NSW GOVERNMENT

Transport Access Program

Wahroonga Station Upgrade

Supporting Studies

Artist's impression of the proposed Wahroonga Station Upgrade, subject to change during detailed design.

December 2019

TRANSPORT ACCESS PROGRAM

Wahroonga Station Upgrade
Noise and Vibration Impact Assessment

Prepared for:

Transport for NSW
Level 5, Tower A, Zenith Centre,
821 Pacific Highway, Chatswood,
NSW, 2067

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BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Transport for NSW (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

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EXECUTIVE SUMMARY

Transport for NSW (TfNSW) proposes to upgrade Wahroonga Station to meet disability access requirements (the Proposal) as outlined in the *Disability Discrimination Act 1992* (DDA Act). The Proposal includes an upgrade of Wahroonga Station as part of the Transport Access Program which would improve accessibility and amenity for customers, as well as the refurbishment of the Redleaf Avenue bridge including the replacement of the existing walkway structure with a new footbridge across the rail corridor.

This report presents an assessment of construction and operational noise and vibration associated with the concept design and identifies feasible and reasonable noise and vibration mitigation and management measures to be incorporated in the detailed design and construction planning stage of the Proposal. This assessment forms part of the input to the Review of Environmental Factors (REF).

Construction noise and vibration impacts

Most of the time, the Proposal's construction works are to be undertaken during standard daytime construction hours. However, some works would need to be undertaken during rail/road shutdowns and would, therefore, need to be undertaken during the more noise sensitive night-time period.

Daytime construction noise management level exceedances are predicted at surrounding residential and commercial receivers on both sides of the rail corridor for most of the Proposal's construction works activities. Due to the nearest residential receivers being located within approximately 15 metres from the construction works, high daytime noise management level (NML) exceedances of up to 29 dB are predicted during the most noise intensive works. Such high magnitude impacts would be limited to residential receivers directly adjacent Wahroonga Station on Millewa Avenue and Woodville Avenue. Receivers which are located further away from the proposed worksite would have much lower NML exceedances.

During rail shutdowns, when works are required to be performed during evening and night-time periods, exceedances of the night-time noise management levels of more than 30 dBA are predicted at the nearest residential receivers. The high magnitude of impacts at the closest receivers is a result of their close proximity to noise intensive works, and the low evening and night-time NMLs.

The separation distance between the proposed vibration generating works and the nearest vibration sensitive receivers would be sufficient to mitigate vibration levels such that the human comfort and cosmetic damage vibration criteria are not exceeded.

Specific and additional mitigation and management measures for construction noise are outlined in this report to address the predicted impacts. If vibration intensive works are required to be undertaken within the specified safe working distances outlined in this report, or in close proximity to vibration-sensitive heritage structures, vibration monitoring should be undertaken to ensure acceptable levels of vibration are satisfied.

EXECUTIVE SUMMARY

Operational noise impacts

This assessment presents the applicable noise criteria for industrial noise sources associated with the Proposal. At this stage of the design, specific mechanical systems have not been selected, which means it is too early to assess compliance with the applicable noise criteria however given this type of noise source (i.e. lift and padmount substation) generally has relatively low noise emissions, it is anticipated that the lift system and the substation design could be relatively easily mitigated if required during the detailed design phase of the Proposal. It is anticipated that the operational noise criteria established in this assessment would inform the detailed design process.

Refurbishment of the Redleaf Avenue bridge is not expected to influence road traffic noise and operational road traffic noise impacts are not considered in this assessment.

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GLOSSARY

Item	Description / Definition
CNVMP	*Construction Noise and Vibration Management Plan*
CNVS	*Construction Noise and Vibration Strategy*
DEC	Department of Environment and Conservation (now OEH / EPA)
DECC	Department of Environment and Climate Change (now OEH / EPA)
DECCW	Department of Environment, Climate Change and Water (now OEH / EPA)
EPA	Environment Protection Authority
ICNG	*Interim Construction Noise Guideline*
INP	*Industrial Noise Policy*
Lidar	Light Detection and Ranging
NCA	Noise Catchment Area
NML	Noise Management Level
NPfI	*Noise Policy for Industry*
NSW	New South Wales
PTNL	Project Trigger Noise Level
RBL	Rating Background Level
REF	Review of Environmental Factors
RING	*Rail Infrastructure Noise Guideline*
RMS	Root Mean Square
RNP	*Road Noise Policy*
SLR	SLR Consulting Australia Pty Ltd
SWL	Sound Power Level
TfNSW	Transport for NSW
VDV	Vibration Dose Value

1 Introduction

Transport for NSW (TfNSW) proposes to upgrade Wahroonga Station to meet disability access requirements (the Proposal) as outlined in the *Disability Discrimination Act 1992* (DD Act). The Proposal would include an upgrade of Wahroonga Station as part of the Transport Access Program which would improve accessibility and amenity for customers, as well as the refurbishment of the Redleaf Avenue bridge including the replacement of the existing walkway structure with a new footbridge across the rail corridor.

The Proposal is part of the Transport Access Program (TAP) which is a NSW Government initiative to provide a better experience for public transport customers by delivering accessible, modern, secure and integrated transport infrastructure. A key objective of the program is to ensure that all stations, and in this instance Wahroonga Station, meet legislative requirements under the *Disability Standards for Accessible Public Transport 2002* (DSAPT).

The Proposal would provide safe and equitable access to the island platform and the surrounding pedestrian network at Wahroonga Station and would also improve customer facilities and amenities. The improvements would, in turn, assist in supporting the growth in public transport use and would provide an improved customer experience for existing and future users of the station.

1.1 Report objectives

SLR Consulting Australia Pty Ltd (SLR) has been engaged by RPS to prepare a construction and operational noise and vibration assessment for the proposed station upgrade at Wahroonga and the refurbishment of the Redleaf Avenue bridge.

The aims of this assessment are to:

- summarise the construction and operational noise and vibration assessment of the concept design for the Proposal
- identify feasible and reasonable noise and vibration mitigation and management measures to be incorporated in the detailed design and construction planning stage of the Proposal.

This assessment forms part of the input to the Review of Environmental Factors (REF).

1.2 Relevant guidelines

The noise and vibration guidelines for construction and operations are based on publications managed by the NSW Environment Protection Authority (EPA). The EPA guidelines applicable to this assessment include:

- Operational noise – *Noise Policy for Industry* (NPfI) (EPA, 2017)
- Construction noise – *Interim Construction Noise Guideline* (DECC, 2009)
- Construction vibration (human comfort) – *Assessing Vibration – a technical guideline* (DEC 2006)
- Construction vibration (cosmetic damage) – Australian Standard AS 2187: Part 2-2006 *Explosives - Storage* and *Use - Part 2: Use of Explosives* and British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2.*

The following additional guidelines are also referenced in this study:

- Construction noise and vibration mitigation - *Construction Noise and Vibration Strategy* (CNVS) (TfSNW, 2018).

1.3 Terminology

Specific acoustic terminology is used within this assessment. An explanation of common acoustic terms is included as **Appendix A**.

2 Proposal description

2.1 Proposal overview

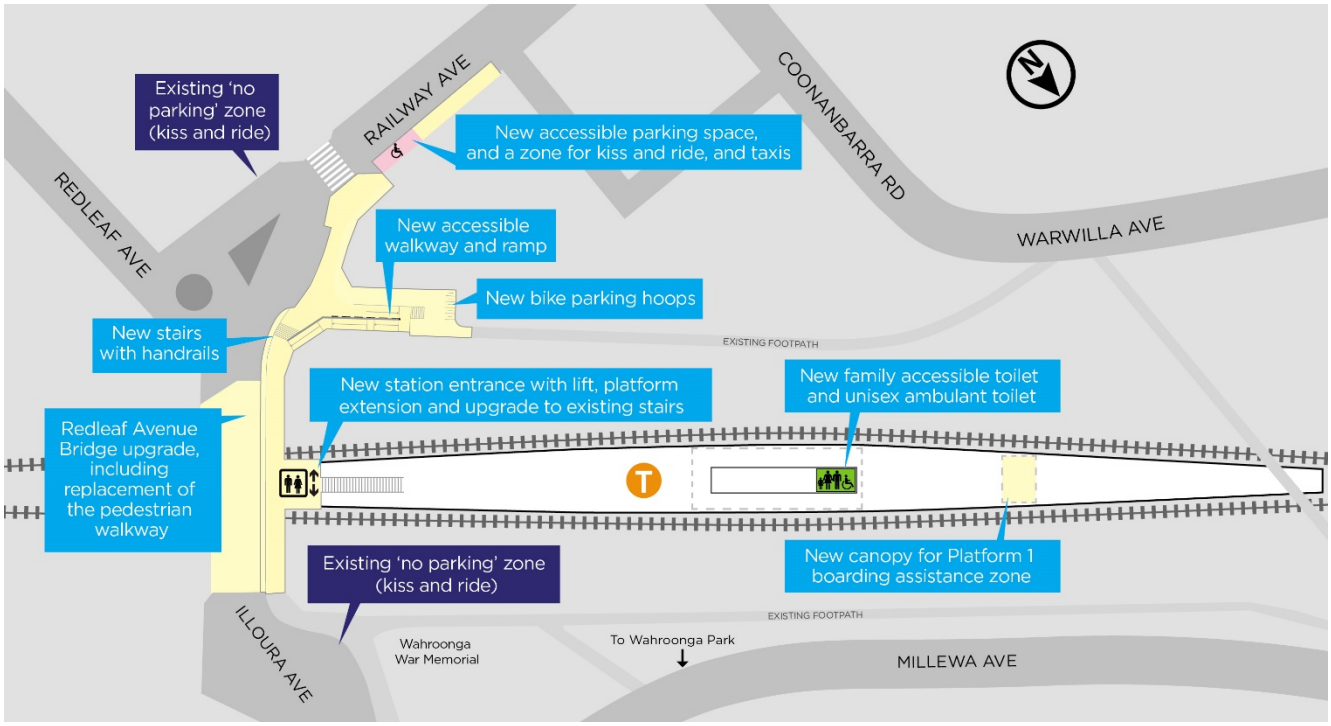
The Proposal involves an upgrade of Wahroonga Station as part of the Transport Access Program which would improve accessibility and amenity for customers, as well as the refurbishment of the Redleaf Avenue bridge including the replacement of the existing walkway structure with a new footbridge across the rail corridor.

The Proposal would include the following key elements:

- refurbishment of the Redleaf Avenue bridge and replacement of the pedestrian walkway structure with a new footbridge
- a new passenger lift and station entrance to provide access from the Redleaf Avenue bridge to the island platform
- a new walkway at platform level linking the lift to the platform
- a new accessible ramp and pathway to provide access from the station to Wahroonga shopping village
- a proposed interchange zone in Railway Avenue, to provide an accessible parking space, and a zone for taxis and kiss and ride
- a new family accessible toilet and unisex ambulant toilet within the station building
- an additional canopy for weather protection on the platform at the boarding assistance zone (north of the station building)
- improvements to station lighting and CCTV to increase safety and security
- improvements to customer information and communication systems including wayfinding modifications, public address (PA) system upgrade and new hearing induction loops.

Key elements of the Proposal are shown in **Figure 1**.

Figure 1 Key elements of the Proposal



2.2 Identification of sensitive receivers

The Proposal works are located as shown in **Figure 2**. Also shown are the locations of the noise sensitive receiver Noise Catchment Areas (NCA01 and NCA02) and noise monitoring location L01.

Figure 2 Site location showing indicative works location

Table 1 provides a summary of the noise catchment areas shown as NCA01 and NCA02 in **Figure 2**.

Table 1 Representative noise sensitive receivers

NCA	Boundary description	Sensitive receiver descriptions
NCA01	Receivers located on the northern side of the rail corridor.	Wahroonga Park is on the opposite side of Millewa Avenue. Mostly double-storey residential buildings. Closest receivers located approximately 25 metres (m) northeast of the Redleaf Avenue bridge. One childcare centre (KU Wahroonga Preschool) located approximately 80 m north of the Wahroonga platform. One education facility (Wahroonga Preparatory School) located approximately 230 m north of Wahroonga Station. Two place of worship receivers (Wahroonga Presbyterian Church and St John's Uniting Church) located approximately 170 m and 220 m north of the Wahroonga Station respectively.
NCA02	Receivers located on the southern side of the rail corridor.	Three-storey apartment buildings and two-storey residential buildings on Warwilla Avenue. Closest receivers located approximately 50 m southwest of the Wahroonga Station platform. Multiple commercial receivers on Railway Avenue and Redleaf Avenue. One medical receiver (Neringah Hospital) located approximately 180 m southwest of Wahroonga Station.

3 Existing acoustic environment

3.1 Continuous unattended monitoring

3.1.1 Noise monitoring procedure

ARL EL215/316, Logger Serial No: 16-203-525 was deployed from 23 July 2018 to 31 July 2018 at 1 Illoura Avenue, Wahroonga, referred to as noise monitoring location L01 in **Figure 2**.

This location was selected based on an inspection of the potentially affected areas, giving consideration to other noise sources that may influence the recordings, security issues for the noise monitoring device and gaining permission for access to the location from the resident or landowner.

The results of the noise monitoring have been processed in accordance with the procedures contained in the *Noise Policy for Industry* (NPfI) so as to establish representative noise levels from all noise sources in the area at the residences.

3.1.2 Noise monitoring results

A summary of the unattended continuous noise monitoring is provided in **Table 2**. A full graphical representation of the unattended noise monitoring results is provided in **Appendix B**.

Table 2 Unattended noise logger results

Location	Address	Period[1]	Measurement parameter (dBA)			
			RBL	LAeq	L10	L1
L01	1 Illoura Avenue, Wahroonga	Daytime	46	54	54	62
		Evening	43	51	52	57
		Night-time	37	49	47	53

Note 1: NPfI Governing Periods - Day: 7am to 6pm Monday to Saturday, 8am to 6pm Sundays & Public Holidays, Evening: 6pm to 10pm, Night: 10pm to 7am Monday to Saturday, 10pm to 8am Sundays & Public Holidays.

The ambient noise logger was positioned in view of Millewa Avenue, the rail corridor to the south and Illoura Avenue to the west. The results of continuous unattended noise monitoring at this location show typical levels of a suburban noise environment with relatively medium to high daytime noise levels. Daytime and evening noise levels in this area are dominated by road traffic on surrounding local roads and rail traffic.

3.2 Operator attended measurements

3.2.1 Noise measurement procedure

Operator-attended ambient noise surveys were conducted on 27 July 2018 at noise monitoring location L01 shown in **Figure 2**.

The operator-attended noise measurements were performed using a calibrated Brüel and Kjær 2260, Sound Level Meter Serial No: 2414604. Instrument calibration was checked before and after the measurement survey, with the variation in calibrated levels not exceeding the acceptable variation of ±0.5 dB (AS 1055).

The acoustic instrumentation employed throughout the noise monitoring survey was designed to comply with the requirements of *AS IEC 61672.1-2004: Electroacoustics - Sound level meters - Specifications* as a type 1 precision sound level meter and has an accuracy suitable for both field and laboratory use. Both the meter and calibrator carry current NATA calibration certificates.

3.2.2 Noise measurement results

A summary of the operator-attended ambient noise survey is shown in **Table 3**.

Table 3 Operator attended ambient noise survey

Measurement Location	Measurement Start Time	Measured noise levels (dBA)			Observations (dBA)
		LAmax	LAeq	LA90	
L01 - 1 Illoura Avenue, Wahroonga	13:52	74	54	49	Light-vehicle traffic: 74-80 dBA Heavy-vehicle traffic: 75 dBA Train Passby – North Shore Line: 71 dBA Car Horn: 68 dBA

Attended noise measurements indicate the ambient noise environment at this location is dominated by road traffic noise from Millewa Avenue to the south. Train pass-by(s) along the North Shore Line, approaching and departing Wahroonga Station also contribute to the L_{Aeq} noise level at this location.

4 Construction noise assessment

4.1 Noise and vibration guidelines

4.1.1 Construction noise metrics

The three primary noise metrics used to describe construction noise emissions:

- **$L_{A1(1minute)}$** - the "typical maximum noise level" for an event, used in the assessment of potential sleep disturbance during night-time periods. Alternatively, the assessment may be conducted using the L_{Amax} or maximum noise level
- **$L_{Aeq(15minute)}$** - the "energy average noise level" evaluated over a 15-minute period. This parameter is used to assess potential construction noise impacts
- **L_{A90}** - the "background noise level" in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively. The $L_{Aeq(15minute)}$ construction Noise Management Levels (NMLs) are based on the L_{A90} background noise levels.

The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (ie A-weighted).

4.1.2 NSW Interim Construction Noise Guideline

The *Interim Construction Noise Guideline* (ICNG) (DECC, 2009) sets out ways to deal with the impacts of construction noise on residences and other sensitive land uses. It does this by presenting assessment approaches that are tailored to the scale of construction projects.

The ICNG requires proposal specific Noise Management Levels (NMLs) to be established for noise affected receivers. In the event construction noise levels are predicted to be above the NMLs, feasible and reasonable work practices are investigated to minimise noise emissions.

4.1.2.1 Residential receivers

The ICNG provides an approach for determining $L_{Aeq(15minute)}$ NMLs at residential receivers adjacent to the works by applying the measured $L_{AF90(15minute)}$ rating background noise levels (RBL), as described in **Table 4**.

Table 4 ICNG - determination of NMLs for residential receivers

Time of day	NML $L_{Aeq(15minute)}$	How to apply
Standard hours Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or public holidays	RBL + 10 dBA	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq(15minute)}$ 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 dBA	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 restructuring the hours that the very noisy activities can occur, taking into account: Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools or mid-morning or mid-afternoon for works near residences. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	RBL[1] + 5 dBA	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5 dBA above the noise affected level, the proponent should negotiate with the community.

Note 1: The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours). The term RBL is described in detail in the NSW *Industrial Noise Policy*.

4.1.2.2 Sleep disturbance

Major infrastructure projects often require certain works to be completed during the night-time. Where night works are located close to residential receivers there is potential for sleep disturbance impacts. Where construction works are planned to extend over more than two consecutive nights, the ICNG recommends that an assessment of sleep disturbance impacts should be completed.

For the purposes of this assessment, the following night-time sleep disturbance noise goal has been used:

- night-time RBL +15 dBA "screening criterion".

4.1.2.3 Other Sensitive Land Uses and Commercial Receivers

Non-residential land uses have been identified in the study area. These include 'other sensitive' land uses such as educational institutes, medical facilities, outdoor recreational areas, and commercial properties. The ICNG NMLs for 'other sensitive' receivers are shown in **Table 5**.

Table 5 ICNG NMLs for 'Other Sensitive' Receivers

Land Use	Noise Management Level $L_{Aeq(15minute)}$ (dBA) (Applied when the property is in use)	
	Internal	External
Classrooms at schools and other educational institutions	45	55[1]
Hospital wards and operating theatres	45	65[1]
Places of worship	45	55[1]
Active recreation areas (characterised by sporting activities and activities which generate noise)	-	65
Passive recreation areas (characterised by contemplative activities that generate little noise)	-	60
Commercial	-	70
Industrial	-	75

Note 1: The criteria are specified as internal noise levels for these other sensitive receiver categories. As the noise model predicts external noise levels, it has been conservatively assumed that all schools and places of worship have openable windows and external noise levels are 10 dB higher than the corresponding internal level, which is representative of windows being partially open to provide ventilation. Hospital wards are assumed to have fixed windows with 20 dB higher external levels.

The ICNG references *AS2107:2016 Acoustics – Recommended design sound levels and reverberation times for building interiors* for criteria for 'other sensitive' receivers which are not listed in the guideline. Neither the ICNG nor AS 2107 provide criteria for childcare centres so the Association of Australian Acoustical Consultants *Guideline for Child Care Centre Acoustic Assessment* (GCCCAA) has also been referenced. The NMLs for 'other sensitive receivers' are shown in **Table 6**.

Table 6 NMLs for Other Sensitive Receivers

Use	Period	NML Derived From	Noise Management Level $L_{Aeq(15minute)}$ (dBA)	
			Internal	External
Hotel	Daytime and evening	AS2107: Bars and lounges	50	70[1]
	Night-time	AS2107: Sleeping areas: Hotels near major roads	40	60[1]
Childcare centres	Daytime	GCCCAA: Outdoor play areas	-	55
		GCCCAA: Sleeping areas	40	50[2]

Note 1: The criteria is specified as an internal noise level for this receiver category. As the noise model predicts external noise levels, it has been assumed that these receivers have fixed windows with a conservative 20 dB reduction for external to internal noise levels.

Note 2: Receiver conservatively assumed to have openable windows and a 10 dB outside to inside facade performance.

4.1.3 NML summary

Adopting the measured background noise levels in **Table 2**, the NMLs derived for the Proposal are outlined in **Table 7**.

Table 7 NMLs for construction

NCA	Receiver type	RBL (dBA)			Noise Management Level LAeq(15minute) (dBA)				Sleep disturbance screening (RBL+15)
		Daytime	Evening	Night	Standard Daytime[1]	OOHW Daytime[2]	Evening [2]	Night[2]	
NCA01	Residential	46	43	37	56	51	48	42	52
	Other Sensitive (Place of worship)	n/a	n/a	n/a	55	55	55	n/a	n/a
	Other Sensitive (Educational)	n/a	n/a	n/a	55	55	n/a	n/a	n/a
	Other Sensitive (Childcare)	n/a	n/a	n/a	50	50	n/a	n/a	n/a
	Other Sensitive (Passive recreation areas)	n/a	n/a	n/a	60	60	n/a	n/a	n/a
NCA02	Residential	46	43	37	56	51	48	42	52
	Other Sensitive (Medical)	n/a	n/a	n/a	65	65	n/a	n/a	n/a
	Other Sensitive (Commercial)	n/a	n/a	n/a	70	70	n/a	n/a	n/a
	Other Sensitive (Educational)	n/a	n/a	n/a	55	55	n/a	n/a	n/a
	Other Sensitive (Passive recreation areas)	n/a	n/a	n/a	60	60	n/a	n/a	n/a

Note 1: Standard daytime working hours are from 7am to 6pm Monday to Friday, 8am to 1pm Saturdays and no work on Sundays or public holidays.

Note 2: Out of Hours construction hours : OOHW Daytime hours are from 1pm to 6pm Saturday and 8am to 6pm Sunday. Evening hours are from 6pm to 10pm. Night-time hours are from 10pm to 7am Sunday to Saturday and 10pm Saturday to 8am Sunday.

4.2 Construction-related vibration assessment criteria

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.

4.2.1 Human comfort vibration

The EPA's *Assessing Vibration: a technical guideline* provides guideline values for continuous, transient and intermittent events that are based on a Vibration Dose Value (VDV) rather than a continuous vibration level. The VDV is dependent upon the level and duration of the short-term vibration event, as well as the number of events occurring during the daytime or night-time period.

The VDVs recommended in the document for vibration of an intermittent nature (ie construction works where more than three distinct vibration events occur) are presented in **Table 8**.

Table 8 Acceptable vibration dose values for intermittent vibration (m/s$^{1.75}$) (*Assessing Vibration: a technical guideline)*

Location	Daytime[1]		Night-time[1]	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Critical areas[2]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	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

Note 1: Daytime is 7:00 AM to 10:00 PM and night-time is 10:00 PM to 7:00 AM.

Note 2: Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas (Source: BS 6472-1992).

4.2.2 Effects on building contents

People can perceive floor vibration at levels well below those likely to cause damage to building contents or affect the operation of typical equipment. For most receivers, the controlling vibration criterion will be the human comfort criterion, and it is therefore not normally required to set separate criteria in relation to the effect of construction vibration on most building contents.

Where appropriate, objectives for the satisfactory operation of critical instruments or manufacturing processes should be sourced from manufacturer's data and/or other published objectives.

4.2.3 Structural damage vibration

Structural damage vibration limits are based on Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* and British Standard BS 7385 Part 2-1993 *Evaluation and measurement for vibration in buildings Part 2*. These standards provide frequency-dependent vibration limits related to cosmetic damage, noting that cosmetic damage is very minor in nature, is readily repairable and does not affect the structural integrity of the building. The recommended vibration limits from BS 7385 for transient vibration for minimal risk of cosmetic damage to residential and industrial buildings are shown in **Table 9**.

Table 9 Transient vibration guide values for minimal risk of cosmetic damage (BS 7385)

Line	Type of building	Peak component particle velocity in the frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

4.2.4 Safe working distances

As a guide, safe working distances for the proposed items of vibration intensive plant are provided in the Transport for NSW *Construction Noise and Vibration Strategy* (CNVS) (2018) and are reproduced below in **Table 10**.

Table 10 Recommended safe working distances for vibration intensive plant

Plant item	Rating/description	Safe working distance	
		Cosmetic damage (BS 7385)	Human response (NSW EPA Vibration Guideline)
Vibratory roller	< 50 kN (Typically 1-2t)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4t)	6 m	20 m
	< 200 kN (Typically 4-6t)	12 m	40 m
	< 300 kN (Typically 7-13t)	15 m	100 m
	> 300 kN (Typically 13-18t)	20 m	100 m
	> 300 kN (Typically > 18t)	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
Jackhammer	Handheld	1 m (nominal)	Avoid contact with structure
Bored piling	< 800 mm	2 m	n/a

Note 1: More stringent conditions may apply to heritage or other sensitive structures, Refer **Section 4.8.3**.

The safe working distances presented in **Table 10** are quoted for both cosmetic damage (refer to BS 7385:2 *Evaluation and Measurement for Vibration in Buildings Part 2: Guide to Damage Levels from Ground-borne Vibration*, 1993) and human comfort (refer to NSW EPA *Assessing Vibration: a technical guideline*, 2006).

The safe working distances for building damage should be complied with at all times. The distances are noted as being indicative and would vary depending on the particular item of plant and local geotechnical conditions. They apply to address the risk of cosmetic (minor – easily reparable) damage of typical buildings under typical geotechnical conditions.

Where vibration intensive works are required to be undertaken within the specified safe working distances, vibration monitoring should be undertaken to ensure acceptable levels of vibration are satisfied.

In relation to human comfort, the safe working distances relate to continuous vibration. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are allowed.

4.3 Construction timing

4.3.1 Staging

Subject to approval, construction is expected to commence in 2020 and take around 24 months to complete. The construction methodology would be further developed during the detailed design of the Proposal by the nominated Contractor in consultation with TfNSW.

The proposed construction activities for the Proposal are identified in **Section 4.4**. The construction staging outlined in this assessment is indicative and is based on the current concept design and may change once the detailed design methodology is finalised. The staging is also dependent on the Contractor's preferred methodology, program, and sequencing of work.

4.3.2 Construction hours

Where possible, works required for the Proposal would be undertaken during standard (NSW) Environment Protection Authority (EPA) construction hours, which are as follows:

- 7am to 6pm Monday to Friday
- 8am to 1pm Saturdays
- no work on Sundays or public holidays.

Works may need to occur outside standard hours and would include night works and works during routine rail shutdowns, which are scheduled closures that would occur regardless of the Proposal when part of the rail network is temporarily closed and trains are not operating.

The refurbishment of Redleaf Avenue bridge will result in temporary road closures during some weekend rail shutdowns. Work associated with road partial and full road closures may be required outside standard hours.

Out of hours works are required in some cases to minimise disruptions to customers, pedestrians, motorists, and nearby sensitive receivers; and to ensure the safety of road and railway workers and operational assets. It is estimated that approximately ten rail shutdowns would be required to facilitate the following, during which time Wahroonga Station would be closed to the public:

- staged removal of concourse and support trestles
- piling for the footbridge
- lift shaft installation
- footbridge and road deck replacements
- installation of the new concourse
- installation of the new canopies
- extension of platform for the new walkway
- utilities and services relocation
- platform regrading and resurfacing
- interchange upgrades

- repair works to the bridge superstructure
- electrical power supply upgrades.

Out of hours works may also be scheduled outside rail shutdown periods. Approval from TfNSW would be required for any out of hours work and the affected community would be notified as outlined in TfNSW's *Construction Noise and Vibration Strategy* (TfNSW, 2018).

4.4 Construction works scenarios

In order to assess the potential noise and vibration impacts during construction, a number of scenarios comprising typical plant and equipment have been developed. These are summarised in **Table 11**.

Piling works are associated with several works activities. For the purpose of this assessment, it is assumed that piling works would be performed using bored piling. If the construction contractor elects to use an alternative piling method, the noise and vibration levels generated by the use of this plant may be different to those presented in this assessment and should be reviewed during detailed design.

Table 11 Construction scenarios

	Plant Item		Chainsaw	Chipper	Circular Saw	Concrete Mixer Truck	Concrete Pump	Concrete Saw	Concrete Vibrator	Dumper (5 tonne)	Elevated Working Platform	Excavator (14 tonne)	Generator (small)	Grinder 4"	Hand Tools	Mobile Crane (100 tonne)	Paving Machine	Piling - Bored	Plate compactor	Roller - Smooth Drum	Suction Truck	Telehandler	Water Gurney	Water Pump	Jackhammer	Truck (Hiab)
	Sound Power Level, LAeq		119	120	111	103	106	124	102	95	97	100	93	110	94	100	105	111	108	107	100	92	110	83	113	108
	Assumed On-time in 15 Minute Period (Minutes)		15	15	15	15	15	5	15	3	3	7.5	15	5	15	7.5	15	7.5	15	15	15	7.5	5	7.5	10	3
ID	**Scenario**	**Activity**																								
1A	Site establishment	Establishment of site compounds											X		X	X						X				X
1B		Vegetation removal	X	X						X		X			X											
1C		Hi-rail pad and crossing installation										X				X					X	X				
2A	Preliminary works	Concourse and walkway demolition/removal						X								X					X	X			X	
2B		Platform walkway surface				X	X		X	X		X														
2C		Piling lift shafts								X		X						X								
3A	Construction works	Installation of lift pit and footbridge elements				X	X		X		X			X	X							X				
3B		Ramp, entrance ramp and stairs and lift shaft installation			X	X	X		X					X	X	X						X				
3C		Platform works										X				X			X		X					
4A	Bridge upgrades	Road deck replacement				X	X	X	X	X		X					X	X		X						
4B		Arch repair									X											X	X			

	Plant Item		Chainsaw	Chipper	Circular Saw	Concrete Mixer Truck	Concrete Pump	Concrete Saw	Concrete Vibrator	Dumper (5 tonne)	Elevated Working Platform	Excavator (14 tonne)	Generator (small)	Grinder 4"	Hand Tools	Mobile Crane (100 tonne)	Paving Machine	Piling - Bored	Plate compactor	Roller - Smooth Drum	Suction Truck	Telehandler	Water Gurney	Water Pump	Jackhammer	Truck (Hiab)
	Sound Power Level, LAeq		119	120	111	103	106	124	102	95	97	100	93	110	94	100	105	111	108	107	100	92	110	83	113	108
	Assumed On-time in 15 Minute Period (Minutes)		15	15	15	15	15	5	15	3	3	7.5	15	5	15	7.5	15	7.5	15	15	15	7.5	5	7.5	10	3
ID	**Scenario**	**Activity**																								
5A	Station building works	Internal demolition			X									X												
5B		Fitout													X	X										
6A	Interchange kerb and footpath adjustments	Cutting and breaking						X				X													X	
6B		Road and footpath works				X	X		X			X					X									
7A	Electrical upgrades	Earthworks, construction, and installation				X	X		X	X		X				X						X				
8A	Finishing works	Comissioning									X				X											
8B		Demobilisation													X	X										X

4.5 Predicted noise impacts

In order to quantify noise emissions from the proposed construction works, a 3D computer noise model has been used to predict the $L_{Aeq(15minute)}$ and $L_{A1(1minute)}$ noise levels at the nearest receivers.

The predictions include the source noise levels of the anticipated equipment, the location of the nearest sensitive receivers, the number of plant items likely to be operating at any given time, the distance between the equipment and the receivers, and any shielding or reflections that the topography or buildings may provide.

The resultant daytime, daytime Out of Hours, evening and night-time worst-case $L_{Aeq(15minute)}$ and $L_{A1(1minute)}$ noise level predictions are presented in **Table 12**. The results are presented as a summary of the worst-case impacts for each works scenario when the works are located at the nearest position within the works area to each receiver.

In practice, the noise levels will vary due to the fact that plant will move around the worksites and will not all be operating concurrently. As such, noise levels are likely to be lower than the worst-case noise levels presented for notable periods of time during the works.

The ICNG states that where construction works are planned to extend over more than two consecutive nights, the impact assessment should cover the maximum noise level from the proposed works.

Table 12 Predicted noise levels

Ref	Works Scenario	Works Activity	Worst Case Construction Period	Receiver	Type[1]	Noise Level – L_{Aeq}(15minute) (dBA)												Noise Level – L_{A1}(60second) (dBA) (sleep disturbance)		
						Worst-case Predicted	RBL			NML				Exceedance				Worst-case Predicted	Screening.Crit (RBL+15 dBA)	Exceedance
							Day	Eve	Night	Day	Day OOH	Eve	Night	Day	Day OOH	Eve	Night			
1A	Site establishment	Establishment of site compounds	Standard Daytime	NCA01	RES	73	46	43	37	56	51	48	42	17	-	-	-	-	-	-
				NCA01	OCC	59	-	-	-	55	55	55	-	4	-	-	-	-	-	-
				NCA01	OED	49	-	-	-	55	55	-	-	0	-	-	-	-	-	-
				NCA01	OOP	74	-	-	-	50	50	-	-	24	-	-	-	-	-	-
				NCA01	OPW	51	-	-	-	60	60	-	-	0	-	-	-	-	-	-
				NCA02	RES	69	46	43	37	56	51	48	42	13	-	-	-	-	-	-
				NCA02	OME	54	-	-	-	65	65	-	-	0	-	-	-	-	-	-
				NCA02	COM	82	-	-	-	70	70	-	-	12	-	-	-	-	-	-
				NCA02	OED	69	-	-	-	55	55	-	-	14	-	-	-	-	-	-
				NCA02	OOP	51	-	-	-	60	60	-	-	0	-	-	-	-	-	-
1B		Vegetation removal	Standard Daytime	NCA01	RES	80	46	43	37	56	51	48	42	24	-	-	-	-	-	-
				NCA01	OCC	65	-	-	-	55	55	55	-	10	-	-	-	-	-	-
				NCA01	OED	66	-	-	-	55	55	-	-	11	-	-	-	-	-	-
				NCA01	OOP	83	-	-	-	50	50	-	-	33	-	-	-	-	-	-
				NCA01	OPW	67	-	-	-	60	60	-	-	7	-	-	-	-	-	-
				NCA02	RES	71	46	43	37	56	51	48	42	15	-	-	-	-	-	-
				NCA02	OME	64	-	-	-	65	65	-	-	0	-	-	-	-	-	-
				NCA02	COM	92	-	-	-	70	70	-	-	22	-	-	-	-	-	-
				NCA02	OED	61	-	-	-	55	55	-	-	6	-	-	-	-	-	-
				NCA02	OOP	63	-	-	-	60	60	-	-	3	-	-	-	-	-	-
1C		Hi-rail pad and crossing installation	Night-time	NCA01	RES	73	46	43	37	56	51	48	42	17	22	25	31	81	52	29
				NCA01	OCC	48	-	-	-	55	55	55	-	0	0	0	-	56	-	-
				NCA01	OED	49	-	-	-	55	55	-	-	0	0	-	-	57	-	-
				NCA01	OOP	74	-	-	-	50	50	-	-	24	24	-	-	82	-	-
				NCA01	OPW	47	-	-	-	60	60	-	-	0	0	-	-	55	-	-
				NCA02	RES	67	46	43	37	56	51	48	42	11	16	19	25	75	52	23
				NCA02	OME	46	-	-	-	65	65	-	-	0	0	-	-	54	-	-
				NCA02	COM	80	-	-	-	70	70	-	-	10	10	-	-	88	-	-
				NCA02	OED	62	-	-	-	55	55	-	-	7	7	-	-	70	-	-
				NCA02	OOP	44	-	-	-	60	60	-	-	0	0	-	-	52	-	-

Ref	Works Scenario	Works Activity	Worst Case Construction Period	Receiver	Type[1]	Noise Level – L_{Aeq}(15minute) (dBA)													Noise Level – L_{A1}(60second) (dBA) (sleep disturbance)		
						Worst-case Predicted	RBL			NML				Exceedance					Worst-case Predicted	Screening.Crit (RBL+15 dBA)	Exceedance
							Day	Eve	Night	Day	Day OOH	Eve	Night	Day	Day OOH	Eve	Night				
2A	Preliminary works	Concourse and footbridge demolition/removal	Night-time	NCA01	RES	84	46	43	37	56	51	48	42	28	33	36	42	92	52	40
				NCA01	OCC	62	-	-	-	55	55	55	-	7	7	7	-	70	-	-
				NCA01	OED	61	-	-	-	55	55	-	-	6	6	-	-	69	-	-
				NCA01	OOP	84	-	-	-	50	50	-	-	34	34	-	-	92	-	-
				NCA01	OPW	64	-	-	-	60	60	-	-	4	4	-	-	72	-	-
				NCA02	RES	74	46	43	37	56	51	48	42	18	23	26	32	82	52	30
				NCA02	OME	62	-	-	-	65	65	-	-	0	0	-	-	70	-	-
				NCA02	COM	82	-	-	-	70	70	-	-	12	12	-	-	90	-	-
				NCA02	OED	59	-	-	-	55	55	-	-	4	4	-	-	67	-	-
				NCA02	OOP	62	-	-	-	60	60	-	-	2	2	-	-	70	-	-
2B		Platform walkway surface	Night-time	NCA01	RES	65	46	43	37	56	51	48	42	9	14	17	23	73	52	21
				NCA01	OCC	50	-	-	-	55	55	55	-	0	0	0	-	58	-	-
				NCA01	OED	49	-	-	-	55	55	-	-	0	0	-	-	57	-	-
				NCA01	OOP	77	-	-	-	50	50	-	-	27	27	-	-	85	-	-
				NCA01	OPW	52	-	-	-	60	60	-	-	0	0	-	-	60	-	-
				NCA02	RES	61	46	43	37	56	51	48	42	5	10	13	19	69	52	17
				NCA02	OME	52	-	-	-	65	65	-	-	0	0	-	-	60	-	-
				NCA02	COM	70	-	-	-	70	70	-	-	0	0	-	-	78	-	-
				NCA02	OED	47	-	-	-	55	55	-	-	0	0	-	-	55	-	-
				NCA02	OOP	49	-	-	-	60	60	-	-	0	0	-	-	57	-	-
2C		Piling lift shafts	Night-time	NCA01	RES	68	46	43	37	56	51	48	42	12	17	20	26	76	52	24
				NCA01	OCC	49	-	-	-	55	55	55	-	0	0	0	-	57	-	-
				NCA01	OED	48	-	-	-	55	55	-	-	0	0	-	-	56	-	-
				NCA01	OOP	72	-	-	-	50	50	-	-	22	22	-	-	80	-	-
				NCA01	OPW	52	-	-	-	60	60	-	-	0	0	-	-	60	-	-
				NCA02	RES	61	46	43	37	56	51	48	42	5	10	13	19	69	52	17
				NCA02	OME	50	-	-	-	65	65	-	-	0	0	-	-	58	-	-
				NCA02	COM	68	-	-	-	70	70	-	-	0	0	-	-	76	-	-
				NCA02	OED	46	-	-	-	55	55	-	-	0	0	-	-	54	-	-
				NCA02	OOP	50	-	-	-	60	60	-	-	0	0	-	-	58	-	-

Ref	Works Scenario	Works Activity	Worst Case Construction Period	Receiver	Type[1]	Noise Level – L_{Aeq}(15minute) (dBA)													Noise Level – L_{A1}(60second) (dBA) (sleep disturbance)		
						Worst-case Predicted	RBL			NML				Exceedance					Worst-case Predicted	Screening.Crit (RBL+15 dBA)	Exceedance
							Day	Eve	Night	Day	Day OOH	Eve	Night	Day	Day OOH	Eve	Night				
3A	Construction works	Installation of lift pit and footbridge elements	Night-time	NCA01	RES	75	46	43	37	56	51	48	42	19	24	27	33	83	52	31
				NCA01	OCC	53	-	-	-	55	55	55	-	0	0	0	-	61	-	-
				NCA01	OED	52	-	-	-	55	55	-	-	0	0	-	-	60	-	-
				NCA01	OOP	76	-	-	-	50	50	-	-	26	26	-	-	84	-	-
				NCA01	OPW	55	-	-	-	60	60	-	-	0	0	-	-	63	-	-
				NCA02	RES	65	46	43	37	56	51	48	42	9	14	17	23	73	52	21
				NCA02	OME	53	-	-	-	65	65	-	-	0	0	-	-	61	-	-
				NCA02	COM	73	-	-	-	70	70	-	-	3	3	-	-	81	-	-
				NCA02	OED	51	-	-	-	55	55	-	-	0	0	-	-	59	-	-
				NCA02	OOP	54	-	-	-	60	60	-	-	0	0	-	-	62	-	-
3B		Ramp, entrance ramp and stairs and lift shaft installation	Night-time	NCA01	RES	74	46	43	37	56	51	48	42	18	23	26	32	82	52	30
				NCA01	OCC	55	-	-	-	55	55	55	-	0	0	0	-	63	-	-
				NCA01	OED	54	-	-	-	55	55	-	-	0	0	-	-	62	-	-
				NCA01	OOP	79	-	-	-	50	50	-	-	29	29	-	-	87	-	-
				NCA01	OPW	57	-	-	-	60	60	-	-	0	0	-	-	65	-	-
				NCA02	RES	67	46	43	37	56	51	48	42	11	16	19	25	75	52	23
				NCA02	OME	56	-	-	-	65	65	-	-	0	0	-	-	64	-	-
				NCA02	COM	80	-	-	-	70	70	-	-	10	10	-	-	88	-	-
				NCA02	OED	52	-	-	-	55	55	-	-	0	0	-	-	60	-	-
				NCA02	OOP	55	-	-	-	60	60	-	-	0	0	-	-	63	-	-
3C		Platform works	Night-time	NCA01	RES	73	46	43	37	56	51	48	42	17	22	25	31	81	52	29
				NCA01	OCC	59	-	-	-	55	55	55	-	4	4	4	-	67	-	-
				NCA01	OED	53	-	-	-	55	55	-	-	0	0	-	-	61	-	-
				NCA01	OOP	74	-	-	-	50	50	-	-	24	24	-	-	82	-	-
				NCA01	OPW	56	-	-	-	60	60	-	-	0	0	-	-	64	-	-
				NCA02	RES	68	46	43	37	56	51	48	42	12	17	20	26	76	52	24
				NCA02	OME	56	-	-	-	65	65	-	-	0	0	-	-	64	-	-
				NCA02	COM	80	-	-	-	70	70	-	-	10	10	-	-	88	-	-
				NCA02	OED	51	-	-	-	55	55	-	-	0	0	-	-	59	-	-
				NCA02	OOP	51	-	-	-	60	60	-	-	0	0	-	-	59	-	-

Ref	Works Scenario	Works Activity	Worst Case Construction Period	Receiver	Type[1]	Noise Level – L_{Aeq}(15minute) (dBA)													Noise Level – L_{A1}(60second) (dBA) (sleep disturbance)		
						Worst-case Predicted	RBL			NML				Exceedance					Worst-case Predicted	Screening.Crit (RBL+15 dBA)	Exceedance
							Day	Eve	Night	Day	Day OOH	Eve	Night	Day	Day OOH	Eve	Night				
4A	Bridge upgrades	Road deck replacement	Night-time	NCA01	RES	85	46	43	37	56	51	48	42	29	34	37	43		93	52	41
				NCA01	OCC	62	-	-	-	55	55	55	-	7	7	7	-		70	-	-
				NCA01	OED	61	-	-	-	55	55	-	-	6	6	-	-		69	-	-
				NCA01	OOP	84	-	-	-	50	50	-	-	34	34	-	-		92	-	-
				NCA01	OPW	63	-	-	-	60	60	-	-	3	3	-	-		71	-	-
				NCA02	RES	75	46	43	37	56	51	48	42	19	24	27	33		83	52	31
				NCA02	OME	62	-	-	-	65	65	-	-	0	0	-	-		70	-	-
				NCA02	COM	84	-	-	-	70	70	-	-	14	14	-	-		92	-	-
				NCA02	OED	60	-	-	-	55	55	-	-	5	5	-	-		68	-	-
				NCA02	OOP	62	-	-	-	60	60	-	-	2	2	-	-		70	-	-
4B		Arch repair	Night-time	NCA01	RES	70	46	43	37	56	51	48	42	14	19	22	28		78	52	26
				NCA01	OCC	47	-	-	-	55	55	55	-	0	0	0	-		55	-	-
				NCA01	OED	46	-	-	-	55	55	-	-	0	0	-	-		54	-	-
				NCA01	OOP	69	-	-	-	50	50	-	-	19	19	-	-		77	-	-
				NCA01	OPW	48	-	-	-	60	60	-	-	0	0	-	-		56	-	-
				NCA02	RES	60	46	43	37	56	51	48	42	4	9	12	18		68	52	16
				NCA02	OME	47	-	-	-	65	65	-	-	0	0	-	-		55	-	-
				NCA02	COM	69	-	-	-	70	70	-	-	0	0	-	-		77	-	-
				NCA02	OED	45	-	-	-	55	55	-	-	0	0	-	-		53	-	-
				NCA02	OOP	47	-	-	-	60	60	-	-	0	0	-	-		55	-	-
5A	Station building works	Internal demolition	Night-time	NCA01	RES	64.6	46	43	37	56	51	48	42	9	14	17	23		73	52	21
				NCA01	OCC	60	-	-	-	55	55	55	-	5	5	5	-		68	-	-
				NCA01	OED	56	-	-	-	55	55	-	-	1	1	-	-		64	-	-
				NCA01	OOP	74	-	-	-	50	50	-	-	24	24	-	-		82	-	-
				NCA01	OPW	58	-	-	-	60	60	-	-	0	0	-	-		66	-	-
				NCA02	RES	70	46	43	37	56	51	48	42	14	19	22	28		78	52	26
				NCA02	OME	56	-	-	-	65	65	-	-	0	0	-	-		64	-	-
				NCA02	COM	78	-	-	-	70	70	-	-	8	8	-	-		86	-	-
				NCA02	OED	53	-	-	-	55	55	-	-	0	0	-	-		61	-	-
				NCA02	OOP	53	-	-	-	60	60	-	-	0	0	-	-		61	-	-

Ref	Works Scenario	Works Activity	Worst Case Construction Period	Receiver	Type[1]	Noise Level – L_{Aeq}(15minute) (dBA)													Noise Level – L_{A1}(60second) (dBA) (sleep disturbance)		
						Worst-case Predicted	RBL			NML				Exceedance					Worst-case Predicted	Screening.Crit (RBL+15 dBA)	Exceedance
							Day	Eve	Night	Day	Day OOH	Eve	Night	Day	Day OOH	Eve	Night				
5B	Station building works	Fitout	Night-time	NCA01	RES	73.3	46	43	37	56	51	48	42	17	22	25	31	81	52	29
				NCA01	OCC	49	-	-	-	55	55	55	-	0	0	0	-	57	-	-
				NCA01	OED	45	-	-	-	55	55	-	-	0	0	-	-	53	-	-
				NCA01	OOP	74	-	-	-	50	50	-	-	24	24	-	-	82	-	-
				NCA01	OPW	47	-	-	-	60	60	-	-	0	0	-	-	55	-	-
				NCA02	RES	59	46	43	37	56	51	48	42	3	8	11	17	67	52	15
				NCA02	OME	45	-	-	-	65	65	-	-	0	0	-	-	53	-	-
				NCA02	COM	80	-	-	-	70	70	-	-	10	10	-	-	88	-	-
				NCA02	OED	42	-	-	-	55	55	-	-	0	0	-	-	50	-	-
				NCA02	OOP	44	-	-	-	60	60	-	-	0	0	-	-	52	-	-
6A	Interchange kerb and footpath adjustments	Cutting and breaking	Night-time	NCA01	RES	77	46	43	37	56	51	48	42	21	26	29	35	85	52	33
				NCA01	OCC	62	-	-	-	55	55	55	-	7	7	7	-	70	-	-
				NCA01	OED	63	-	-	-	55	55	-	-	8	8	-	-	71	-	-
				NCA01	OOP	79	-	-	-	50	50	-	-	29	29	-	-	87	-	-
				NCA01	OPW	64	-	-	-	60	60	-	-	4	4	-	-	72	-	-
				NCA02	RES	69	46	43	37	56	51	48	42	13	18	21	27	77	52	25
				NCA02	OME	60	-	-	-	65	65	-	-	0	0	-	-	68	-	-
				NCA02	COM	90	-	-	-	70	70	-	-	20	20	-	-	98	-	-
				NCA02	OED	60	-	-	-	55	55	-	-	5	5	-	-	68	-	-
				NCA02	OOP	58	-	-	-	60	60	-	-	0	0	-	-	66	-	-
6B		Road and footpath works	Night-time	NCA01	RES	68	46	43	37	56	51	48	42	12	17	20	26	76	52	24
				NCA01	OCC	53	-	-	-	55	55	55	-	0	0	0	-	61	-	-
				NCA01	OED	54	-	-	-	55	55	-	-	0	0	-	-	62	-	-
				NCA01	OOP	70	-	-	-	50	50	-	-	20	20	-	-	78	-	-
				NCA01	OPW	55	-	-	-	60	60	-	-	0	0	-	-	63	-	-
				NCA02	RES	60	46	43	37	56	51	48	42	4	9	12	18	68	52	16
				NCA02	OME	51	-	-	-	65	65	-	-	0	0	-	-	59	-	-
				NCA02	COM	81	-	-	-	70	70	-	-	11	11	-	-	89	-	-
				NCA02	OED	51	-	-	-	55	55	-	-	0	0	-	-	59	-	-
				NCA02	OOP	49	-	-	-	60	60	-	-	0	0	-	-	57	-	-

Ref	Works Scenario	Works Activity	Worst Case Construction Period	Receiver	Type[1]	Noise Level – L_{Aeq}(15minute) (dBA)													Noise Level – L_{A1}(60second) (dBA) (sleep disturbance)		
						Worst-case Predicted	RBL			NML				Exceedance					Worst-case Predicted	Screening.Crit (RBL+15 dBA)	Exceedance
							Day	Eve	Night	Day	Day OOH	Eve	Night	Day	Day OOH	Eve	Night				
7A	Electrical upgrades	Earthworks, construction, and installation	Night-time	NCA01	RES	73	46	43	37	56	51	48	42	17	22	25	31		81	52	29
				NCA01	OCC	50	-	-	-	55	55	55	-	0	0	0	-		58	-	-
				NCA01	OED	49	-	-	-	55	55	-	-	0	0	-	-		57	-	-
				NCA01	OOP	89	-	-	-	50	50	-	-	39	39	-	-		97	-	-
				NCA01	OPW	54	-	-	-	60	60	-	-	0	0	-	-		62	-	-
				NCA02	RES	59	46	43	37	56	51	48	42	3	8	11	17		67	52	15
				NCA02	OME	51	-	-	-	65	65	-	-	0	0	-	-		59	-	-
				NCA02	COM	80	-	-	-	70	70	-	-	10	10	-	-		88	-	-
				NCA02	OED	48	-	-	-	55	55	-	-	0	0	-	-		56	-	-
				NCA02	OOP	51	-	-	-	60	60	-	-	0	0	-	-		59	-	-
8A	Finishing works	Comissioning	Night-time	NCA01	RES	69	46	43	37	56	51	48	42	13	18	21	27		77	52	25
				NCA01	OCC	59	-	-	-	55	55	55	-	4	4	4	-		67	-	-
				NCA01	OED	49	-	-	-	55	55	-	-	0	0	-	-		57	-	-
				NCA01	OOP	69	-	-	-	50	50	-	-	19	19	-	-		77	-	-
				NCA01	OPW	51	-	-	-	60	60	-	-	0	0	-	-		59	-	-
				NCA02	RES	69	46	43	37	56	51	48	42	13	18	21	27		77	52	25
				NCA02	OME	54	-	-	-	65	65	-	-	0	0	-	-		62	-	-
				NCA02	COM	82	-	-	-	70	70	-	-	12	12	-	-		90	-	-
				NCA02	OED	69	-	-	-	55	55	-	-	14	14	-	-		77	-	-
				NCA02	OOP	51	-	-	-	60	60	-	-	0	0	-	-		59	-	-
8B		Demobilisation	Night-time	NCA01	RES	73	46	43	37	56	51	48	42	17	22	25	31		81	52	29
				NCA01	OCC	59	-	-	-	55	55	55	-	4	4	4	-		67	-	-
				NCA01	OED	49	-	-	-	55	55	-	-	0	0	-	-		57	-	-
				NCA01	OOP	74	-	-	-	50	50	-	-	24	24	-	-		82	-	-
				NCA01	OPW	51	-	-	-	60	60	-	-	0	0	-	-		59	-	-
				NCA02	RES	69	46	43	37	56	51	48	42	13	18	21	27		77	52	25
				NCA02	OME	54	-	-	-	65	65	-	-	0	0	-	-		62	-	-
				NCA02	COM	82	-	-	-	70	70	-	-	12	12	-	-		90	-	-
				NCA02	OED	69	-	-	-	55	55	-	-	14	14	-	-		77	-	-
				NCA02	OOP	51	-	-	-	60	60	-	-	0	0	-	-		59	-	-

Note 1: Receiver classification abbreviations are residential (RES), other sensitive - childcare centre (OCC), other sensitive – education facilities (OED), other sensitive - hotel (OHO), commercial (COM), other sensitive - place of worship (OPW), other sensitive - medical (OME) and other sensitive - passive recreation areas (OOP).

Note 2: Worst-case predicted noise levels greater than 75 dBA are highlighted in pink and indicates highly affected receiver noise levels as defined in the ICNG.

4.6 Discussion

4.6.1 Site establishment

In NCA01, the most potentially affected residential receivers are predicted to exceed the daytime NMLs by up to 24 dBA during the use of high noise construction equipment such as chainsaws, wood chippers, and saws. High NML exceedances of this magnitude would be limited to sensitive receivers located directly adjacent tree removal, and vegetation pruning during the *Vegetation removal* works. Depending on site access and site safety requirements, the wood chipper may be operated in close proximity to sensitive receivers during the *Vegetation removal* works scenario. Receivers in NCA01 which are located further away from the proposed worksite and wood chipper operation positions would have lower NML exceedances. For example, the predicted noise levels at the second row of receivers typically reduce by more than 10 dBA compared to the front row.

Moderate exceedances of the daytime NMLs are predicted for the nearest residential and commercial receivers in NCA02 during most of the proposed works activities associated with site establishment, with the exception of the high noise including *removal of existing trees* works. Vegetation clearing works are predicted to generate high exceedances the daytime NMLs in NCA02 of up to 25 dBA respectively during the use of chainsaw and chipper equipment.

Residential receivers immediately adjacent to the site establishment works areas in NCA01 and NCA02 are predicted to be 'highly noise affected' at times. The operation of the chipper during the *removal of existing trees* works would result in the highest number of highly noise affected receivers for enabling works.

All site establishment works are proposed to be undertaken during standard daytime construction hours only with the exception of works activity 'Hi-rail pad installation'. The use of high noise equipment associated with vegetation clearing works is not anticipated to extend for more than a few days in any one area.

Hi-rail pad installation is proposed to be undertaken during rail possession periods, some of which will be during out-of-hours. During hi-rail pads installation works, exceedances of the night-time NMLs of up to 31 dBA are predicted at the potentially most affected receivers in NCA01. This activity is not expected to take longer than half a day to complete.

4.6.2 Preliminary works and construction works

The noisiest works associated with the construction of the footbridge, lift, entrance ramp and stairs are scheduled to occur during standard daytime construction hours and also during out-of-hours periods when rail/road shutdowns are in effect.

Noise intensive activities associated with preliminary works and construction works of the footbridge, lift, entrances ramp and stairs are located on the platform or on the footbridge and concourse of Wahroonga Station and sensitive receivers in NCA01 to the north of the station would be most impacted by these works. Exceedances of the daytime NMLs of up to 28 dBA are predicted for the nearest residential receivers in NCA01 during the proposed preliminary works. The highest noise impacts would be from the c*oncourse and walkway demolition/removal* scenarios where noise intensive equipment including concrete saws and jackhammers are used in close proximity to residential receivers. The most impacted residential and commercial receivers would be positioned as close as 25 metres away from noise intensive works.

During rail/road shutdowns when works are required to be performed during evening and night-time periods, exceedances of up to 42 dBA are predicted at the potentially most affected receivers in NCA01. These exceedances are dominated by the use of the above-mentioned noise intensive equipment. The use of this noise intensive equipment during the night-time period increases the risk of sleep disturbance at nearby and surrounding residential receivers. Where practicable, it is strongly recommended that the use of noise intensive equipment is scheduled to the less sensitive daytime period to reduce the magnitude of NML exceedances and to reduce sleep disturbance impacts.

For some works activities including main works, transport of materials to the Wahroonga Station work sites would be via rail-mounted vehicles (also called 'Hi-rail' vehicles). These vehicles would likely access the rail network and be loaded with required materials at the new rail access point (also called 'Hi-rail' pad) located 300 metres south of Wahroonga Station. Vehicles may also gain access to the rail network at nearby existing Hi-rail pads near Hornsby Street, Hornsby and near Alexandria Parade (opposite to 73 Alexandria Parade, Hornsby). This activity is expected to have a relatively low noise impact but may be noticeable at nearby sensitive receivers if undertaken during the evening and night-time periods. This loading and launch activity would be expected to be relatively short in duration and normally less than an hour.

4.6.3 Bridge upgrades

The noisiest works associated with the refurbishment of the Redleaf Avenue bridge are scheduled to occur during standard daytime construction hours and several days that have out-of-hours periods.

Exceedances of the daytime NMLs of up to 29 dBA are predicted for the nearest residential receivers in NCA01 during the refurbishment of the Redleaf Avenue bridge with worst-case impacts around 10 dB lower in NCA02. The highest potential noise impacts will be from road deck replacement activities where noise intensive equipment including concrete saws and jackhammers are used in close proximity to residential receivers. The most impacted receivers, which are on Millewa Avenue, would be positioned as close as 25 metres away from noise intensive works.

During rail/road shutdowns when works are required to be performed during evening and night-time periods, exceedances of up to 43 dBA are predicted at the potentially most affected receivers in NCA01. These exceedances are largely driven by the aforementioned equipment such as concrete saws. The use of this noise intensive equipment during the night-time period increases the risk of sleep disturbance at nearby and surrounding residential receivers. Where practicable, it is strongly recommended that the use of noise intensive equipment is rescheduled to the less sensitive daytime period to reduce the magnitude of NML exceedances and to reduce sleep disturbance impacts.

4.6.4 Station building works

Exceedances of the standard daytime NMLs of up to 29 dBA and 19 dBA are predicted for the nearest residential receivers in NCA01 and NCA02 respectively during the proposed main works activities at the station building.

During rail shutdowns, when works are required to be performed during evening and night-time periods, exceedances of the night-time NMLs of up to 43 dBA and 33 dBA are predicted for the nearest residential receivers in NCA01 and NCA02 respectively.

These exceedances are largely driven by noise intensive equipment including saws, hammer drills, and jackhammers. Consistent with the other main works scenarios, the use of noise intensive equipment during the night-time period increases the risk of sleep disturbance at nearby and surrounding residential receivers. Where practicable, it is strongly recommended that the use of noise intensive equipment is rescheduled to the less sensitive daytime period to reduce the magnitude of NML exceedances and to reduce sleep disturbance impacts.

4.6.5 Interchange kerb and footpath adjustments, electrical upgrades, and finishing works

Exceedances of the standard daytime NMLs of up to 21 dBA and 13 dBA are predicted for the nearest residential receivers in NCA01 and NCA02 respectively during the proposed activites associated with interchange kerb and footpath adjustments, electrical upgrades, and finishing works.

During rail/road shutdowns, when works are required to be performed during evening and night-time periods, exceedances of the night-time NMLs of up to 35 dBA and 27 dBA are predicted for the nearest residential receivers in NCA01 and NCA02 respectively.

These exceedances are largely driven by noise intensive equipment including saws, hammer drills, and jackhammers. Consistent with the other main works scenarios, the use of noise intensive equipment during the night-time period increases the risk of sleep disturbance at nearby and surrounding residential receivers. Where practicable, it is strongly recommended that the use of noise intensive equipment is rescheduled to the less sensitive daytime period to reduce the magnitude of NML exceedances and to reduce sleep disturbance impacts.

4.6.6 Highly noise affected receivers

Residential receivers are considered to be highly noise affected if noise levels from construction exceed 75 dBA $L_{Aeq(15minute)}$.

With reference to **Table 12**, most construction scenarios are predicted to result in the nearest receivers being 'highly noise affected' at times. Due to the close proximity of the works to residential receivers directly adjacent Wahroonga Station on Millewa Avenue and other residential receivers on Woodville Avenue, during daytime noise levels are predicted to be above 75 dBA $L_{Aeq(15minute)}$ at the closest three residential receivers in NCA01 for works involved with demolition equipment such as concrete saws and vegetation removal equipment such as chipper; and at the nearest receivers during road deck replacement works.

The location of receivers with the potential to be highly noise affected at times during these activities is shown in **Figure 3**.

Figure 3 Highly noise affected residential receivers

Figure 3 shows the three residential receiver buildings that are predicted to be highly noise affected during high noise intensive works. Operation of the chipper during the *Vegetation removal* works would result in the highest number of highly noise affected receivers for enabling works while the use of concrete saws and jackhammers would influence the maximum impacts from the remaining works scenarios.

4.6.7 Cumulative noise impacts

Cumulative noise impacts warrant assessment where more than one works scenario operates at the same time and in the same location such that the same receiver is impacted by noise from more than one works scenario. Generally, the proposed works are scheduled in consecutive phases and therefore cumulative noise impacts are not predicted as the assessment is controlled by noise impacts from the individual phases (as assessed).

4.7 Construction road traffic

It is understood that the traffic generated as a part of the construction works is not expected to exceed 20 light vehicles and 10 heavy vehicles per day during peak construction periods. The proposed construction activities would not generate a significant amount of construction traffic during a 15-minute assessment period. The relatively small number of construction vehicles accessing the site is predicted to have an insignificant effect on existing road traffic noise levels and further consideration of noise impacts due to construction traffic is not required.

4.8 Construction vibration assessment

4.8.1 Vibration intensive equipment

Vibration intensive equipment is proposed during the service relocation works scenarios which include the use of jackhammers, plate compactors, and bored piling.

Piling works are associated with several works activities. For the purpose of this assessment, it is assumed that piling works would be performed using non-vibration intensive bored piling. If the construction contractor elects to use an alternative piling method, the vibration levels generated by the use of this plant may be higher than those presented in this assessment.

4.8.2 Cosmetic damage assessment

For most sources of intermittent vibration during construction, the predominant vibration energy usually occurs at frequencies in the 10 Hz to 100 Hz range. On this basis, and with reference to BS 7385:2 and **Section 4.2**, a vibration damage screening level of 7.5 mm/s has been adopted for the purpose of assessing potential impacts from continuous vibration.

BS 7385:2 sets guide values for vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk is usually taken as 95 per cent probability of no effect.

Based on the safe working distances presented in the TfNSW CNVS, indicative vibration levels at the representative receivers are shown in **Table 13**.

Table 13 Indicative vibration levels at nearby receivers

Receiver	Approximate distance to works	Indicative Vibration Level (mm/s)[1]
NCA01	15 m	0.2 mm/s
NCA02	20 m	0.1 mm/s

Note 1: Estimated from the safe working distances specified in TfNSW CNVS and assumed dense rock.

The information presented in **Table 13** indicates that the separation distance from the nearest receivers is sufficient to mitigate the potential impacts. As such it is considered that structural or cosmetic damage impacts from vibration intensive works are unlikely for the adjacent receivers.

If vibration intensive works such as vibratory roller or compaction plate are required to be undertaken within the specified safe working distances outlined in **Section 4.2.4**, or in close proximity to potentially vibration-sensitive structures such as the station footbridge or buildings near the worksites on Redleaf Avenue, Railway Avenue, and Millewa Avenue, vibration monitoring should be undertaken to ensure acceptable levels of vibration are satisfied.

Part of the proposed works is the refurbishment of Redleaf Avenue bridge. Other concurrent works in the vicinity such as lift installation will have vibration impacts on this bridge structure. As the bridge is listed as a heritage item, it will be assessed in **Section 4.8.3.**

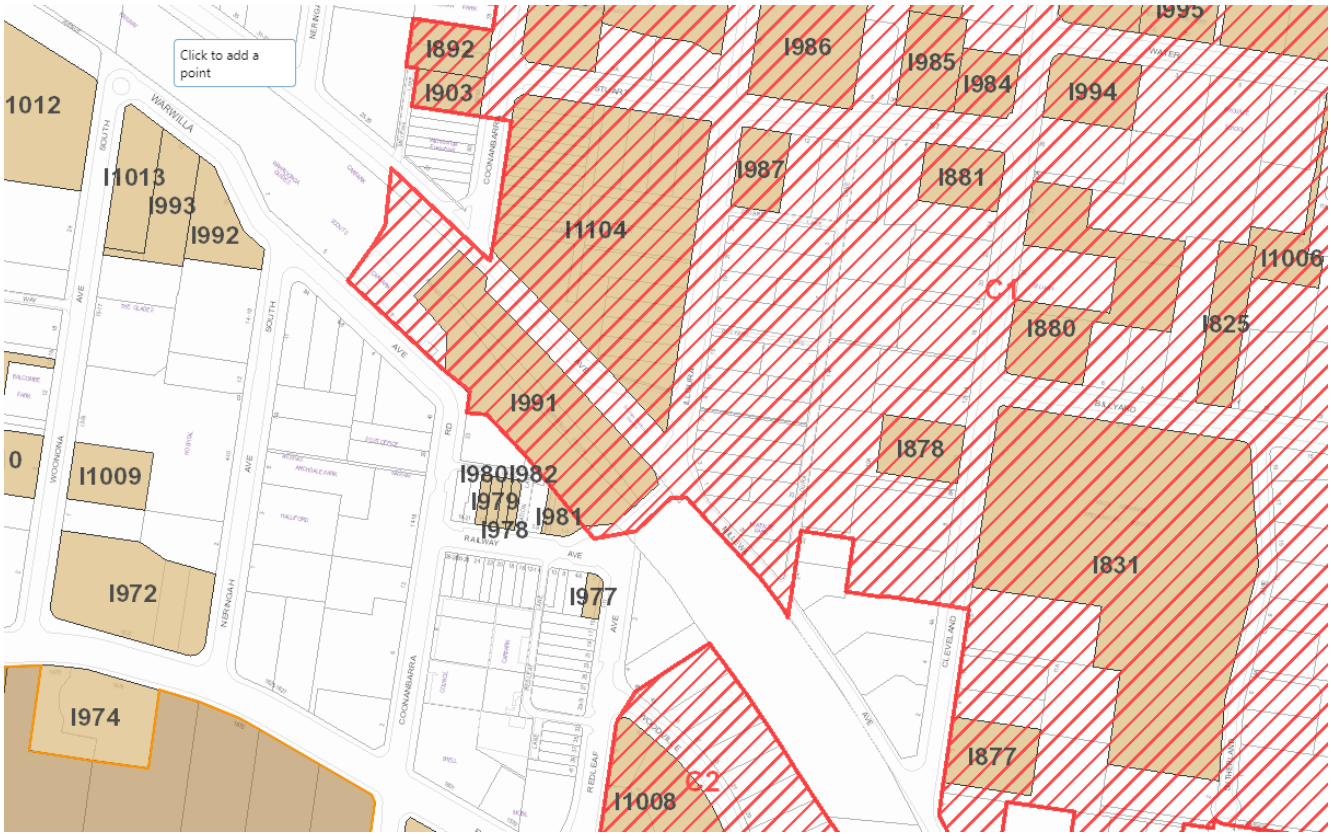
4.8.3 Heritage buildings

At this stage in the Proposal, the following heritage-listed structures have been identified within approximately 100 metres of the proposed works involving vibration-generating plant described in **Section 4.8.1**. These locations are shown in **Figure 4**.

Table 14 Heritage-listed structures within 100 metres of vibration generating works

Suburb	Item	Address	Property description	Significance	Item no
Wahroonga	Inter-war Shops	1–5 Railway Avenue	Lots 2, 3 and 4, DP 202677	Local	I981
Wahroonga	Red Leaf Chambers	2 Railway Avenue	Lots 1 and 2, DP 726590	Local	I977
Wahroonga	Federation Queen Anne Style Terrace Shops	9A–17 Railway Avenue	Lot D, DP 400881	Local	I982
Wahroonga	Commercial building	11 Railway Avenue	Lot C, DP 400881	Local	I978
Wahroonga	Commercial building	15 Railway Avenue	Lot B, DP 400881	Local	I979
Wahroonga	Commercial building	17 Railway Avenue	Lot A, DP 400881	Local	I980
Wahroonga	Wahroonga Railway Station Group	1 Warwilla Avenue	Lot 2076, DP 1133894	State	I991
Wahroonga	Wahroonga Park and Wahroonga War Memorial	51 Coonanbarra Road	Lot 21, DP 976471	Local	I1104

Figure 4 Ku-ring-gai Heritage Map – Ku-ring-gai Council - Online Map Viewer (accessed and printed 08 October 2019)



BS 7385 states that "*a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive*".

Heritage buildings are to be considered on a case by case basis. Where a historic building is deemed to be sensitive to damage from vibration (following inspection), it is recommended to reduce the vibration criteria accordingly in line with the TfNSW CNVS. The more conservative DIN 4150 superficial cosmetic damage criteria of 2.5 mm/s should be considered for vibration-sensitive structures. Where heritage buildings of a typical residential-type construction are not found to be structurally unsound, DIN 4150 superficial cosmetic damage criteria of 5 mm/s may be more suitable as a screening criterion.

The separation distance between the proposed equipment and the above non-station war memorial and bridge heritage items on Railway Avenue would be sufficient to mitigate vibration levels from the use of vibration generating plant described in **Section 4.8.1** such that the DIN4150 criteria are not exceeded.

If vibration intensive works are required to be undertaken within the specified safe working distances outlined in **Section 4.2.4**, or in close proximity to potentially vibration-sensitive heritage structures such as the station buildings, Redleaf Ave bridge, or shops on Railway Avenue, vibration monitoring should be undertaken to ensure acceptable levels of vibration are satisfied.

4.8.4 Human comfort vibration assessment

In relation to human comfort (response), the safe working distances in **Section 4.2.4** 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 permitted, as discussed in *Assessing Vibration - a technical guideline*.

Based on the safe working distances in **Section 4.2.4**, and the distance of the proposed works to nearby sensitive receivers outlined in **Table 13**, the proposed works are expected to comply with the human comfort vibration criteria at all residential receivers.

If vibration intensive works such as vibratory roller or compaction plate are required to be undertaken within the specified safe working distances outlined in **Section 4.2.4**, or in close proximity to inhabited buildings near the worksites of the interchanges on Redleaf Avenue, Railway Avenue, and Millewa Avenue, vibration monitoring should be undertaken to ensure acceptable human comfort levels of vibration are satisfied.

5 Construction noise and vibration mitigation measures

5.1 Standard mitigation measures

Particular effort should be directed towards the implementation of all feasible and reasonable noise mitigation and management strategies as per the standard mitigation measures detailed in the ICNG.

Reference can also be made to the TfNSW *Construction Noise and Vibration Strategy* (CNVS) which detail a number of standard mitigation measures for construction activities likely to result in adverse noise or vibration impacts associated with infrastructure projects.

Where identified in the impact assessment, particular effort should be directed towards the implementation of all feasible and reasonable noise mitigation and management strategies, noting that additional site-specific measures may also be recommended.

Standard mitigation measures which may be considered appropriate for the Proposal, as taken from the CNVS, are shown in **Table 15**.

Table 15 Recommended standard noise mitigation measures

Action required	Applies to	Details
Management measures		
Implementation of any project-specific mitigation measures required	Airborne noise and vibration	In addition to the measures set out in this table, any *project-specific* mitigation measures identified in the environmental assessment documentation (eg Review of Environmental Factors, submissions or representations report) or approval or license conditions must be implemented
Implement stakeholder consultation measures	Airborne noise and vibration	Periodic Notification (monthly letterbox drop)[1] Website Project information and construction response telephone line Email distribution list Place Managers

Action required	Applies to	Details
Register of Noise Sensitive Receivers	Airborne noise and vibration	A register of all noise and vibration sensitive receivers (NSRs) would be kept on site. The register would include the following details for each NSR: • address of receiver • category of receivers (eg Residential, Commercial etc.) • contact name and phone number
Site inductions	Airborne noise and vibration	All employees, contractors and subcontractors are to receive an environmental induction. The induction must at least include: • all relevant project specific and standard noise and vibration mitigation measures • relevant licence and approval conditions • permissible hours of work • any limitations on high noise generating activities • location of nearest sensitive receivers • construction employee parking areas • designated loading/unloading areas and procedures • site opening/closing times (including deliveries) • environmental incident procedures.
Behavioural practices	Airborne noise	No swearing or unnecessary shouting or loud stereos/radios on site. No dropping of materials from height; throwing of metal items; and slamming of doors. No excessive revving of plant and vehicle engines Controlled release of compressed air.
Monitoring	Airborne noise and vibration	A noise monitoring program is to be carried out for the duration of the works in accordance with the Construction Noise and Vibration Management Plan and any approval and licence conditions.
Attended vibration measurements	Vibration	Attended vibration measurements are required at the commencement of vibration generating activities to confirm that vibration levels satisfy the criteria for that vibration generating activity. Where there is potential for exceedances of the criteria further vibration site law (ie the site-specific reduction in vibration level with distance) investigations would be undertaken to determine the site-specific safe working distances for that vibration generating activity. Continuous vibration monitoring with audible and visible alarms would be conducted at the nearest sensitive receivers whenever vibration generating activities need to take place inside the applicable safe-working distances.
Building condition surveys	Vibration	Undertake building dilapidation surveys on all buildings located within the buffer zone prior to major project construction activities with the potential to cause property damage.
Construction respite period	Vibration Airborne noise	High noise and vibration generating activities[2] may only be carried out in continuous blocks, not exceeding 3 hours each, with a minimum respite period of one hour between each block[3].
Source controls		
Construction hours and scheduling	Airborne noise and vibration	Where feasible and reasonable, construction should be carried out during the standard daytime working hours. Work generating noise with special audible characteristics and/or vibration levels should be scheduled during less sensitive time periods where feasible and reasonable.
Equipment selection	Airborne noise and vibration	Use quieter and less vibration emitting construction methods where feasible and reasonable.
Maximum noise	Airborne-noise	The noise levels of plant and equipment must have operating Sound Power

Action required	Applies to	Details
levels		Levels compliant with the criteria in Table 11 (of the CNVS).
Rental plant and equipment	Airborne-noise	The noise levels of plant and equipment items are to be considered in rental decisions and in any case cannot be used on site unless compliant with the criteria in Table 11 (of the CNVS).
Plan worksites and activities to minimise noise and vibration	Airborne noise and vibration	Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site.
Non-tonal reversing alarms	Airborne noise	Non-tonal reversing beepers (or an equivalent mechanism) must be fitted and used on all construction vehicles and mobile plant regularly used on site and for any out of hours work.
Path controls		
Shield stationary noise sources such as pumps, compressors, fans etc	Airborne noise	Stationary noise sources would be enclosed or shielded whilst ensuring that the occupational health and safety of workers is maintained where necessary. Appendix F of AS 2436: 1981 lists materials suitable for shielding.
Shield sensitive receivers from noisy activities	Airborne noise	Use structures to shield residential receivers from noise such as site shed placement; earth bunds; fencing; erection of operational stage noise barriers (where necessary) and consideration of site topography when situating plant.

Note 1 Detailing all upcoming construction activities at least 7 days prior to commencement of relevant works.
Note 2 Includes jack and rock hammering, sheet and pile driving, rockbreaking and vibratory rolling.
Note 3 "Continuous" includes any period during which there is less than a 60 minutes respite between ceasing and recommencing any of the work.

5.2 Additional noise mitigation measures

Additional noise mitigation measures to be explored in the CNVMPs in the event of predicted exceedances of the noise goals, particularly during Out of Hours Works (OOHWs), are described in the TfNSW *Construction Noise and Vibration Strategy* (CNVS). This strategy includes definition of the level of noise impact which triggers consideration of each additional mitigation measure (reproduced in **Table 16**).

The additional mitigation measures described in the CNVS are summarised below, with discussion of their potential applicability to these works. The objective of these additional noise mitigation measures is to engage, inform and provide project-specific messages to the community, recognising that advanced warning of potential disruptions can assist in reducing the impact.

- **Periodic Notifications** – Periodic notifications include regular newsletters, letterbox drops or advertisements in local papers to provide an overview of current and upcoming works and other topics of interest
- **Website** – The project website would form a resource for members of the community to seek further information, including noise and vibration management plans and current and upcoming construction activities
- **Project Info-line and Construction Response Line** – TfNSW operate a Construction Response Line and Project Info-line. These numbers provide a dedicated 24 hour contact point for any complaints regarding construction works and for any project enquiries. All complaints require a verbal response within two hours. All enquiries require a verbal response within 24 hours during standard construction hours, or on the next working day during out of hours work (unless the enquirer agrees otherwise)

- **Email Distribution List** – An email distribution list would be used to disseminate project information to interested stakeholders
- **Signage** – Signage on construction sites would be provided to notify stakeholders of project details and project emergency or enquiry information
- **Specific Notifications (SN)** – Specific notifications would be letterbox dropped or hand distributed to the nearby residences and other sensitive receivers no later than seven days ahead of construction activities that are likely to exceed the noise objectives. This form of communication is used to support periodic notifications, or to advertise unscheduled works
- **Phone Calls (PC)** – Phone calls may be made to identified/affected stakeholders within seven days of proposed work
- **Individual Briefings (IB)** – Individual briefings may be used to inform stakeholders about the impacts of high noise activities and mitigation measures that would be implemented. Communications representatives from the contractor would visit identified stakeholders at least 48 hours ahead of potentially disturbing construction activities
- **Monitoring (M)** – Ongoing noise monitoring during construction at sensitive receivers during critical periods would be used to identify and assist in managing high risk noise events. Monitoring of noise would also be undertaken in response to complaints. All noise monitoring would be carried out by an appropriately trained person in the measurement and assessment of construction noise and vibration, who is familiar with the requirements of the relevant standards and procedures
- **Project Specific Respite Offer (RO)** – Residents subjected to lengthy periods of noise or vibration may be eligible for a project specific respite offer. The purpose of such an offer is to provide residents with respite from an ongoing impact
- **Alternative Accommodation (AA)** – As described in the TfNSW *Construction Noise and Vibration Strategy*, provision of alternative accommodation for residents would be considered in the event that highly intrusive noise impacts are predicted during the night-time period (between 10pm and 7am).

Table 16 Additional mitigation measures matrix – Airborne construction noise (TfNSW *Construction Noise and Vibration Strategy*)

Time period	Receiver perception	dBA above RBL	dBA above NML	Additional management measures
Standard Mon-Fri (7am - 6pm) Sat (8am - 1pm) Sun/Pub Hol (Nil)	Noticeable	5 to 10	0	-
	Clearly Audible	>10 to 20	<10	-
	Moderately Intrusive	>20 to 30	>10 to 20	PN, V
	Highly Intrusive	>30	>20	PN, V
	Above 75 dBA	N/A	N/A	PN, V, SN
OOHW Period 1 Mon-Fri (6pm - 10pm) Sat (7am - 8am) & (1pm - 10pm) Sun/Pub Hol. (8am - 6pm)	Noticeable	5 to 10	<5	-
	Clearly Audible	>10 to 20	5 to 15	PN
	Moderately Intrusive	>20 to 30	>15 to 25	PN, V, SN, RO
	Highly Intrusive	>30	>25	PN, V, SN, RO, RP, DR
OOHW Period 2 Mon-Fri (10pm - 7am) Sat (10pm - 8am) Sun/Pub Hol. (6pm - 7am)	Noticeable	5 to 10	<5	PN
	Clearly Audible	>10 to 20	5 to 15	PN, V
	Moderately Intrusive	>20 to 30	>15 to 25	PN, V, SN, RP, DR
	Highly Intrusive	>30	>25	PN, V, SN, AA, RP, DR

Notes: PN = Project notification, SN = Specific notification, individual briefings, or phone call, V = Verification of monitoring, AA = Alternative accommodation, DR = Duration Reduction RO = Project specific respite offer, RP = Respite Period

5.3 Additional vibration mitigation measures

No construction vibration impacts are predicted for non-station sensitive receivers surrounding the Proposal. As such vibration mitigation is only required to manage exceedances of the cosmetic damage criteria, particularly for Wahroonga Station heritage-listed structures.

Where the vibration management levels for building damage may be exceeded, vibration monitoring should be conducted to determine site-specific minimum working distances. Alternative construction methodologies may need to be considered where it is not possible to complete the works within the building damage vibration management levels. The additional mitigation measures described in the CNVS are summarised below in **Table 17**.

Table 17 Additional mitigation measures matrix – Construction vibration (TfNSW Construction Noise Strategy Revision 4)

Time Period	Receiver Perception	Vibration Management Level	Additional Management Measures
Standard Mon-Fri (7am - 6pm) Sat (8am - 1pm) Sun/Pub Hol (Nil)	Human comfort	Exceeds HVML	PN, V, RO
	Cosmetic damage	Exceeds DVML	V, AC
OOHW Period 1 Mon-Fri (6pm - 10pm) Sat (7am - 8am) & (1pm - 10pm) Sun/Pub Hol. (8am - 6pm)	Human comfort	Exceeds HVML	PN, V, SN, RO, RP, DR
	Cosmetic damage	Exceeds DVML	V, AC
OOHW Period 2 Mon-Fri (10pm - 7am) Sat (10pm - 8am) Sun/Pub Hol. (6pm - 7am)	Human comfort	Exceeds HVML	PN, V, SN, RO, AA, RP, DR
	Cosmetic damage	Exceeds DVML	V, AC

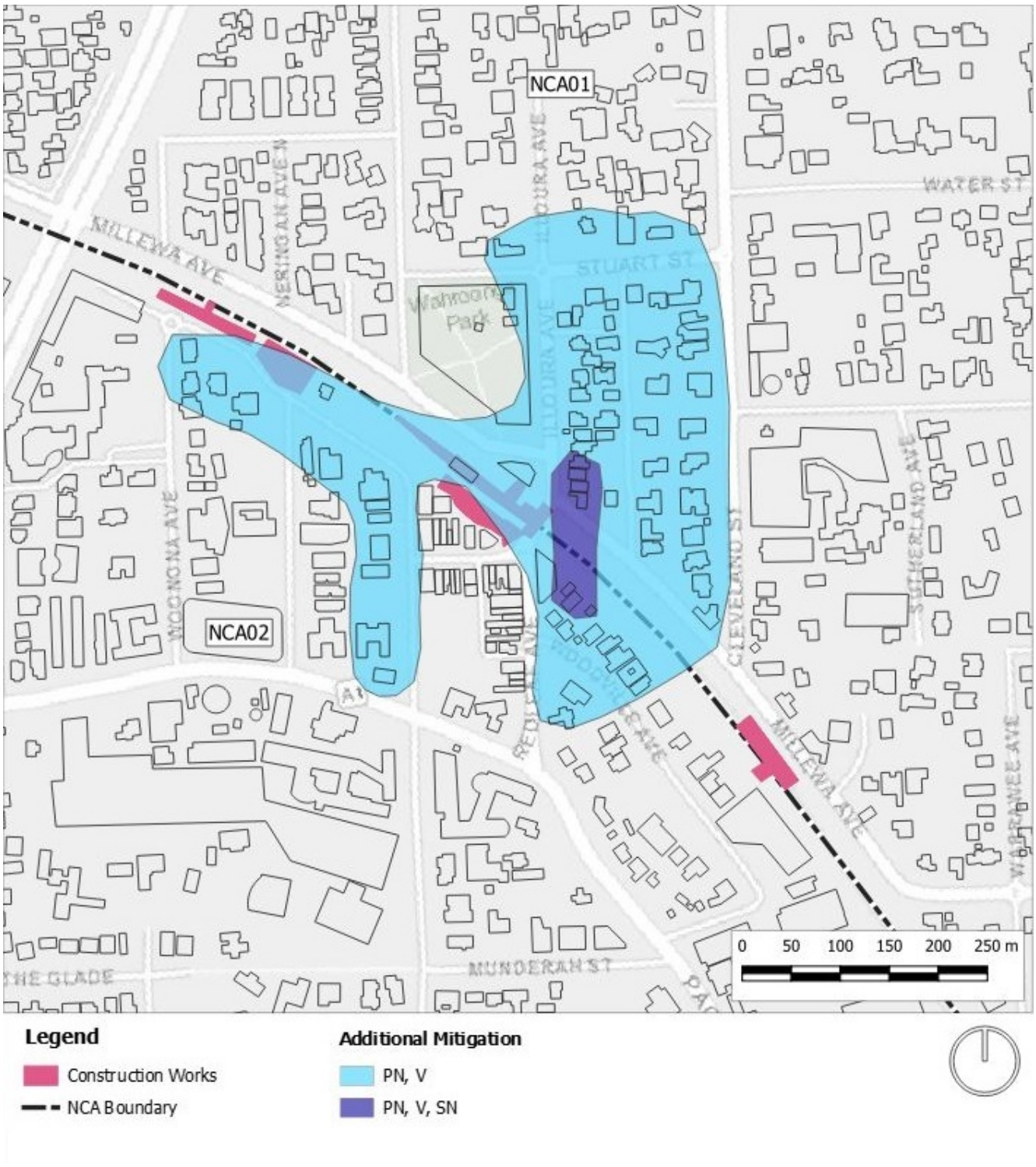
Notes: PN = Project notification SN = Specific notification, individual briefings, or phone call, V = Verification of monitoring, AA = Alternative accommodation, DR = Duration Reduction, RO = Project specific respite offer, RP = Respite Period, AC = Alternative construction methodology, HVML = Human Disturbance Management Level, DVML = Damage to Buildigs Vibration Management Level

5.4 Summary of additional mitigation

Based on the predicted noise levels in **Section 4.5**, additional mitigation measures as per the requirements shown in **Table 16** have been determined for works during the proposed construction hours. The extent of additional mitigation measures are representative of the worst-case construction activities with the daytime and night-time affected receiver areas shown **Figure 5** and **Figure 6** respectively.

Respite offers and respite periods 1 and 2 may be counterproductive in reducing the impact on the community for longer duration projects. In this instance and where it can be strongly justified, it may be beneficial to increase the work duration, number of evenings or nights worked so that the project can be progressed and completed in a shorter timeframe. The approach to respite periods would be confirmed during preparation of the CNVMP and consultation with the community.

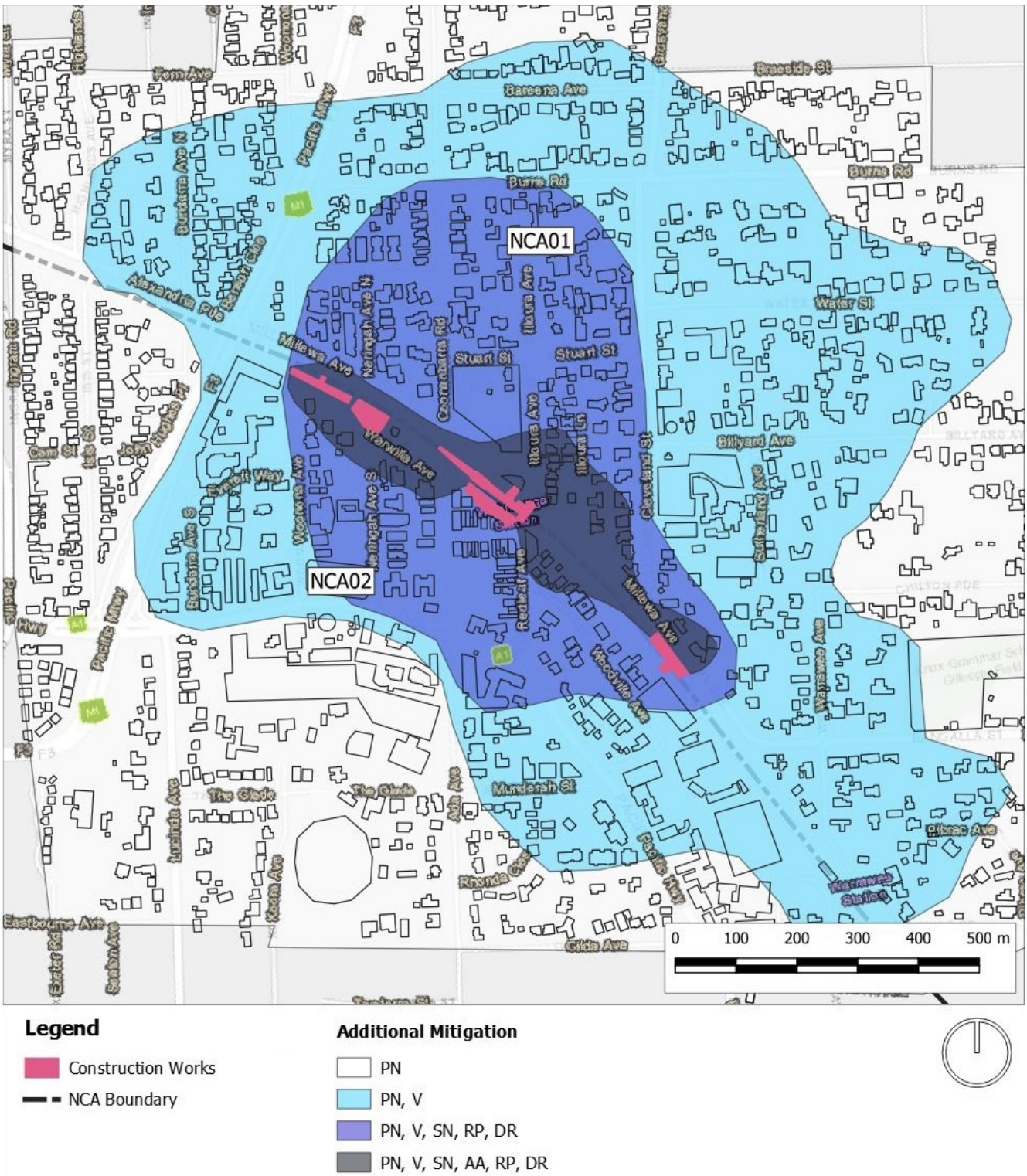
Figure 5 Additional mitigation summary - Standard daytime



Notes: PN = Project notification SN = Specific notification, individual briefings, or phone call, V = Verification of monitoring

Additional mitigation measures are required for daytime works at residential receivers to the north and south of Wahroonga Station. These mitigation requirements are a result of the close proximity from the work areas to the sensitive receivers.

Figure 6 Additional mitigation summary - Out of hours period 2 works



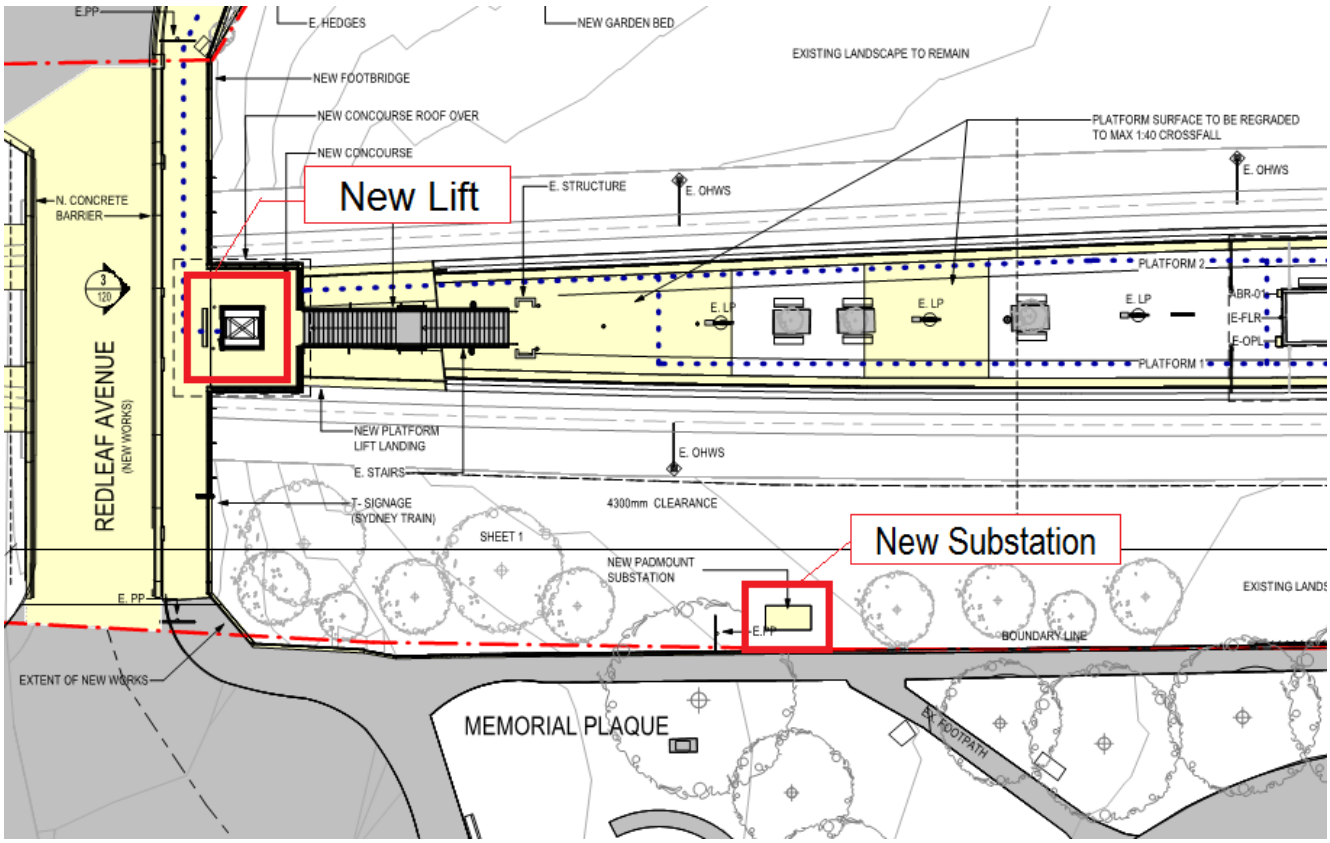
Notes: PN = Project notification SN = Specific notification, individual briefings, or phone call, V = Verification of monitoring, AA = Alternative accommodation, DR = Duration Reduction, RO = Project specific respite offer, RP = Respite Period, AC = Alternative construction methodology

Additional mitigation measures are required for out of hours works at residential receivers surrounding the Proposal. These mitigation measures mostly involve project notification and verification monitoring during both OOHW period 1 and OOHW period 2. Receivers located to the north and south of Wahroonga Station require consideration of additional measures with residential receivers located in close proximity to the works qualifying for consideration of alternative accommodation for works during the OOHW period 2. Where works are proposed over a rail shutdown weekend, mitigation measures to address the OOHW period 2 impacts would cover the requirements of the OOHW period 1 for those works. The extent of impacts would depend on the finalised shutdown activities and would be confirmed in a CNVS for the shutdown activities and managed in accordance with the CNVMP.

6 Operational noise assessment

The key identified fixed noise sources associated with the station upgrade include a new station lift and padmount substation. One new lift would provide access from the footbridge on Redleaf Avenue to the station platform and would be installed adjacent to the footbridge. The new platform lift would connect the station platform to the pedestrian footbridge. A new substation is proposed as part of the station power supply to cater for the new lift. The position of the new lift and the new substation are displayed in **Figure 7**.

Figure 7 Position of new mechanical plant and substation



Refurbishment of the Redleaf Avenue bridge is not expected to influence road traffic noise and operational road traffic noise impacts are cont considered in this assessment.

6.1 NPfI trigger noise levels

The EPA has regulatory responsibility for the control of noise from 'scheduled premises' under the *Protection of the Environment Operations Act 1997*. In implementing the NPfI, the EPA has two broad objectives:

- controlling intrusive noise levels in the short term
- maintaining noise amenity levels for particular land uses over the medium to long-term.

In general terms, the NPfI sets out procedures for establishing the project intrusiveness $L_{Aeq(15minute)}$ and project amenity $L_{Aeq(period)}$ noise levels, with a view to determining the lower (that is, the more stringent) being the Project Trigger Noise Level (PTNL), NPfI Section 2.1 states:

> *The project intrusiveness noise level aims to protect against significant changes in noise levels, whilst the project amenity noise level seeks to protect against cumulative noise impacts from industry and maintain amenity for particular land uses. Applying the most stringent requirement as the project noise trigger level ensures that both intrusive noise is limited and amenity is protected and that no single industry can unacceptably change the noise level of an area.*

For assessing intrusiveness, the existing background noise generally needs to be measured. The intrusiveness trigger level essentially means that the equivalent continuous noise level (L_{Aeq}) of the source should not be more than 5 dBA above the measured (or default) Rating Background Level (RBL).

The amenity assessment is based on amenity noise levels specific to the land use and associated activities. The project noise levels relate only to industrial-type noise and do not include road, rail or community-related noise. Based on the NPfI land use descriptions residences surrounding the development have been classified for the purposes of this noise assessment as 'Suburban'.

Applicable PTNLs for all noise-sensitive receiver areas surrounding the Proposal have been established with reference to the NPfI and are contained in **Table 18**.

Table 18 Project Trigger Noise Levels

Type of receiver	Noise amenity area	NCA	Time of day	Measured level, dBA		Project Trigger Noise Level LAeq(period) dBA		
				RBL[1]	LAeq(period)	Intrusive	Amenity	**Overall**
Residential	Suburban	NCA01	**Day**	46	54	51	55	**51**
			Evening	43	51	48	45	**45**
			Night	37	49	42	40	**40**
		NCA02	**Day**	46	54	51	55	**51**
			Evening	43	51	48	45	**45**
			Night	37	49	42	40	**40**

Note 1: Project Intrusive is the RBL plus 5 dB

Note 2: Resulting PTNL is the lower of the project intrusive and the project amenity noise levels.

6.2 Operational noise source management

At this stage of the design-specific lift systems and supporting plants including the new substation have not been selected, which means it is too early to assess compliance with the applicable noise criteria. These noise sources should be mitigated if required during the detailed phase of the Proposal through the selection of appropriate equipment. The applicable criteria for operational noise from the new station lift shown in **Table 18**.

Where a noise source contains certain characteristics, such as tonality, impulsiveness, intermittency, irregularity or dominant low-frequency content, there is evidence to suggest that it can cause greater annoyance than other less-obtrusive noise sources at the same level. To account for this additional annoyance, the NPfI describes modifying factors to be applied when assessing amenity and intrusiveness. It is assumed that the new noise sources would not exhibit these characteristics if designed and constructed in accordance with industry best practice procedures.

Given that the specifications for the new mechanical plant and reconfigurations of existing plant will not be available or finalised until the detailed design phase of the Proposal, this assessment is limited to setting the applicable noise criteria. Compliance with the criteria would be assessed at the detailed design phase of the Proposal and form part of the detailed design documentation.

Cumulative noise impacts from all Wahroonga Station noise sources should be assessed in the detailed design stage when selecting specific equipment locations and models for the lift facilities.

APPENDIX A

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 L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2×10^{-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

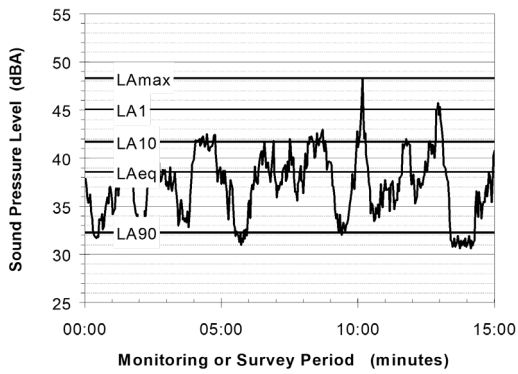
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

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 L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} 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:

L_{A1} The noise level exceeded for 1% of the 15 minute interval.

L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

L_{A90} 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.

L_{Aeq} 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" L_{A90} 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 (L_{Aeq}, L_{A10}, 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. 7. Impulsiveness

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

6 Frequency Analysis

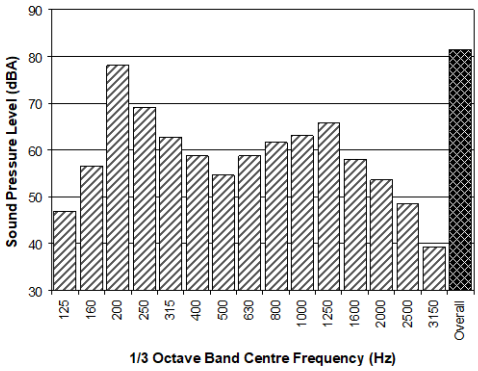
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

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.



7 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.

8 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.

9 Over-Pressure

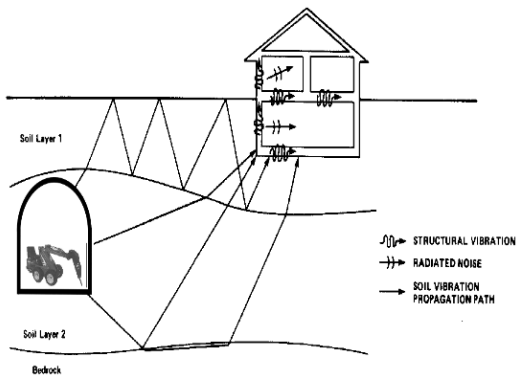
The term "over-pressure" is used to describe the air pressure pulse emitted during blasting or similar events. The peak level of an event is normally measured using a microphone in the same manner as linear noise (ie unweighted), at frequencies both in and below the audible range.

10 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

APPENDIX B

Ambient Noise Monitoring Results

Noise Monitoring Location	L.01
Noise Monitoring Address	**1 Illoura Avenue, Wahroonga**

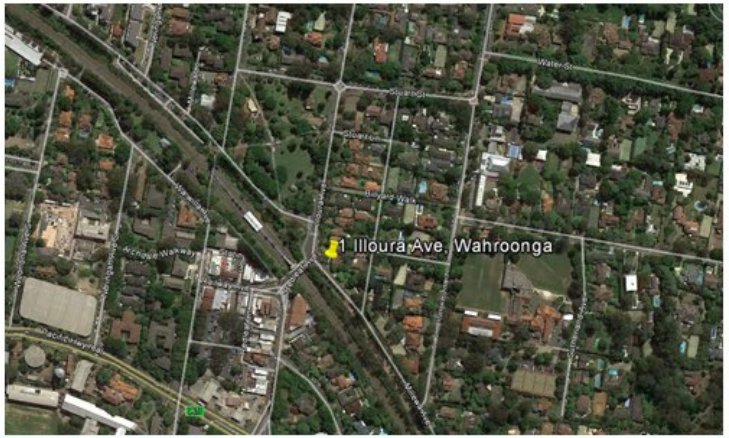
Logger Device Type: ARL EL215/316, Logger Serial No: 16-203-525
Sound Level Meter Device Type: Brüel and Kjær 2260, Sound Level Meter Serial No: 2414604

Ambient noise logger deployed at residential address 1 Illoura Avenue, Wahroonga Logger located with view of Millewa Avenue and the North Shore Rail Line to the south and Illoura Avenue to the west.

Attended noise measurements indicate the ambient noise environment at this location is dominated by road traffic noise from Millewa Ave to the south. Train passbys along the North Shore Line, approaching and departing Wahroonga Station also contribute to the LAeq at this location.

Recorded Noise Levels (LAmax):
27/07/2018: Light-vehicle traffic: 74-80 dBA, Heavy-vehicle traffic: 75 dBA, Train Passby – North Shore Line: 71 dBA, Car Horn: 68 dBA

Map of Noise Monitoring Location



Ambient Noise Logging Results – ICNG Defined Time Periods

Monitoring Period	Noise Level (dBA)			
	RBL	LAeq	L10	L1
Daytime	46	54	54	62
Evening	43	51	52	57
Night-time	37	49	47	53

Ambient Noise Logging Results – RNP Defined Time Periods

Monitoring Period	Noise Level (dBA)	
	LAeq(period)	LAeq(1hour)
Daytime (7am-10pm)	53	56
Night-time (10pm-7am)	49	55

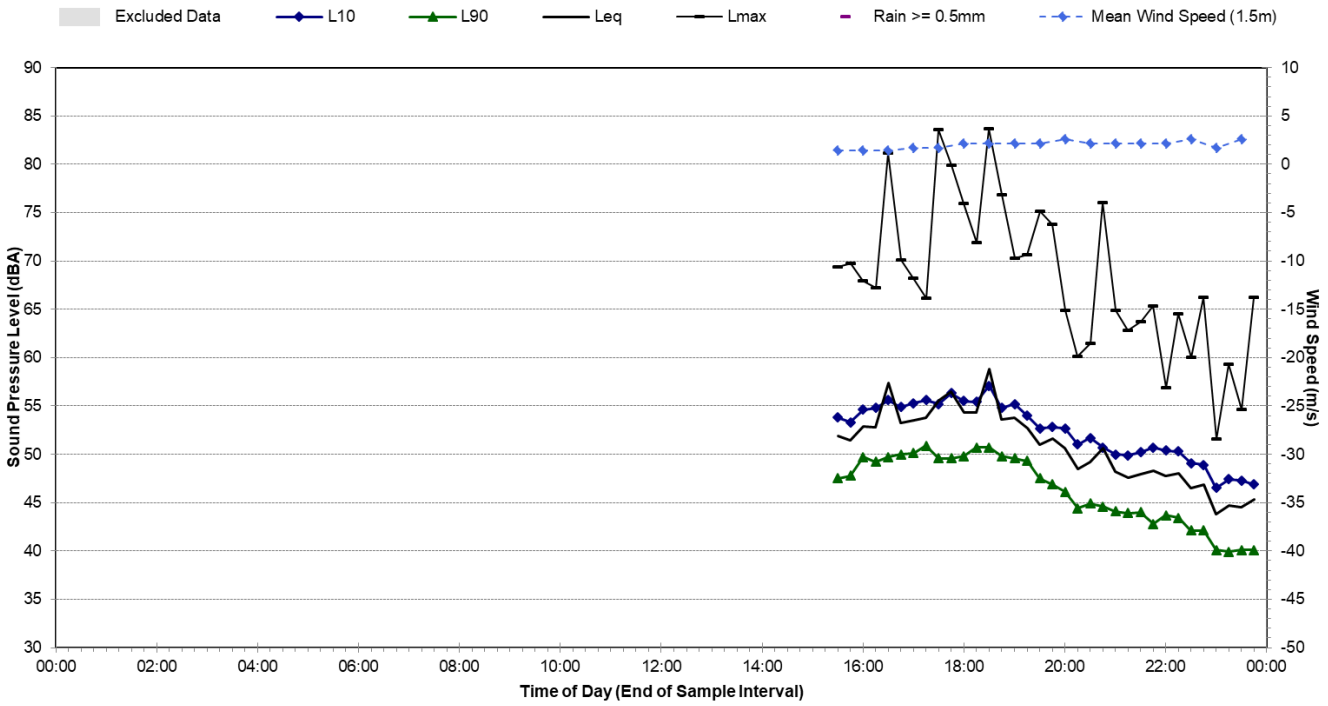
Attended Noise Measurement Results

Date	Start Time	Measured Noise Level (dBA)		
		LA90	LAeq	LAmax
27/07/2018	13:52	49	54	74

Photo of Noise Monitoring Location

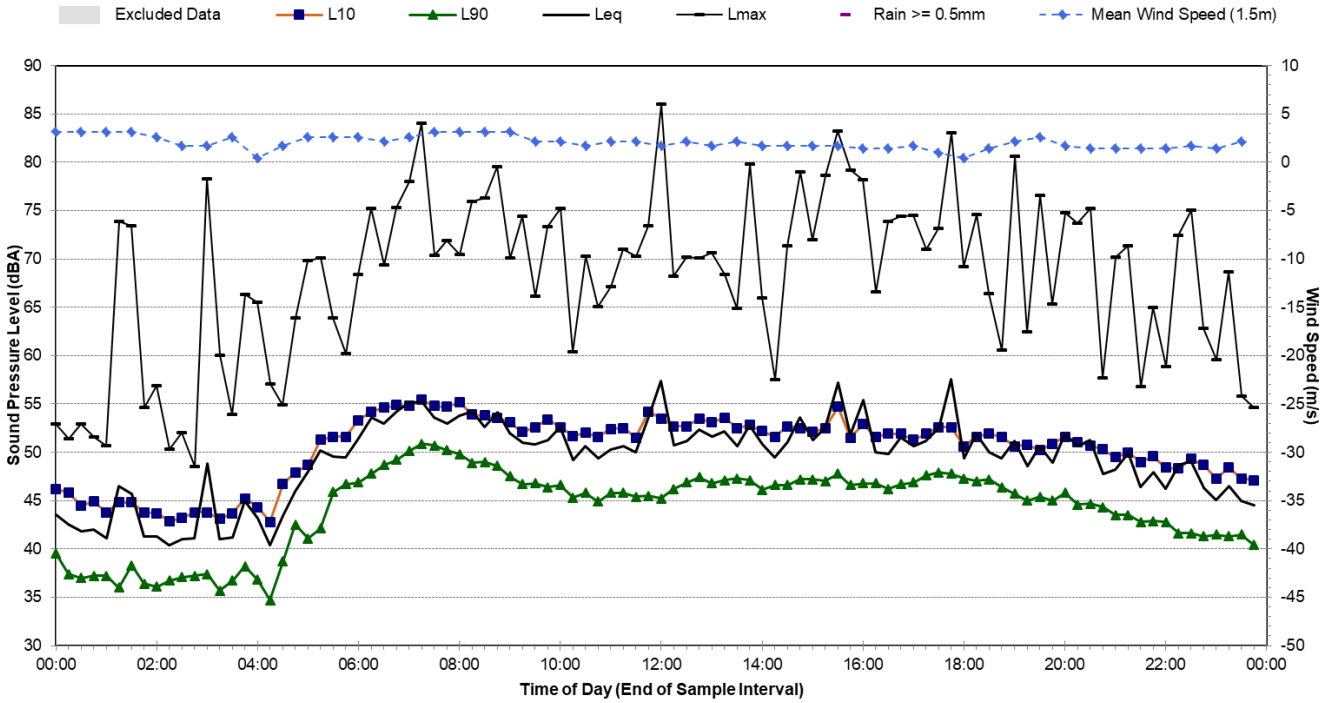
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Monday, 23 July 2018



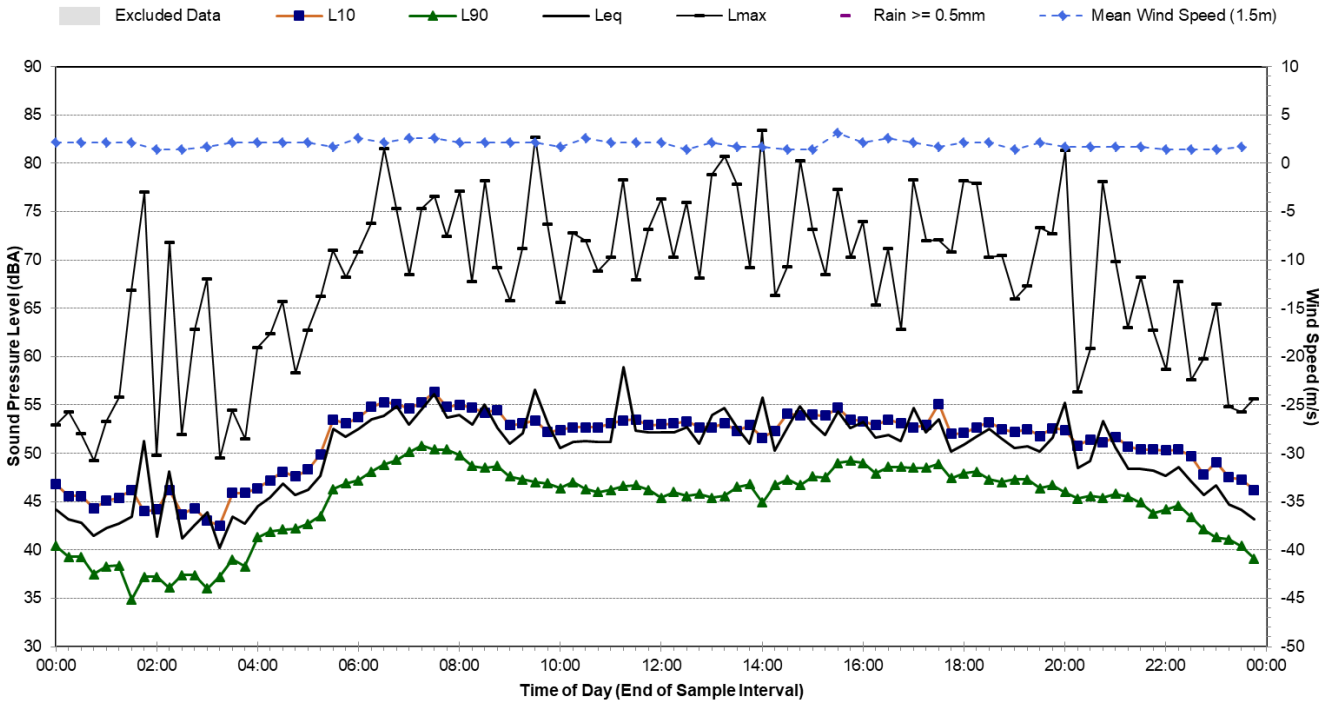
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Tuesday, 24 July 2018



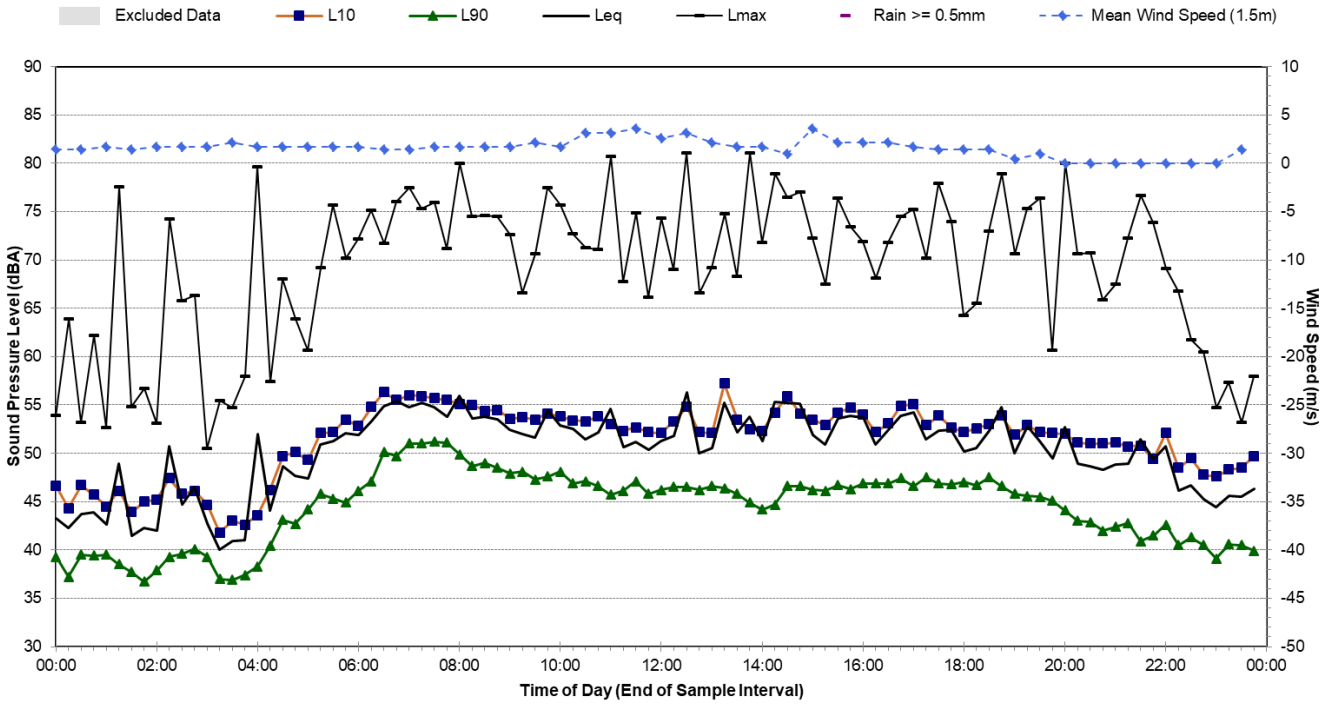
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Wednesday, 25 July 2018



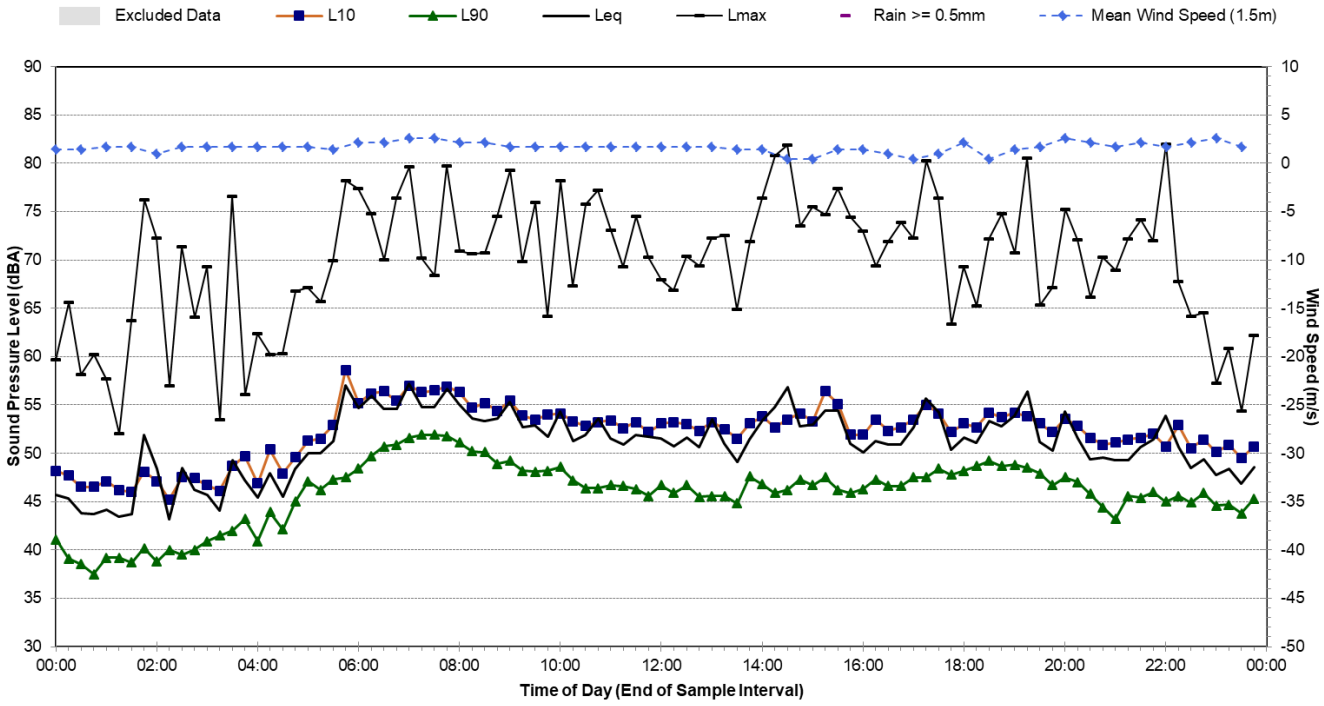
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Thursday, 26 July 2018



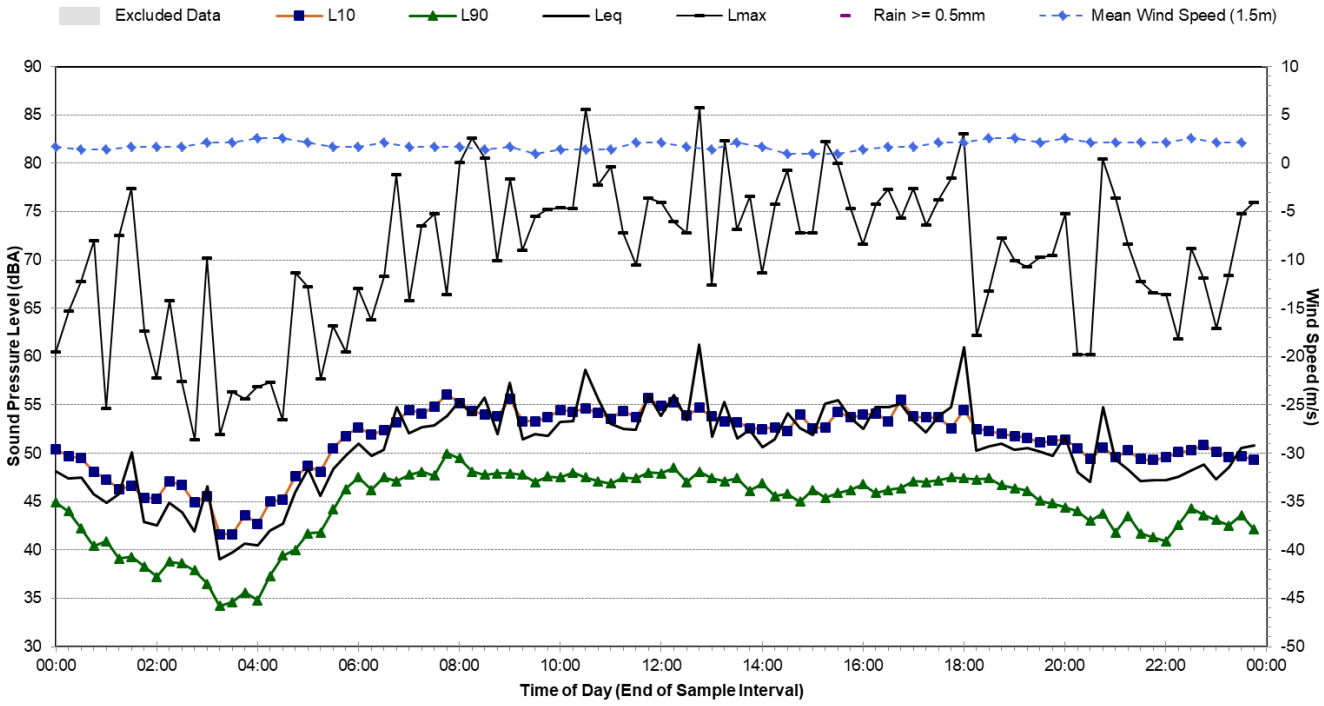
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Friday, 27 July 2018



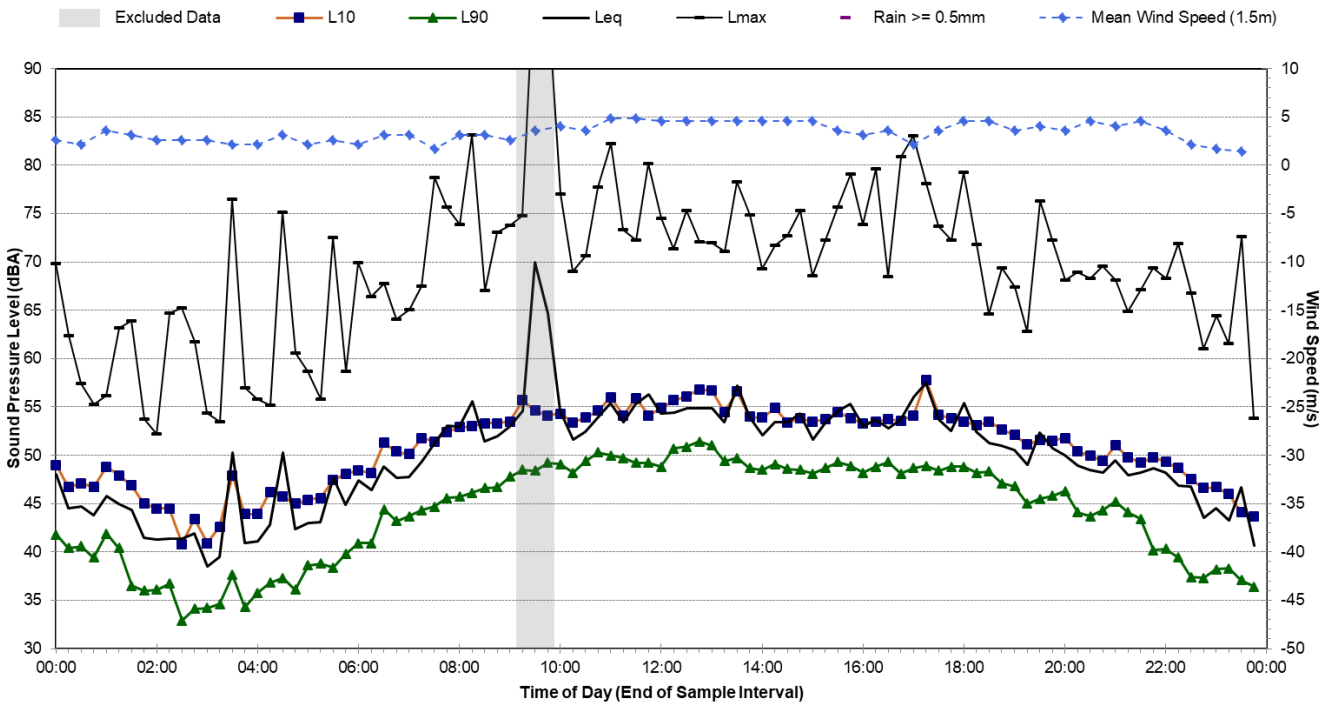
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Saturday, 28 July 2018



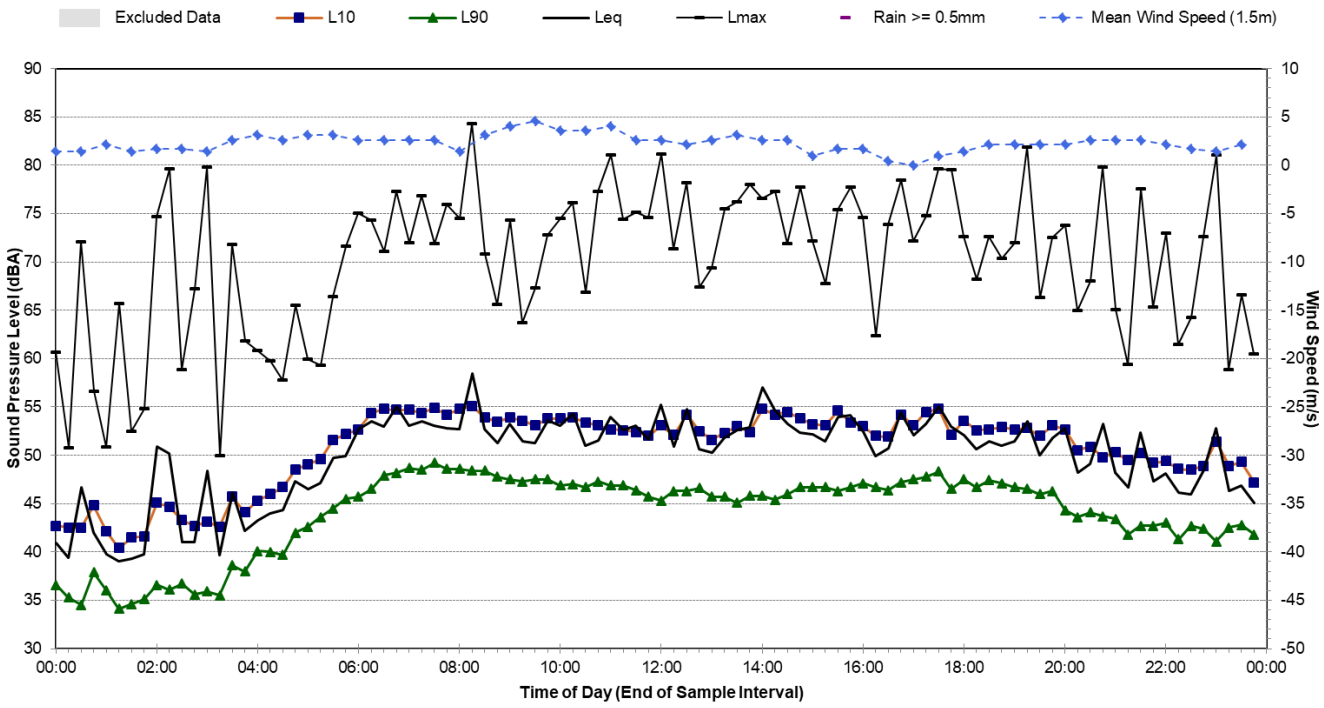
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Sunday, 29 July 2018



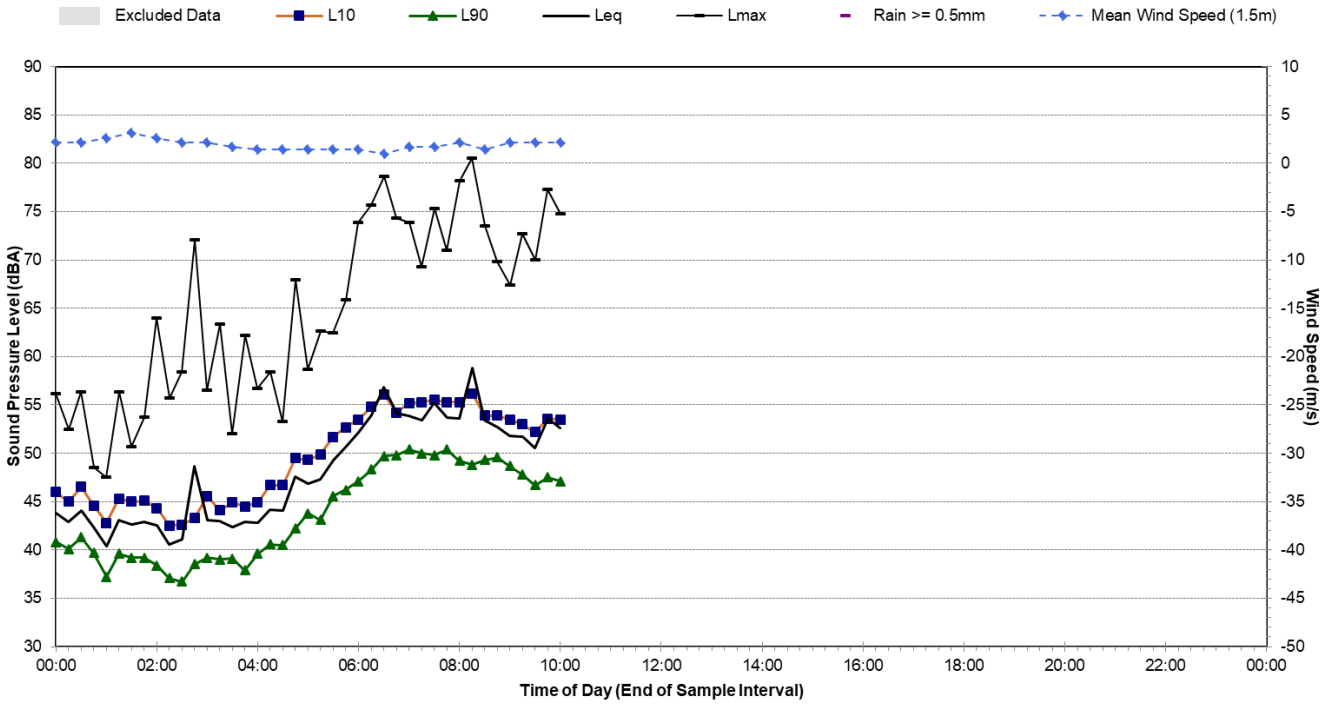
Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Monday, 30 July 2018



Statistical Ambient Noise Levels

1 Illoura Avenue, Wahroonga - Tuesday, 31 July 2018



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