REPORT

PENNANT HILLS RD AND NORTH ROCKS RD UPGRADES

CARLINGFORD, NSW

OPERATIONAL TRAFFIC AND CONSTRUCTION NOISE & VIBRATION IMPACT ASSESSMENT

RWDI # 2101278

March 11, 2021

SUBMITTED TO

Maria Doumit
Environment Officer
Transport for NSW
Level 9, 10-14 Smith Street
Parramatta NSW 2150
maria.doumit@transport.nsw.gov.au

SUBMITTED BY

Remi Larmandieu
Project Engineer
Remi.larmandieu@rwdi.com

RWDI Australia Pty Ltd (RWDI)
Level 4, 272 Pacific Highway
Crows Nest, NSW, 2065, Australia
T: +61.2.9437.4611
E-mail: solutions@rwdi.com
ABN: 86 641 303 871

DOCUMENT CONTROL

Version	Status	Date	Prepared By	Reviewed By
A	Draft	9 February 2021	Remi Larmandieu	Neil Gross
B	Draft	11 March 2021	Remi Larmandieu	Neil Gross
C	Final	30 March 2021	Remi Larmandieu	Neil Gross

NOTE

All materials specified by RWDI Australia Pty Ltd (RWDI) have been selected solely on the basis of acoustic performance. Any other properties of these materials, such as fire rating, chemical properties etc. should be checked with the suppliers or other specialised bodies for fitness for a given purpose.

The information contained in this document produced by RWDI is solely for the use of the client identified on the front page of this report. Our client becomes the owner of this document upon full payment of our **Tax Invoice** for its provision. This document must not be used for any purposes other than those of the document's owner. RWDI undertakes no duty to or accepts any responsibility to any third party who may rely upon this document.

WILKINSON MURRAY

In October 2020, Wilkinson Murray Pty Limited merged with RWDI Group, a leading international consulting firm. Wilkinson Murrays core practice areas of noise, acoustics, vibration and air quality consulting built since 1962 servicing Australia and Asia-Pacific region will complement RWDI practice areas. Combined, RWDI+Wilkinson Murray is one of the largest teams globally specialising in the area of noise, acoustics, vibration and air quality.

RWDI

RWDI is a team of highly-specialised consulting engineers and scientists working to improve the built environment through three core areas of practice: building performance, climate engineering and environmental engineering. More information is available at www.rwdi.com.

QUALITY ASSURANCE

RWDI Australia Pty Ltd operates a Quality Management System which complies with the requirements of AS/NZS ISO 9001:2015. This management system has been externally certified by SAI Global and Licence No. QEC 13457 has been issued for the following scope: The provision of consultancy services in acoustic engineering and air quality; and the sale, service, support and installation of acoustic monitoring and related systems and technologies.

GLOSSARY OF ACOUSTIC TERMS

Most environments are affected by environmental noise which continuously varies, largely as a result of road traffic. To describe the overall noise environment, a number of noise descriptors have been developed and these involve statistical and other analysis of the varying noise over sampling periods, typically taken as 15 minutes. These descriptors, which are demonstrated in the graph below, are here defined.

Maximum Noise Level (L_{Amax}) – The maximum noise level over a sample period is the maximum level, measured on fast response, during the sample period.

L_{A1} – The L_{A1} level is the noise level which is exceeded for 1% of the sample period. During the sample period, the noise level is below the L_{A1} level for 99% of the time.

L_{A10} – The L_{A10} level is the noise level which is exceeded for 10% of the sample period. During the sample period, the noise level is below the L_{A10} level for 90% of the time. The L_{A10} is a common noise descriptor for environmental noise and road traffic noise.

L_{A90} – The LA_{90} level is the noise level which is exceeded for 90% of the sample period. During the sample period, the noise level is below the L_{A90} level for 10% of the time. This measure is commonly referred to as the background noise level.

L_{Aeq} – The equivalent continuous sound level (L_{Aeq}) is the energy average of the varying noise over the sample period and is equivalent to the level of a constant noise which contains the same energy as the varying noise environment. This measure is also a common measure of environmental noise and road traffic noise.

ABL – The Assessment Background Level is the single figure background level representing each assessment period (daytime, evening and night time) for each day. It is determined by calculating the 10th percentile (lowest 10th percent) background level (L_{A90}) for each period.

RBL – The Rating Background Level for each period is the median value of the ABL values for the period over all of the days measured. There is therefore an RBL value for each period – daytime, evening and night time.

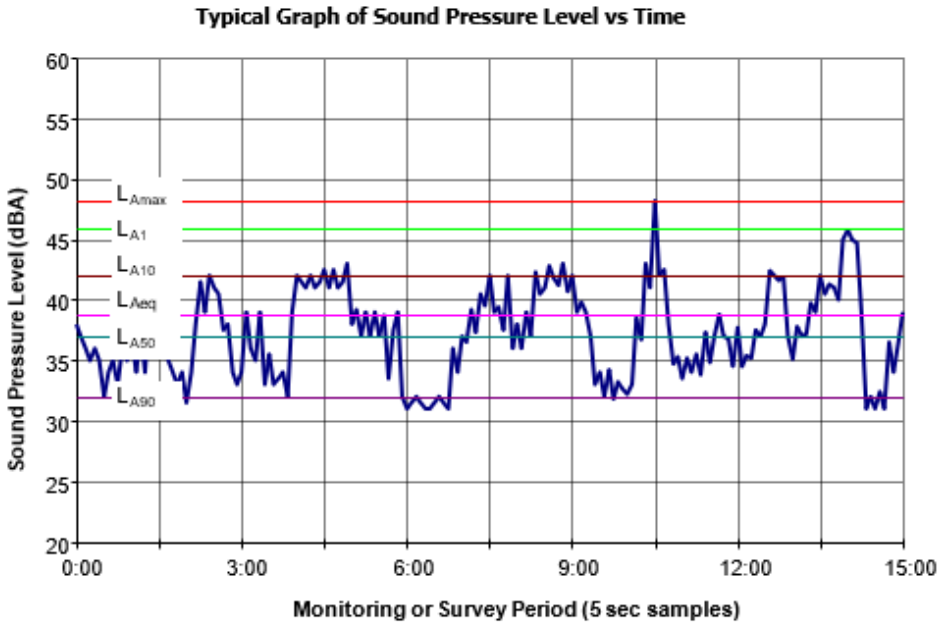


TABLE OF CONTENTS

LIST OF APPENDICES

1 INTRODUCTION

Transport for NSW (TfNSW) proposes to upgrade Pennant Hills Road and North Rocks Road in Carlingford, along the route identified in **Figure 1-1**.

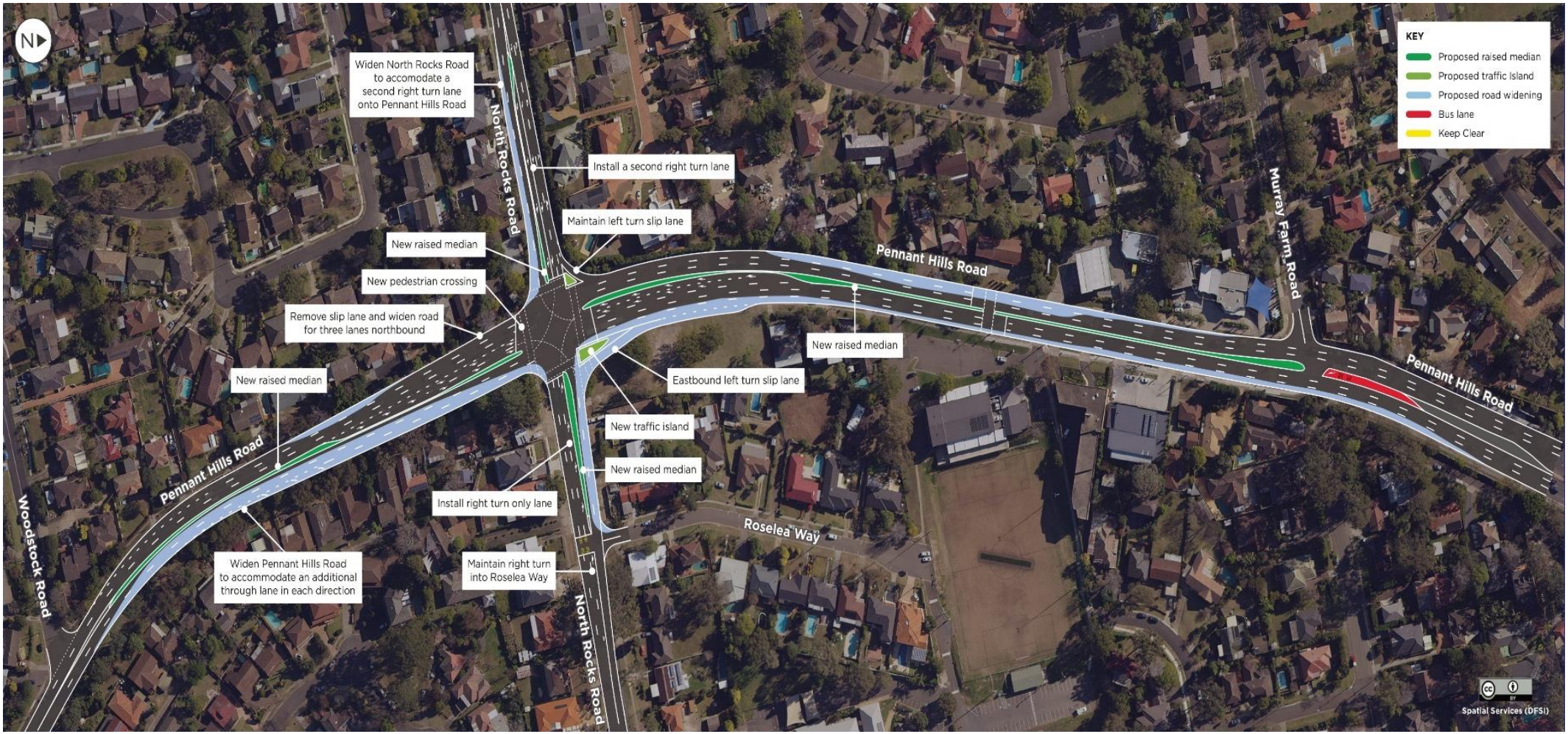
RWDI has been engaged to undertake an operational traffic and construction noise and vibration impacts of the proposal.

Based on the existing information provided, this report summarises the assessment findings, including the potential construction and operational noise impacts for the proposal and the recommended management measures.

This assessment has been undertaken in accordance with the *RMS Procedure – Preparing an Operational Traffic and Construction Noise and Vibration Assessment Report*. Additionally, the provisions of the following state policies and guidelines have been considered:

- *Road Noise Policy (RNP, DECCW, 2011);*
- *Noise Criteria Guideline / Noise Mitigation Guideline (NMG, RMS, 2015);*
- *Environmental Noise Management Manual (ENMM, RTA, 2001);*
- *German Standard DIN 4150, Part 3: Structural Vibration in Buildings: Effects on Structures (DIN 4150-3; 1999)*
- *Assessing Vibration: A Technical Guideline (DEC, 2006);*
- *Interim Construction Noise Guideline (ICNG, DECC, 2009); and*
- *Construction Noise and Vibration Guideline (CNVG, RMS, 2016)*
- *Evaluation and Measurement for Vibration in Buildings Part 2, (British Standard (BS) 7385:Part 2-1993) (BS 7385)*

Figure 1-1 - Proposed Upgrades on Pennant Hills Rd / North Rocks Rd, Carlingford



2 PROJECT DESCRIPTION

The proposed upgrades to be carried out by TfNSW involve:

- Widen Pennant Hills Road between Woodstock Road and Murray Farm Road to accommodate an additional through lane in each carriageway, providing three through lanes in each direction
- Widen North Rocks Road west to install a second right turn lane from North Rocks Road onto Pennant Hills Road heading south
- Widen North Rocks Road east to accommodate for a dedicated right turn bay
- Convert the left turn only condition for road users travelling on Pennant Hills Road northbound to a shared left and through lane to enable three northbound lanes through the intersection
- Install left turn slip lane with new traffic island on Pennant Hills Road southbound to North Rocks Road eastbound
- Maintain the existing left turn slip lane on North Rocks Road eastbound into northbound Pennant Hills Road northbound
- Install a raised median in the centre of Pennant Hills Road between Woodstock Road and Murray Farm Road and on North Rocks Road on the approach of the intersection
- Implement a new signalised pedestrian crossing on the southern leg of Pennant Hills Road/North Rocks Road intersection
- Adjust driveways and realign the pedestrian footpath to the edge of the new kerb due to the widening works on both Pennant Hills Road and North Rocks Road
- Adjust property front fence in front of twelve residences and the BP service station due to the proposed widening (property acquisitions required)
- Adjust utilities, street lighting, drainage, signage and line marking

The purpose of the works is principally to ease congestion and improve safety. No change in light or heavy vehicle volumes is associated with the proposal.

3 SENSITIVE RECEIVERS

An aerial view of the site and Noise Catchment Areas (NCAs) considered by this assessment is shown in **Figure 3-1**. Receivers within NCAs 1A to 1O front onto the road and typically have direct lines of sight to the various works areas. **Figure 3-2** and **Table 3-1** further identify the individual receivers located in NCA-1A to NCA-10.

Receivers setback further from the road are grouped into NCAs 2 to 7. These are typically shielded from the works areas by intervening buildings.

Figure 3-1: Site Plan Identifying Noise Catchment Areas Considered

Figure 3-2: Site Plan Identifying Sensitive Receivers within NCA1

Table 3-1 - NCA Sensitive Receiver Details

Receiver	Receiver Type	Address	NCA
R1	Residential	13 Wondabah Place	NCA1-A
R2	Residential	15 Wondabah Place	
R3	Residential	21 Wondabah Place	
R4	Residential	23 Wondabah Place	
R5	Residential	27 Wondabah Place	NCA1-B
R6	Residential	18 Wondabah Place	
R7	Residential	16 Wondabah Place	
R8	Residential	14 Wondabah Place	
R9	Residential	722 Pennant Hills Road	
R10	Residential	720 Pennant Hills Road	
R11	Residential	718 Pennant Hills Road	NCA1-C
R12	Residential	716 Pennant Hills Road	
R13	Residential	714D Pennant Hills Road	
R14	Residential	714C Pennant Hills Road	
R15	Residential	714 Pennant Hills Road	
R16	Commercial	BP1 Pennant Hills Road	NCA1-D
R17	Commercial	BP2 Pennant Hills Road	
R18	Commercial	Car Wash Pennant Hills Road	
R19	Residential	633 Pennant Hills Road	NCA1-E
R20	Residential	635 Pennant Hills Road	
R21	Residential	637 Pennant Hills Road	
R22	Commercial	Plus Fitness Pennant Hills Road	NCA1-F
R23	Residential	Temple Accom 643 Pennant Hills Road	
R24	Recreational	Community Centre Pennant Hills Road	
R25	Residential	673 Pennant Hills Road	NCA1-G
R26	Residential	675 Pennant Hills Road	
R27	Residential	677 Pennant Hills Road	
R28	Residential	5 Roselea Way	
R29	Residential	1 Roselea Way	
R30	Residential	527 North Rocks Road	
R31	Residential	529 North Rocks Road	
R32	Residential	531 North Rocks Road	
R33	Residential	533 North Rocks Road	NCA1-H
R34	Residential	535 North Rocks Road	
R35	Residential	537 North Rocks Road	
R36	Residential	539 North Rocks Road	
R37	Residential	541 North Rocks Road	

Receiver	Receiver Type	Address	NCA
R38	School	School North Rocks Road	NCA1-I
R39	Residential	462 North Rocks Road	NCA1-J
R40	Residential	424 North Rocks Road	
R41	Residential	422 North Rocks Road	
R42	Residential	420 North Rocks Road	
R43	Residential	418 North Rocks Road	
R44	Residential	416 North Rocks Road	
R45	Residential	414 North Rocks Road	NCA1-K
R46	Residential	412 North Rocks Road	
R47	Residential	410 North Rocks Road	
R48	Residential	404 North Rocks Road	
R49	Residential	402 North Rocks Road	
R50	Residential	400 North Rocks Road	
R51	Residential	687 Pennant Hills Road	NCA1-L
R52	Residential	689 Pennant Hills Road	
R53	Residential	691 Pennant Hills Road	
R54	Residential	18 Tripoli Avenue	
R55	Residential	20 Tripoli Avenue	
R56	Residential	22 Tripoli Avenue	
R57	Residential	24 Tripoli Avenue	
R58	Residential	26 Tripoli Avenue	
R79	Residential	54 Tripoli Avenue	
R80	Residential	52 Tripoli Avenue	
R81	Residential	50 Tripoli Avenue	
R82	Residential	48 Tripoli Avenue	
R83	Residential	46 Tripoli Avenue	
R84	Residential	30 Tripoli Avenue	
R85	Residential	28 Tripoli Avenue	
R59	Residential	738 Pennant Hills Road	NCA1-M
R60	Residential	736A Pennant Hills Road	
R61	Residential	736 Pennant Hills Road	
R62	Residential	734A Pennant Hills Road	
R63	Residential	734 Pennant Hills Road	
R64	Residential	732 Pennant Hills Road	
R74	Residential	740 Pennant Hills Road	
R75	Residential	742 Pennant Hills Road	
R76	Residential	744 Pennant Hills Road	
R77	Residential	4/1A Woodstock Road	
R78	Residential	6/1A Woodstock Road	

Receiver	Receiver Type	Address	NCA
R65	Residential	730 Pennant Hills Road	NCA1-N
R66	Residential	728A Pennant Hills Road	
R67	Residential	728 Pennant Hills Road	
R68	Residential	378B North Rocks Road	NCA1-O
R69	Residential	378A North Rocks Road	
R70	Residential	376B North Rocks Road	
R71	Residential	376A North Rocks Road	
R72	Residential	374A North Rocks Road	
R73	Residential	374 North Rocks Road	
R86	Residential	NCA2_Near	NCA2
R87	Residential	NCA2_Far	
R88	Residential	NCA3_Near	NCA3
R89	Residential	NCA3_Far	
R90	Residential	NCA4_Near	NCA4
R91	Residential	NCA4_Far	
R92	Residential	NCA5_Near	NCA5
R93	Residential	NCA5_Far	
R94	Residential	NCA6_Near	NCA6
R95	Residential	NCA6_Far	
R96	Residential	NCA7_Near	NCA7
R97	Residential	NCA7_Far	

4 OPERATIONAL NOISE ASSESSMENT

4.1 Traffic Noise Criteria

Roads and Maritime recently released the Noise Criteria Guideline (NCG) which states the following in relation to minor works:

- *Minor works are works that primarily improve safety, including minor straightening of curves, installing traffic control devices, intersection widening, turning bay extensions or making minor road realignments.*
- *These (minor) works are not considered 'redeveloped' or 'new' (in the context of the Road Noise Policy definitions) as they are not intended to increase the traffic carrying capacity of the overall road or accommodate a significant increase in heavy vehicle traffic.*
- *Roads and Maritime applies existing road criteria (as set out in Table 8 of the NSW Road Noise Policy (RNP)) where the minor works increase noise levels by more than 2 dB relative to the existing noise levels at the worst affected receiver.*

In accordance with the NCG, for this proposal, there is considered to be negligible impact where operational noise levels increase by less than 2 dB relative to the existing noise level. Under such circumstances, mitigation is not required to be considered.

In cases where the proposal results in operational noise level increases of more than 2 dB, the NSW *RNP* criteria of $L_{Aeq,\ 15hour}$ 60 dBA (daytime) and $L_{Aeq,\ 9hour}$ 55 dBA (night time) apply.

4.2 Traffic Noise Monitoring

RWDI (formerly Wilkinson Murray), has undertaken noise monitoring within the proposal corridor to evaluate the existing traffic noise and background noise environment. Unattended monitoring has been undertaken at the location identified in **Figure 4-1**, to broadly characterise the noise environment and to verify the traffic noise model (as discussed in Section 4.3).

Figure 4-1: Noise Monitoring Location

The monitoring was conducted between Monday 22 January and Wednesday 31 January 2018. In addition, fully classified traffic counting was undertaken concurrently on Pennant Hills Road during the unattended noise monitoring. The traffic counting was undertaken by Austraffic Pty Ltd (Austraffic).

An ARL-Ngara environmental noise logger was used to undertake the noise monitoring. The logger was configured to A-weighted, fast response and set to continuously monitor noise levels. This instrument is capable of monitoring and storing various noise level descriptors for later detailed analysis.

The logger determines L_{A1}, L_{A10}, L_{A90} and L_{Aeq} levels of the existing noise environment. The L_{A1}, L_{A10} and L_{A90} levels are the levels exceeded for 1 per cent, 10 per cent and 90 per cent of the sample time, respectively. The L_{A1} is indicative of maximum noise levels due to individual noise events such as the occasional passby of a heavy vehicle. The L_{A90} level is normally taken as the background noise level. The L_{Aeq} level is the equivalent continuous sound level and has the same sound energy over the sampling period as the actual noise environment with its fluctuating sound levels. While the L_{A10} has in the past been used as a descriptor for traffic noise, the L_{Aeq} is now the standard descriptor for traffic noise in NSW.

The logger was placed in a free field position outside the property boundary (not at the dwelling), with more than 140 degrees view of the road. Observations made during the site survey confirmed that Pennant Hills Road traffic was the principal source of influence on the measured L_{Aeq} noise levels, whilst background LA90 noise levels may be influenced by other noise sources such as distant urban 'hum' and fauna (i.e. insects).

The measured noise levels are presented in graphical form in **Appendix A** and summarised below in **Table 4-1**. All data considered to be affected by adverse weather conditions and other extraneous sources were discarded prior to analysis.

Table 4-1: Summary of Measured Noise Levels (22-31 January 2018)

Site	Approx. Setback Distance to the Nearside Carriageway (metres)	Daytime $L_{Aeq,15hr}$ (dBA)	Night Time $L_{Aeq,9hr}$ (dBA)	Rating Background Level (RBL) (dBA)		
				Day	Evening	Night
L1	6	74	72	58	53	40

4.3 Traffic Noise Modelling

To determine existing traffic noise levels at the closest potentially-affected receivers to the road, a model has been implemented using the Cadna-A noise prediction software (Version 2021 MR1), based on the alignment data supplied by Transport for NSW. The traffic counts obtained by Austraffic during the noise monitoring have been applied to the model for validation purposes (this is discussed further in Section 4.4). Full traffic counts for all roads (undertaken in 2017) have also been provided by Transport for NSW. These have been applied in the validated traffic noise model.

The model takes account of the following factors:

- Traffic volume and percentage of heavy vehicles for daytime and night time;
- Vehicle speeds for daytime and night time;
- Road surface types;
- Road gradient;
- Different vehicle noise emission levels and source heights;
- Location of the noise sources on the road;
- Topographical information along and surrounding the entire proposal corridor;
- Shielding from mounds, landforms and buildings; and
- Receiver locations.

Noise levels from the proposed road designs were calculated using procedures based on the *CoRTN* prediction algorithms (*Calculation of Road Traffic Noise, UK Department of Transport, 1988*). The standard prediction procedures were modified in the following ways:

- L_{Aeq} values were calculated from the L_{A10} values predicted by the *CoRTN* algorithms using the well-validated approximation $L_{Aeq,1hour} = L_{A10,1hr} - 3$ (NSW RTA, 2001). It is worth noting the predicted $L_{Aeq,1hr}$ is equivalent to the $L_{Aeq,Period}$ as required by the noise criteria since the input is the "average" traffic flow over the given daytime and night time periods.
- Noise source heights were set at 0.5 m for cars, 1.5 m for heavy vehicle engines and 3.6 m for heavy vehicle exhausts, representative of typical values for Australian vehicles *(Road Traffic Noise: Interim Traffic Noise Policy, 1992)*.
- Noise from heavy vehicle exhausts has been set 8 dB lower than the (steady continuous) noise from the engine.
- Previous research in Australia has established a negative correction to the *CoRTN* predictions of -1.7 dB for façade-corrected levels and -0.7 dB for free-field levels. (Samuels and Saunders, 1982). These corrections for Australian conditions have been included in noise modelling for the daytime period. Consistent with preferred practice, no Australian conditions correction has been applied to the night time traffic noise modelling.
- The same corrections (for a given road pavement surface) were applied to all light and heavy vehicle sources in the 3-source height model.

Table 4-2 summarises other variables used in the noise model.

Table 4 2: Variables used for Noise Modelling

Parameter	Comment
Traffic Volume	Traffic counting data provided by Austraffic (Validation Model) Traffic counting data provided by Roads and Maritime ('Build' and 'No-Build' Models)
Traffic Speed	85th percentile data supplied by Austraffic (Validation Model)
Road Surface	0 dB correction for dense grade asphalt (DGA)
Façade Correction	+2.5 dB in accordance with *CoRTN*
ARRB's Australian Condition Correction	Daytime: -1.7 dB (at 1 m from a façade) or -0.7 dB (free-field) Night: No correction applied
Calculation Settings	Grid space of 20 m; height above ground = 1.5 m; grid interpretation field size = 9 x 9; grid interpretation min/max = 2 dB; grid interpretation difference = 0.1 dB; angle increment = 1 degree; reflection depth = 0; number of reflections = 0; and maximal search radius = 7000 m
Receivers	1.5 m above existing ground level for single storey dwellings 4.5 m above existing ground level for two storey dwellings
Buildings	4.5 m and 6 m above maximum terrain height of building footprint for single and double storey premises respectively
Ground Absorption	Ground absorption factor of 0.6

4.4 Traffic Noise Validation Model

Based on the fully classified traffic counts obtained by Austraffic, the traffic volumes and 85th percentile speeds shown in **Table 4-3** have been used to validate the noise model.

Table 4-3: Existing Traffic (Hourly Average Counts, 22-31 January 2018)

Location	Direction	Day (7am – 10pm)		Night (10pm – 7am)		85th Percentile Speed	
		Light	Heavy	Light	Heavy	Day	Night
T1 – Pennant Hills Road, Carlingford	Northbound L1	496	76	161	29	50	57
	Northbound L2	496	76	161	29	50	57
T1 – Pennant Hills Road, Carlingford	Southbound L1	470	71	157	25	44	55
	Southbound L2	470	71	157	25	44	55

Measured results are compared with model predictions at the identified noise monitoring location in Table 4 4. The differences between measured and predicted values are also shown.

Table 4-4: Predicted and Measured Results – (based on 22-31 January 2018 Survey

Location	Daytime $L_{Aeq,15hr}$			Night Time $L_{Aeq,9hr}$		
	Measured	Predicted	Difference	Measured	Predicted	Difference
L1 – 716 Pennant Hills Road, Carlingford	73.6	73.3	-0.3	72	71.4	-0.6

A tolerance of 2 dB is generally considered acceptable given the expected accuracy of standard noise modelling procedures, and also variability in traffic speeds along the whole alignment. At the monitoring location, the

predicted levels are well within this range for both day and night periods, therefore the model is considered to be validated without any further calibration adjustments.

4.5 Predicted Traffic Noise Levels

As previously noted, no changes in vehicle volumes are associated with the proposal. On this basis, for the purpose of this assessment, posted speeds and vehicle volumes provided by TfNSW and have been used in No Build and Build traffic noise predictions. The Build traffic noise operations will consist in operations during the Opening year and the Design year.

Predicted traffic noise levels for the No Build and Build scenarios within the identified NCAs are set out in **Table 4-5**. The NCA predictions and relative traffic noise increases shown in the table are based on predictions at individual receivers identified in **Table 3-1**.

For each NCA, the maximum predicted $L_{Aeq,Period}$ noise levels and relative changes are shown.

Table 4-5 also identifies mitigation consideration requirements, as guided by the Roads and Maritime NMG which states the following:

Where the total noise level for the 'build' year exceeds the criterion and there is an increase of more than 2.0dBA (i.e. 2.1dBA), relative to the 'no-build' year, then the receiver qualifies for consideration of noise mitigation. This includes the situation where the 'no-build' noise level is below the criterion value(s).

Table 4-5: Predicted Traffic Noise Levels – 'Build' cf 'No Build'

Receiver ID	$L_{Aeq,Period}$ (dBA) 'No Build'		$L_{Aeq,Period}$ (dBA) 'Build'		*NCG* Assessment Criteria		*NCG* Criteria Exceeded?		Change in Noise Levels – Build cf No Build		Consider Mitigation?
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	
NCA1-A	71	65	71	65	60	55	Yes	Yes	0.0	0.1	No
NCA1-B	73	70	73	70	60	55	Yes	Yes	0.0	0.1	No
NCA1-C	72	69	72	69	60	55	Yes	Yes	0.3	0.3	No
NCA1-D	74	70	74	71	60	55	Yes	Yes	0.3	0.4	No
NCA1-E	73	69	72	69	60	55	Yes	Yes	0.0	0.0	No
NCA1-F	72	69	72	69	60	55	Yes	Yes	0.0	0.0	No
NCA1-G	73	70	73	70	60	55	Yes	Yes	0.3	0.2	No
NCA1-H	64	57	65	57	60	55	Yes	Yes	0.1	0.1	No
NCA1-I	56	50	56	50	60	55	No	No	0.0	0.0	No
NCA1-J	64	57	64	57	60	55	Yes	Yes	0.1	0.1	No
NCA1-K	73	69	73	69	60	55	Yes	Yes	0.4	0.2	No
NCA1-L	74	70	74	71	60	55	Yes	Yes	0.6	0.6	No
NCA1-M	73	70	73	70	60	55	Yes	Yes	-0.1	-0.1	No
NCA1-N	73	69	73	69	60	55	Yes	Yes	0.1	0.0	No
NCA1-O	69	63	69	64	60	55	Yes	Yes	0.0	0.8	No
NCA2	61	58	61	58	60	55	Yes	Yes	0.0	0.0	No
NCA3	58	53	58	53	60	55	No	No	0.0	0.0	No
NCA4	62	55	62	55	60	55	Yes	Yes	0.0	0.0	No
NCA5	61	59	59	59	60	55	No	Yes	0.0	0.0	No
NCA6	56	56	56	56	60	55	No	Yes	0.0	0.0	No
NCA7	51	51	51	52	60	55	No	No	0.0	0.0	No

Note: Build and No-Build traffic noise predictions have been undertaken at each receiver within the NCAs. For reporting purposes, the maximum predicted $L_{Aeq,Period}$ noise levels are shown.

As shown in the table, whilst the existing traffic noise levels already exceed the NCG criteria, the project is only expected to result in marginal traffic noise increases at the closest (most affected) receivers.

At the most affected receivers, the L_{Aeq} daytime and night time levels are predicted to increase by less than 1.0 dB, which would not be perceptible to most people and well within the 2 dB permissible increase range.

4.6 Operational Noise Mitigation Requirements

It is concluded that in accordance with the requirements of the NCG and NMG, no specific mitigation measures are required for operational traffic noise.

5 CONSTRUCTION NOISE ASSESSMENT

5.1 Construction Noise Criteria

5.1.1 NSW Interim Construction Noise Guideline (ICNG)

The noise criteria set out in the *ICNG* have been used to assess the potential impacts from construction noise. This document guides the EPA in setting statutory conditions in licences or other regulatory instruments for construction noise.

Table 5-1 summarises the construction noise management levels (NMLs) relevant to residences, as specified in the *ICNG*.

Table 5-1: Construction Noise Management Levels – Residences

Time of Day	Management Level $L_{Aeq,15min}$	How to Apply
Recommended Standard Hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or Public Holidays	Noise affected RBL + 10dBA	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq,15min}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. 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; 2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2 of the Guideline.

5.1.2 Project-Specific Construction Noise Management Levels

For the purpose of assessment, the daytime, evening and night time RBLs determined by the monitoring have been used to establish construction NMLs for all residential receivers potentially impacted by the works. In accordance with the above guideline, the construction NMLs set out in **Table 5-2** would be applicable during the works.

Table 5-2: Project-Specific Construction Noise Management Levels for Standard Hours and Outside Standard Construction Hours

Receivers	Standard Construction Hours		Outside Standard Construction Hours		
	Noise Affected Level $L_{Aeq,15min}$ dB(A)	Highly Noise Affected Level $L_{Aeq,15min}$ dB(A)	Noise Affected Level – Day $L_{Aeq,15min}$ dB(A)	Noise Affected Level – Evening $L_{Aeq,15min}$ dB(A)	Noise Affected Level – Night $L_{Aeq,15min}$ dB(A)
Residential	68	75	63	58	45

Note: The determined residential criteria apply at the most affected point on or within the receiver property boundary.

The *ICNG* does not include any criteria to assess off-site traffic noise associated with the construction.

For the purpose of this assessment, construction road traffic noise is assessed using the same approach as minor works under the NCG, that is, construction traffic should not increase existing traffic noise levels by more than 2 dB.

5.1.3 Sleep Disturbance Criteria

The potential issue of sleep disturbance is only applicable to construction activities conducted in the night time period between 10pm and 7am (following approval of such works).

Regarding sleep disturbance, the ICNG states:

"Where construction works are planned to extend over more than two consecutive nights, and a quantitative assessment method is used, the analysis should cover the maximum noise level, and the extent and the number of times that the maximum noise levels exceeds the RBL…"

As stated above, all out of hours works would be conducted in accordance with RMS CNVG and therefore, residential receivers would not be exposed to significant construction noise levels for more than two consecutive nights. Accordingly, a detailed assessment of sleep disturbance is not warranted.

Notwithstanding the above, it is prudent to establish criteria for the assessment of sleep disturbance. If out of hours works near individual dwellings are required over more than two consecutive nights, a detailed assessment of potential sleep disturbance should be conducted.

Noise sources that operate over short durations at night have the potential to cause sleep disturbance despite complying with criteria based upon L_{Aeq} noise descriptors. For this reason, the NSW EPA's *Noise Guide for Local Government* (NGLG) suggests that a screening test be applied such that if the $L_{A1,1min}$ or L_{Amax} noise levels do not exceed the background noise level by more than 15 dBA, then it is unlikely that the development has the potential to cause sleep disturbance.

The EPA's Application Notes state:

"Research on sleep disturbance is reviewed in the NSW Road Noise Policy. This review concluded that the range of results is sufficiently diverse that it was not reasonable to issue new noise criteria for sleep disturbance.

From the research, the EPA recognised that the current sleep disturbance criterion of an $L_{A1,(1\ min)}$ not exceeding the $L_{A90,(15\ min)}$ by more than 15 dB(A) is not ideal. Nevertheless, as there is insufficient evidence to determine what should replace it, the EPA will continue to use it as a guide to identify the likelihood of sleep disturbance. This means that where the criterion is met, sleep disturbance is not likely, but where it is not met, a more detailed analysis is required."

The sleep disturbance criteria for the NCAs are presented in Table 7 8.

On the basis that the night time RBL in the area is in the range of 40 dBA, a $L_{A1,1min}$ sleep disturbance screening criterion of $L_{A1,1min}$ 55 dBA has been considered for this assessment.

This "*sleep disturbance*" screening criterion applies externally to dwellings and is only applicable to night time (10.00pm to 7.00am) operations.

Additionally, the NSW Road Noise Policy states that from the research on sleep disturbance to date it can be concluded that :

- *Maximum internal noise levels below 50-55dBA are unlikely to cause awakening reactions; and*
- *One or two noise events per night, with maximum internal noise levels of 65-70dBA, are not likely to affect health and wellbeing significantly.*

With consideration to the ECRTN and the typical noise reduction of 10dB that is achieved through a bedroom facade with partially open windows, it is considered that an external noise level of $L_{A1,1min}$ 60-65dBA would be unlikely to cause sleep disturbance.

Where windows remain closed, external noise level of up to $L_{A1,1min}$ 75-80 may not necessarily result in sleep disturbances.

5.2 Construction Stages

Transport for NSW currently expects construction to start in 2019 and take about 9 months to complete. The likely construction activities for the proposal are presented in **Table 5-3**.

There may be expected to be some overlap between the construction stages identified in **Table 5-3**. A preliminary indicative works schedule is shown in **Table 5-4**.

Table 5-3: Construction Activities

Construction Phase	Activities
Early Work	• Compound set up TfNSW vacant block Nth / East corner • Early utility adjustments as required
Stage 1 – West Side Pennant Hills Rd Additional Lane	• Property adjustments and tree clearing to relocate boundary fences to correct alignments. • Ground clearing / grubbing • Utility adjustments into new service corridor • Removal of existing footpath, driveways and kerb • Excavate to foundation level (behind barriers) • Install new stormwater pit and or pipes • Place and compact foundation & concrete pavement materials to finished levels • Place new kerb, driveway, footpath and landscaping • Seal & asphalt new lane (Nightworks) • Line mark (Nightworks)
Stage 2 – South East Side additional lane and North East Side Turning Lane on Pennant Hills Rd	• Adjustments to RMS property - Retaining walls, tree removal • Ground clearing / grubbing and earthworks to finished property levels • Utility adjustments into new service corridor • Excavate to foundation level for new road area • Place and compact foundation & base materials to finished levels for new lane and footpath • Relocate TCS as required • Concrete pavement works • Build new foot path & kerb for new centre island • Place new kerb, driveway, footpath and landscaping • Seal & asphalt new lane (Nightworks) • Line mark (Nightworks)
Stage 3 – South West Side Additional lane on North Rocks Rd	• Ground clearing / grubbing • Utility adjustments into new service corridor • Excavate to foundation level • Place and compact foundation & base materials to finished levels for new lane and footpath • Place new kerb, driveway, footpath and landscaping • Seal & asphalt new lane (Nightworks) • Line mark (Nightworks)

Table 5-4: Indicative Construction Schedule

Early Works – Indicative Works Schedule									
Month	1	2	3	4	5	6	7	8	9
Compound Setup									
Early Utility Adjustments									
Stage 1 – West Side Pennant Hills Rd Additional Lane – Indicative Works Schedule									
Month	1	2	3	4	5	6	7	8	9
Property adjustments and tree clearing to relocate boundary fences to correct alignments									
Ground clearing / grubbing									
Utility adjustments into new service corridor									
Removal of existing footpath, driveways and kerb									
Excavate to foundation level (behind barriers)									
Install new stormwater pit and or pipes									
Place and compact foundation & concrete pavement materials to finished levels									
Place new kerb, driveway, footpath and landscaping									
Seal & asphalt new lane (Nightworks)									
Line mark (Nightworks)									
Stage 2 – South East Side additional lane and North East Side Turning Lane on Pennant Hills Rd – Indicative Works Schedule									
Month	1	2	3	4	5	6	7	8	9
Adjustments to RMS property – Retaining walls, tree removal									
Ground clearing / grubbing and earthworks to finished property levels									
Utility adjustments into new service corridor									
Excavate to foundation level for new road area									
Place and compact foundation & base materials to finished levels for new lane and footpath									
Relocate TCS as required									
Concrete pavement works									
Build new foot path & kerb for new centre island									
Place new kerb, driveway, footpath and landscaping									
Seal & asphalt new lane (Nightworks)									
Line mark (Nightworks)									
Stage 3 – South West Side Additional lane on North Rocks Rd – Indicative Works Schedule									
Month	1	2	3	4	5	6	7	8	9
Ground clearing / grubbing									
Utility adjustments into new service corridor									
Excavate to foundation level									
Place and compact foundation & base materials to finished levels for new lane and footpath									
Place new kerb, driveway, footpath and landscaping									
Seal & asphalt new lane (Nightworks)									
Line mark (Nightworks)									

5.3 Construction Hours

The early works such as establishing the site compound and clearing and grubbing outside the existing corridor would as far as practicable be undertaken during standard construction hours in accordance with the *ICNG* as follows:

- Monday to Friday 7.00am to 6.00pm
- Saturday 8.00am to 1.00pm
- Sunday and public holidays No work

The works that would be expected to be entirely constrained to within standard hours are highlighted in gold in **Table 5-4**. Works that would likely be required to be undertaken outside standard hours, during the night, are highlighted in blue in **Table 5-4**. The nightworks would be required in order to minimise disruption to road users and to ensure the health and safety of the public and construction crews. The final number of hours per night will also be dependent on the issuing of the road occupancy licence to permit the works to occur.

Any out-of-hours works would be undertaken in accordance with the *ICNG* and Practice Note vii of RMS' *Environmental Noise Management Manual (RTA 2001)*.

Prior consultation would be given to the community of any works proposed to be undertaken outside standard construction hours.

5.4 Construction Equipment

The construction equipment assumed to be used, as advised by TfNSW is set out in **Table 5-5**.

Associated sound power levels for the identified plant are also included in **Table 5-5** based on RWDI's experience with similar projects. These sound power levels have been applied in the predictions of 'worst-case' noise that may arise during the identified construction stages.

Table 5-5: Assumed Construction Equipment used during Works

Equipment Used	Equipment SWL, dB(A)
Rigid and articulated trucks	109
Semi-trailers to deliver materials	109
Bobcat	95
Forklift	90
Up to 20 tonne excavators with hammer for demolition of concrete pavements	122
Vibrating and smooth drum rollers	107
Asphalt paver	114
Multi tyred roller	109
30 tonne trucks for delivering asphalt and concrete	109
Road profiler	114
Lighting towers	85

Equipment Used	Equipment SWL, dB(A)
Generators	90
Light vehicles	80
Electric and fuel powered hand tools	100
Water cart	107
Line marking machine	108
Concrete saw / Road cutting saw	118
Bitumen sprayer	106
Tree pruning truck and mulcher	116
Trucks with boom lift and hiab	98
Jackhammers	113

Note: The sound power levels for the individual plant items are worst-case levels representative of the equipment operating at maximum capacity. In practice, not all plant items would operate at maximum capacity at the same time and therefore the activity sound power levels modelled have been adjusted by -5 dB to reflect this. This adjustment is consistent with Wilkinson Murray / RWDI experience on similar projects.

5.5 Construction Noise Modelling

Construction noise emissions from the works have been modelled using the CadnaA (Version 2021 MR1) acoustic noise prediction software. Factors that are addressed in the noise modelling are:

- Equipment noise level emissions and location;
- Screening from structures;
- Receiver locations;
- Ground topography;
- Noise attenuation due to geometric spreading;
- Ground absorption; and
- Atmospheric absorption.

5.6 Construction Noise Predictions

Noise emissions would impact different receivers to various degrees as construction progresses. Based on the preliminary work schedule, the upper $L_{Aeq,15min}$ construction noise levels predicted within each NCA for the key stages are provided in **Table 5-6**. Levels exceeding the standard hours NML are highlighted in red and those exceeding the 'highly affected' 75 dBA level are shown in bold.

It is expected that the compound setup would be undertaken during standard hours, whereas other activities (including clear & grub works) would generally be undertaken at night. Predicted potential exceedances of the standard hours NML are provided in **Table 5-7** and the predicted potential exceedances of the out-of-hours (night time) NML are provided in **Table 5-8**.

Section 7 of this report identifies appropriate mitigation strategies to assist in the management of noise impacts during the construction. These should be incorporated in a Construction Noise and Vibration Management Plan (CNVMP) prepared by the contractor conducting the works.

Table 5-6: Worst-Case Predicted Construction Noise Levels ($L_{Aeq,15min}$ dBA)

NCA	Compound Setup	Clear & Grub			Excavate			New Kerb			Seal & Asphalt			Line Mark		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
NCA1-A	56	54	66	**81**	54	66	**81**	54	65	**81**	48	58	73	42	54	66
NCA1-B	70	72	73	79	72	74	80	71	74	79	65	67	72	60	61	65
NCA1-C	64	**79**	73	50	**80**	73	50	**79**	73	50	73	67	44	67	61	38
NCA1-D	50	**79**	54	43	**77**	54	44	**78**	54	43	72	48	37	65	43	31
NCA1-E	50	69	59	46	68	58	47	68	59	46	63	52	40	56	46	34
NCA1-F	62	71	64	49	70	62	50	70	64	49	65	58	43	58	52	36
NCA1-G	**79**	73	**77**	60	73	**77**	61	73	**78**	61	67	71	54	61	66	47
NCA1-H	58	55	70	54	55	68	54	56	64	54	50	59	47	44	54	40
NCA1-I	50	52	51	42	53	51	42	53	51	42	46	45	34	41	39	28
NCA1-J	51	51	64	50	51	64	51	51	63	51	45	57	44	39	50	37
NCA1-K	64	54	**76**	67	54	**77**	66	54	**76**	67	48	70	60	42	64	53
NCA1-L	58	50	**80**	66	50	**80**	66	50	**80**	66	44	73	59	38	68	52
NCA1-M	61	52	74	68	52	74	69	52	74	69	46	68	59	40	62	52
NCA1-N	62	55	74	75	55	74	**76**	55	74	**76**	49	67	69	43	62	62
NCA1-O	59	49	65	**81**	49	65	**82**	49	65	**82**	43	59	75	37	53	69
NCA2	49	67	59	47	67	55	48	66	60	48	60	54	42	54	48	35
NCA3	48	57	51	43	58	51	44	58	51	44	52	44	37	46	38	30
NCA4	51	56	53	47	56	53	47	56	53	47	50	47	40	44	41	33
NCA5	59	60	60	48	61	59	49	61	60	48	55	53	41	49	47	34
NCA6	51	46	63	52	47	63	53	46	63	52	40	57	45	35	51	39
NCA7	52	42	55	61	42	56	61	42	55	61	36	49	55	31	44	48

Note: Levels exceeding the standard hours NMLs are highlighted in red.

Levels exceeding the 'highly affected' 75 dBA level are shown in bold.

Table 5 7: Predicted Standard Hours NML Exceedances

NCA	Compound Setup	Clear & Grub		
		Work Stage 1	Work Stage 2	Work Stage 3
NCA1-A	Nil	Nil	Nil	13
NCA1-B	2	4	5	11
NCA1-C	Nil	11	5	Nil
NCA1-D	Nil	11	Nil	Nil
NCA1-E	Nil	Nil	Nil	Nil
NCA1-F	Nil	3	Nil	Nil
NCA1-G	11	5	9	Nil
NCA1-H	Nil	Nil	2	Nil
NCA1-I	Nil	Nil	Nil	Nil
NCA1-J	Nil	Nil	Nil	Nil
NCA1-K	Nil	Nil	8	Nil
NCA1-L	Nil	Nil	12	Nil
NCA1-M	Nil	Nil	6	Nil
NCA1-N	Nil	Nil	6	7
NCA1-O	Nil	Nil	Nil	13
NCA2	Nil	Nil	Nil	Nil
NCA3	Nil	Nil	Nil	Nil
NCA4	Nil	Nil	Nil	Nil
NCA5	Nil	Nil	Nil	Nil
NCA6	Nil	Nil	Nil	Nil
NCA7	Nil	Nil	Nil	Nil

As shown in **Table 5-7**, predictions indicate that during standard hours exceedances of up to approximately 13 dB may be expected at the most affected receivers.

Table 5-8: Predicted Out-of-Hours (Night) NML Exceedances

NCA	Excavate			New Kerb			Seal & Asphalt			Line Mark		
	Work Stage			Work Stage			Work Stage			Work Stage		
	1	2	3	1	2	3	1	2	3	1	2	3
NCA1-A	9	21	36	9	20	36	3	13	28	Nil	9	21
NCA1-B	27	29	35	26	29	34	20	22	27	15	16	20
NCA1-C	35	28	5	34	28	5	28	22	Nil	22	16	Nil
NCA1-D	32	9	Nil	33	9	Nil	27	3	Nil	20	Nil	Nil
NCA1-E	23	13	2	23	14	1	18	7	Nil	11	1	Nil
NCA1-F	25	17	5	25	19	4	20	13	Nil	13	7	Nil
NCA1-G	28	32	16	28	33	16	22	26	9	16	21	2
NCA1-H	10	23	9	11	19	9	5	14	2	Nil	9	Nil
NCA1-I	8	6	Nil	8	6	Nil	1	Nil	Nil	Nil	Nil	Nil
NCA1-J	6	19	6	6	18	6	Nil	12	Nil	Nil	5	Nil
NCA1-K	9	32	21	9	31	22	3	25	15	Nil	19	8
NCA1-L	5	35	21	5	35	21	Nil	28	14	Nil	23	7
NCA1-M	7	29	24	7	29	24	Nil	23	14	Nil	17	7
NCA1-N	10	29	31	10	29	31	4	22	24	Nil	17	17
NCA1-O	4	20	37	4	20	37	Nil	14	30	Nil	8	24
NCA2	22	10	3	21	15	3	15	9	Nil	9	3	Nil
NCA3	13	6	Nil	13	6	Nil	7	Nil	Nil	Nil	Nil	Nil
NCA4	11	8	2	11	8	2	5	2	Nil	Nil	Nil	Nil
NCA5	16	14	4	16	15	3	10	8	Nil	4	2	Nil
NCA6	2	18	8	1	18	7	Nil	12	Nil	Nil	6	Nil
NCA7	Nil	11	16	Nil	10	16	Nil	4	10	Nil	Nil	3

As shown in **Table 5-8**, the out-of-hours nightworks have the greatest potential to generate noise impacts. Significant exceedances of the night time 45 dBA NML are to be expected for works undertaken out-of-hours. Potential exceedances of up to approximately 37 dB are predicted during the out-of-hours works at the most exposed residential receivers.

Figure 5-1 and Figure 5-2 show aerial maps detailing maximum construction noise levels at sensitive receivers for all construction phases.

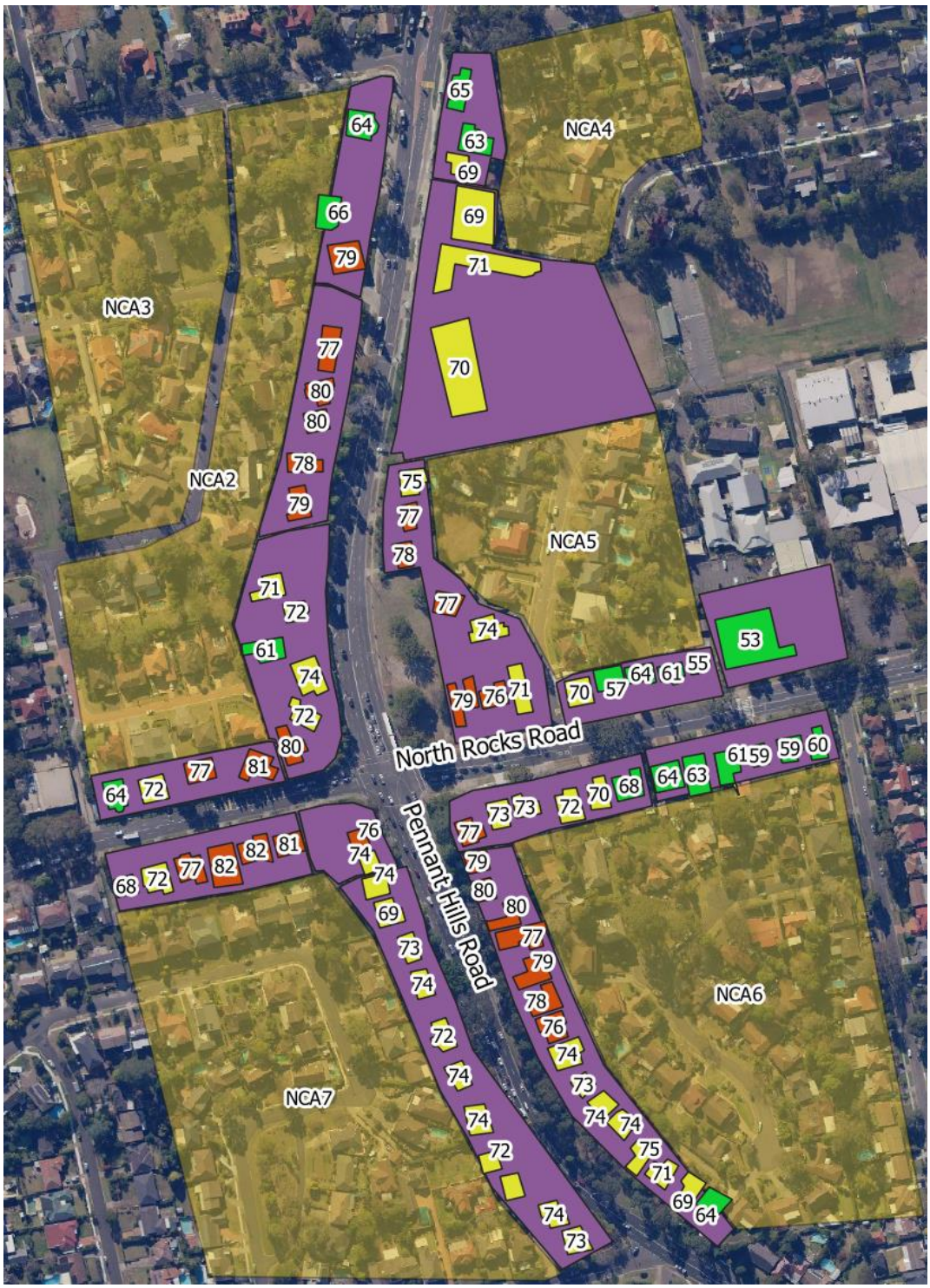


Figure 5-1 – Maximum Construction Noise Levels against Standard Hours NMLs

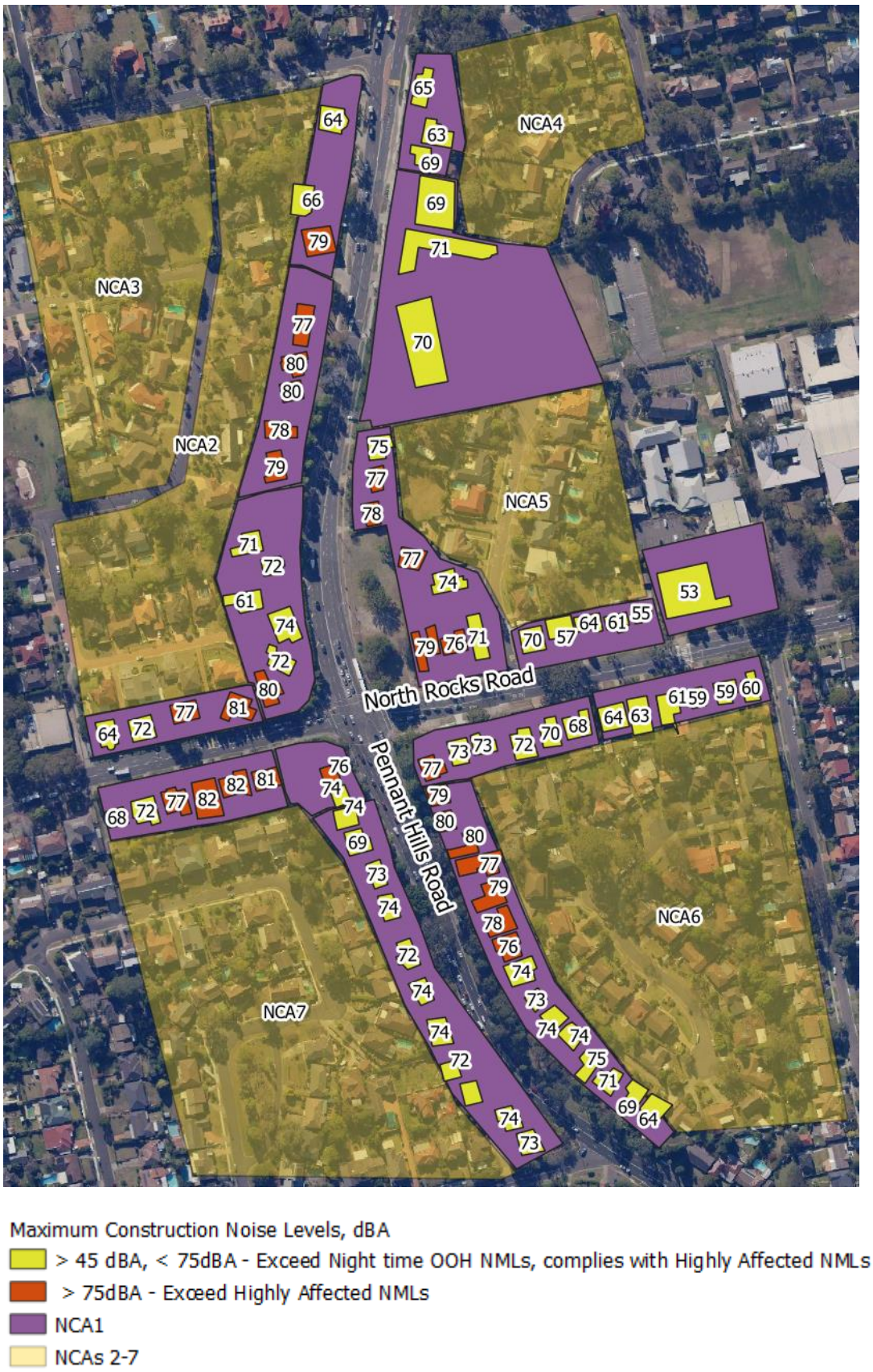


Figure 5-2 – Maximum Construction Noise Levels against Night-time NMLs

5.7 Sleep Disturbance Predictions

Nightworks including pavement and asphalting would be expected to generate extensive exceedance of the $L_{A1,1min}$ 60 dBA sleep disturbance criterion adopted by this assessment.

The $L_{A1,1min}$ noise levels calculated for the works set out in **Table 5-9** indicate the potential for sleep disturbance at several receivers, with the exceedances of the $L_{A1,1min}$ 60 dBA criterion shown in red.

Whilst extensive potential sleep disturbance impacts are indicated, it should be noted that these are based on the conservative assumption that bedroom windows may be partially open for ventilation purposes. It is expected that given the proximity of receivers to the road, many will normally keep their windows closed. In these cases, it is considered that external noise levels of up to $L_{A1,1min}$ 75-80 dBA may not result in sleep disturbances. Levels exceeding $L_{A1,1min}$ 75 dBA, are shown in bold. These are considered to indicate the greatest sleep disturbance risks.

Section 7 identifies appropriate mitigation strategies to assist in the management of sleep disturbance impacts during the construction. These should be incorporated in a Noise Management Plan prepared by the contractor conducting the works.

Table 5-9: Predicted $L_{A1,1min}$ Construction Levels – Night (dB)

NCA	Excavate			New Kerb			Seal & Asphalt			Line Mark		
	Work Stage			Work Stage			Work Stage			Work Stage		
	1	2	3	1	2	3	1	2	3	1	2	3
NCA1-A	57	69	**84**	57	68	**84**	51	61	**76**	45	57	69
NCA1-B	75	**77**	**83**	74	**77**	**82**	68	70	75	63	64	68
NCA1-C	**83**	**76**	53	**82**	**76**	53	**76**	70	47	70	64	41
NCA1-D	**80**	57	47	**81**	57	46	75	51	40	68	46	34
NCA1-E	71	61	50	71	62	49	66	55	43	59	49	37
NCA1-F	73	65	53	73	67	52	68	61	46	61	55	39
NCA1-G	**76**	**80**	64	**76**	**81**	64	70	74	57	64	69	50
NCA1-H	58	71	57	59	67	57	53	62	50	47	57	43
NCA1-I	56	54	45	56	54	45	49	48	37	44	42	31
NCA1-J	54	67	54	54	66	54	48	60	47	42	53	40
NCA1-K	57	**80**	69	57	**79**	70	51	73	63	45	67	56
NCA1-L	53	**83**	69	53	**83**	69	47	76	62	41	71	55
NCA1-M	55	**77**	72	55	**77**	72	49	71	62	43	65	55
NCA1-N	58	**77**	**79**	58	**77**	**79**	52	70	72	46	65	65
NCA1-O	52	68	**85**	52	68	**85**	46	62	**78**	40	56	72
NCA2	70	58	51	69	63	51	63	57	45	57	51	38
NCA3	61	54	47	61	54	47	55	47	40	49	41	33
NCA4	59	56	50	59	56	50	53	50	43	47	44	36
NCA5	64	62	52	64	63	51	58	56	44	52	50	37
NCA6	50	66	56	49	66	55	43	60	48	38	54	42
NCA7	45	59	64	45	58	64	39	52	58	34	47	51

Note: Levels exceeding the sleep disturbance criterion of $L_{A1,1min}$ 60 dBA (RBL Night + 15dB) are shown in red

Levels exceeding $L_{A1,1min}$ 75 dBA, are shown in bold. These are considered to indicate the greatest sleep disturbance risks.

5.8 Construction Traffic Noise

The majority of construction truck movements would be expected during standard works hours, with no more than two or three movements per hour expected during the night at either site at peak times.

By comparison with the existing vehicle volumes shown in **Table 4-4**, construction traffic would not be expected to increase traffic noise levels by more than 2 dB. An increase of no more than 2 dB is not considered significant and therefore specific construction traffic noise impacts are not anticipated.

6 CONSTRUCTION VIBRATION ASSESSMENT

6.1 Vibration Criteria

When assessing potential vibration impacts from construction activities there are two components that require consideration:

- human exposure to vibration; and
- the potential for building damage from vibration.

Construction work is generally considered an intermittent source of vibration.

6.1.1 Human Exposure to Vibration

Assessing Vibration: A Technical Guideline provides guidance for assessing human exposure to vibration. The publication is based on British Standard BS 6472:1992. Intermittent vibration is assessed by the Vibration Dose Value (VDV) which is based on the weighted root mean quartic (rmq) acceleration in each component.

Table 6-1 sets out VDV values as specified by *Assessing Vibration: A Technical Guideline*.

Table 6-1: Human Comfort Vibration Goals – VDV ($m/s^{1.75}$)

Place	Day (7am – 10pm)		Night (10pm – 7am)	
	Preferred	Maximum	Preferred	Maximum
Residences	0.20	0.4	0.13	0.26

6.1.2 Building Damage from Vibration

There are currently no Australian Standards or guidelines to provide guidance on assessing the potential for building damage from vibration. It is common practice to derive goal levels from international standards.

TfNSW typically refer to British Standard BS 7385-2:1993 *Evaluation and Measurement for Vibration in Buildings – Part 2: Guide to Damage Levels from Groundborne Vibration* (BS 7385-2) for residential and commercial buildings. **Table 6-2** summarises the goal levels specified in BS 7385-2:1993.

In addition to the tabulated values dependant on dominate frequency, BS 7385 states:

> *"Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity. This is not inconsistent with an extensive review of the case history information available in the UK".*

Table 6-2: Vibration Guide Values for Cosmetic Damage

Guideline Values for Velocity – mm/s		
Type of Building	**PCPV in frequency range of predominant pulse**	
	4 to 15 Hz	**15 Hz and above**
Reinforced or framed structures. Industrial and heavy commercial buildings.	50mm/s at 4 Hz and above	
Unreinforced or light framed structures. Residential or light commercial type buildings.	15mm/s at 4 Hz increasing to 20mm/s at 15 Hz	20mm/s at 15 Hz increasing to 50mm/s at 40 Hz and above

Note 1: Values referenced to are at the base of the building.
Note 2: The values refer to the peak component particle velocity (PCPV).
Note 3: At frequencies < 4 Hz, a maximum displacement of 0.6mm (zero to peak) should not be exceeded.

Because the dominant frequency of vibration cannot be determined with certainty at this stage and to allow measurement with equipment more readily available, a screening goal of 12.5mm/s is recommended (independent of frequency) for any nearby building.

It is noted that impacts from vibration will be governed by perception (human comfort) as discussed in the previous section.

6.2 Safe Working Distances

The Transport for NSW *Construction Noise and Vibration Guideline (CNVG)* provides guideline safe working distances for typical items of vibration intensive plant. These are reproduced in **Table 6-3**. The safe working distances are quoted for both "cosmetic" damage (refer BS 7385) and human comfort (refer DECCW's *Assessing Vibration – A Technical Guideline*).

It is noted that the nearest heritage buildings are located approximately 1.6km away from the works area. Therefore, vibration impact on heritage buildings have not been considered.

Table 6-3: Recommended Safe Working Distances for Vibration Intensive Plant

Plant Item	Rating / Description	Safe Working Distance	
		Cosmetic Damage (BS 7385)	**Human Response (DECCW Vibration Guideline)**
Vibratory Roller	< 50 kN (Typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4 tonnes)	6 m	20 m
	< 200 kN (Typically 4-6 tonnes)	12 m	40 m
	< 300 kN (Typically 7-13 tonnes)	15 m	100 m
	> 300 kN (Typically 13-18 tonnes)	20 m	100 m
	> 300 kN (> 18 tonnes)	25 m	100 m
Small Hydraulic Hammer	(300 kg - 5 to 12t excavator)	2 m	7 m
Medium Hydraulic Hammer	(900 kg – 12 to 18t excavator)	7 m	23 m

Plant Item	Rating / Description	Safe Working Distance	
		Cosmetic Damage (BS 7385)	Human Response (DECCW Vibration Guideline)
Large Hydraulic Hammer	(1600 kg – 18 to 34t excavator)	22 m	73 m
Vibratory Pile Driver	Sheet Piles	2-20 m	20 m
Pile Boring	800 mm	2 m (nominal)	4m
Jackhammer	Hand Held	1 m (nominal)	2m

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

Of all the equipment that would be used during the works, the excavator with hydraulic hammer attachment and vibratory rollers would be expected to generate the highest levels of vibration.

The CNVG notes that the identified safe working distances are indicative and will vary depending on the particular item of plant and local geotechnical conditions. They apply to cosmetic damage of typical buildings under typical geotechnical conditions.

In relation to human comfort (response), the safe working distances 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 may be considered tolerable.

6.3 Human Comfort

The closest receivers are located at approximately 12-20 m from the works areas. At these setback distances there is some risk of exceeding the human comfort criteria.

In practice, it is usually found that vibration impacts can be largely controlled by virtue of the progressing works, that is, the vibratory rollers and hammers would not remain in static locations for prolonged periods of time, but would typically move around the works areas, thereby limiting the vibration dose received by individual receivers.

However, given the risk of human comfort exceedance, it is recommended that pre-construction vibration trials are undertaken on site to confirm that the use of vibratory rollers and hydraulic hammers can comply with the maximum VDV levels set out in **Table 6-1** at the closest dwellings.

This testing should consider the recommendations of Assessing Vibration: A Technical Guideline, giving due consideration to the vibration dose method described by the guideline.

It is considered that the trial monitoring would likely confirm that compliance may be achieved by limiting either:

- the size of the roller/hydraulic hammer;
- the rollers vibratory settings;
- periods of continuous operation; or
- any combination of the above.

Should trials indicate that maximum level for human comfort cannot be practicably achieved, it would be recommended to negotiate an acceptable limit with the affected receivers or consider relocating the impacted receivers during the compacting and hammering works.

6.4 Building Damage

There would be limited risk of damage to buildings, even cosmetic, during the works as the predicted vibration levels are below the identified damage criteria adopted. Notwithstanding this, it is recommended to select plant to ensure that the recommended safe working distances for cosmetic damage, as set out in **Table 6-3** are maintained and trial measurements undertaken where the adopted criteria is approached.

7 MITIGATION

7.1 Operational Noise

This assessment has identified no specific requirements for the mitigation of operational noise effects.

7.2 Construction Noise

Given that exceedances of the Noise Management Levels (NMLs) are predicted, in accordance with the *ICNG*, all work practices should be employed in order to minimise the impacts. A number of noise mitigation measures are included herein that should be employed as feasible and reasonable. These are considered as standard mitigation measures and should be incorporated into the contractor's Construction Noise and Vibration Management Plan (CNVMP). The CNVMP should include a detailed management approach for the out of hours works.

7.2.1 Minimum Roadworks Programming Requirements

The following shall be applied when programming the works:

- *Very noisy activities should, as much as practicable, be programmed for normal working hours. If the work cannot be undertaken during the day, it should be completed before 12:00 am. In particular, there should be no jackhammering or saw cutting after midnight.*
- *If it is not practical to apply these minimum programming requirements, extra care will need to be taken in selecting and applying alternative and effective noise and vibration management measures.*
- *The CEMP must be regularly revised to account for changes in noise and vibration management strategies.*

7.2.2 Consultation and Procedural Requirements

Table 7-1 outlines a range of construction and maintenance noise and vibration management measures which should be generally applied throughout the works where reasonable and feasible. These should be included in the contractor's CNVMP. Note that control of noise at the source is generally the most effective strategy.

Table 7 1: Construction and Maintenance Noise and Vibration Management Options

Source Controls	
Time Constraints	Limit work to daylight hours, when possible. However, it is understood that most works will be required to be conducted at night.
Scheduling	Perform noisy work such as jack hammering or saw cutting during less sensitive time periods, before midnight.
Equipment Restrictions	Select low-noise plant and equipment. Ensure equipment has quality mufflers installed.
Substitute Methods	Where practicable use smaller/lower capacity plant in reference to the safe working distances identified in Table 6-3.
Limit Equipment on Site	Only have necessary equipment on site.
Limit Activity Duration	Where possible, concentrate noisy activities at one location and move to another as quickly as possible.

Source Controls	
Site Access	Vehicle movements outside construction hours, including loading and unloading operations, should be minimised and avoided where possible.
Equipment Maintenance	Ensure equipment is well maintained and fitted with adequately maintained silencers.
Reduced Equipment Power	Use only necessary size and power.
Quieter Work Practices	Implement worksite induction training, educating staff on noise sensitive issues and the need to make as little noise as possible.
Reversing Alarms	Consider alternatives, such as manually adjustable or ambient noise sensitive types ("smart" reversing alarms) and closed-circuit TV systems.
Path Controls	
Noise Barriers	Consider installing temporary construction noise barriers. Locate equipment to take advantage of the noise barriers provided by existing site features and structures, such as embankments and storage sheds.
Enclosures	Install noise-control kits for noisy mobile equipment and shrouds around stationary plant, as necessary.
Increased Distance	Locate noisy plant as far away from noise-sensitive receptors as possible.
Receptor Controls	
Temporary Relocation	In extreme cases (refer to Section 7.3)
Consultation	Community consultation, information, participation and complaint responses are essential aspects of all construction noise management programs. They typically involve: • A community information program before construction and/or high-risk activities are commenced. This usually involves a leaflet distribution and direct discussions and negotiations with affected residents, explaining the type, time and duration of expected noise emissions. • Residents must be notified at least five working days before works commence. • The involvement of affected residents in the development of acceptable noise management strategies. • A nominated community liaison officer with a contact telephone number. • A complaints hotline. • Timely responses to complaints, providing information on planned actions and progress towards the resolution of concerns.

Road construction or maintenance works should not commence until a Road Occupancy or Road Development Licence has been granted. The Road Occupancy/Development Licence application form should include an "Out-of-hours" contact name and telephone number for the work. This person should have the power to issue directions concerning the commencement, performance or termination of the work. The "Out-of-hours" contact person must be accessible during the course of work.

7.3 Additional Mitigation Measures

It is most likely that the impacts during the anticipated approved standard hours will be able to be managed effectively with standard mitigation measures and with the assistance of TfNSW Communication and Stakeholder Engagement.

However, despite the above, and due to the inherent nature of construction works, it is recognised that compliance with the NMLs during out of hours work, is often unachievable. "Out-of-hours work" (OOHW), is any work which takes place outside the standard construction work hours.

The *Construction Noise and Vibration Guideline (CNVG), August 2016*, prepared by Roads & Maritime Services provides guidance and outlines a number of additional mitigation measures, as listed in **Table 7-2**.

It should be noted that where a range of mitigation measures are recommended, the final measures that would be applied are determined on a case-by-case basis as they may not all be applicable to the affected receiver. This is true especially in this case, where constraints such as proximity to the roads, to the receivers and the requirement to work at night, will limit the type of mitigation measures that can be implemented. Again, assistance to deliver such measures can be provided by TfNSW Communication and Stakeholder Engagement.

The application of any mitigation measure depends on the level of noise above the NML (not the RBL) and the period of the day when construction is to take place, as listed in **Table 7-3**.

Once the final works scheduling has been confirmed, the successful contractor should confirm construction noise predictions and based on these determine the additional mitigation requirements for each NCA, in line with **Table 7-3**.

The following tables have been reproduced from Appendix C of *CNVG* for the relevant out of hours time periods applicable to this project.

Table 7-2: Additional Mitigation Measures

Measure	Abbreviation
Notification (letterbox drop or equivalent	N
Specific Notifications	SN
Phone Calls	PC
Individual Briefings	IB
Respite Offers	RO
Respite Period 1	R1
Respite Period 2	R2
Duration Respite	DR
Alternative Accommodation	AA
Verification	V

While the above measures are typically implemented in similar projects, the following measures cannot be implemented as they would not be considered feasible or reasonable, due to the nature of the works and the proposed construction hours:

- Alternative Accommodation (AA)
- Phone Calls (PC)
- Respite Period 1 (R1)
- Respite Period 2 (R2)

Table 7-3: Triggers for Additional Mitigation Measures – Airborne Noise

Time Period		Airborne Noise			
		$L_{Aeq,15min}$ Mitigation Levels above			
		NML	NML + 5	NML + 15	NML + 25
		Noticeable	Clearly Audible	Moderately Intrusive	Highly Intrusive
OOHW Period 1	Mon-Sat (6pm-10pm)	-	N, R1*, DR	V, N, R1*, DR	V, IB, PC*, SN, N, R1*, DR
	Sat (7am-8am & 1pm-10pm)				
	Sun / Pub Hol (8am-6pm)				
OOHW Period 2	Mon-Fri (10pm-7am)	N	V, N, R1*, DR	V, IB, PC*, SN, N, R2*, DR	AA*, V, IB, PC*, SN, N, R2*, DR
	Sat (10pm-8am)				
	Sun / Pub Hol (6pm-7am)				

Note: * For this proposal it is noted that alternate accommodation (AA), Phone Calls (PC), Respite Peropds 1 and 2 (R1, R2) are not considered feasible or reasonable to implement. This would be reviewed in response to receiving a complaint.

A worst-case construction noise scenario was modelled in order to identify receivers impacted by different levels of construction noise as per the above table. The Figure in Appendix B shows a map with noise contours in the context of construction activities conducted at night during the OOHW Period 2.

7.4 Construction Vibration

As discussed in **Sections 6-3** and **6-4**, given the risk of human comfort exceedance, it is recommended that pre-construction vibration trials are undertaken on site to confirm that the use of vibratory rollers and hydraulic hammers can comply with the maximum VDV levels set out in **Table 6-1** at the closest dwellings. This testing should consider the recommendations of *Assessing Vibration: A Technical Guideline*, giving due consideration to the vibration dose method described by the guideline.

It is recommended to select plant to ensure that the recommended safe working distances for cosmetic damage, as set out in **Table 6-3** are maintained.

The retaining walls on the south-western corner of the intersection, adjacent 687 Pennant Hills Rd, Carlingford and 400 North Rocks Rd, Carlingford will require to be demolished, along with other retaining walls along Pennant Hills Road.

These works will occur at approximately 10-15 metres from residential buildings. When the use of hammers is required within 20 m of any structure, it is recommended to undertake vibration monitoring during these activities to ensure that levels do not exceed criteria detailed in section 6.1.

8 CONCLUSION

RWDI has undertaken a construction and operational noise and vibration assessment for the proposed upgrades to Pennant Hills Road and North Rocks Road in Carlingford. The finding of this assessment are as follows:

8.1 Operational Noise

Under the relevant guidelines, there is no requirement for the provision of measures to mitigate operational noise associated with the proposal.

8.2 Construction Noise

The upgrade works would be constrained to within standard construction hours as far as practicable. Based on the preliminary indicative construction schedule, during standard hours some exceedances of the relevant Noise Management Levels are predicted, and some residences may be highly affected at times.

Where they are required, out-of-hours works have the greatest potential to generate noise impacts. Some significant exceedances of the out-of-hours criteria are indicated for the most exposed residential receivers.

In accordance with the ICNG, all feasible and reasonable work practices should be employed in order to limit the extent of any construction noise impacts. A number of noise mitigation measures have been outlined which should be adopted and included in the contractor's CNVMP.

It is recommended that details of noisy works should be provided to residents prior to commencement, including letterbox drops. If noise complaints are received, they should be immediately investigated and where appropriate, noise monitoring should be undertaken at the locations concerned to determine compliance with the determined construction noise criteria. Reasonable and feasible measures would then need to be implemented to reduce any noise impacts.

Once the final works scheduling has been confirmed, the successful contractor should confirm construction noise predictions - and based on these, determine the additional mitigation requirements for each NCA, in line with CNVG. Specifically, an out of hours noise and vibration impact assessment and management plan should be prepared and updated as necessary.

8.3 Construction Vibration

It is recommended that pre-construction vibration trials are undertaken on site to confirm that the use of vibratory rollers and hydraulic hammers can comply with the maximum VDV levels set out in **Table 6-1** at the closest dwellings. This testing should consider the recommendations of AVTG, giving due consideration to the vibration dose method described by the guideline.

It is recommended to select plant to ensure that the recommended safe working distances for cosmetic damage, as set out in **Table 6-3** are maintained.

Attended vibration monitoring is to be undertaken if vibration sensitive activities (vibratory rollers/hammering) are undertaken within 20m of any sensitive buildings.

9 REFERENCES

Roads and Maritime Services. 2015. RMS Procedure – *Preparing an Operational Traffic and Construction Noise and Vibration Assessment Report*

Department of Environment and Climate Change and Water. 2011. *NSW Road Noise Policy* (RNP)

Roads and Maritime Services. 2015. *Noise Criteria Guideline* (NCG)

Roads and Maritime Services. 2015. *Noise Mitigation Guideline* (NMG)

NSW Roads and Traffic Authority. 2001. *Environmental Noise Management Manual* (ENMM)

German Standard DIN 4150-3. 1999. DIN 4150 Part 3: *Structural Vibration in Buildings: Effects on Structures*

Department of Environment and Conservation. 2006. *Assessing Vibration: A Technical Guideline*

Department of Environment and Climate Change. 2009. *Interim Construction Noise Guideline* (ICNG)

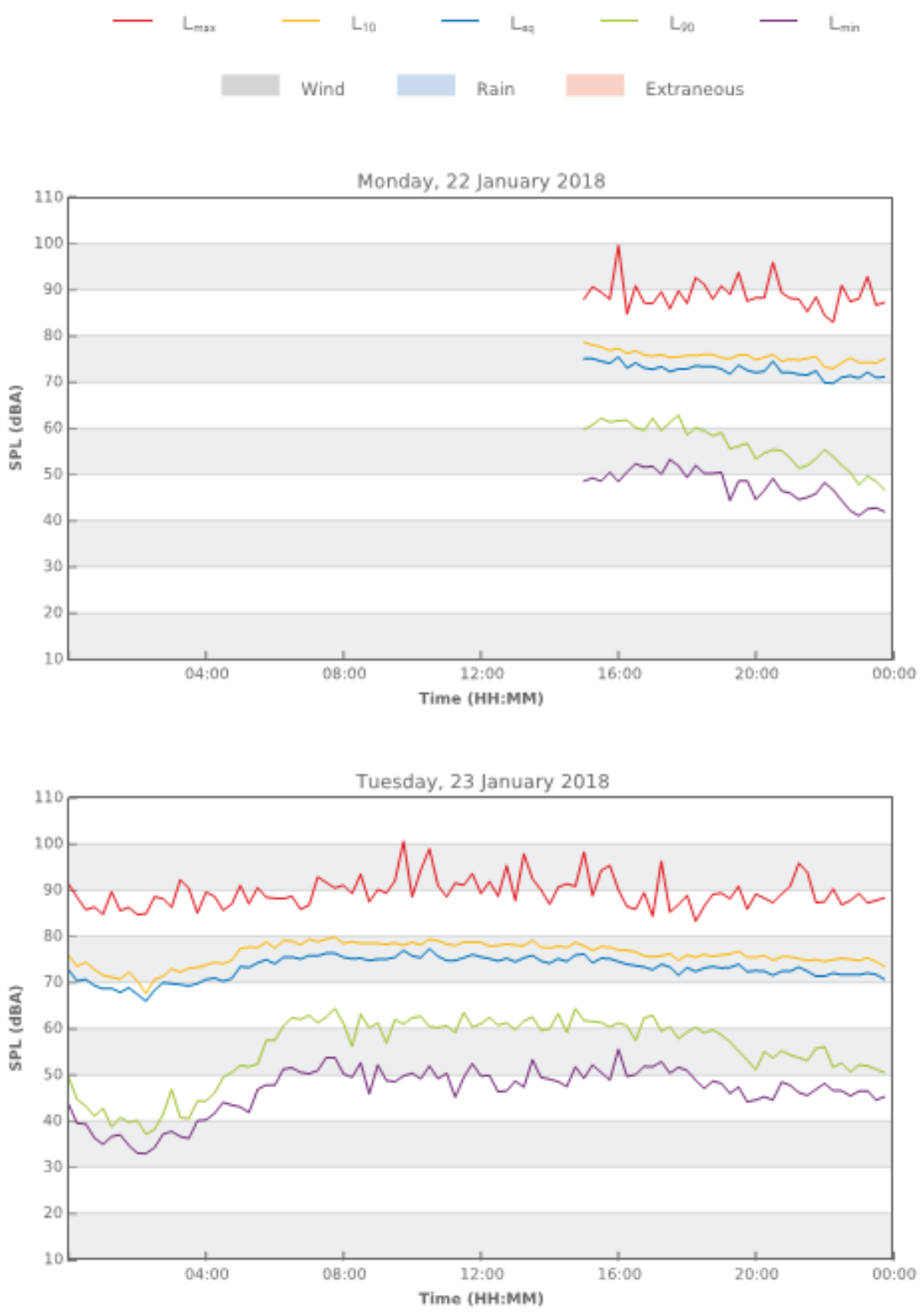
Department of Transport UK. 1988. *Calculation of Road Traffic Noise* (CoRTN)

Department of Planning NSW. 2008. *Development Near Rail Corridors and Busy Roads – Interim Guideline*

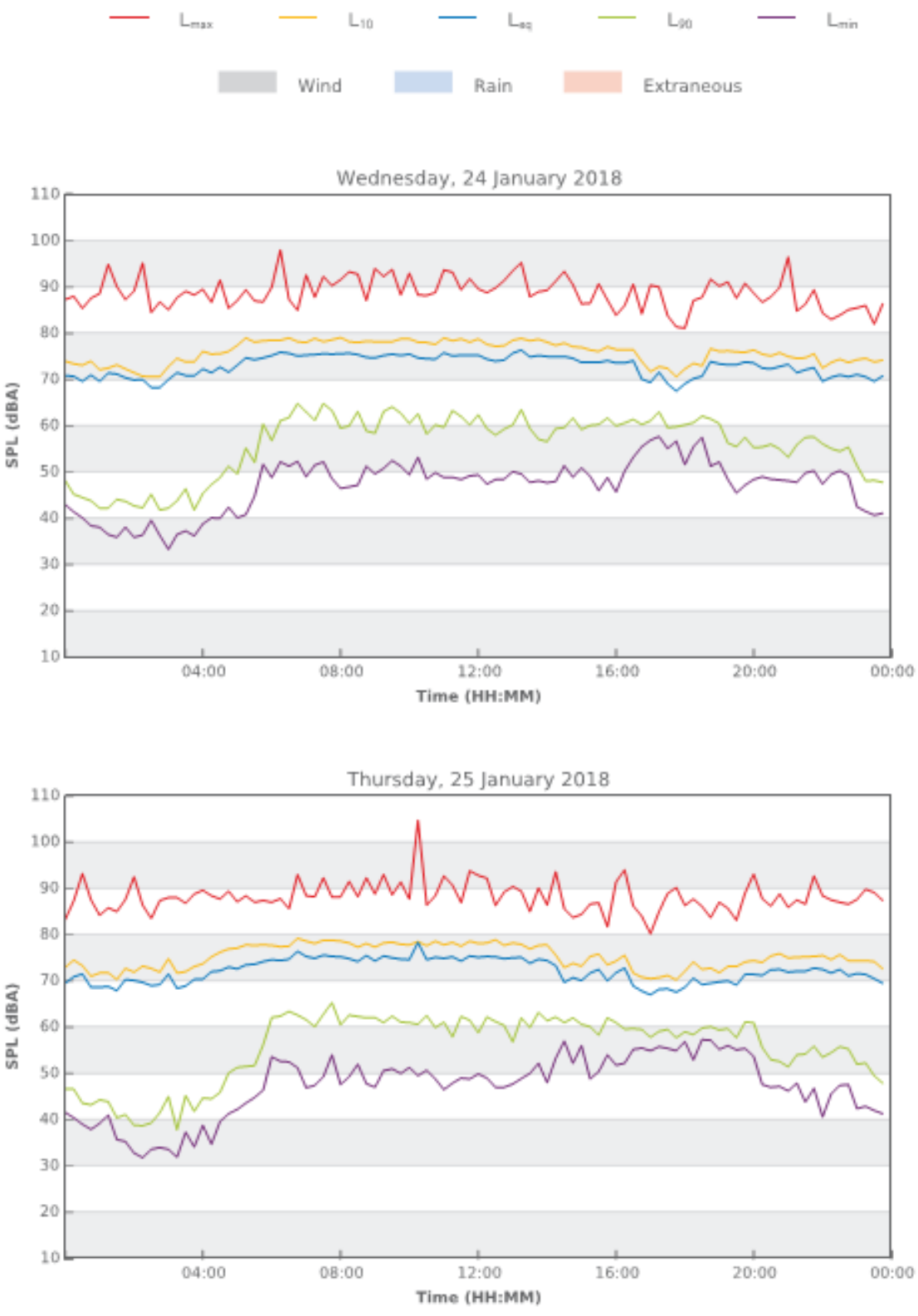
Samuels, S E and Saunders. 1982. The Australian Performance of the UK DoE Traffic Noise Prediction Method Proc 11th Australian Road Research Board Conference 11(6),30-44

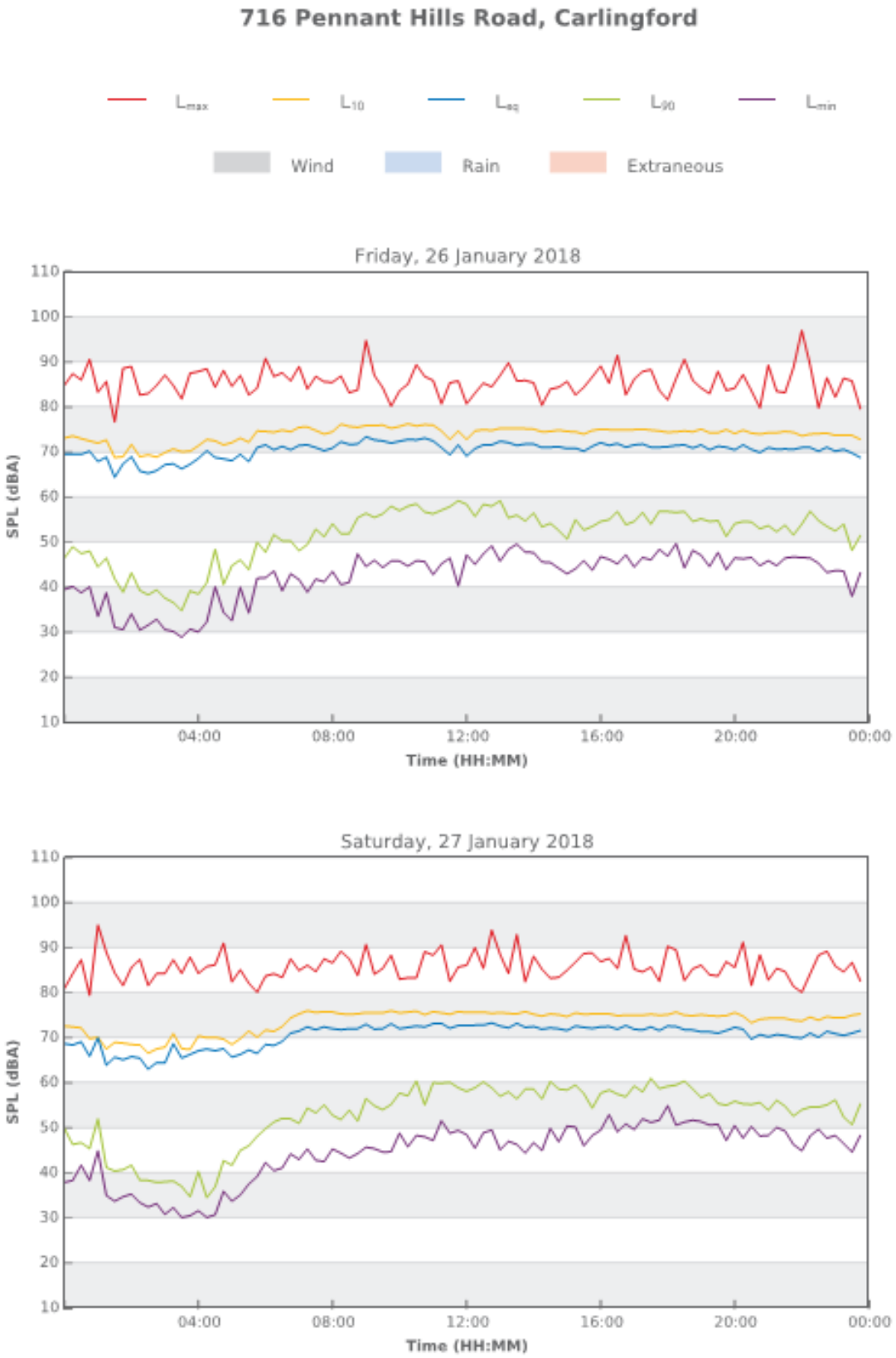
APPENDIX A: UNATTENDED MONITORING RESULTS

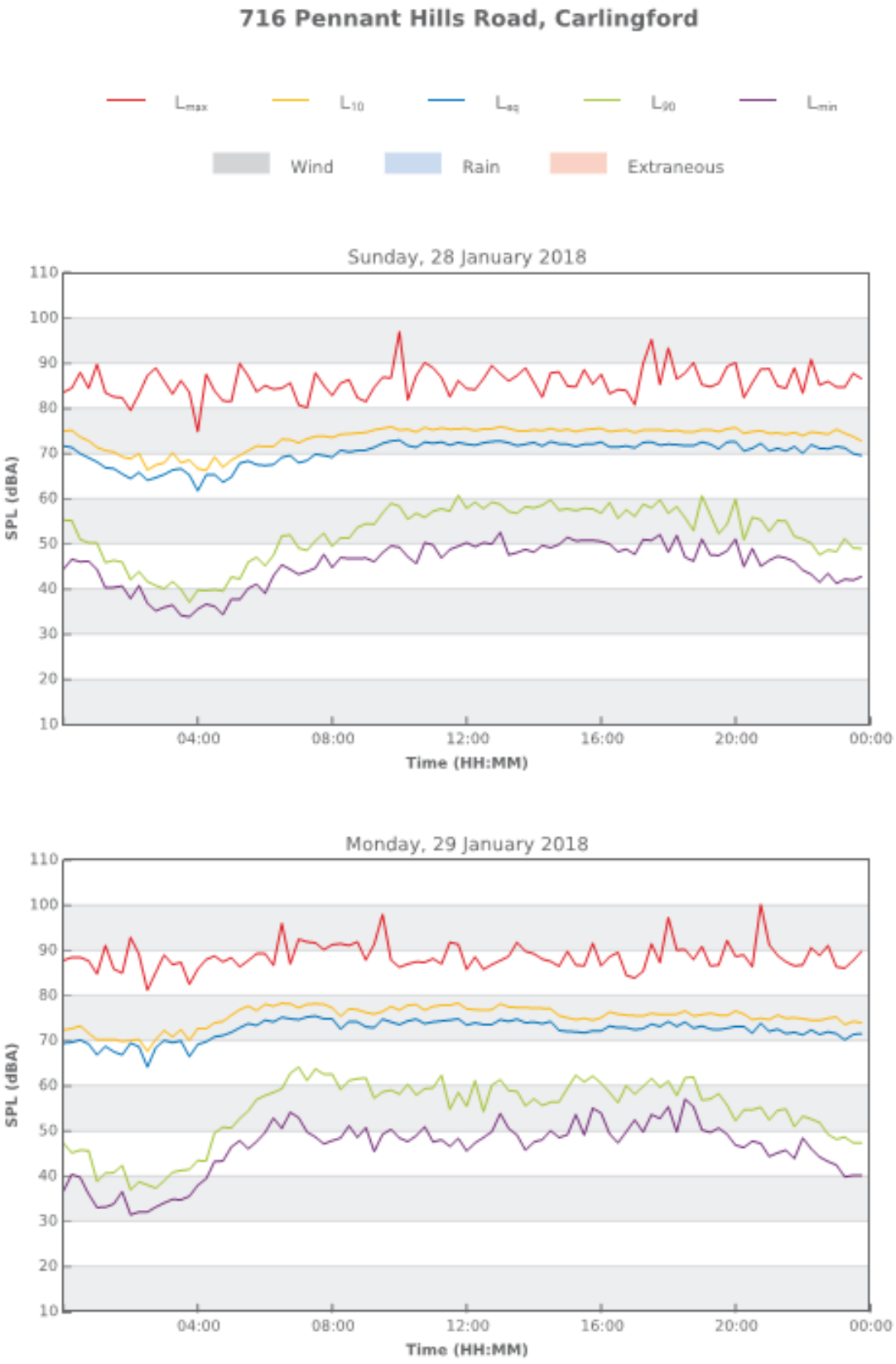
716 Pennant Hills Road, Carlingford

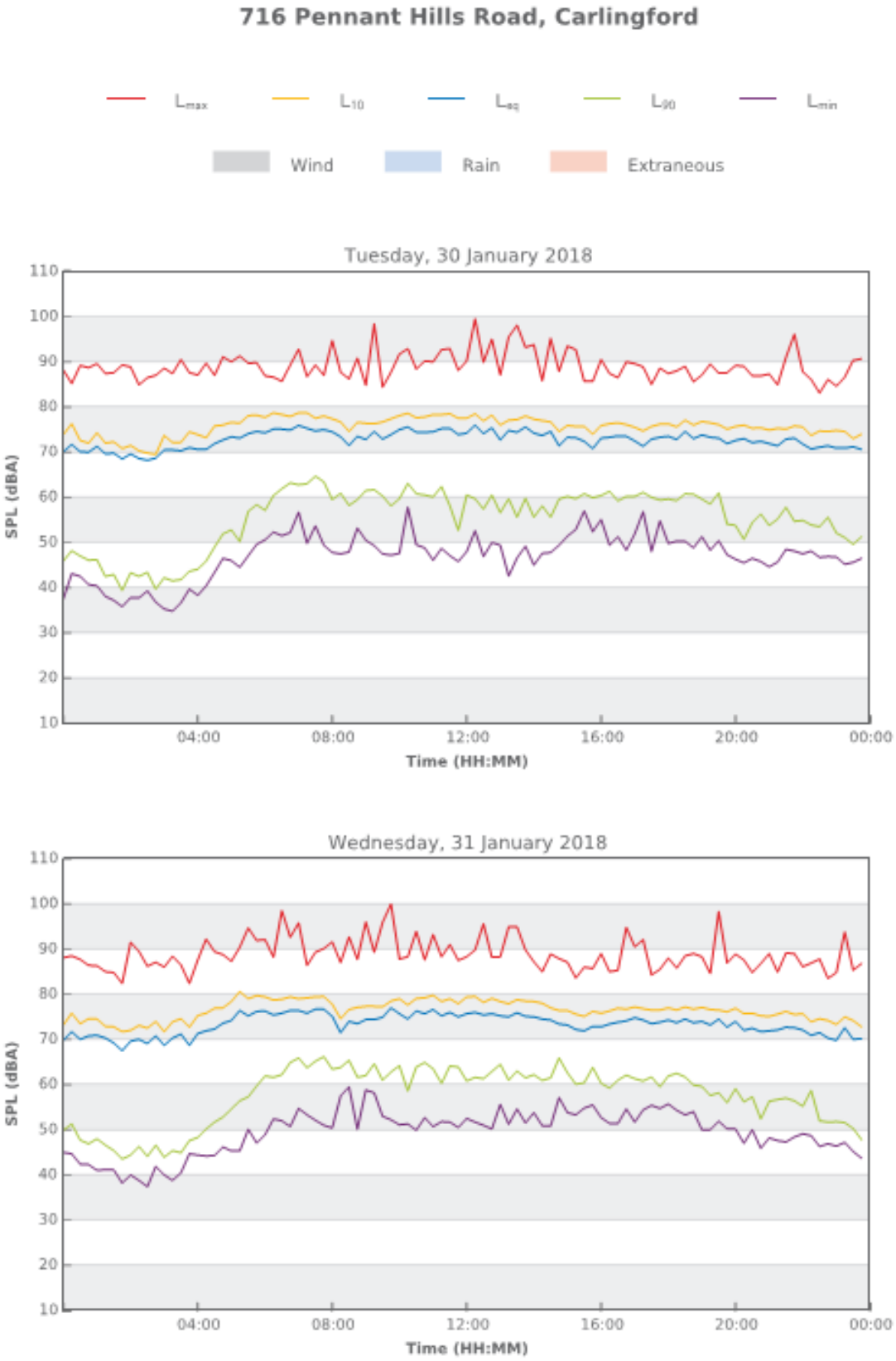


716 Pennant Hills Road, Carlingford




716 Pennant Hills Road, Carlingford
L_{max}
L_{10}
L_{eq}
L_{90}
L_{min}
Wind
Rain
Extraneous
Friday, 26 January 2018
SPL (dBA)
110
100
90
80
70
60
50
40
30
20
10
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)
Saturday, 27 January 2018
SPL (dBA)
110
100
90
80
70
60
50
40
30
20
10
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)


716 Pennant Hills Road, Carlingford
L_{max}
L_{10}
L_{eq}
L_{90}
L_{min}
Wind
Rain
Extraneous
Sunday, 28 January 2018
SPL (dBA)
110
100
90
80
70
60
50
40
30
20
10
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)
Monday, 29 January 2018
SPL (dBA)
110
100
90
80
70
60
50
40
30
20
10
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)


716 Pennant Hills Road, Carlingford
L_{max}
L_{10}
L_{eq}
L_{90}
L_{min}
Wind
Rain
Extraneous
Tuesday, 30 January 2018
SPL (dBA)
110
100
90
80
70
60
50
40
30
20
10
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)
Wednesday, 31 January 2018
SPL (dBA)
110
100
90
80
70
60
50
40
30
20
10
04:00
08:00
12:00
16:00
20:00
00:00
Time (HH:MM)

APPENDIX B: CONSTRUCTION NOISE CONTOURS FOR WORST-CASE SCENARIO

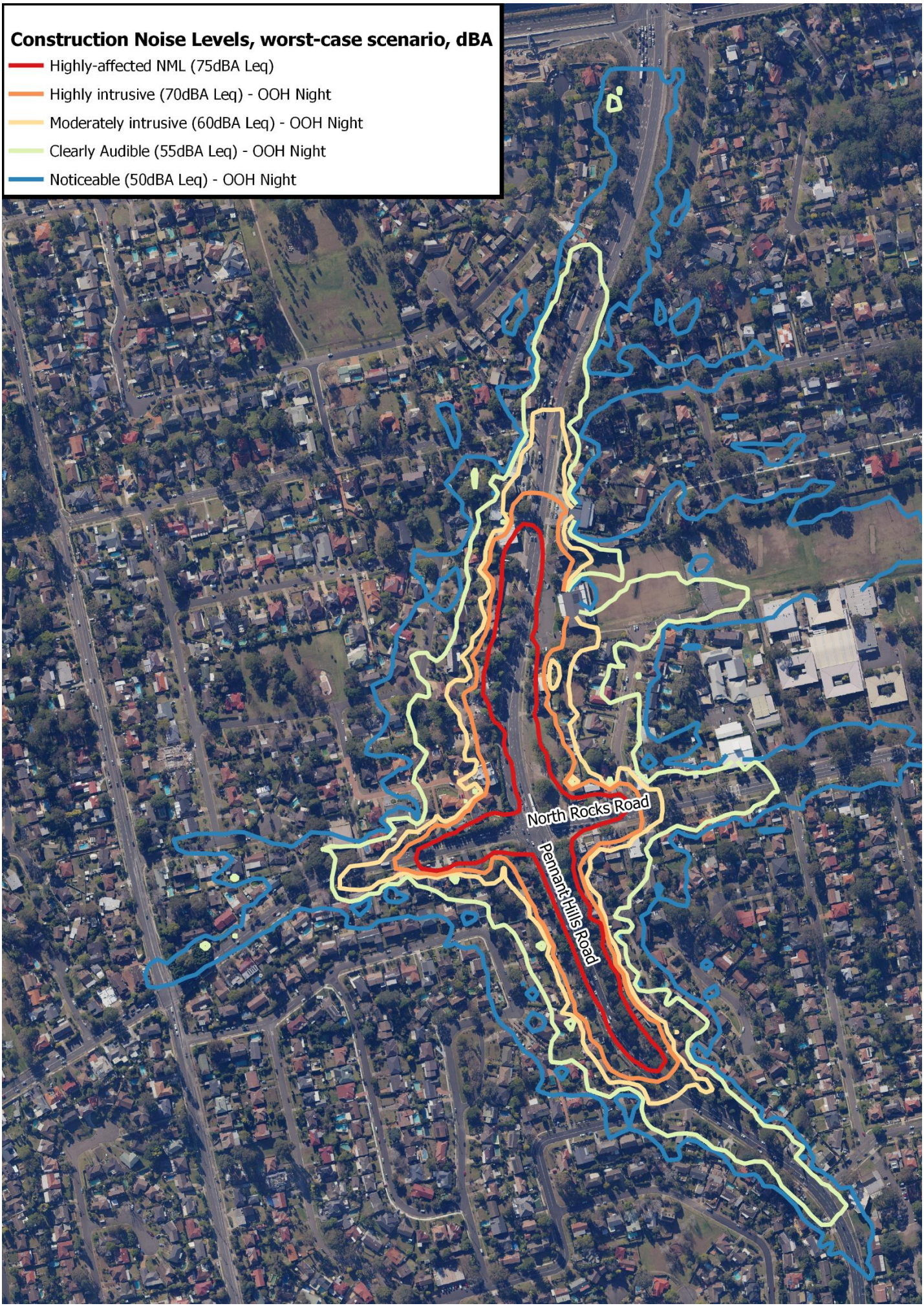


Figure B – Noise Contours for Worst-case construction scenario during OOH Period 2