DA Noise Impact Assessment

Oakdale Central Lot 3B

Milner Avenue, Eastern Creek

Report Number 610.16103-R2

21 March 2016

Goodman Property Services (Aust) Pty Ltd
Level 17
60 Castlereagh Street
Sydney NSW 2000

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Oakdale Central Lot 3B

Milner Avenue, Eastern Creek

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1 INTRODUCTION

1.1 Background

Goodman Property Services (Aust) Pty Ltd (Goodman) is currently developing the Oakdale Central site on Milner Avenue, Eastern Creek. Oakdale Central Lot 3B (the proposal) is proposed to be developed and integrated into the Oakdale Central site.

SLR Consulting Australia Pty Ltd (SLR) has been engaged by Goodman to prepare a Noise Impact Assessment (NIA) for Oakdale Central Lot 3B assessing the potential noise impacts associated with the proposal. This report presents the results of the assessment and forms part of the Development Application (DA) for the proposal.

The report responds to the Secretary's Environmental Assessment Requirements (SEARs) as they relate to noise and vibration. The SEARs relevant to this report have been considered and are addressed as outlined in **Table 1**.

Table 1 Secretary's Environmental Assessment Requirements (SEARs)

Relevant SEARs	Response
A description of all potential noise and vibration sources such as construction, operational, on and off-site traffic noise.	This report includes a description of potential noise sources associated with the development. Operational noise including traffic noise is addressed in **Section 4**. Construction noise and vibration is addressed in **Section 5**.
A noise impact assessment that considers the cumulative noise impact of the proposed development in accordance with relevant Environment Protection Authority guidelines.	This assessment includes consideration of the cumulative noise impacts of the potential noise emissions from the development in accordance with relevant Environmental Protection Authority guidelines (refer to **Section 4.2**).
Details of noise mitigation, management and monitoring measures.	Details of recommended noise mitigation, management and monitoring measures are outlined in **Section 4** and **Section 5** for operational noise and construction noise and vibration respectively.

1.2 Relevant Guidelines

Noise from the operation of the proposal has been assessed in accordance with the *NSW Industrial Noise Policy* (INP), NSW EPA, 2000, with guidance on sleep disturbance criteria taken from the online Application Notes to the INP.

Construction noise has been assessed in accordance with the *Interim Construction Noise Guideline* (ICNG), DECC, 2009.

Vibration from operation and construction has been assessed in accordance with *Assessing Vibration: A Technical Guideline*, DEC, 2006.

1.3 Terminology

The assessment has used specific acoustic terminology. An explanation of common terms is included as **Appendix A**.

2 PROJECT DESCRIPTION

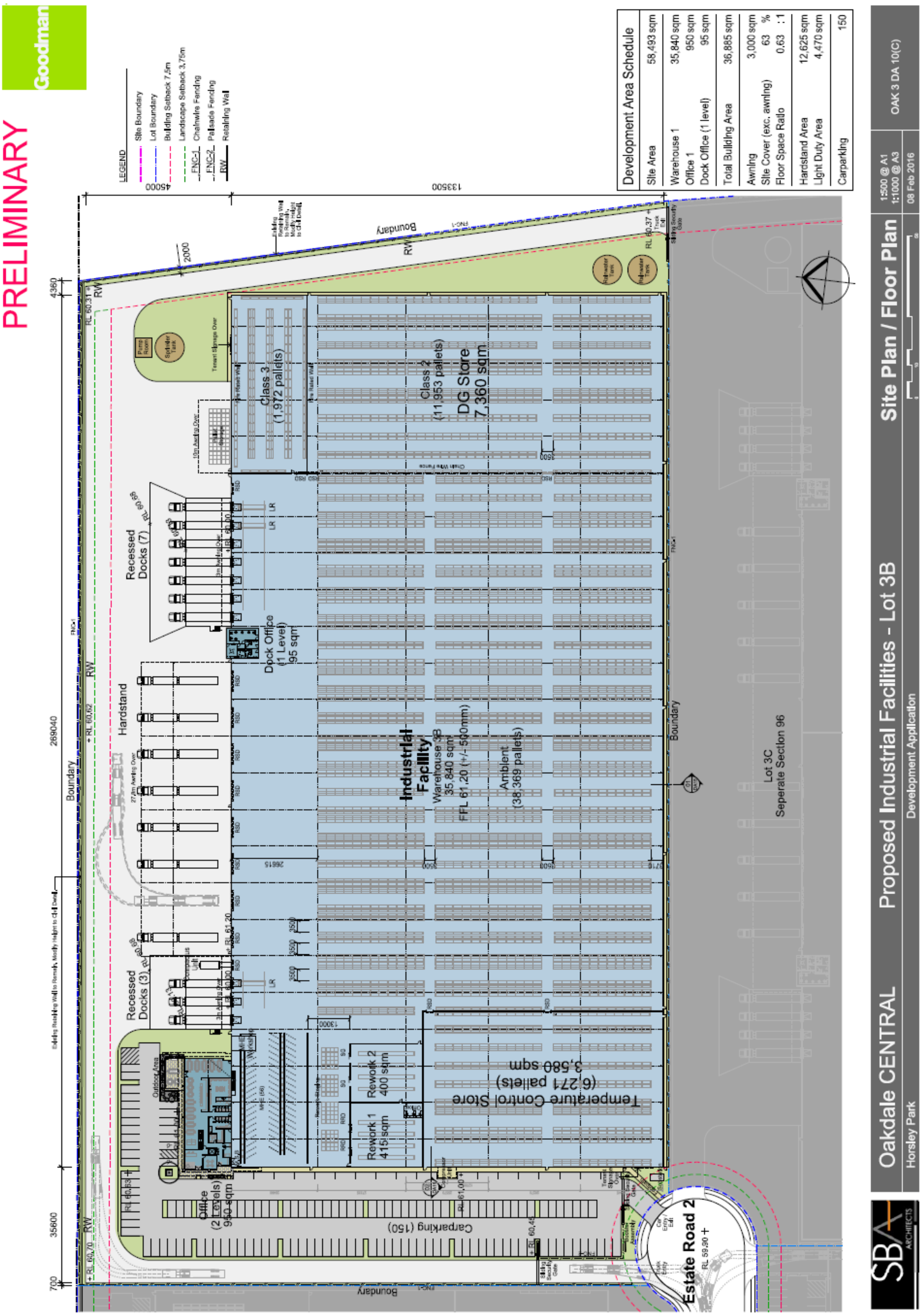
The location of the Oakdale Central development site is shown in **Figure 1**. The current DA covers the construction and operation of Lot 3B as indicated in **Figure 2**. Approval for the rest of Oakdale Central has been granted under the sites Development Consent SSD 6078, dated 18 March 2015.

For the purpose of this assessment, it has been assumed that the development will operate 24 hours a day, 7 days a week.

Figure 1 Oakdale Central Site Location

Note 1: Site boundaries for Oakdale Central and Lot 3B are indicated in red.

Figure 2 Lot 3B Design Plans



Note 1: Drawing supplied by Goodman, dated 8 February 2016.

3 NOISE LIMITS AND SENSITIVE RECEIVER LOCATIONS

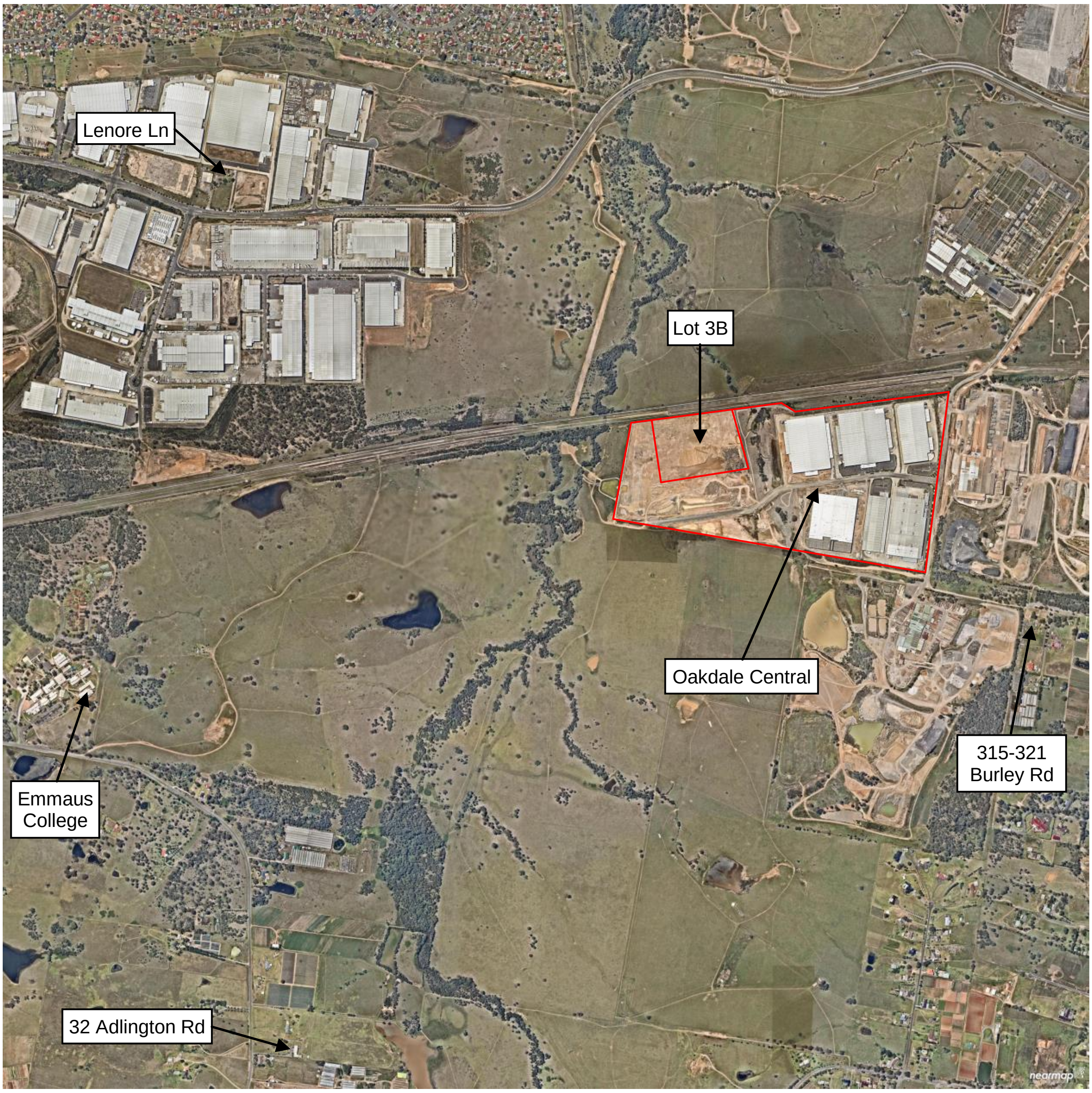
3.1 Operational Noise Limits

The operational noise limits applicable to the Oakdale Central site are defined in the sites Development Consent SSD 6078, dated 18 March 2015. It is considered suitable that these same noise limits are applicable for Oakdale Central Lot 3B. The operational noise limits are reproduced in **Table 2** and the receiver locations are shown in **Figure 3**.

Table 2 Oakdale Central Development Noise Limits – Operational

Location	Day	Evening	Night	
	$L_{Aeq(15minute)}$ (dB)			$L_{A1(1minute)}$ or L_{Amax} (dB)
Location 1 315-321 Burley Road	38	38	38	49
Location 2 Lenore Lane	35	35	35	45
Location 3 Emmaus College	35	n/a	n/a	n/a
Location 4 32 Adlington Road	35	35	35	48

Figure 3 Receiver Locations Identified in Oakdale Central Development Consent



Note 1: Site boundaries for Oakdale Central and Lot 3B are indicated in red.

3.2 Construction Noise Limits

Development Consent SSD 6078 for Oakdale Central does not specify noise limits for construction noise. However, it specifies that construction activities must be limited to standard construction hours of Monday to Friday 7:00 am to 6:00 pm and Saturday 8:00 am to 1:00 pm, unless the activities are not audible at any residence beyond the boundary of the site.

Construction noise goals for Oakdale Central Lot 3 are defined in the DA Noise Impact Assessment for Oakdale Central Lots 1C, 2B and 3 (SLR Report *670.10585_Noise_R1*, dated 11 October 2013). These noise goals are considered to be suitable for Oakdale Central Lot 3B. The construction noise goals are reproduced in **Table 3** and the receiver locations are shown in **Figure 3**.

Table 3 Oakdale Central Lot 3 Noise Goals – Construction

Location	Construction $L_{Aeq(15minute)}$ Noise Goal (dBA)	
	Noise Affected	Highly Noise Affected
Location 1 315-321 Burley Road	47	75
Location 2 Lenore Lane	46	
Location 3 Emmaus College	55 (45 internal)	
Location 4 32 Adlington Road	43	

Note 1: Construction activities must be limited to standard construction hours of Monday to Friday 7:00 am to 6:00 pm and Saturday 8:00 am to 1:00 pm, unless the activities are not audible at any residence beyond the boundary of the site.

4 OPERATIONAL NOISE IMPACT ASSESSMENT

4.1 Operational Noise Modelling

Noise modelling of the development site was undertaken using the CONCAWE noise prediction algorithms in SoundPLAN V7.1 modelling software.

A 3D digital noise model was constructed from a combination of aerial photography, existing ground topography, design ground topography, receiver buildings / structures and design plans for the development.

In order to assess the operational noise impacts from Lot 3B, peak light and heavy vehicle movements, along with associated unloading activities and mechanical plant have been modelled across the development. Modelled vehicle volumes are provided in **Table 4**.

Table 4 Vehicle Volumes for Lot 3B

Lot	Total GFA (m^2)	Vehicles per Hour (Peak)	Vehicle per Day	Heavy Vehicle Percentage
3B	36,885	67	775	25%

Note 1: Vehicle volumes were provided by the client.

For a worst case 15 minute INP assessment, peak hour vehicle volumes of 67 vehicles per hour have been modelled. This equates to 17 vehicle movements in a worst case 15 minute period, comprising 13 light vehicles and 4 heavy vehicles.

Sound power levels for the modelled vehicle movements and speed assumptions, and fixed plant are outlined in **Table 5**.

Table 5 Sound Power Levels for Onsite Vehicle Movements

Noise Source	Sound Power Level (L_{WA})
Heavy Vehicles – Average Speed 25 km/h	106 dB per vehicle
Light Vehicles – Average Speed 40 km/h	96 dB per vehicle
Gas Powered Forklifts (Loading activities)	95 dB per unit
Outdoor fixed plant (includes units associated with airconditioning etc)	75 dB per unit

4.2 Predicted Operational Noise Impacts

Noise modelling of the operations of Lot 3B as discussed in **Section 4.1** has been used to predict the noise emissions at the surrounding sensitive receivers.

The predicted operational noise levels for Lot 3B are shown in **Table 6** for the receiver locations identified in the **Section 3**.

Table 6 Predicted Operational Noise Levels – Lot 3B

Receiver Location	Noise Limit LAeq(15minute) (Controlling Period)	Predicted Noise Level LAeq(15minute)	Exceedance of Limit
Location 1 315-321 Burley Road	38	26	-
Location 2 Lenore Lane	35	28	-
Location 3 Emmaus College	35	23	-
Location 4 32 Adlington Road	35	22	-

In order to assess the cumulative impacts of the current DA for Lot 3B with the existing Oakdale Central operations and the proposed Lot 3A, 3C and 3D operations, an assessment of cumulative noise has been undertaken. The cumulative noise levels are shown in **Table 7**. Noise modelling of predicted noise and measurements of existing noise from Oakdale Central (other than Lot 3B) are based on previous noise impact assessments and onsite measurements conducted by SLR for these Lots.

Table 7 Predicted Cumulative Operational Noise Levels – Oakdale Central

Receiver Location	Noise Limit LAeq(15minute) (Controlling Period)	Predicted Noise Level LAeq(15minute)				Exceedance of Cumulative Limit
		Lot 3B	Lots 3A, 3C & 3D	Oakdale Central Lots 1 & 2	Oakdale Central Cumulative	
Location 1 315-321 Burley Road	38	26	29	35	36	-
Location 2 Lenore Lane	35	28	25	26	31	-
Location 3 Emmaus College	35	23	26	26	30	-
Location 4 32 Adlington Road	35	22	25	27	30	-

As shown in **Table 6** and **Table 7**, no exceedances of the operational noise limits for Oakdale Central Lot 3B were predicted. Cumulative operational impacts due to the rest of Oakdale Central, including Lots 1, 2, 3A, 3C and 3D were also predicted to be below the defined operational noise limits.

4.3 Off-site Operational Traffic Movements

While light and heavy vehicle movements within Oakdale Central Lot 3 are classified as part of the operational site noise, once they move off the Lot 3 site and onto public roads they are assessed under the *NSW Road Noise Policy* (RNP).

The RNP requires noise mitigation where new land use developments increase road traffic noise by more than 2 dB. An increase of greater than 2 dB requires an increase in traffic volumes of approximately 60% or higher.

The main access route to the development site is via the arterial roads of Lenore Drive and Old Wallgrove Road. The existing volume of traffic on Lenore Drive is significantly higher than the estimated traffic volumes from Lot 3B, therefore, an increase in traffic noise due to the operation of Lot 3B of greater than 2 dB is not considered likely. No mitigation is likely to be required as a result.

5 CONSTRUCTION NOISE AND VIBRATION IMPACT ASSESSMENT

5.1 Construction Noise Modelling

Construction noise modelling of the development site was undertaken using SoundPLAN V7.1 modelling software.

The noise model was constructed from a combination of aerial photography, existing ground topography, design ground topography and design masterplans for the development. The local terrain, receiver buildings and structures have been digitised in the noise model to develop a three-dimensional representation of the construction works and surrounding environment.

Maximum sound power levels (L_{WA}) for the typical construction equipment (item) and construction activities that have been used in the noise modelling are listed in **Table 8**.

Table 8 Sound Power Levels for Construction Equipment

Construction Activity	Equipment	Operating minutes in 15-min period	No of items in same location	Sound Power Level L_{WA} (dB)	
				Item	Activity
Earthworks	Dozer	15	1	110	116
	Dump Truck (approx 15 tonne)	15	3	100	
	Excavator (25 tonne)	15	1	102	
	Front End Loader (FEL) 962	15	1	112	
	Grader	15	1	108	
Paving Works including Concrete Pours	Concrete Pump	7.5	1	106	113
	Concrete Truck / Agitator	7.5	1	106	
	Concrete Vibrator	15	1	102	
	Paving Machine	15	1	104	
	Plate Compactor	5	1	108	
	Vibratory Roller (10-12 tonne)[1]	15	1	109	

Construction Activity	Equipment	Operating minutes in 15-min period	No of items in same location	Sound Power Level LWA (dB)	
				Item	Activity
Construction of Roadways	Asphalt Milling Machine[1]	15	1	111	115
	Bitumen Spray Truck	15	1	100	
	Line Marking Plant	15	1	98	
	Paving Machine	15	1	104	
	Plate Compactor	5	1	108	
	Road Profiler	15	1	107	
	Vibratory Roller (10-12 tonne)[1]	15	1	109	
Construction of Warehouse and Office Structures	Elevated Working Platform	15	2	97	107
	Flatbed Truck	15	1	100	
	Hand Tools (electric)	15	4	96	
	Mobile Crane (100 tonne)	15	1	101	
	Welding Equipment	15	1	97	
Landscaping and Finishing Works	Hydromulching Equipment	15	1	97	102
	Skidsteer Loader (approx. ½ tonne)	15	1	97	
	Ute	15	1	98	

Note 1: In accordance with the ICNG, for activities identified as particularly annoying (such as jackhammering, rock breaking and power saw operations), a 5 dB 'penalty' is added to the source sound power level when predicting noise using the quantitative method.

Consistent with the requirements of the ICNG, and to inform the scheduling of construction activity and management of noise during the detailed design phase, the construction noise impacts are based on a worst-case assessment. The ICNG recommends that the realistic worst-case or conservative noise levels from the source should be predicted for assessment locations representing the most noise-exposed residences or other sensitive land uses. For each receiver area the noise levels are predicted at the most noise-exposed location, which would usually be the closest receiver.

For most construction activities, it is expected that the construction noise levels would frequently be lower than predicted at the most-exposed receiver as the noise levels presented in this report are based on a realistic worst-case assessment.

Furthermore, other receivers within each receiver area would generally experience lower noise levels compared to the most noise-exposed location as construction work is undertaken at greater separation distance from receivers. To provide an indication of the likely reduction in construction noise levels, the following can be assumed:

- A doubling of the distance between the source and receiver would provide an approximate 6 dB reduction in noise level. For example the sound pressure levels from most items of plant would decrease by around 6 dB as the distance increases from 10 metres to 20 metres.
- Buildings and other solid structures located between the construction noise source and sensitive receivers would act as barriers and would typically reduce noise levels by up to 15 dB. For example, in a residential area adjoining a construction site the first row of houses would provide an effective shield to the second and subsequent rows with resulting noise levels up to 10 dB lower than would otherwise be experienced in the absence of the first row.

5.2 Predicted Construction Noise Impacts

Construction noise impacts at the surrounding sensitive receivers have been quantitatively assessed for several construction activities. The activities considered are described in **Table 8**.

The typical $L_{Aeq(15minute)}$ noise levels at the surrounding noise sensitive receivers are provided in **Table 9** for each of the construction activities and are representative of the 'noisiest' construction periods allowing for the simultaneous operation of noise intensive construction plant in close proximity.

Table 9 Predicted Construction Noise Levels

Sensitive Receiver Area	Construction $L_{Aeq(15minute)}$ Noise Goal (dBA)	Noise Level – $L_{Aeq(15minute)}$ (dBA)	
		Worst-case Predicted	Noise Goal Exceedance
Earthworks			
Location 1 315-321 Burley Road	47	Up to 40	-
Location 2 Lenore Lane	46	Up to 35	-
Location 3 Emmaus College	55	Up to 33	-
Location 4 32 Adlington Road	43	Up to 33	-
Paving Works including Concrete Pours			
Location 1 315-321 Burley Road	47	Up to 37	-
Location 2 Lenore Lane	46	Up to 32	-
Location 3 Emmaus College	55	Up to 30	-
Location 4 32 Adlington Road	43	Up to 30	-
Construction of Roadways			
Location 1 315-321 Burley Road	47	Up to 39	-
Location 2 Lenore Lane	46	Up to 34	-
Location 3 Emmaus College	55	Up to 32	-
Location 4 32 Adlington Road	43	Up to 32	-
Construction of Warehouse and Office Structures			
Location 1 315-321 Burley Road	47	Up to 31	-
Location 2 Lenore Lane	46	< 30	-
Location 3 Emmaus College	55	< 30	-
Location 4 32 Adlington Road	43	< 30	-

Sensitive Receiver Area	Construction $L_{Aeq(15minute)}$ Noise Goal (dBA)	Noise Level – $L_{Aeq(15minute)}$ (dBA)	
		Worst-case Predicted	Noise Goal Exceedance
Landscaping and Finishing Works			
Location 1 315-321 Burley Road	47	< 30	-
Location 2 Lenore Lane	46	< 30	-
Location 3 Emmaus College	55	< 30	-
Location 4 32 Adlington Road	43	< 30	-

During standard construction hours, worst-case construction noise emissions of up to 40 dBA $L_{Aeq(15minute)}$ are predicted at the identified sensitive receivers.

However, no exceedance of the noise goals is predicted.

The ICNG describes strategies for construction noise mitigation and control that are applicable to this proposal. The strategies are designed to minimise, to the fullest extent practicable, noise during construction.

As per the Development Consent for Oakdale Central Lot 3, construction must be limited to standard construction hours, ie:

- Monday to Friday 7.00 am to 6.00 pm.
- Saturday 8.00 am to 1.00 pm

Although construction noise levels are not predicted to exceed the noise goals, it is recommended that the following construction noise mitigation measures should be considered, where reasonable and feasible. Typical construction noise mitigation measures include the following:

- Avoiding the coincidence of noisy plant working simultaneously close together would result in reduced noise emissions.
- Equipment which is used intermittently is to be shut down when not in use.
- Where possible, equipment with directional noise emissions should be oriented away from sensitive receivers.
- Regular compliance checks on the noise emissions of all plant and machinery used for the proposal would indicate whether noise emissions from plant items were higher than predicted. This also identifies defective silencing equipment on the items of plant.
- Non-tonal reversing alarms should be used on all items of plants and heavy vehicles used for construction.

5.3 Construction Vibration Impacts

The effects of vibration in buildings can be divided into three main categories – those in which the occupants or users of the building are inconvenienced or possibly disturbed, those where the building contents may be affected and those in which the integrity of the building or the structure itself may be prejudiced.

The propagation of vibration emitted from a source would be site specific with the level of vibration potentially experienced at a receiver dependent upon the vibration energy generated by the source, the predominant frequencies of vibration, the localised geotechnical conditions and the interaction of structures and features which can dampen vibration.

The recommended safe working distances for construction plant in **Table 10** are referenced from the TfNSW *Construction Noise Strategy*.

Consistent with British Standard BS 7385 Part 2-1993 and the *Assessing Vibration: A Technical Guideline*, the recommendations are for the practical management of potential vibration to minimise the likelihood of cosmetic damage to buildings and disturbance or annoyance in humans. The human comfort safe working distances are conservative, developed with reference to the more stringent objectives for continuous vibration for typical residential building constructions.

Table 10 Recommended Safe Working Distances for Vibration Intensive Plant

Plant Item	Rating / Description	Safe Working Distance	
		Cosmetic Damage[1]	Human Response[2]
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m
	< 50 kN (Typically 2-4 tonnes)	6 m	20 m
	< 50 kN (Typically 4-6 tonnes)	12 m	40 m
	< 50 kN (Typically 7-13 tonnes)	15 m	100 m
	< 50 kN (Typically 13-18 tonnes)	20 m	100 m
	< 50 kN (Typically > 18 tonnes)	25 m	100 m
Small Hydraulic Hammer	300 kg – 5 to 12t excavator	2 m	7 m
Medium Hydraulic Hammer	1600 kg – 12 to 18t excavator	7 m	23 m
Large Hydraulic Hammer	1600 kg – 18 to 34t excavator	22 m	73 m
Vibratory Pile Driver	Sheet piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2 m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

Note 1: Referenced from British Standard BS 7385 Part 2-1993.
Note 2: Referenced from *Assessing Vibration: A Technical Guideline*.

Vibration intensive items of plant proposed for use during the construction of the development would include plate compactors and vibratory rollers. These items of equipment are proposed to be used during paving works including concrete pours and construction of roadways.

The nearest residential receivers to the development construction works are located over 1,000 m from the nearest point of Lot 3B, and the nearest commercial receivers are over 100 m from Lot 3B. This separation distance between Lot 3B and the nearest vibration sensitive receivers is sufficient that there will be no vibration impacts at any receivers. Therefore, vibration mitigation measures are not required for construction of Lot 3B.

6 CONCLUSION

The proposed development is considered to be feasible on the basis of acoustics.

It should be noted that the recommendations made in this report are based on 24 hour operation of warehouse and distribution facilities in the site. As such, this is considered a worst-case assessment of potential impacts. Typical impacts are likely to be lower than the worst-case predicted impacts.

6.1 Operational Noise Impacts

An operational noise impact assessment has been conducted for Oakdale Central Lot 3B. Noise Limits consistent with those in the Development Consent SSD 6078 for the rest of Oakdale Central have been adopted.

The operational noise modelling for Oakdale Central Lot 3B found no exceedances of the Noise Limits at the identified noise sensitive receivers. Cumulative impacts with the rest of Oakdale Central, including Lots 1, 2, 3A, 3C and 3D were also found to be below the defined Noise Limits. Therefore, no operational noise mitigation measures are required.

Off-site traffic movements associated with Lot 3B are predicted to have a negligible impact on road traffic noise levels in the vicinity of the main access routes of Lenore Drive and Old Wallgrove Road, given the existing comparatively high volume of traffic on these arterial roads.

6.2 Construction Noise and Vibration Impacts

A construction noise and vibration impact assessment has been conducted for Oakdale Central Lot 3B. Construction noise goals consistent with those in the Noise Impact Assessment conducted for the rest of Oakdale Central Lot 3 have been adopted.

No exceedances of the construction noise goals at the identified noise sensitive receivers are predicted during standard construction hours.

Furthermore, the separation distance between Lot 3B and the nearest vibration sensitive receivers is sufficient that there will be no vibration impacts at these receivers.

Acoustic Terminology

1 Sound Level or Noise Level

The terms ‘sound’ and ‘noise’ are almost interchangeable, except that in common usage ‘noise’ is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or LP are commonly used to represent Sound Pressure Level. The symbol LA represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2 x 10^{-5} Pa.

2 ‘A’ Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an ‘A-weighting’ filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People’s hearing is most sensitive to sounds at mid frequencies (500 Hz to 4000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dBA or 2 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels

Sound Pressure Level (dBA)	Typical Source	Subjective Evaluation
130	Threshold of pain	Intolerable
120	Heavy rock concert	Extremely noisy
110	Grinding on steel	
100	Loud car horn at 3 m	Very noisy
90	Construction site with pneumatic hammering	
80	Kerbside of busy street	Loud
70	Loud radio or television	
60	Department store	Moderate to quiet
50	General Office	
40	Inside private office	Quiet to very quiet
30	Inside bedroom	
20	Recording studio	Almost silent

Other weightings (eg B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as ‘linear’, and the units are expressed as dB(lin) or dB.

3 Sound Power Level

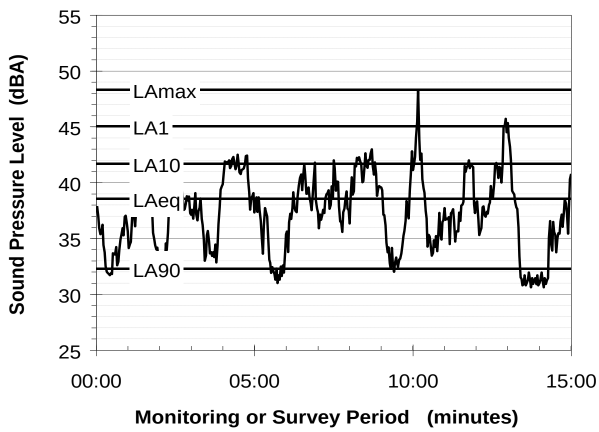
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or LW, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels LAN, where LAN is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the LA1 is the noise level exceeded for 1% of the time, LA10 the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of particular relevance, are:

LA1 The noise level exceeded for 1% of the 15 minute interval.

LA10 The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

LA90 The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

LAeq The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces a level representing the ‘repeatable minimum’ LA90 noise level over the daytime and night-time measurement periods, as required by the EPA. In addition the method produces mean or ‘average’ levels representative of the other descriptors (LAeq, LA10, etc).

5 Tonality

Tonal noise contains one or more prominent tones (ie distinct frequency components), and is normally regarded as more offensive than ‘broad band’ noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

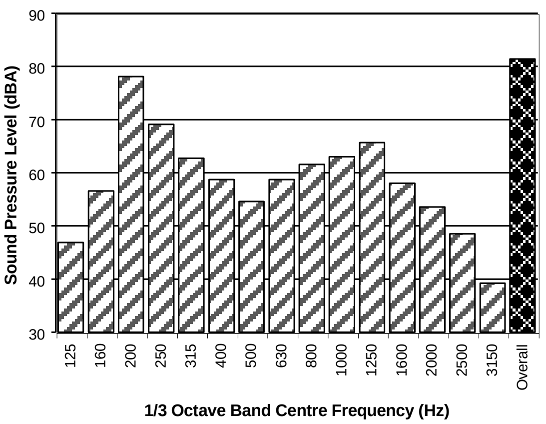
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of 'peak' velocity or 'rms' velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as 'peak particle velocity', or PPV. The latter incorporates 'root mean squared' averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s). Care is required in this regard, as other reference levels may be used by some organizations.

9 Human Perception of Vibration

People are able to 'feel' vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as 'normal' in a car, bus or train is considerably higher than what is perceived as 'normal' in a shop, office or dwelling.

10 Over-Pressure

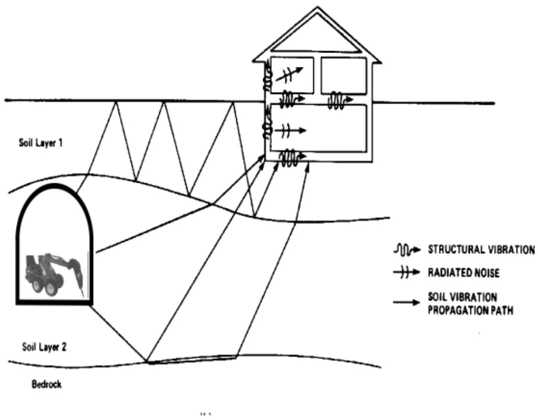
The term 'over-pressure' is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

11 Ground-borne Noise, Structure-borne Noise and Regenerated Noise

Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed 'structure-borne noise', 'ground-borne noise' or 'regenerated noise'. This noise originates as vibration and propagates between the source and receiver through the ground and/or building structural elements, rather than through the air.

Typical sources of ground-borne or structure-borne noise include tunnelling works, underground railways, excavation plant (eg rockbreakers), and building services plant (eg fans, compressors and generators).

The following figure presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.



The term 'regenerated noise' is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise