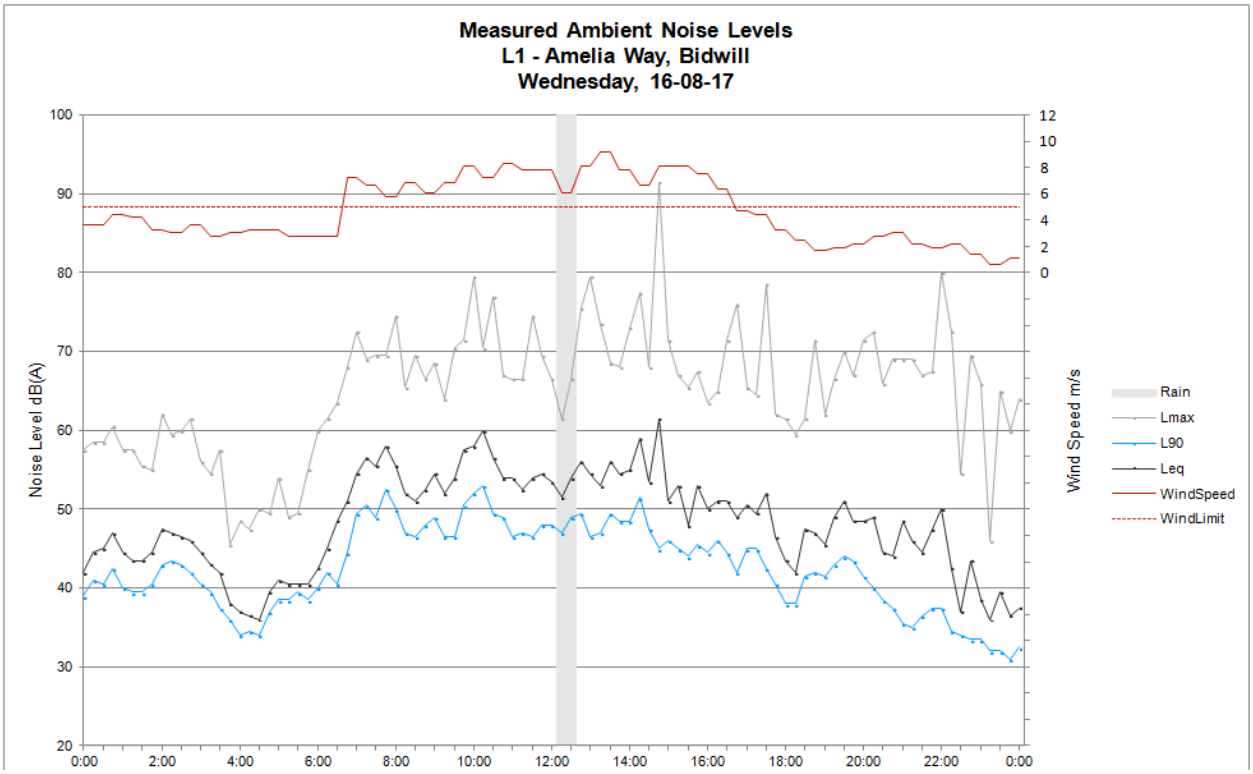

Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Friday, 11-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00

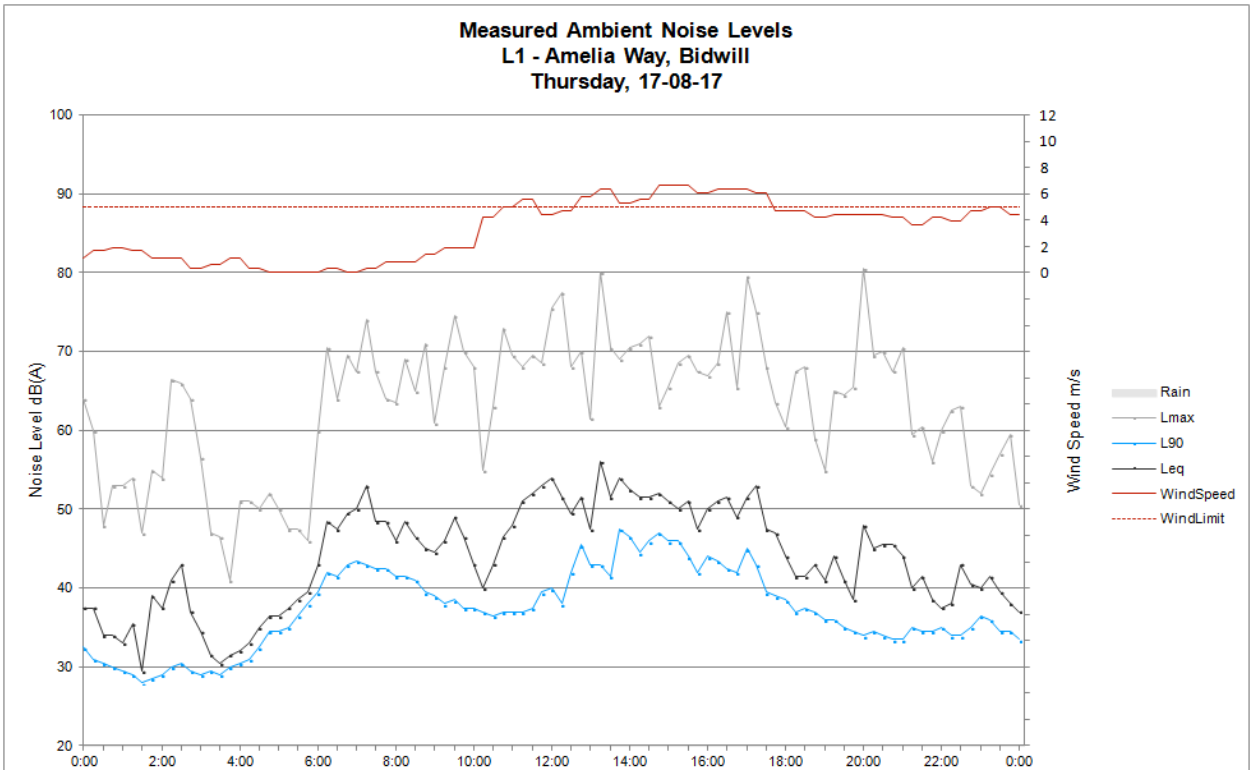

Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Saturday, 12-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00

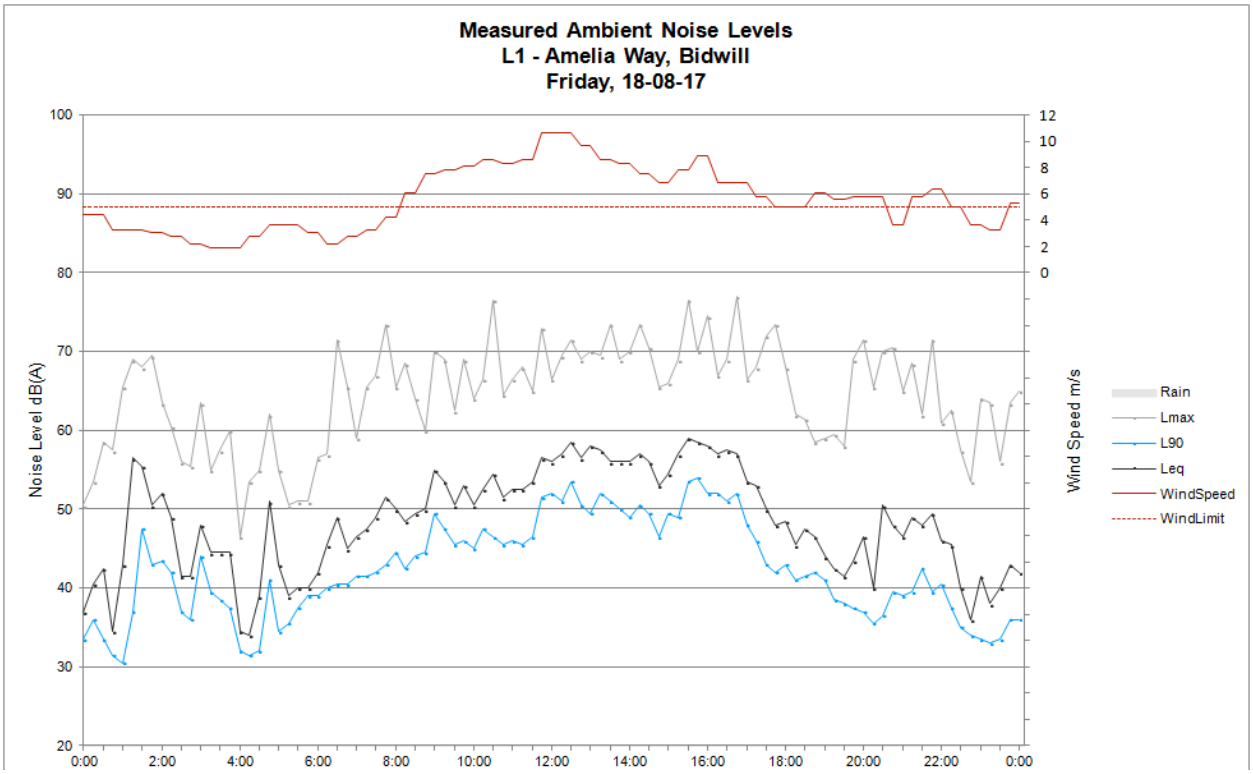

Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Sunday, 13-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit

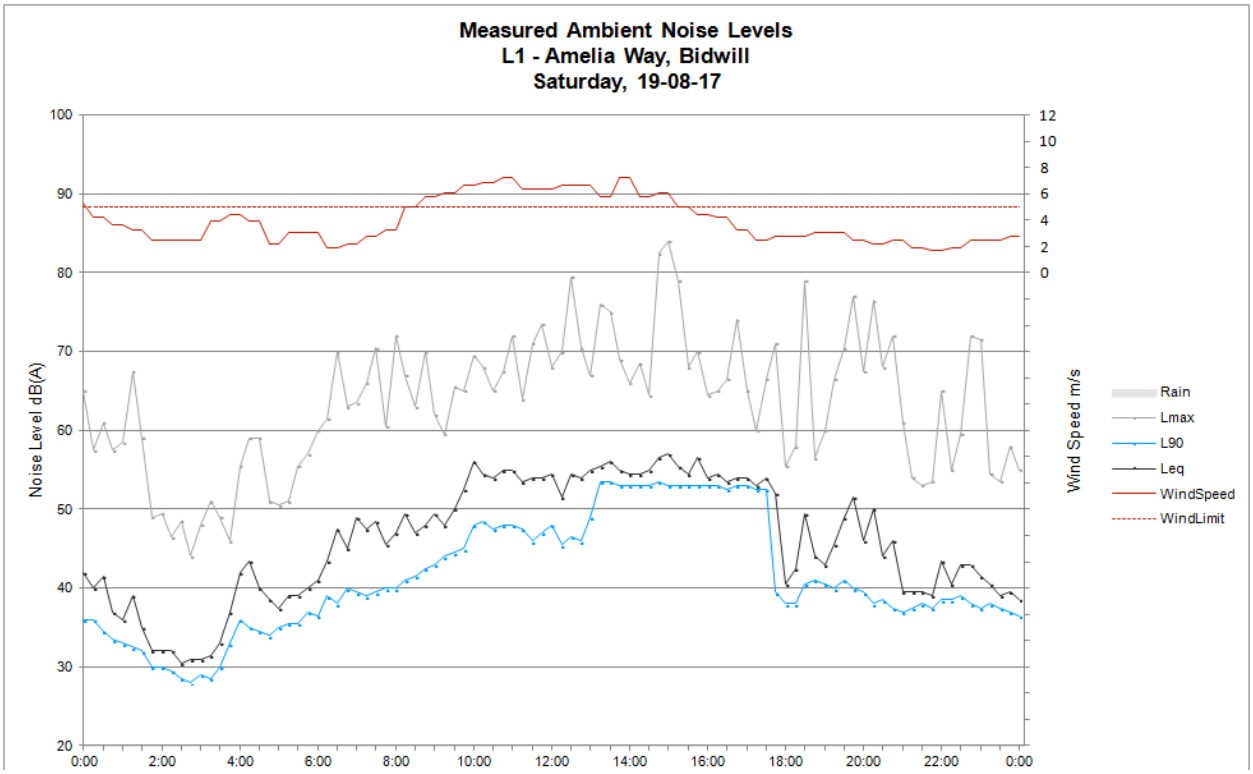

Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Monday, 14-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit

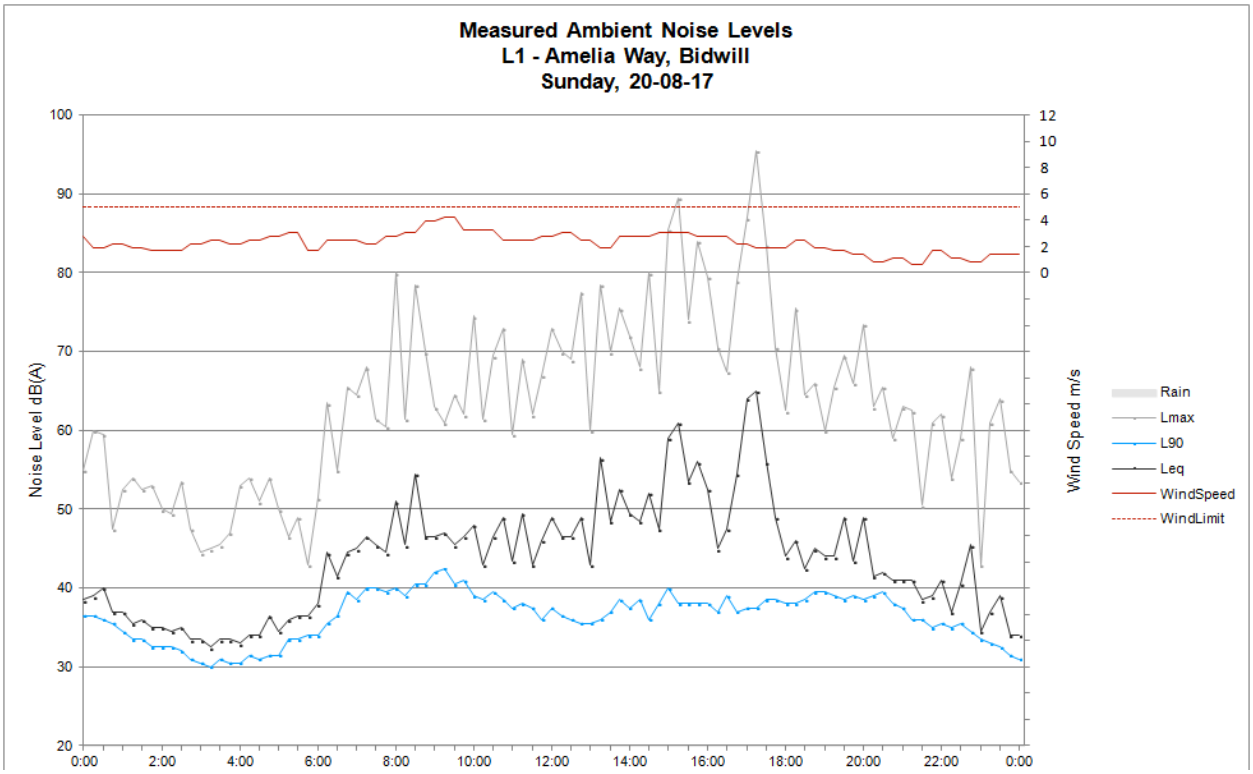

Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Tuesday, 15-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit

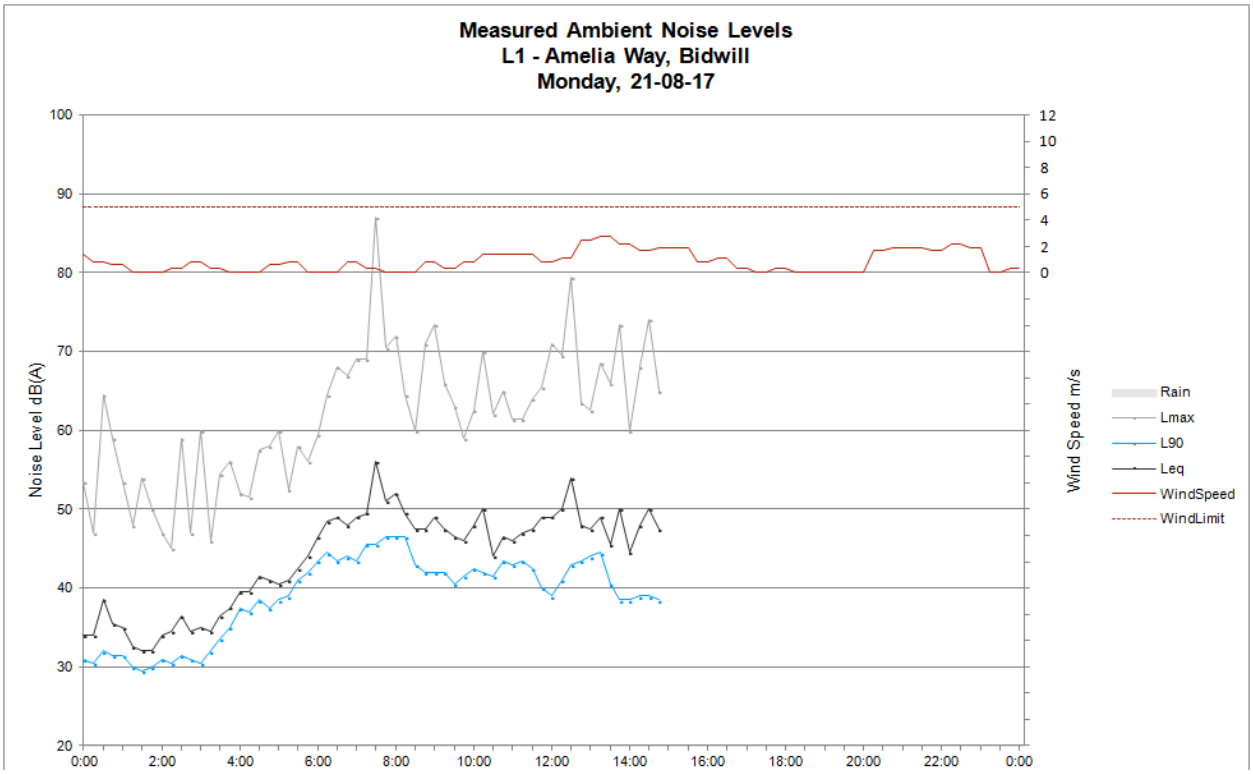

Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Wednesday, 16-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit


Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Thursday, 17-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit


Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Friday, 18-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit


Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Saturday, 19-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit


Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Sunday, 20-08-17
Noise Level dB(A)
Wind Speed m/s
Rain
Lmax
L90
Leq
WindSpeed
WindLimit


Measured Ambient Noise Levels
L1 - Amelia Way, Bidwill
Monday, 21-08-17
Noise Level dB(A)
Wind Speed m/s
100
90
80
70
60
50
40
30
20
12
10
8
6
4
2
0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
0:00
Rain
Lmax
L90
Leq
WindSpeed
WindLimit

Appendix E

Prevailing weather analysis

Table E.4 Prevailing wind analysis results

Wind direction (degrees)[1]	Season	Assessment period	Percentage of occurrence (%)
360	Summer	Day	24
22.5	Summer	Day	25
45	Summer	Day	26
67.5	Summer	Day	25
90	Summer	Day	21
112.5	Summer	Day	17
135	Summer	Day	15
157.5	Summer	Day	13
180	Summer	Day	12
202.5	Summer	Day	10
225	Summer	Day	9
247.5	Summer	Day	8
270	Summer	Day	8
292.5	Summer	Day	12
315	Summer	Day	17
337.5	Summer	Day	21
360	Summer	Evening	18
22.5	Summer	Evening	24
45	Summer	Evening	28
67.5	Summer	Evening	33
90	Summer	Evening	36
112.5	Summer	Evening	38
135	Summer	Evening	35
157.5	Summer	Evening	28
180	Summer	Evening	24
202.5	Summer	Evening	19
225	Summer	Evening	14
247.5	Summer	Evening	10
270	Summer	Evening	6
292.5	Summer	Evening	5
315	Summer	Evening	6
337.5	Summer	Evening	9
360	Summer	Night	10
22.5	Summer	Night	10
45	Summer	Night	11
67.5	Summer	Night	12
90	Summer	Night	15
112.5	Summer	Night	19
135	Summer	Night	24
157.5	Summer	Night	31
180	Summer	Night	35
202.5	Summer	Night	35
225	Summer	Night	32

Table E.4 Prevailing wind analysis results

Wind direction (degrees)[1]	Season	Assessment period	Percentage of occurrence (%)
247.5	Summer	Night	27
270	Summer	Night	22
292.5	Summer	Night	16
315	Summer	Night	9
337.5	Summer	Night	8
360	Autumn	Day	23
22.5	Autumn	Day	22
45	Autumn	Day	21
67.5	Autumn	Day	20
90	Autumn	Day	16
112.5	Autumn	Day	16
135	Autumn	Day	16
157.5	Autumn	Day	18
180	Autumn	Day	19
202.5	Autumn	Day	20
225	Autumn	Day	20
247.5	Autumn	Day	21
270	Autumn	Day	22
292.5	Autumn	Day	25
315	Autumn	Day	25
337.5	Autumn	Day	24
360	Autumn	Evening	13
22.5	Autumn	Evening	15
45	Autumn	Evening	17
67.5	Autumn	Evening	19
90	Autumn	Evening	21
112.5	Autumn	Evening	24
135	Autumn	Evening	27
157.5	Autumn	Evening	28
180	Autumn	Evening	31
202.5	Autumn	Evening	32
225	Autumn	Evening	30
247.5	Autumn	Evening	27
270	Autumn	Evening	24
292.5	Autumn	Evening	20
315	Autumn	Evening	13
337.5	Autumn	Evening	11
360	Autumn	Night	8
22.5	Autumn	Night	7
45	Autumn	Night	5
67.5	Autumn	Night	3
90	Autumn	Night	3
112.5	Autumn	Night	6

Table E.4 Prevailing wind analysis results

Wind direction (degrees)[1]	Season	Assessment period	Percentage of occurrence (%)
135	Autumn	Night	9
157.5	Autumn	Night	22
180	Autumn	Night	33
202.5	Autumn	Night	37
225	Autumn	Night	38
247.5	Autumn	Night	39
270	Autumn	Night	38
292.5	Autumn	Night	34
315	Autumn	Night	18
337.5	Autumn	Night	10
360	Winter	Day	23
22.5	Winter	Day	19
45	Winter	Day	15
67.5	Winter	Day	11
90	Winter	Day	8
112.5	Winter	Day	8
135	Winter	Day	10
157.5	Winter	Day	13
180	Winter	Day	17
202.5	Winter	Day	20
225	Winter	Day	22
247.5	Winter	Day	25
270	Winter	Day	28
292.5	Winter	Day	32
315	Winter	Day	32
337.5	Winter	Day	27
360	Winter	Evening	16
22.5	Winter	Evening	13
45	Winter	Evening	11
67.5	Winter	Evening	8
90	Winter	Evening	9
112.5	Winter	Evening	13
135	Winter	Evening	17
157.5	Winter	Evening	24
180	Winter	Evening	31
202.5	Winter	Evening	35
225	Winter	Evening	36
247.5	Winter	Evening	38
270	Winter	Evening	38
292.5	Winter	Evening	36
315	Winter	Evening	26
337.5	Winter	Evening	20
360	Winter	Night	17

Table E.4 Prevailing wind analysis results

Wind direction (degrees)[1]	Season	Assessment period	Percentage of occurrence (%)
22.5	Winter	Night	13
45	Winter	Night	8
67.5	Winter	Night	3
90	Winter	Night	1
112.5	Winter	Night	1
135	Winter	Night	3
157.5	Winter	Night	13
180	Winter	Night	24
202.5	Winter	Night	29
225	Winter	Night	33
247.5	Winter	Night	37
270	Winter	Night	41
292.5	Winter	Night	42
315	Winter	Night	30
337.5	Winter	Night	21
360	Spring	Day	24
22.5	Spring	Day	23
45	Spring	Day	21
67.5	Spring	Day	19
90	Spring	Day	15
112.5	Spring	Day	12
135	Spring	Day	10
157.5	Spring	Day	10
180	Spring	Day	10
202.5	Spring	Day	11
225	Spring	Day	11
247.5	Spring	Day	12
270	Spring	Day	15
292.5	Spring	Day	20
315	Spring	Day	23
337.5	Spring	Day	24
360	Spring	Evening	16
22.5	Spring	Evening	20
45	Spring	Evening	21
67.5	Spring	Evening	23
90	Spring	Evening	26
112.5	Spring	Evening	28
135	Spring	Evening	27
157.5	Spring	Evening	26
180	Spring	Evening	25
202.5	Spring	Evening	24
225	Spring	Evening	20
247.5	Spring	Evening	18

Table E.4 Prevailing wind analysis results

Wind direction (degrees)[1]	Season	Assessment period	Percentage of occurrence (%)
270	Spring	Evening	16
292.5	Spring	Evening	14
315	Spring	Evening	11
337.5	Spring	Evening	12
360	Spring	Night	12
22.5	Spring	Night	11
45	Spring	Night	9
67.5	Spring	Night	7
90	Spring	Night	7
112.5	Spring	Night	9
135	Spring	Night	12
157.5	Spring	Night	21
180	Spring	Night	28
202.5	Spring	Night	30
225	Spring	Night	31
247.5	Spring	Night	31
270	Spring	Night	31
292.5	Spring	Night	29
315	Spring	Night	18
337.5	Spring	Night	14

Notes: 1. Degrees from North (0 degree).

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St Leonards, New South Wales, 2065
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NEWCASTLE
Level 5, 21 Bolton Street
Newcastle, New South Wales, 2300
T 02 4927 0506 F 02 4926 1312

BRISBANE
Level 4, Suite 01, 87 Wickham Terrace
Spring Hill, Queensland, 4000
T 07 3839 1800 F 07 3839 1866