Appendix J

Traffic Assessment – Traffic Diversion Routes

MEMO

To: Ana Perez; James Calderon	**Date:** 08/08/2018
CC: Ben Midgley	
From: Thomas Ng	**Pages:** 9
Subject: Marshall Avenue and Finlay Road – Right Turn Restrictions & Alternative Routes Assessment	**Reference:** P.0021728

1.0 Introduction

Marshall Avenue is a local road[1] (cul-de-sac) used only for local access to residential properties of Warrawee.

Finlay Road is a local road[1] providing local circulation and access to residential properties of Warrawee and Turramurra. It also provides a direct connection to Pacific Highway to the north, and indirect connections to Kissing Point Road to the east and Fox Valley Road to the west.

Pacific Highway is a state road[1] which forms a critical part of the Sydney road network. It links people and goods within the urban centers of Sydney, Newcastle, Central Coast, and Wollongong and throughout the State. It carries approximately 67,000[2] vehicles daily along the Warrawee section of road – about 32,000 northbound and 35,000 southbound.

Existing issues include delays caused by vehicles waiting to turn right from Marshall Avenue and Finlay Road onto Pacific Highway, and by vehicles waiting to turn right (filter) from Pacific Highway onto Finlay Road. Given the significant amount of traffic carrying on Pacific Highway, these turns are considered unsafe and have caused a total of five direct related accidents at the interactions of Marshall Avenue / Pacific Highway and Finlay Road / Pacific Highway, between July 2011 and June 2016.

The purpose of the study is to identify alternative routes and to assess the impact of implementing right turn restrictions at the following intersections:

- Marshall Avenue / Pacific Highway.
- Finlay Road / Pacific Highway.

With the proposed right turn restrictions, both Marshall Avenue and Finlay Road will have a ‘left in left out’ connection to Pacific Highway.

[1] Source: NSW road classification review – Sydney Inner Map.
[2] Source: Roads and Maritime Services Traffic Volume Viewer, 2018 data.

1.1 Site location

The intersections of Marshall Avenue / Pacific Highway and Finlay Road / Pacific Highway are located within the suburbs of Warrawee and Turramurra, as shown in **Figure 1**.

Source: SIX Maps

Figure 1: Site location

1.2 Modelling tool & background

The operational efficiency of the two intersections was assessed using the previously built VISSIM model along the Pacific Highway corridor, between Coonanbarra Road and Grandview Street. The 2017 VISSIM base model was developed and calibrated using the traffic and signal data collected through traffic surveys and SCATS inputs and was validated with site observations and the Roads and Maritime Q Travel Time Analysis data. Details of the model calibration and validation outcomes were discussed in the Base VISSIM Model Report[3].

[3] Pacific Highway Base VISSIM Model Validation Report - prepared by AECOM and issued in September 2017.

2.0 Right turn restriction

This section discusses the locations and reasons of the proposed right turn restriction.

2.1 Locations of restriction

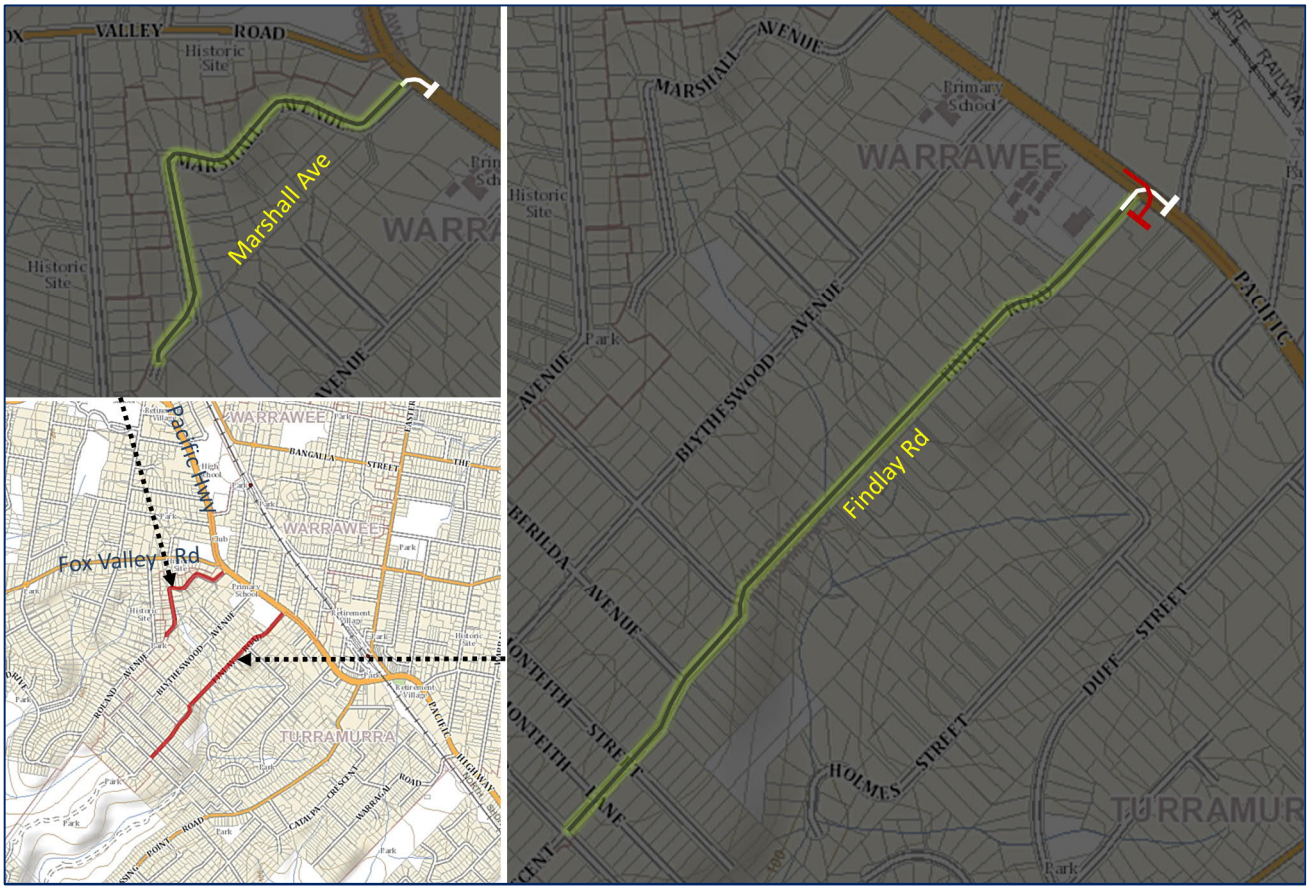
As shown in **Figure 2**, a total of three right turn restrictions are proposed at the following locations:

Marshall Avenue / Pacific Highway

- Banning the right turn from Marshall Avenue onto Pacific Highway.

Finlay Road / Pacific Highway

- Banning the right turn from Pacific Highway onto Finlay Road.
- Banning the right turn from Finlay Road onto Pacific Highway.



Source: SIX Maps

Figure 2: Locations of right turn restriction

2.2 Reasons for restriction

Safety

The purpose of the restrictions is primarily due to traffic safety. The provided crash reports, collected between July 2011 and June 2016, were analysed at the intersections of Marshall Avenue / Pacific Highway, Finlay Road / Pacific Highway and Fox Valley Road / Pacific Highway (given its proximity to Marshall Avenue). In total, there were 31 crashes reported in the study area, with the degree of crash classification presented in **Table 1**. Crash reports are presented in **Appendix A**.

Note that a total of five accidents were related to right-through collisions at Marshall Avenue and Finlay Road. Restricting right turns at these locations could potentially reduce accident rate while improving the safety of traffic operation at / adjacent to the study area.

Table 1: Degree of crash – July 2011 to June 2016

Degree of crash	Number of crashes	Percentage
Fatal	0	0.0 %
Serious injury	2	6.5 %
Moderate injury	4	12.9 %
Minor/other injury	7	22.6 %
Uncategorised injury	0	0.0 %
Non-casualty	18	58.0 %

Intersection Performance

Table 2 compares traffic performance with and without the proposed right turn restrictions at the intersections of Marshall Avenue / Pacific Highway and Finlay Road / Pacific Highway.

In summary, the proposed right turn restrictions would reduce traffic delays at both the Marshall Avenue and Finlay Road intersections, in particular in 2027 PM peak at the Finlay Road / Pacific Highway intersection. Note that the right turn volumes in and out of Marshall Avenue and Finlay Road are insignificant (maximum 68 veh/hr, from Pacific Highway onto Finlay Road). As such, the benefit of the right turn ban is limited. Individual movement delays of the intersection are presented in **Appendix B**.

The restricted right turns at Marshall Avenue and Finlay Road are predicted to redirect traffic onto Fox Valley Road. Analysis of alternative routes and the potential impacts will be discussed in Section 3 – Alternative routes.

Table 2 Intersection performance – with and without right turn restrictions

Intersection Performance (Average Delays in sec)		2017				2027			
		No RT Ban [1]		With RT Ban [2]		No RT Ban [1]		With RT Ban [2]	
		Delays	LoS	Delays	LoS	Delays	LoS	Delays	LoS
AM Peak 6.30-7.30	Marshall Ave / Pacific Hwy	1.7	A	1.6	A	2.3	A	2.2	A
	Finlay Rd / Pacific Hwy	0.9	A	0.6	A	16.5	B	15.8	B
PM Peak 5.15-6.15	Marshall Ave / Pacific Hwy	1.2	A	1.2	A	1.2	A	1.2	A
	Finlay Rd / Pacific Hwy	0.4	A	0.3	A	14.8	B	11.6	A

[1] Proposed upgrade on Pacific Highway, with right turn permitted in and out of Marshall Avenue and Finlay Road.
[2] Proposed upgrade on Pacific Highway, with right turn prohibited in and out of Marshall Avenue and Finlay Road (ie LILO design).

3.0 Alternative routes

By investigating the road function, service area and connection to the adjacent road network, local origins and destinations are determined as the areas south of the study intersections (**Figure 3**),

Marshall Avenue is a cul-de-sac, the only access to local properties is through Pacific Highway. Restricting the right turn out of Marshall Avenue would likely result in the alternative route as marked in **Figure 3**, which involves vehicles exiting left onto Pacific Highway and making a further left turn to perform a U-turn at the roundabout along Fox Valley Road.

With the “no through roads” on Monteith Street and Rothwell Road, restricting the right turn out of Finlay Road would likely direct the affected traffic onto Fox Valley Road, a shorter alternative route compared to another alternative route onto Kissing Point Road. Both Fox Valley Road and Kissing Point Road are right turn permitted onto Pacific Highway.

With the right turn ban from Pacific Highway onto Finlay Road, the affected traffic is expected to perform right turn from Pacific Highway onto Fox Valley Road, and then left turn onto Roland Avenue to reach the local destinations.

Based on the above, it is understood that the turn restrictions at Marshall Avenue and Finlay Road would redirect additional traffic through the Fox Valley Road / Pacific Highway intersection. This impact has been assessed in the VISSIM model, with results presented in **Table 3**.

In summary, the additional trips at Fox Valley Road / Pacific Highway would slightly increase the intersection delays, by approximately three seconds in the AM peak (both in 2017 and 2027) and about two seconds in the PM peak (both in 2017 and 2027). This intersection is estimated to operate at a similar level of service after the implementation of right turn restrictions at Marshall Avenue and Finlay Road, for all peaks in 2017 and 2027.

Individual delays of the intersection are presented in **Appendix B**.

Source: SIX Maps

Figure 3: Alternative routes to and from the local origins / destinations

Table 3 Impact of additional trips at Fox Valley Road / Pacific Highway

Intersection Performance (Average Delays in sec)		2017				2027			
		No RT Ban [1]		With RT Ban [2]		No RT Ban [1]		With RT Ban [2]	
		Delays	LoS	Delays	LoS	Delays	LoS	Delays	LoS
AM Peak 6.30-7.30	Fox Valley Rd / Pacific Hwy	39.4	C	42.2	C	47.4	D	50.0	D
PM Peak 5.15-6.15	Fox Valley Rd / Pacific Hwy	24.1	B	25.9	B	21.7	B	23.5	B

[1] Proposed upgrade on Pacific Highway, with right turn permitted in and out of Marshall Avenue and Finlay Road.
[2] Proposed upgrade on Pacific Highway, with right turn prohibited in and out of Marshall Avenue and Finlay Road (ie LILO design).

4.0 Comparison of alternative routes by time and distance

To enable a quantitative comparison between the existing and alternative routes, an analysis was carried out to determine the time and distance taken to traverse each route using Google Maps, an online mapping service. The estimated travel time from Google is based on a variety of factors, ranging from posted speed limit, speed derived from road types and historical average speed. The travel time estimation also considers traffic conditions and delays at intersections. As the estimated travel time and distance are approximate, time has been given to within a minute's accuracy, and distance is given to within an accuracy of 50 meters.

The identified AM and PM peak hours, derived from traffic surveys undertaken in 2017, are between 6:30 – 7.30 am and 17:15 – 18:15 pm. These periods were adopted for the comparisons.

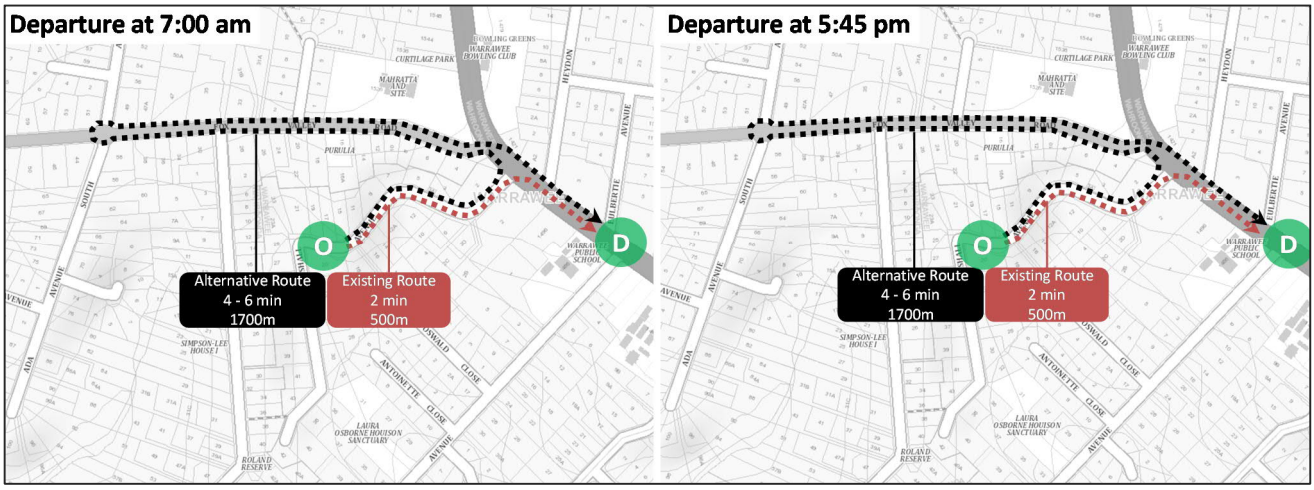
The existing and alternative routes were compared in terms of vehicle travel time and distance along the study routes. These points were defined as O (origin) and D (destination).

Figure 4 to **Figure 6** show the estimated travel times and distances between the existing and alternative routes. For a like-for-like comparison, both routes were set to depart at 7:00 am and 17:45 pm on a typical Thursday.

In summary, the restricted right turn out of Marshall Avenue (**Figure 4**) is estimated to increase vehicle travel time and distance by approximately 2 to 4 minutes and 1,200 meters, in both the AM and PM peak periods.

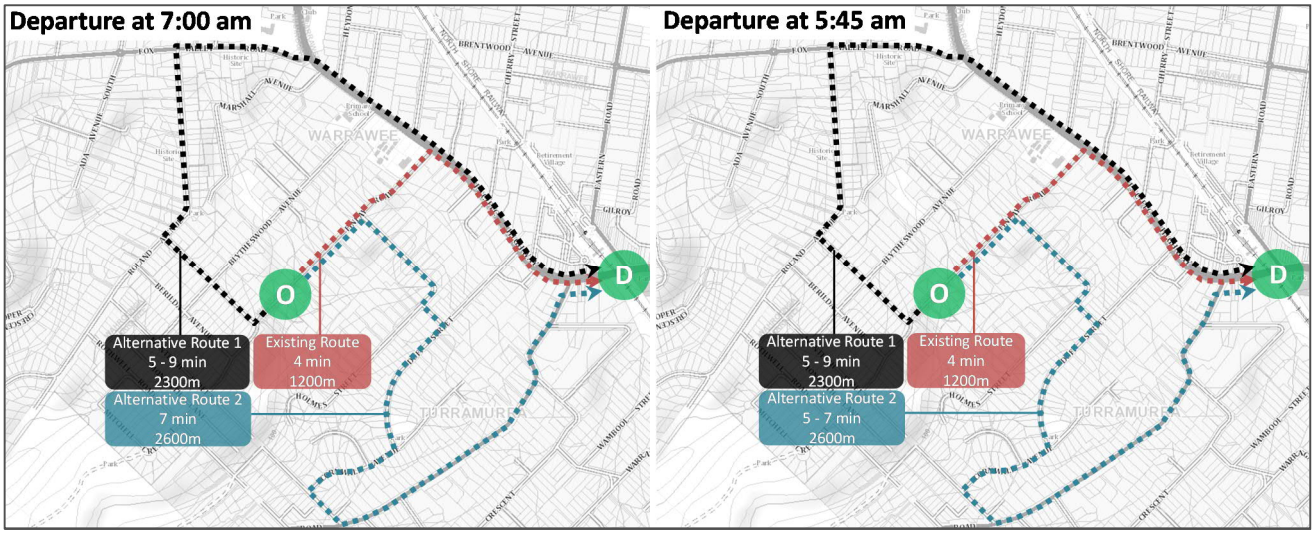
The restricted right turn out of Finlay Road (**Figure 5**) is anticipated to increase vehicle travel time and distance by approximately 1 to 5 minutes and 1,100 meters in both peaks if the Fox Valley Road route (alternative route 1) is selected. If the Kissing Point Road route (alternative route 2) is chosen, the estimated increase of travel time and distance would possibly be 3 minutes and 1,400 meters in the AM peak and 1 to 3 minutes and 1,400 meters in the PM peak.

The restricted right turn into Finlay Road (**Figure 6**) would result in a similar vehicle travel time in the AM peak and approximately 1 minute increase in travel time in the PM peak. The travel distance is expected to increase by 300m.



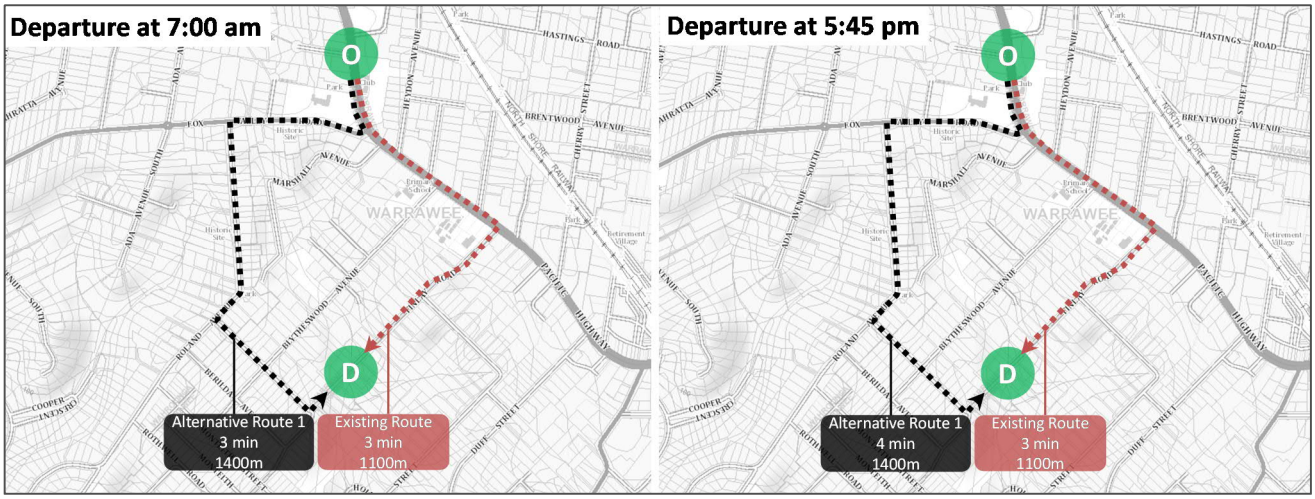
Source: image from SIX Maps, time and distance estimations from Google Maps

Figure 4: Right turn restricted out of Marshall Avenue – Time and distance comparison



Source: image from SIX Maps, time and distance estimations from Google Maps

Figure 5: Right turn restricted out of Finlay Road – Time and distance comparison



Source: image from SIX Maps, time and distance estimations from Google Maps

Figure 6: Right turn restricted into Finlay Road – Time and distance comparison

5.0 Conclusion

This technical memo investigated potential impacts of implementing right turn restrictions at the following intersections (**Figure 2**):

Marshall Avenue / Pacific Highway

- Banning the right turn from Marshall Avenue onto Pacific Highway.

Finlay Road / Pacific Highway

- Banning the right turn from Pacific Highway onto Finlay Road.
- Banning the right turn from Finlay Road onto Pacific Highway.

The primary reason for turn restrictions is due to traffic safety. The provided crash reports (**Appendix A**), collected between July 2011 and June 2016 indicates that there were 31 crashes reported at the intersections of Marshall Avenue / Pacific Highway, Finlay Road / Pacific Highway and Fox Valley Road / Pacific Highway (assessed given its proximity to Marshall Avenue). It is noted that a total of five accidents were related to right-through collisions at Marshall Avenue and Finlay Road intersecting with Pacific Highway. Therefore, the proposed turn restrictions at these locations could potentially reduce accident rate while improving the safety of traffic operation at / adjacent to the study area.

Traffic assessment indicates that the proposed turn restrictions would reduce traffic delays at both the Marshall Avenue and Finlay Road intersections, in particular in 2027 PM peak at the Finlay Road / Pacific Highway intersection (**Table 2**).

The assessment also shows that the restricted right turns at Marshall Avenue and Finlay Road are likely to redirect additional traffic through the Fox Valley Road / Pacific Highway intersection. Analysis of the alternative routes is discussed in Section 3, with **Figure 3** presenting the possible alternative routes.

The impact of the additional trips at Fox Valley Road / Pacific Highway has been assessed in VISSIM, with results presented in **Table 3**. In summary, this intersection is estimated to operate at a similar level of service after the implementation of right turn restrictions at Marshall Avenue and Finlay Road, for all assessed scenarios in 2017 and 2027.

To enable a quantitative comparison between the existing and alternative routes, an analysis was carried out to determine the time and distance taken to traverse each route using Google Maps. In summary:

- The restricted right turn out of Marshall Avenue (**Figure 4**) is estimated to increase vehicle travel time and distance by approximately 2 to 4 minutes and 1,200 meters, in both the AM and PM peaks.
- The restricted right turn out of Finlay Road (**Figure 5**) is anticipated to increase vehicle travel time and distance by approximately 1 to 5 minutes and 1,100 meters in both peaks if the Fox Valley Road route (alternative route 1) is selected. If the Kissing Point Road route (alternative route 2) is picked, the estimated increase of vehicle travel time and distance would be 3 minutes and 1,400 meters in the AM peak and about 1 to 3 minutes and 1,400 meters in the PM peak.
- The restricted right turn into Finlay Road (**Figure 6**) would result in a similar vehicle travel time in the AM peak and approximately 1 minute increase in travel time in the PM peak. The travel distance is expected to increase by 300m.

It is concluded that the right turn restrictions at Marshall Avenue and Finlay Road would result in a safer traffic operation at and adjacent to the study intersections. The impacts of traffic rerouting are considered minimum.

Appendix A – Crash reports

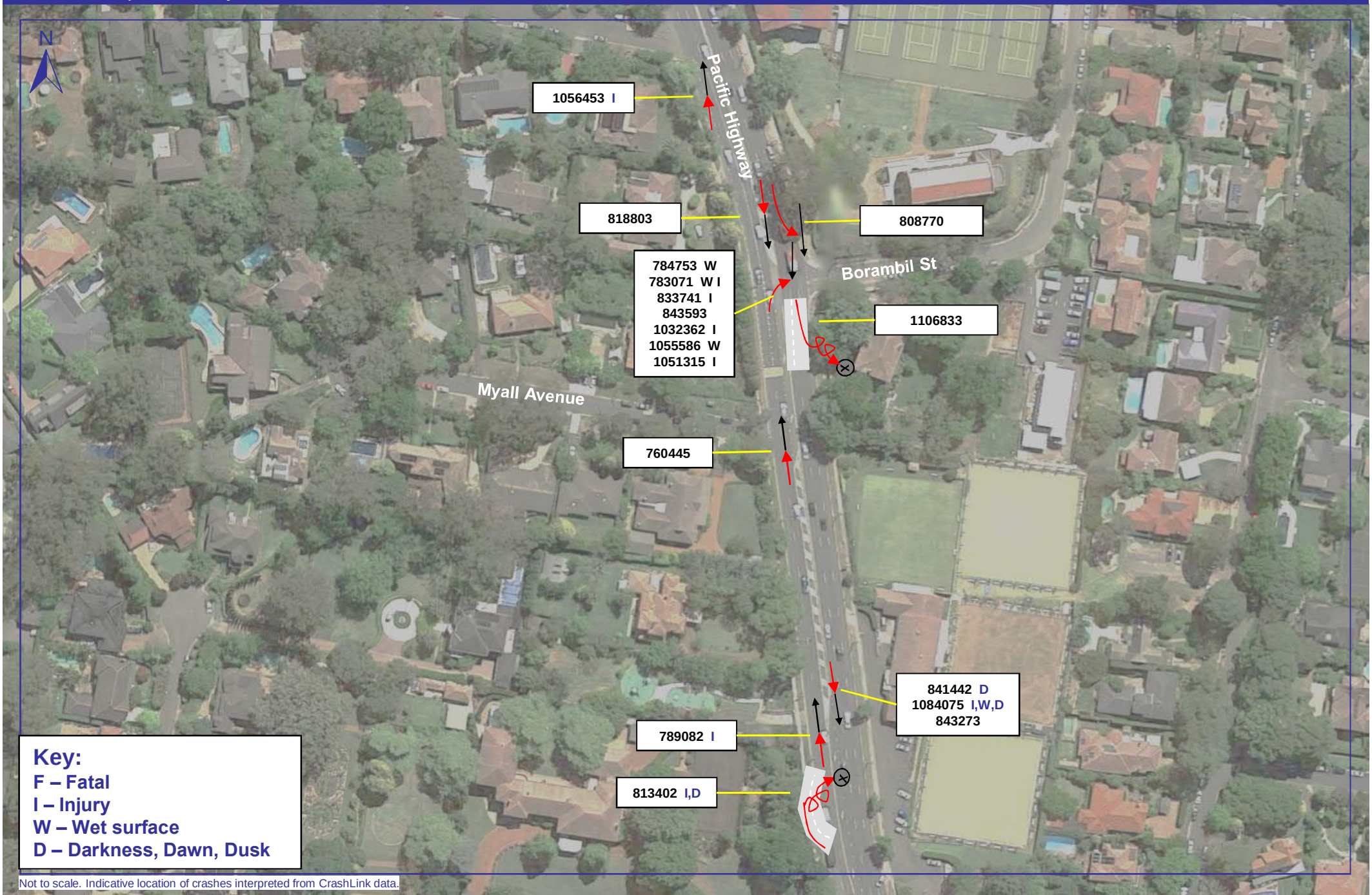
Pacific Hwy / Fox Valley Rd Intersection, Wahroonga - Warrawee

100 m North of Borambil St and 60m North of Fox Valley Rd, Wahroonga - Warrawee

Transport Roads & Maritime Services

NSW GOVERNMENT

Crashes reported 1 July 2011 to 30 June 2016



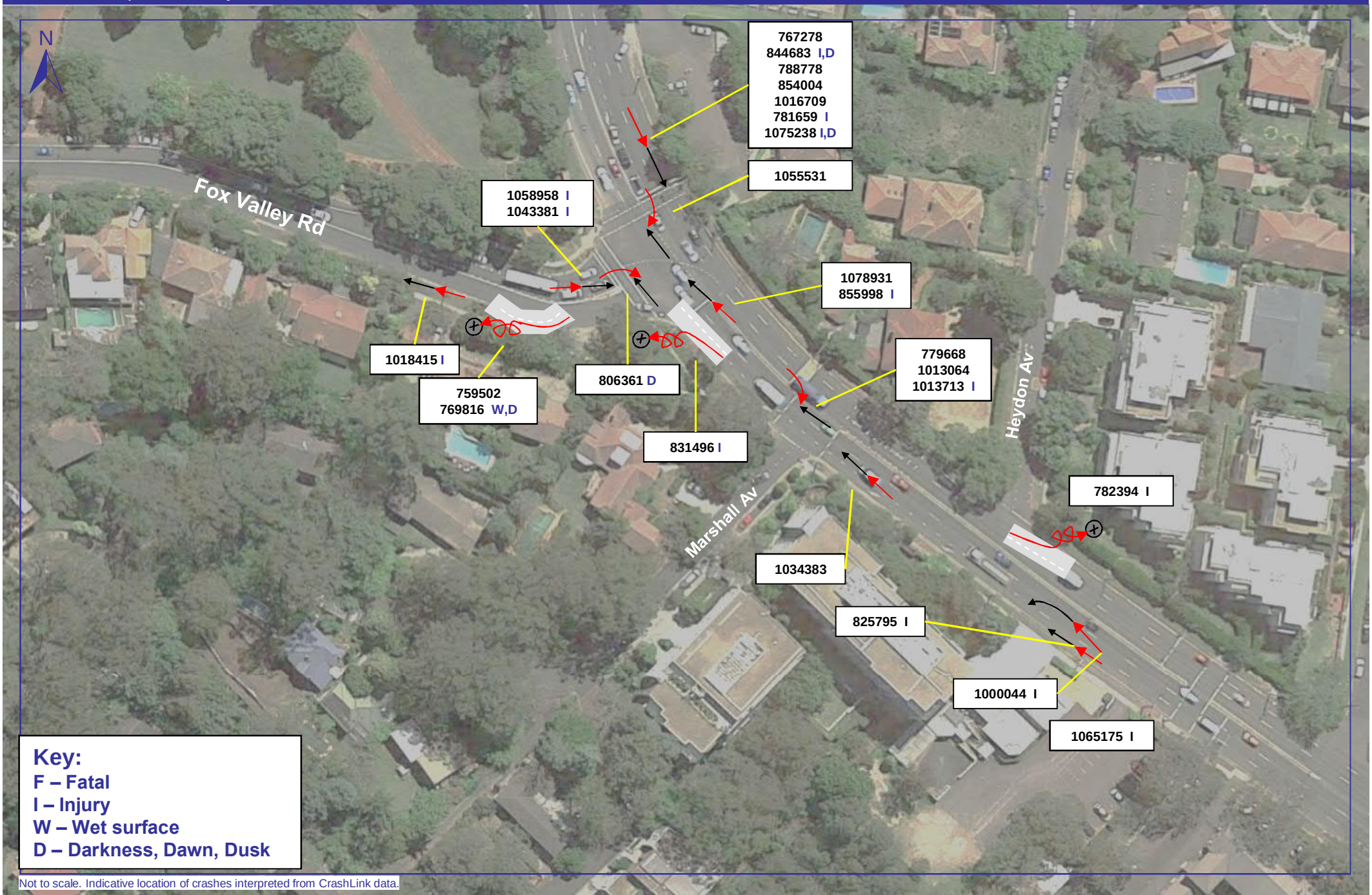
Not to scale. Indicative location of crashes interpreted from CrashLink data.

Pacific Hwy / Fox Valley Rd Intersection, Wahroonga - Warrawee

Between 100 m West of Fox Valley Rd, 60 m North of Fox Valley Rd and 150m South of Fox Valley Rd, Wahroonga - Warrawee

Crashes reported 1 July 2011 to 30 June 2016

NSW GOVERNMENT Transport Roads & Maritime Services



Not to scale. Indicative location of crashes interpreted from CrashLink data.

Summary Crash Report

Transport for NSW — Centre for Road Safety

# Crash Type		
Car Crash	42	100.0%
Light Truck Crash	4	9.5%
Rigid Truck Crash	1	2.4%
Articulated Truck Crash	0	0.0%
'Heavy Truck Crash	*(1)*	*(2.4%)*
Bus Crash	0	0.0%
"Heavy Vehicle Crash	*(1)*	*(2.4%)*
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	3	7.1%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	24	57.1%
Non intersection	18	42.9%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	5	11.9%
Multi Vehicle	37	88.1%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	39	92.9%
Other Classified Road	0	0.0%
Unclassified Road	3	7.1%

Contributing Factors		
Speeding	3	7.1%
Fatigue	4	9.5%

Weather		
Fine	33	78.6%
Rain	5	11.9%
Overcast	4	9.5%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	5	11.9%
Dry	37	88.1%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	2	4.8%
Daylight	33	78.6%
Dusk	2	4.8%
Darkness	5	11.9%

Crash Movement		
Intersection, adjacent approaches	1	2.4%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	11	26.2%
U-turn	0	0.0%
Rear-end	22	52.4%
Lane change	1	2.4%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	3	7.1%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	3	7.1%
Out of control on curve	0	0.0%
Other crash type	1	2.4%

Speed Limit				
40 km/h or less	2	4.8%	80 km/h zone	0	0.0%
50 km/h zone	1	2.4%	90 km/h zone	0	0.0%
60 km/h zone	38	90.5%	100 km/h zone	1	2.4%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less	2	22.2%	~ School Travel Time Involvement	9	21.4%

Day of the Week												
Monday	5	11.9%	Wednesday	5	11.9%	Friday	8	19.0%	Sunday	6	14.3%	WEEKEND	8	19.0%
Tuesday	9	21.4%	Thursday	7	16.7%	Saturday	2	4.8%	WEEKDAY	34	81.0%			

#Holiday Periods																
New Year	0	0.0%	Easter	1	2.4%	Queen's BD	0	0.0%	Christmas	1	2.4%	Easter SH	0	0.0%	Sept./Oct. SH	2	4.8%
Aust. Day	0	0.0%	Anzac Day	0	0.0%	Labour Day	1	2.4%	January SH	6	14.3%	June/July SH	5	11.9%	December SH	1	2.4%

CRASHES	42	
Fatal	0	0.0%
Serious inj.	2	4.8%
Moderate inj.	7	16.7%
Minor/Other inj.	13	31.0%
Uncategorised inj.	0	0.0%
Non-casualty	20	47.6%

CASUALTIES	26	
Killed	0	0.0%
Seriously inj.	2	7.7%
Moderately inj.	9	34.6%
Minor/Other inj.	15	57.7%
Uncategorised inj.	0	0.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Self Reported Crash	7	16.67%

Time Group		% of Day	
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	1	2.4%	8.3%
05:00 - 05:59	1	2.4%	4.2%
06:00 - 06:59	4	9.5%	4.2%
07:00 - 07:59	2	4.8%	4.2%
08:00 - 08:59	1	2.4%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	1	2.4%	4.2%
11:00 - 11:59	3	7.1%	4.2%
12:00 - 12:59	3	7.1%	4.2%
13:00 - 13:59	6	14.3%	4.2%
14:00 - 14:59	2	4.8%	4.2%
15:00 - 15:59	2	4.8%	4.2%
16:00 - 16:59	6	14.3%	4.2%
17:00 - 17:59	4	9.5%	4.2%
18:00 - 18:59	3	7.1%	4.2%
19:00 - 19:59	1	2.4%	4.2%
20:00 - 21:59	1	2.4%	8.3%
22:00 - 24:00	1	2.4%	8.3%

Street Lighting Off/Nil		% of Dark
0	of 5	in Dark 0.0%

Crashes		Casualties
1	2016	0
8	2015	7
8	2014	4
10	2013	8
10	2012	7
5	2011	0

McLean Periods		% Week	
A	9	21.4%	17.9%
B	0	0.0%	7.1%
C	9	21.4%	17.9%
D	1	2.4%	3.5%
E	5	11.9%	3.6%
F	6	14.3%	10.7%
G	9	21.4%	7.1%
H	2	4.8%	7.1%
I	1	2.4%	12.5%
J	0	0.0%	10.7%

Crashid dataset Reported crashes on Pacific Hwy btwn 100m north of Borambil St & 150m south of Fox Valley Rd (+50m on Fox Valley Rd leg) - 1 Jul 11 to 30 Jun 16

Note: *Data for the 9 month period prior to the generated date of this report are incomplete and are subject to change.*
Crash self reporting, including self reported injuries began Oct 2014. Trends from 2014 are expected to vary from previous yrs. More unknowns are expected in self reported data.
Reporting yrs 1996-2004 and 2016 onwards contain uncategorised inj crashes.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Detailed Crash Report

NOTES: Reported crashes on Pacific Hwy btwn 100m north of Borambil St & 150m south of Fox Valley Rd (+50m on Fox Valley Rd leg) - 1 Jul 11 to 30 Jun 16

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash-Detailed	Killed	Seriously Inj.	Moderately Inj.	Minor/Other Inj.	Uncateg'd Inj.	Factors
																									S F
Sydney Region																									
Ku-Ring-Gai LGA																									
Turramurra																									
Pacific Hwy																									
855998	P	11/10/2013	Fri	18:00		at	FOX VALLEY RD	TJN	CRV	Fine	Dry	60	2	CAR	F45	N in PACIFIC HWY	Unk	Proceeding in lane	MC	0	0	2	0	0	
E52540952								RUM	30	Rear end				CAR	F18	N in PACIFIC HWY	Unk	Proceeding in lane							
Wahroonga																									
Fox Valley Rd																									
1058958	S	13/02/2015	Fri	16:30	5 m	W	PACIFIC HWY	TJN	CRV	Fine	Dry	60	2	CAR	M75	E in FOX VALLEY RD	Unk	Proceeding in lane	OC	0	0	0	1	0	
E866976790								RUM	30	Rear end				CAR	F57	E in FOX VALLEY RD	Unk	Proceeding in lane							
1043381	P	12/09/2014	Fri	14:35	10 m	W	PACIFIC HWY	TJN	CRV	Fine	Dry	40	3	CAR	F72	E in FOX VALLEY RD	Unk	Proceeding in lane	OC	0	0	0	1	0	
E55896248								RUM	30	Rear end				4WD	F37	E in FOX VALLEY RD	0	Stationary							
														4WD	M29	E in FOX VALLEY RD	0	Stationary							
759502	P	12/07/2011	Tue	03:05	25 m	W	PACIFIC HWY	2WY	CRV	Fine	Dry	60	1	CAR	M21	W in FOX VALLEY RD	Unk	Proceeding in lane	NC	0	0	0	0	0	S F
E45811578								RUM	81	Off left/rt bnd=>obj				Signpost											
769816	P	28/09/2011	Wed	20:15	30 m	W	PACIFIC HWY	2WY	CRV	Raining	Wet	60	1	4WD	F37	W in FOX VALLEY RD	Unk	Proceeding in lane	NC	0	0	0	0	0	S
E45485124								RUM	81	Off left/rt bnd=>obj				Fence (prior to 2014)											
1018415	P	09/04/2014	Wed	16:18	50 m	W	PACIFIC HWY	2WY	STR	Fine	Dry	50	2	M/C	M21	W in FOX VALLEY RD	50	Proceeding in lane	MC	0	0	1	0	0	
E54236022								RUM	30	Rear end				CAR	M56	W in FOX VALLEY RD	20	Proceeding in lane							
Pacific Hwy																									
784753	P	17/02/2012	Fri	17:15		at	BORAMBIL ST	TJN	STR	Raining	Wet	60	2	CAR	F50	N in PACIFIC HWY	15	Turning right	NC	0	0	0	0	0	
E47396579								RUM	21	Right through				CAR	M19	S in PACIFIC HWY	60	Proceeding in lane							
806361	P	31/07/2012	Tue	06:00		at	FOX VALLEY RD	TJN	CRV	Fine	Dry	60	2	CAR	M45	E in FOX VALLEY RD	25	Turning right	NC	0	0	0	0	0	
E48624312								RUM	13	Right near				CAR	M37	N in PACIFIC HWY	Unk	Proceeding in lane							
1055531	S	18/01/2015	Sun	13:30		at	FOX VALLEY RD	TJN	STR	Fine	Dry	60	2	CAR	M34	S in PACIFIC HWY	Unk	Turning right	NC	0	0	0	0	0	
E57262949								RUM	21	Right through				CAR	F U	N in PACIFIC HWY	Unk	Proceeding in lane							
1078931	S	10/09/2015	Thu	10:00		at	FOX VALLEY RD	TJN	STR	Fine	Dry	60	2	CAR	M29	N in PACIFIC HWY	Unk	Proceeding in lane	NC	0	0	0	0	0	
E58908975								RUM	30	Rear end				4WD	M58	N in PACIFIC HWY	Unk	Proceeding in lane							
767278	P	16/08/2011	Tue	07:45	5 m	N	FOX VALLEY RD	TJN	CRV	Fine	Dry	60	2	VAN	M18	S in PACIFIC HWY	40	Proceeding in lane	NC	0	0	0	0	0	S
E47463489								RUM	30	Rear end				M/C	M23	S in PACIFIC HWY	0	Stationary							
844683	P	09/07/2013	Tue	06:40	5 m	N	FOX VALLEY RD	TJN	STR	Fine	Dry	60	2	WAG	M43	S in PACIFIC HWY	60	Proceeding in lane	SC	0	1	0	0	0	
E446333091								RUM	30	Rear end				CAR	F31	S in PACIFIC HWY	10	Proceeding in lane							

Detailed Crash Report

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash-Detailed	Killed	Seriously Inj.	Moderately Inj.	Minor/Other Inj.	Uncateg'd Inj.	Factors
																									S F
813402	P	09/10/2012	Tue	22:50	80 m	N	FOX VALLEY RD	DIV	CRV	Fine	Dry	60	1	4WD	M22	N in PACIFIC HWY	59	Proceeding in lane	MC	0	0	2	0	0	F
E49271254								RUM	83	Off rt/rt bnd=>obj				Utility pole											
843273	P	11/05/2013	Sat	16:00	100 m	N	FOX VALLEY RD	DIV	STR	Overcast	Dry	60	2	CAR	F61	S in PACIFIC HWY	40	Proceeding in lane	NC	0	0	0	0	0	
E441652591								RUM	30	Rear end				CAR	F22	S in PACIFIC HWY	0	Stationary							
760445	P	14/07/2011	Thu	18:00	195 m	N	FOX VALLEY RD	DIV	STR	Fine	Dry	60	2	CAR	M60	N in PACIFIC HWY	40	Proceeding in lane	NC	0	0	0	0	0	
E45247803								RUM	30	Rear end				4WD	M35	N in PACIFIC HWY	0	Stationary							
1056453	S	20/01/2015	Tue	15:40	10 m	S	GILDA AVE	TJN	STR	Fine	Dry	60	2	4WD	F43	N in PACIFIC HWY	Unk	Proceeding in lane	OC	0	0	0	1	0	
E56760533								RUM	30	Rear end				4WD	F30	N in PACIFIC HWY	0	Stationary							
1034383	P	24/07/2014	Thu	07:55	10 m	S	MARSHALL AVE	TJN	STR	Fine	Dry	60	2	CAR	M50	N in PACIFIC HWY	45	Proceeding in lane	NC	0	0	0	0	0	
E55371234								RUM	30	Rear end				VAN	F50	N in PACIFIC HWY	0	Stationary							
789082	P	04/02/2012	Sat	11:30	1.5 km	S	NEWCASTLE EXPR OP	2WY	STR	Fine	Dry	100	2	CAR	F18	N in PACIFIC HWY	10	Proceeding in lane	OC	0	0	0	1	0	
E46859932								RUM	30	Rear end				CAR	M37	N in PACIFIC HWY	0	Stationary							
Warrawee																									
Pacific Hwy																									
1065175	S	26/03/2015	Thu	13:20	2 km	N	BEECHWORTH RD	DIV	STR	Fine	Dry	60	2	LOR	M57	S in PACIFIC HWY	Unk	Pull out opposite	OC	0	0	0	1	0	
E58020143								RUM	39	Other same direction				CAR	M72	S in PACIFIC HWY	Unk	Proceeding in lane							
825795	P	24/01/2013	Thu	17:30	100 m	W	BLYTHESWOOD AVE	DIV	STR	Fine	Dry	60	3	CAR	M48	W in PACIFIC HWY	40	Proceeding in lane	MC	0	0	1	0	0	
E50167536								RUM	30	Rear end				CAR	F47	W in PACIFIC HWY	40	Proceeding in lane							
														TRK	M52	W in PACIFIC HWY	30	Proceeding in lane							
783071	P	25/01/2012	Wed	17:00		at	BORAMBIL ST	TJN	STR	Raining	Wet	60	2	WAG	M29	N in PACIFIC HWY	15	Turning right	MC	0	0	1	0	0	
E47140262								RUM	21	Right through				M/C	M39	S in PACIFIC HWY	45	Proceeding in lane							
833741	P	01/04/2013	Mon	14:00		at	BORAMBIL ST	TJN	CRV	Fine	Dry	60	2	WAG	M46	N in PACIFIC HWY	10	Turning right	OC	0	0	0	1	0	
E51906353								RUM	21	Right through				CAR	M53	S in PACIFIC HWY	60	Proceeding in lane							
843593	P	05/06/2013	Wed	08:30		at	BORAMBIL ST	TJN	CRV	Overcast	Dry	40	2	WAG	F48	N in PACIFIC HWY	5	Turning right	NC	0	0	0	0	0	
E50906130								RUM	21	Right through				CAR	F27	S in PACIFIC HWY	35	Proceeding in lane							
1032362	P	09/07/2014	Wed	15:15		at	BORAMBIL ST	TJN	STR	Fine	Dry	60	2	CAR	F55	N in PACIFIC HWY	Unk	Turning right	OC	0	0	0	1	0	
E57561284								RUM	21	Right through				CAR	M17	S in PACIFIC HWY	Unk	Proceeding in lane							
1055586	S	30/11/2014	Sun	18:00		at	BORAMBIL ST	TJN	STR	Raining	Wet	60	2	CAR	F19	N in PACIFIC HWY	Unk	Turning right	NC	0	0	0	0	0	
E56633206								RUM	21	Right through				WAG	M44	S in PACIFIC HWY	Unk	Proceeding in lane							
1051315	P	02/01/2015	Fri	11:00		at	BORAMBIL ST	TJN	STR	Fine	Dry	60	2	CAR	F42	N in PACIFIC HWY	10	Turning right	OC	0	0	0	1	0	
E56495611								RUM	21	Right through				CAR	M25	S in PACIFIC HWY	40	Proceeding in lane							
818803	P	02/12/2012	Sun	13:00	10 m	N	BORAMBIL ST	TJN	STR	Fine	Dry	60	3	CAR	M36	S in PACIFIC HWY	40	Proceeding in lane	NC	0	0	0	0	0	
E52019589								RUM	30	Rear end				CAR	F52	S in PACIFIC HWY	60	Proceeding in lane							
														CAR	F72	S in PACIFIC HWY	Unk	Proceeding in lane							

Detailed Crash Report

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash-Detailed	Killed	Seriously Inj.	Moderately Inj.	Minor/Other Inj.	Uncateg'd Inj.	Factors
																									S F
1106833	P	16/02/2016	Tue	13:45	10 m	S	BORAMBIL ST	TJN	STR	Fine	Dry	60	1	CAR	U U	S in PACIFIC HWY	60	Proceeding in lane	NC	0	0	0	0	0	F
E61346378								RUM	71	Off rd left => obj				Signpost											
808770	P	27/08/2012	Mon	05:50		at	BORAMBLE ST	TJN	STR	Fine	Dry	60	2	CAR	M36	S in PACIFIC HWY	Unk	Veering left	OC	0	0	0	1	0	
E420743691								RUM	35	Lane change left				CAR	F30	S in PACIFIC HWY	50	Proceeding in lane							
831496	P	21/03/2013	Thu	16:30		at	FOX VALLEY RD	TJN	STR	Fine	Dry	60	1	CAR	M68	N in PACIFIC HWY	40	Proceeding in lane	SC	0	1	0	1	0	
E52712282								RUM	71	Off rd left => obj				Signal pole											
1000044	P	25/11/2013	Mon	16:15	125 m	E	FOX VALLEY RD	DIV	STR	Fine	Dry	60	3	CAR	F21	W in PACIFIC HWY	30	Proceeding in lane	OC	0	0	0	1	0	
E53298203								RUM	31	Left rear				CAR	M52	W in PACIFIC HWY	0	Waiting turn left							
														CAR	M42	N in PACIFIC HWY	0	Forward from drive							
788778	P	18/03/2012	Sun	13:00	12 m	N	FOX VALLEY RD	DIV	CRV	Overcast	Dry	60	2	CAR	M28	S in PACIFIC HWY	50	Proceeding in lane	NC	0	0	0	0	0	
E223949993								RUM	30	Rear end				CAR	M55	S in PACIFIC HWY	Unk	Proceeding in lane							
854004	P	06/10/2013	Sun	12:00	20 m	N	FOX VALLEY RD	DIV	CRV	Fine	Dry	60	3	TRK	M38	S in PACIFIC HWY	30	Proceeding in lane	NC	0	0	0	0	0	
E221768794								RUM	30	Rear end				CAR	F29	S in PACIFIC HWY	0	Stationary							
														WAG	M49	S in PACIFIC HWY	0	Stationary							
1016709	P	04/03/2014	Tue	12:27	30 m	N	FOX VALLEY RD	DIV	STR	Fine	Dry	60	3	CAR	F26	S in PACIFIC HWY	Unk	Proceeding in lane	NC	0	0	0	0	0	
E54618529								RUM	30	Rear end				CAR	F26	S in PACIFIC HWY	0	Stationary							
														TRK	M46	S in PACIFIC HWY	0	Stationary							
841442	P	20/06/2013	Thu	06:15	100 m	N	FOX VALLEY RD	DIV	STR	Fine	Dry	60	3	TRK	M20	S in PACIFIC HWY	20	Proceeding in lane	NC	0	0	0	0	0	
E760805290								RUM	30	Rear end				4WD	M38	S in PACIFIC HWY	0	Stationary							
														4WD	M43	S in PACIFIC HWY	0	Stationary							
1084075	P	10/07/2015	Fri	17:30	100 m	N	FOX VALLEY RD	DIV	STR	Raining	Wet	60	3	4WD	M30	S in PACIFIC HWY	Unk	Proceeding in lane	MC	0	0	1	1	0	
E59211204								RUM	30	Rear end				4WD	M82	S in PACIFIC HWY	Unk	Proceeding in lane							
														4WD	F32	S in PACIFIC HWY	Unk	Proceeding in lane							
781659	P	16/01/2012	Mon	13:40	20 m	N	FOX VALLEY WAY	DIV	CRV	Fine	Dry	60	3	CAR	M19	S in PACIFIC HWY	60	Proceeding in lane	OC	0	0	0	1	0	
E46543522								RUM	30	Rear end				CAR	F64	S in PACIFIC HWY	0	Stationary							
														WAG	M44	S in PACIFIC HWY	0	Stationary							
782394	P	29/01/2012	Sun	12:16	20 m	E	HEYDON AVE	DIV	STR	Fine	Dry	60	2	CAR	M60	S in PACIFIC HWY	40	Proceeding in lane	MC	0	0	1	0	0	F
E151333798								RUM	71	Off rd left => obj				4WD	M25	S in PACIFIC HWY	50	Proceeding in lane							
														Signpost											
779668	P	27/12/2011	Tue	11:50		at	MARSHALL AVE	TJN	STR	Overcast	Dry	60	2	CAR	F50	S in PACIFIC HWY	10	Turning right	NC	0	0	0	0	0	
E46920858								RUM	21	Right through				CAR	M61	N in PACIFIC HWY	25	Proceeding in lane							
1013064	P	14/02/2014	Fri	16:45		at	MARSHALL AVE	TJN	STR	Fine	Dry	60	2	CAR	F54	S in PACIFIC HWY	40	Turning right	NC	0	0	0	0	0	
E54141819								RUM	21	Right through				CAR	F47	N in PACIFIC HWY	40	Proceeding in lane							

Detailed Crash Report

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash-Detailed	Killed	Seriously Inj.	Moderately Inj.	Minor/Other Inj.	Uncateg'd Inj.	Factors
																									S F
1013713	P	14/02/2014	Fri	19:30		at	MARSHALL AVE	TJN	STR	Fine	Dry	60	2	WAG	M70	S in PACIFIC HWY	10	Turning right	OC	0	0	0	1	0	
E54780165								RUM	21	Right through				CAR	M45	N in PACIFIC HWY	60	Proceeding in lane							
1075238	S	03/08/2015	Mon	06:00		at	NUMBER 1479 HN	DIV	STR	Fine	Dry	60	2	CAR	M38	S in PACIFIC HWY	Unk	Proceeding in lane	OC	0	0	0	1	0	
E58497804								RUM	30	Rear end				CAR	M43	S in PACIFIC HWY	0	Stationary							

Report Totals: Crashes: 42 Fatal Crashes(FC): 0 Serious Injury Crashes(SC): 2 Moderate Injury Crashes(MC): 7 Minor/Other Injury Crashes(OC): 13 Uncategorised Injury Crashes(UC): 0 Non-Casualty Crashes(NC): 20

Killed(K): 0 Seriously Injured(S): 2 Moderately Injured(M): 9 Minor/Other Injured(O): 15 Uncategorised Injured(U): 0

Crashid dataset Reported crashes on Pacific Hwy btwn 100m north of Borambil St & 150m south of Fox Valley Rd (+50m on Fox Valley Rd leg) - 1 Jul 11 to 30 Jun 16

Note: *Data for the 9 month period prior to the generated date of this report are incomplete and are subject to change.*

Crash self reporting, including self reported injuries began Oct 2014. Trends from 2014 are expected to vary from previous yrs. More unknowns are expected in self reported data. Reporting yrs 1996-2004 and 2016 onwards contain uncategorised inj crashes.

Pacific Hwy / Finlay Rd Intersection, Warrawee

Between 150m north & 150 south of Borambil St & 150m south of Finlay Rd, Warrawee

Crashes reported 1 July 2011 to 30 June 2016

NSW GOVERNMENT | Transport Roads & Maritime Services

Not to scale. Indicative location of crashes interpreted from CrashLink data.

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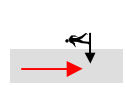
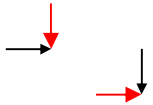
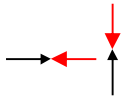
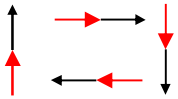
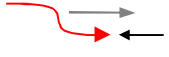
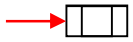
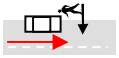
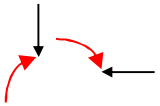
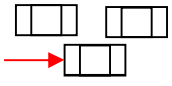
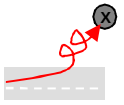
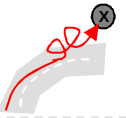
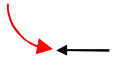
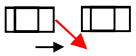
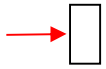
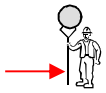
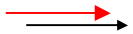
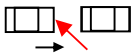
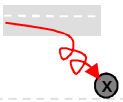
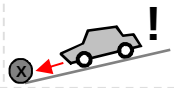
0										
1										
2										
3										
4										
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Detailed Crash Report

NOTES: Reported crashes on Pacific Hwy btwn 150m north & 150m south of Borambil St & 150m south of Finlay Rd - 1 Jul 11 to 30 Jun 16

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash-Detailed	Killed	Seriously Inj.	Moderately Inj.	Minor/Other Inj.	Uncateg'd Inj.	Factors S F
Sydney Region																									
Ku-Ring-Gai LGA																									
Turramurra																									
Pacific Hwy																									
785559	P	24/02/2012	Fri	12:00	160 m	N	CHERRY ST	DIV	CRV	Fine	Dry	60	2	CAR	F56	N in PACIFIC HWY	10	Veering right	NC	0	0	0	0	0	
E47309550								RUM: 34	Lane change right					LOR	M55	N in PACIFIC HWY	10	Proceeding in lane							
851594	P	19/09/2013	Thu	15:45	45 m	E	FINLAY RD	DIV	STR	Fine	Dry	50	2	LOR	U U	W in PACIFIC HWY	Unk	Merging	OC	0	0	0	1	0	
E53480053								RUM: 34	Lane change right					UTE	M26	W in PACIFIC HWY	15	Proceeding in lane							
814966	P	24/08/2012	Fri	17:30	100 m	E	FINLAY RD	DIV	STR	Fine	Dry	60	3	CAR	F24	E in PACIFIC HWY	50	Proceeding in lane	NC	0	0	0	0	0	
E48795972								RUM: 30	Rear end					CAR	M74	E in PACIFIC HWY	0	Stationary							
														CAR	F43	E in PACIFIC HWY	0	Stationary							
774779	P	16/11/2011	Wed	15:20		at	LOTHER PARK AVE	TJN	STR	Raining	Wet	60	2	CAR	M73	N in PACIFIC HWY	30	Proceeding in lane	NC	0	0	0	0	0	
E46277948								RUM: 30	Rear end					UTE	M32	N in PACIFIC HWY	30	Proceeding in lane							
Warrawee																									
Pacific Hwy																									
1075845	S	23/03/2015	Mon	17:30		at	FINLAY RD	TJN	STR	Fine	Dry	60	2	CAR	M50	S in PACIFIC HWY	Unk	Turning right	MC	0	0	1	0	0	
E57960129								RUM: 21	Right through					M/C	M21	N in PACIFIC HWY	Unk	Proceeding in lane							
1083900	S	01/11/2015	Sun	17:45	500 m	N	RAY ST	DIV	STR	Raining	Wet	60	2	CAR	M26	S in PACIFIC HWY	Unk	Other forward	NC	0	0	0	0	0	
E357542392								RUM: 39	Other same direction					CAR	F18	S in PACIFIC HWY	Unk	Other forward							

Report Totals: Crashes: 6 Fatal Crashes(FC): 0 Serious Injury Crashes(SC): 0 Moderate Injury Crashes(MC): 1 Minor/Other Injury Crashes(OC): 1 Uncategorised Injury Crashes(UC): 0 Non-Casualty Crashes(NC): 4

Killed(K): 0 Seriously Injured(S): 0 Moderately Injured(M): 1 Minor/Other Injured(O): 1 Uncategorised Injured(U): 0

Crashid dataset Reported crashes on Pacific Hwy btwn 150m north & 150m south of Borambil St & 150m south of Finlay Rd - 1 Jul 11 to 30 Jun 16

Crash self reporting, including self reported injuries began Oct 2014. Trends from 2014 are expected to vary from previous yrs. More unknowns are expected in self reported data.
Reporting yrs 1996-2004 and 2016 onwards contain uncategorised inj crashes.

Summary Crash Report

# Crash Type		
Car Crash	6	100.0%
Light Truck Crash	0	0.0%
Rigid Truck Crash	2	33.3%
Articulated Truck Crash	0	0.0%
'Heavy Truck Crash	*(2)*	*(33.3%)*
Bus Crash	0	0.0%
"Heavy Vehicle Crash	*(2)*	*(33.3%)*
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	16.7%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	2	33.3%
Non intersection	4	66.7%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	0	0.0%
Multi Vehicle	6	100.0%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	6	100.0%
Other Classified Road	0	0.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	0	0.0%
Fatigue	0	0.0%

Weather		
Fine	4	66.7%
Rain	2	33.3%
Overcast	0	0.0%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	2	33.3%
Dry	4	66.7%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	4	66.7%
Dusk	2	33.3%
Darkness	0	0.0%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	1	16.7%
U-turn	0	0.0%
Rear-end	2	33.3%
Lane change	2	33.3%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	0	0.0%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	0	0.0%
Out of control on curve	0	0.0%
Other crash type	1	16.7%

Speed Limit				
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	1	16.7%	90 km/h zone	0	0.0%
60 km/h zone	5	83.3%	100 km/h zone	0	0.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

CRASHES	6	
Fatal	0	0.0%
Serious inj.	0	0.0%
Moderate inj.	1	16.7%
Minor/Other inj.	1	16.7%
Uncategorised inj.	0	0.0%
Non-casualty	4	66.7%

CASUALTIES	2	
Killed	0	0.0%
Seriously inj.	0	0.0%
Moderately inj.	1	50.0%
Minor/Other inj.	1	50.0%
Uncategorised inj.	0	0.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Self Reported Crash	2	33.33%

Time Group		% of Day	
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	0	0.0%	4.2%
08:00 - 08:59	0	0.0%	4.2%
09:00 - 09:59	0	0.0%	4.2%
10:00 - 10:59	0	0.0%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	1	16.7%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	0	0.0%	4.2%
15:00 - 15:59	2	33.3%	4.2%
16:00 - 16:59	0	0.0%	4.2%
17:00 - 17:59	3	50.0%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Crashes		Casualties
2	2015	1
1	2013	1
2	2012	0
1	2011	0

McLean Periods			% Week
A	0	0.0%	17.9%
B	0	0.0%	7.1%
C	1	16.7%	17.9%
D	0	0.0%	3.5%
E	0	0.0%	3.6%
F	2	33.3%	10.7%
G	2	33.3%	7.1%
H	1	16.7%	7.1%
I	0	0.0%	12.5%
J	0	0.0%	10.7%

Street Lighting Off/Nil		% of Dark
0	of 0	in Dark 0.0%

~ 07:30-09:30 or 14:30-17:00 on school days | **~ 40km/h or less** 0 0.0% | **~ School Travel Time Involvement** 2 33.3%

Day of the Week												
Monday	1	16.7%	Wednesday	1	16.7%	Friday	2	33.3%	Sunday	1	16.7%	WEEKEND	1	16.7%
Tuesday	0	0.0%	Thursday	1	16.7%	Saturday	0	0.0%	WEEKDAY	5	83.3%			

#Holiday Periods														
New Year	0	0.0%	Easter	0	0.0%	Queen's BD	0	0.0%	Christmas	0	0.0%	Easter SH	0	0.0%	Sept./Oct. SH	0	0.0%
Aust. Day	0	0.0%	Anzac Day	0	0.0%	Labour Day	0	0.0%	January SH	0	0.0%	June/July SH	0	0.0%	December SH	0	0.0%

Crashid dataset Reported crashes on Pacific Hwy btwn 150m north & 150m south of Borambil St & 150m south of Finlay Rd - 1 Jul 11 to 30 Jun 16

Note: Crash self reporting, including self reported injuries began Oct 2014. Trends from 2014 are expected to vary from previous yrs. More unknowns are expected in self reported data. Reporting yrs 1996-2004 and 2016 onwards contain uncategorised inj crashes.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Appendix B – Detailed intersection performance

Intersection Performance (Average Delays in sec)				2017				2027			
				No RT Ban [1]		With RT Ban [2]		No RT Ban [1]		With RT Ban [2]	
				Delays	LoS	Delays	LoS	Delays	LoS	Delays	LoS
AM Peak [3]	Fox Valley Rd / Pacific Hwy	N - Pacific Hwy	T	30.8	C	32.5	C	50.6	D	52.1	D
			R	54.1	D	69.1	E	61.9	E	76.0	F
		S - Pacific Hwy	L	6.4	A	6.5	A	6.0	A	6.1	A
			T	4.0	A	4.4	A	3.4	A	3.3	A
		W - Fox Valley Rd	L	262.5	F	264.1	F	227.9	F	233.0	F
			R	258.6	F	252.1	F	220.7	F	222.6	F
		Intersection		**39.4**	**C**	**42.2**	**C**	**47.4**	**D**	**50.0**	**D**
	Marshall Ave / Pacific Hwy	N - Pacific Hwy	T	0.3	A	0.3	A	1.1	A	1.3	A
		S - Pacific Hwy	L	7.4	A	7.6	A	5.4	A	5.8	A
			T	4.2	A	4.1	A	4.5	A	3.9	A
		W – Marshall Ave	L	12.9	A	7.4	A	7.1	A	7.1	A
			R	29.1	C	-	-	28.6	C	-	-
		Intersection		**1.7**	**A**	**1.6**	**A**	**2.3**	**A**	**2.2**	**A**
	Finlay Rd / Pacific Hwy	N - Pacific Hwy	T	0.9	A	0.8	A	24.1	B	24.3	B
			R	14.6	B	-	-	35.6	C	-	-
		S - Pacific Hwy	L	0.2	A	0.2	A	1.0	A	0.2	A
			T	0.6	A	0.7	A	0.7	A	0.7	A
		W – Finlay Rd	L	6.2	A	4.1	A	75.6	F	3.9	A
			R	26.1	B	-	-	80.8	F	-	-
		Intersection		**0.9**	**A**	**0.6**	**A**	**16.5**	**B**	**15.8**	**B**
PM Peak [3]	Fox Valley Rd / Pacific Hwy	N - Pacific Hwy	T	6.9	A	6.8	A	8.0	A	7.9	A
			R	61.0	E	68.8	E	60.9	E	68.2	E
		S - Pacific Hwy	L	4.0	A	3.7	A	4.3	A	4.1	A
			T	2.7	A	2.8	A	2.3	A	2.5	A
		W - Fox Valley Rd	L	224.2	F	247.1	F	195.4	F	222.0	F
			R	224.1	F	245.5	F	197.1	F	216.8	F
		Intersection		**24.1**	B	**25.9**	**B**	**21.7**	**B**	**23.5**	**B**
	Marshall Ave / Pacific Hwy	N - Pacific Hwy	T	0.2	A	0.2	A	0.3	A	0.3	A
		S - Pacific Hwy	L	3.6	A	5.5	A	4.6	A	4.3	A
			T	1.8	A	1.9	A	1.8	A	1.9	A
		W – Marshall Ave	L	8.4	A	8.2	A	8.0	A	7.5	A
			R	40.4	C	-	-	47.5	D	-	-
		Intersection		**1.2**	**A**	**1.2**	**A**	**1.2**	**A**	**1.2**	**A**
	Finlay Rd / Pacific Hwy	N - Pacific Hwy	T	0.2	A	0.2	A	32.5	C	25.8	B
			R	26.6	B	-	-	41.5	C	-	-
		S - Pacific Hwy	L	0.4	A	0.4	A	0.4	A	0.4	A
			T	0.8	A	1.5	A	1.1	A	1.9	A
		W – Finlay Rd	L	10.7	A	6.7	A	38.3	C	8.0	A
			R	31.5	C	-	-	141.8	F	-	-
		Intersection		**0.4**	**A**	**0.3**	**A**	**14.8**	**B**	**11.6**	**A**

[1] Proposed upgrade on Pacific Highway, with right turn permitted in and out of Marshall Avenue and Finlay Road.
[2] Proposed upgrade on Pacific Highway, with right turn prohibited in and out of Marshall Avenue and Finlay Road (ie LILO design).

Appendix K

Aboriginal Heritage Searches and PACHCI Letter

AHIMS Web Services (AWS)
Search Result

Purchase Order/Reference : PacHighway - Finlay Road

Client Service ID : 345867

Roads and Maritime Services - 27 Argyle Street - Parramatta

Date: 18 May 2018

27 Argyle Street
Parramatta New South Wales 2150
Attention: Easing Sydneys Congestion Rms

Email: radha.rockwood@rms.nsw.gov.au

Dear Sir or Madam:

AHIMS Web Service search for the following area at Lot : A, DP:DP374006 with a Buffer of 1000 meters, conducted by Easing Sydneys Congestion Rms on 18 May 2018.

The context area of your search is shown in the map below. Please note that the map does not accurately display the exact boundaries of the search as defined in the paragraph above. The map is to be used for general reference purposes only.

A search of the Office of the Environment and Heritage AHIMS Web Services (Aboriginal Heritage Information Management System) has shown that:

2	Aboriginal sites are recorded in or near the above location.
0	Aboriginal places have been declared in or near the above location. *

If your search shows Aboriginal sites or places what should you do?

- You must do an extensive search if AHIMS has shown that there are Aboriginal sites or places recorded in the search area.
- If you are checking AHIMS as a part of your due diligence, refer to the next steps of the Due Diligence Code of practice.
- You can get further information about Aboriginal places by looking at the gazettal notice that declared it. Aboriginal places gazetted after 2001 are available on the NSW Government Gazette (http://www.nsw.gov.au/gazette) website. Gazettal notices published prior to 2001 can be obtained from Office of Environment and Heritage's Aboriginal Heritage Information Unit upon request

Important information about your AHIMS search

- The information derived from the AHIMS search is only to be used for the purpose for which it was requested. It is not be made available to the public.
- AHIMS records information about Aboriginal sites that have been provided to Office of Environment and Heritage and Aboriginal places that have been declared by the Minister;
- Information recorded on AHIMS may vary in its accuracy and may not be up to date .Location details are recorded as grid references and it is important to note that there may be errors or omissions in these recordings,
- Some parts of New South Wales have not been investigated in detail and there may be fewer records of Aboriginal sites in those areas. These areas may contain Aboriginal sites which are not recorded on AHIMS.
- Aboriginal objects are protected under the National Parks and Wildlife Act 1974 even if they are not recorded as a site on AHIMS.
- This search can form part of your due diligence and remains valid for 12 months.

3 Marist Place, Parramatta NSW 2150
Locked Bag 5020 Parramatta NSW 2220
Tel: (02) 9585 6380 Fax: (02) 9873 8599

ABN 30 841 387 271
Email: ahims@environment.nsw.gov.au
Web: www.environment.nsw.gov.au

AHIMS Web Services (AWS)
Search Result

Purchase Order/Reference : PacHighway - FoxValleyRd

Client Service ID : 345866

Roads and Maritime Services - 27 Argyle Street - Parramatta

Date: 18 May 2018

27 Argyle Street
Parramatta New South Wales 2150
Attention: Easing Sydneys Congestion Rms

Email: radha.rockwood@rms.nsw.gov.au

Dear Sir or Madam:

AHIMS Web Service search for the following area at Lot : 1, DP:DP62488 with a Buffer of 1000 meters, conducted by Easing Sydneys Congestion Rms on 18 May 2018.

The context area of your search is shown in the map below. Please note that the map does not accurately display the exact boundaries of the search as defined in the paragraph above. The map is to be used for general reference purposes only.

A search of the Office of the Environment and Heritage AHIMS Web Services (Aboriginal Heritage Information Management System) has shown that:

1	**Aboriginal sites are recorded in or near the above location.**
0	**Aboriginal places have been declared in or near the above location. ***

If your search shows Aboriginal sites or places what should you do?

- You must do an extensive search if AHIMS has shown that there are Aboriginal sites or places recorded in the search area.
- If you are checking AHIMS as a part of your due diligence, refer to the next steps of the Due Diligence Code of practice.
- You can get further information about Aboriginal places by looking at the gazettal notice that declared it. Aboriginal places gazetted after 2001 are available on the NSW Government Gazette (http://www.nsw.gov.au/gazette) website. Gazettal notices published prior to 2001 can be obtained from Office of Environment and Heritage's Aboriginal Heritage Information Unit upon request

Important information about your AHIMS search

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- Information recorded on AHIMS may vary in its accuracy and may not be up to date .Location details are recorded as grid references and it is important to note that there may be errors or omissions in these recordings,
- Some parts of New South Wales have not been investigated in detail and there may be fewer records of Aboriginal sites in those areas. These areas may contain Aboriginal sites which are not recorded on AHIMS.
- Aboriginal objects are protected under the National Parks and Wildlife Act 1974 even if they are not recorded as a site on AHIMS.
- This search can form part of your due diligence and remains valid for 12 months.

3 Marist Place, Parramatta NSW 2150
Locked Bag 5020 Parramatta NSW 2220
Tel: (02) 9585 6380 Fax: (02) 9873 8599

ABN 30 841 387 271
Email: ahims@environment.nsw.gov.au
Web: www.environment.nsw.gov.au

AHIMS Web Services (AWS)
Search Result

Purchase Order/Reference : PacHighway-Turramurra

Client Service ID : 345869

Roads and Maritime Services - 27 Argyle Street - Parramatta

Date: 18 May 2018

27 Argyle Street
Parramatta New South Wales 2150
Attention: Easing Sydneys Congestion Rms

Email: radha.rockwood@rms.nsw.gov.au

Dear Sir or Madam:

AHIMS Web Service search for the following area at Lot : 6, DP:DP26828 with a Buffer of 1000 meters, conducted by Easing Sydneys Congestion Rms on 18 May 2018.

The context area of your search is shown in the map below. Please note that the map does not accurately display the exact boundaries of the search as defined in the paragraph above. The map is to be used for general reference purposes only.

A search of the Office of the Environment and Heritage AHIMS Web Services (Aboriginal Heritage Information Management System) has shown that:

2	Aboriginal sites are recorded in or near the above location.
0	Aboriginal places have been declared in or near the above location. *

If your search shows Aboriginal sites or places what should you do?

- You must do an extensive search if AHIMS has shown that there are Aboriginal sites or places recorded in the search area.
- If you are checking AHIMS as a part of your due diligence, refer to the next steps of the Due Diligence Code of practice.
- You can get further information about Aboriginal places by looking at the gazettal notice that declared it. Aboriginal places gazetted after 2001 are available on the NSW Government Gazette (http://www.nsw.gov.au/gazette) website. Gazettal notices published prior to 2001 can be obtained from Office of Environment and Heritage's Aboriginal Heritage Information Unit upon request

Important information about your AHIMS search

- The information derived from the AHIMS search is only to be used for the purpose for which it was requested. It is not be made available to the public.
- AHIMS records information about Aboriginal sites that have been provided to Office of Environment and Heritage and Aboriginal places that have been declared by the Minister;
- Information recorded on AHIMS may vary in its accuracy and may not be up to date .Location details are recorded as grid references and it is important to note that there may be errors or omissions in these recordings,
- Some parts of New South Wales have not been investigated in detail and there may be fewer records of Aboriginal sites in those areas. These areas may contain Aboriginal sites which are not recorded on AHIMS.
- Aboriginal objects are protected under the National Parks and Wildlife Act 1974 even if they are not recorded as a site on AHIMS.
- This search can form part of your due diligence and remains valid for 12 months.

3 Marist Place, Parramatta NSW 2150
Locked Bag 5020 Parramatta NSW 2220
Tel: (02) 9585 6380 Fax: (02) 9873 8599

ABN 30 841 387 271
Email: ahims@environment.nsw.gov.au
Web: www.environment.nsw.gov.au

Transport
Roads & Maritime
Services

5/7/2018

Maria Doumit
Environmental Officer
Easing Sydney's Congestion Program Office | Sydney Office

Dear Maria

Re: Preliminary assessment results for Pacific Highway at Finlay Road, Warrawee, Intersection upgrade proposal based on Stage 1 of the *Procedure for Aboriginal cultural heritage consultation and investigation* (the procedure).

The project, as described in the Stage 1 assessment checklist, was assessed as being unlikely to have an impact on Aboriginal cultural heritage. The assessment is based on the following due diligence considerations:

- The project is unlikely to harm known Aboriginal objects or places.
- The AHIMS search did not indicate any known Aboriginal objects or places in the immediate study area.
- The study area does not contain landscape features that indicate the presence of Aboriginal objects, based on the Office of Environment and Heritage's *Due diligence Code of Practice for the Protection of Aboriginal objects in NSW* and the Roads and Maritime Services' procedure.
- The cultural heritage potential of the study area appears to be reduced due to past disturbance.

Your project may proceed in accordance with the environmental impact assessment process, as relevant, and all other relevant approvals.

If the scope of your project changes, you must contact me and your regional environmental staff to reassess any potential impacts on Aboriginal cultural heritage.

If any potential Aboriginal objects (including skeletal remains) are discovered during the course of the project, all works in the vicinity of the find must cease. Follow the steps outlined in the Roads and Maritime Services' *Unexpected Archaeological Finds Procedure*.

For further assistance in this matter and do not hesitate to contact me.

Yours sincerely

M. Lester

Mark Lester
Aboriginal Cultural Heritage Officer – Sydney Region
27-31 Argyle St Parramatta NSW 2150
Phone - 02 8849 2583 Mobile – 0448 731 510

Transport
Roads & Maritime
Services

5/7/2018

Maria Doumit
Environmental Officer
Easing Sydney's Congestion Program Office | Sydney Office

Dear Maria

Re: Preliminary assessment results for the Pacific Highway at Fox Valley Road, Wahroonga, Wahroonga, Intersection upgrade proposal based on Stage 1 of the *Procedure for Aboriginal cultural heritage consultation and investigation* (the procedure).

The project, as described in the Stage 1 assessment checklist, was assessed as being unlikely to have an impact on Aboriginal cultural heritage. The assessment is based on the following due diligence considerations:

- The project is unlikely to harm known Aboriginal objects or places.
- The AHIMS search did not indicate any known Aboriginal objects or places in the immediate study area.
- The study area does not contain landscape features that indicate the presence of Aboriginal objects, based on the Office of Environment and Heritage's *Due diligence Code of Practice for the Protection of Aboriginal objects in NSW* and the Roads and Maritime Services' procedure.
- The cultural heritage potential of the study area appears to be reduced due to past disturbance.

Your project may proceed in accordance with the environmental impact assessment process, as relevant, and all other relevant approvals.

If the scope of your project changes, you must contact me and your regional environmental staff to reassess any potential impacts on Aboriginal cultural heritage.

If any potential Aboriginal objects (including skeletal remains) are discovered during the course of the project, all works in the vicinity of the find must cease. Follow the steps outlined in the Roads and Maritime Services' *Unexpected Archaeological Finds Procedure*.

For further assistance in this matter and do not hesitate to contact me.

Yours sincerely

M Lester

Mark Lester
Aboriginal Cultural Heritage Officer – Sydney Region
27-31 Argyle St Parramatta NSW 2150
Phone - 02 8849 2583 Mobile – 0448 731 510

31/10/2018

Katie Round
Environmental Officer
Easing Sydney's Congestion Program Office | Journey Management

Dear Katie

Re: Preliminary assessment results for the Pacific Highway Intersection Improvements (Turramurra to Wahroonga) Compound Site at 1334 and 1354 Pacific Highway, Turramurra proposal, based on Stage 1 of the *Procedure for Aboriginal cultural heritage consultation and investigation* (the procedure).

The project, as described in the Stage 1 assessment checklist, was assessed as being unlikely to have an impact on Aboriginal cultural heritage. The assessment is based on the following due diligence considerations:

- The project is unlikely to harm known Aboriginal objects or places.
- The AHIMS search did not indicate any known Aboriginal objects or places in the immediate study area.
- The study area does not contain landscape features that indicate the presence of Aboriginal objects, based on the Office of Environment and Heritage's *Due diligence Code of Practice for the Protection of Aboriginal objects in NSW* and the Roads and Maritime Services' procedure.
- The cultural heritage potential of the study area appears to be reduced due to past disturbance.

Your project may proceed in accordance with the environmental impact assessment process, as relevant, and all other relevant approvals.

If the scope of your project changes, you must contact me and your regional environmental staff to reassess any potential impacts on Aboriginal cultural heritage.

If any potential Aboriginal objects (including skeletal remains) are discovered during the course of the project, all works in the vicinity of the find must cease. Follow the steps outlined in the Roads and Maritime Services' *Unexpected Archaeological Finds Procedure*.

For further assistance in this matter and do not hesitate to contact me.

Yours sincerely

M. Lester

Mark Lester
Aboriginal Cultural Heritage Officer – Sydney Region
27-31 Argyle St Parramatta NSW 2150
Phone - 02 8849 2583 Mobile – 0448 731 510

Appendix L

Noise and Vibration Assessment (Construction and Operation)

RENZO TONIN & ASSOCIATES
inspired to achieve

Acoustics
Vibration
Structural Dynamics

PINCH POINT UPGRADES AT INTERSECTIONS OF THE PACIFIC HIGHWAY BETWEEN TURRAMURRA AND WAHROONGA

Construction and Operational Noise & Vibration Assessment

4 February 2019

Roads and Maritime Services

TK319-01F02 Report (r8).docx

30 1982 2012 ACOUSTIC EXCELLENCE
Sydney Melbourne Brisbane Gold Coast Kuwait
Renzo Tonin & Associates (NSW) Pty Ltd ABN 29 117 462 861
Level 1/418A Elizabeth St SURRY HILLS NSW 2010 | PO Box 877 STRAWBERRY HILLS NSW 2012
P (02) 8218 0500 F (02) 8218 0501 sydney@renzotonin.com.au www.renzotonin.com.au

Document details

Detail	Reference
Doc reference:	TK319-01F02 Report (r8).docx
Prepared for:	Roads and Maritime Services
Address:	Level 9, 10-14 Smith Street Parramatta NSW 2150
Attention:	Ms Maria Doumit

Document control

Date	Revision history	Non-issued revision	Issued revision	Prepared	Instructed	Authorised
10.07.2018	Preliminary draft report	0-2	3	WC	MCH	-
26.09.2018	Revised report	4	5-7	WC	MCH	MCH
04.02.2019	Revised design		8	WC	MCH	MCH

Contents

List of tables

List of figures

1 Introduction

Renzo Tonin & Associates was engaged by Roads and Maritime Services to undertake an environmental noise and vibration assessment for the construction and operation of the proposed upgrade of three (3) intersections along the Pacific Highway from Turramurra to Wahroonga. The locations of the proposed upgrades are as follows:

1. Pacific Highway at Finlay Road, Warrawee/Turramurra
2. Pacific Highway at Fox Valley Road, Wahroonga/Warrawee
3. Pacific Highway at Coonanbarra Road and Redleaf Avenue, Wahroonga

This study addresses the following issues:

- Construction noise & vibration emission from the use of mobile plant and equipment; and
- Operational noise emission resulting from traffic lanes moving closer to residences.

The study identifies the nearby sensitive receiver locations that are potentially most affected by the construction and operation of the upgrades. The potential noise and vibration impacts are assessed against noise and vibration criteria presented in the following policies and guidelines:

- NSW Environment Protection Authority's (EPA) 'Interim Construction Noise Guideline' (ICNG)
- NSW Roads & Maritime Services' 'Construction Noise and Vibration Guideline' (CNVG)
- EPA 'Assessing Vibration: A technical guideline'
- EPA 'Road Noise Policy' (RNP),
- Roads and Maritime Services' 'Noise Criteria Guideline' (NCG),
- Roads and Maritime Services' 'Noise Mitigation Guideline' (NMG)

The existing ambient noise environment was determined through unattended long-term noise monitoring at nearby residential receiver locations.

The work documented in this report was carried out in accordance with the Renzo Tonin & Associates Quality Assurance System, which is based on Australian Standard / NZS ISO 9001. Appendix A contains a glossary of acoustic terms used in this report.

2 Project Description

Roads and Maritime Services proposes to upgrade three (3) intersections along the Pacific Highway from Turramurra to Wahroonga, to improve safety and alleviate traffic congestion.

2.1 Scope of Works

The proposed Pacific Highway upgrades are located at:

- Pacific Highway and Finlay Road, Warrawee/Turramurra
- Pacific Highway and Fox Valley Road, Wahroonga/Warrawee
- Pacific Highway at Redleaf Avenue and Coonanbarra Road, Wahroonga.

Potential upgrades would include road widening, adjustments to traffic lanes, medians, traffic lights, footpaths, drainage, utilities and road pavement.

Road widening would require strip adjustments to a small number of properties in this area on the northbound side of the Pacific Highway.

The proposed works would require the use of a compound site. At this stage, on site has been identified at 1334 Pacific Highway, Turramurra as a compound site.

Site 1 – Pacific Highway and Finlay Road, Warrawee/Turramurra

- widening on the northbound side of Pacific Highway (north and south of Finlay Road) to provide three continuous northbound through lanes
- banning the right turn from Pacific Highway southbound into Finlay Road

Site 2 – Pacific Highway and Fox Valley Road, Wahroonga/Warrawee

- widening on the northbound side of Pacific Highway (north and south of Fox Valley Road) to provide three continuous northbound through lanes
- maintaining the left turn lane from Pacific Highway northbound into Fox Valley Road
- extending the right turn bay from Pacific Highway southbound into Fox Valley Road
- widening the raised median on Pacific Highway northbound (north and south of Fox Valley Road) to improve road curve and lane alignment
- banning the right turn from Marshall Avenue onto Pacific Highway southbound
- providing a 'Do Not Queue Across Intersection' sign on Pacific Highway southbound at Borambil Avenue
- banning the right turn from Finlay Road onto Pacific Highway southbound

Site 3 – Pacific Highway at Coonanbarra Road and Redleaf Avenue, Wahroonga

- widening on the northbound side of Pacific Highway (north and south of Redleaf Avenue) to provide three continuous northbound through lanes
- banning the right turn from Pacific Highway northbound into Coonanbarra Avenue
- maintaining the right turn bay from Pacific Highway northbound into Redleaf Avenue
- widening the raised median on Pacific Highway northbound (south of Redleaf Avenue) to improve road curve and lane alignment
- providing a pedestrian refuge on Redleaf Avenue
- installing pedestrian traffic signals on Redleaf Avenue
- new drainage network south of Redleaf Avenue to accommodate for the road widening
- option for installing a solid retaining wall of 1.2m height on the receiver property at 1630 Pacific Highway, Wahroonga

Site 4 – Site compound at 1334 Pacific Highway, Turramurra

- the site compound is intended for the site office, stockpile area, concrete washout, laydown hardstand for materials, staff parking and refuelling of plant and equipment
- the site compound would be established on relatively level ground and away from areas of ecological value, and would be situated within an existing locally listed heritage conservation area and heritage items
- no utility relocation would be required for the purposes of the site compound
- stockpiling of excavated or raw material may be required at the proposed site compound
- no tree removal would be required for the purposes of the site compound, however some minor trimming may be required to facilitate access for heavy vehicles

2.2 Noise Catchment Areas

The following noise catchment areas (NCAs) were nominated to provide an assessment of areas exposed to construction noise impacts.

Table 2.1 – Noise Catchment Areas

NCA	Description
Site 1 – Pacific Highway at Finlay Road, Warrawee/Turramurra	
NCA 1A	Noise catchment area directly adjacent to the project area with direct line of sight to the construction works and predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels >25dB(A) above the applicable construction noise management level (NML)
NCA 1B	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 15dB(A) and 25dB(A) above the applicable NML. This NCA would typically be behind rows of buildings

NCA	Description
NCA 1C	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 5dB(A) and 15dB(A) above the applicable NML. This NCA would typically be behind rows of buildings
NCA 1D	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are <5dB(A) above the applicable NML. This NCA would typically be behind rows of buildings and well removed from the project site
Site 2 – Pacific Highway at Fox Valley Road, Wahroonga/Warrawee	
NCA 2A	Noise catchment area directly adjacent to the project area with direct line of sight to the construction works and predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels >25dB(A) above the applicable construction noise management level (NML)
NCA 2B	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 15dB(A) and 25dB(A) above the applicable NML. This NCA would typically be behind rows of buildings
NCA 2C	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 5dB(A) and 15dB(A) above the applicable NML. This NCA would typically be behind rows of buildings
NCA 2D	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are <5dB(A) above the applicable NML. This NCA would typically be behind rows of buildings and well removed from the project site
Site 3 – Pacific Highway at Coonanbarra and Redleaf Avenue, Wahroonga	
NCA 3A	Noise catchment area directly adjacent to the project area with direct line of sight to the construction works and predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels >25dB(A) above the applicable construction noise management level (NML)
NCA 3B	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 15dB(A) and 25dB(A) above the applicable NML. This NCA would typically be behind rows of buildings
NCA 3C	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 5dB(A) and 15dB(A) above the applicable NML. This NCA would typically be behind rows of buildings
NCA 3D	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are <5dB(A) above the applicable NML. This NCA would typically be behind rows of buildings and well removed from the project site
Site 4 – Site Compound at 1334 Pacific Highway, Turramurra	
NCA 4A	Noise catchment area directly adjacent to the project area with direct line of sight to the construction works and predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels >25dB(A) above the applicable construction noise management level (NML)
NCA 4B	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 15dB(A) and 25dB(A) above the applicable NML. This NCA would typically be behind rows of buildings
NCA 4C	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are between 5dB(A) and 15dB(A) above the applicable NML. This NCA would typically be behind rows of buildings
NCA 4D	Noise catchment area predicted to be exposed to $L_{Aeq(15min)}$ construction noise levels that are <5dB(A) above the applicable NML. This NCA would typically be behind rows of buildings and well removed from the project site

Figure 1 to Figure 4 present the project site and surrounds of the study area.

2.3 Construction Hours

To minimise disruption to traffic and potential safety risks to construction personnel and road users it would be necessary to carry out most of the works outside of standard hours. The proposed construction hours are as follows:

- Evening / night (out of hours) work hours: 8pm to 5am, Sunday to Thursday
- No works on public holidays

It is anticipated that work would be conducted for a maximum of five night shifts per week. High noise generating activities, such as saw cutting and jackhammering, would take place prior to midnight.

The duration of the works is estimated to be up to 18 months.

Figure 1 – Locality Map for Site 1 – Pacific Highway at Finlay Road, Warrawee/Turramurra

Figure 2 – Locality Map for Site 2 – Pacific Highway at Fox Valley Road, Wahroonga/Warrawee

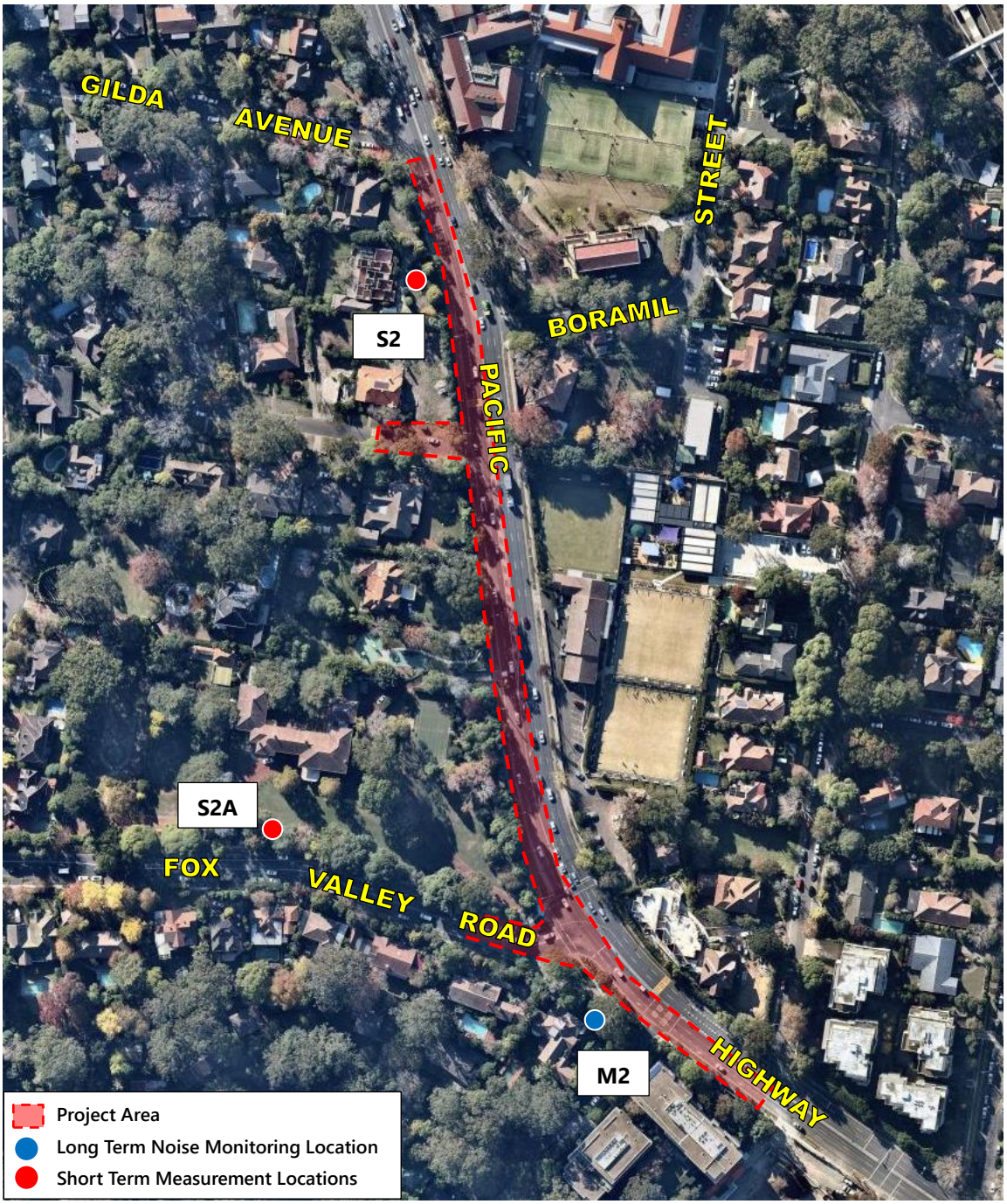


Figure 3 – Locality Map for Site 3 – Pacific Highway at Coonanbarra Road and Redleaf Ave, Wahroonga

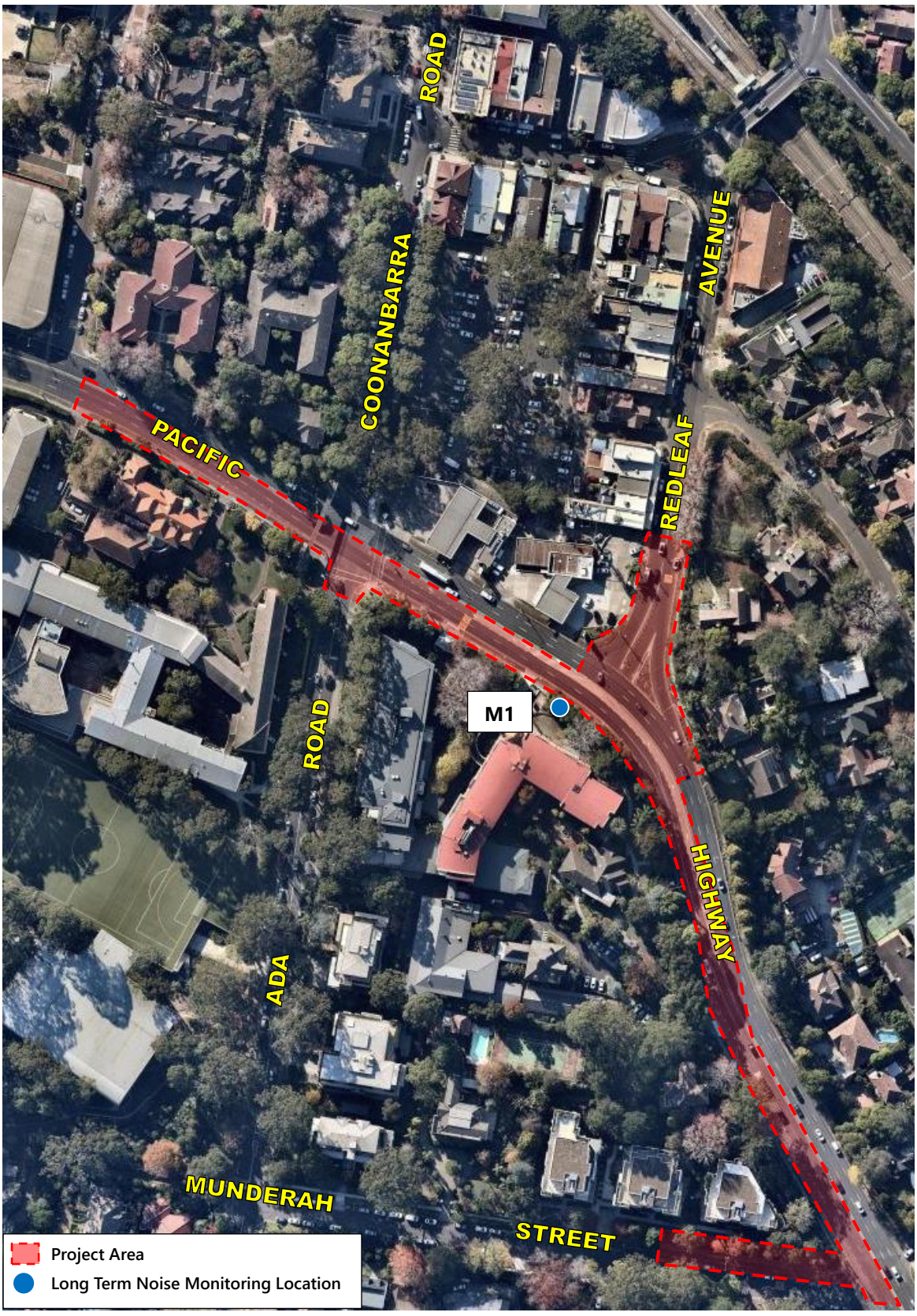
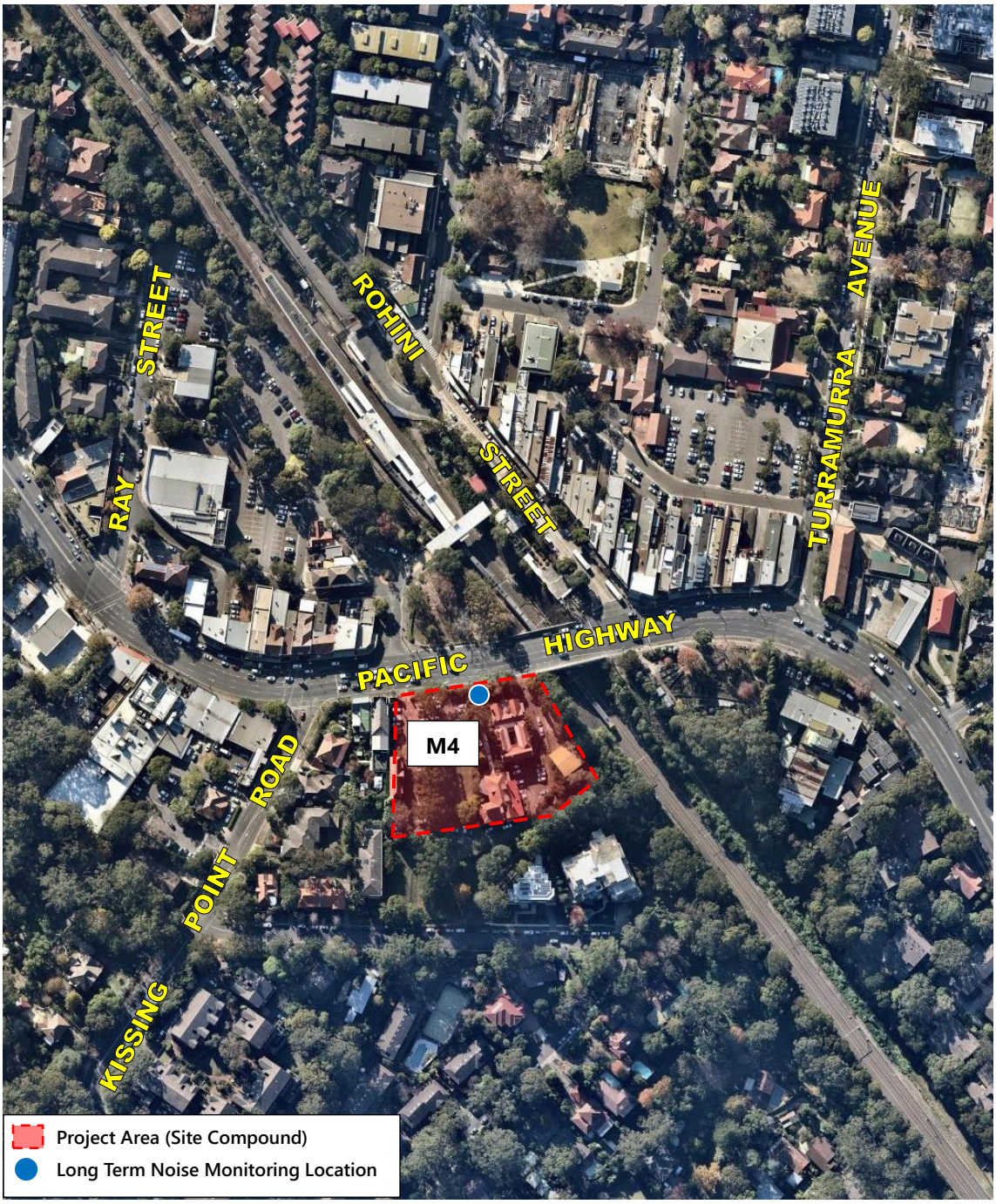


Figure 4 – Locality Map for Site 4 – Site compound at 1334 Pacific Highway, Turramurra



3 Existing Noise Environment

3.1 Noise Monitoring Locations

To determine existing L_{eq} traffic noise levels and L_{90} background noise levels along the Pacific Highway and near the intersection upgrade sites, noise monitoring was undertaken at the following locations.

Table 3.1 – Noise Monitoring Location

Location	Address	Description
M1	1630 Pacific Highway, Wahroonga (Aged Care Facility)	Noise monitor was located in the free field (ie. away from the building) on the eastern side of the property, facing the Pacific Highway, with line of sight to the Pacific Highway and at a distance of approximately 10m from the edge of the existing Pacific Highway carriageway. Noise environment representative of the nearest affected sensitive receivers surrounding Site 3.
M2	2 Fox Valley Road, Wahroonga (residence)	Noise monitor was located in the free field on the eastern side of the property, facing the Pacific Highway. The noise monitor was placed so that the microphone was positioned above the boundary fence at approximately 1.8m high to obtain a line of sight to the Pacific Highway and at a distance of approximately 6m from the edge of the existing Pacific Highway carriageway. Noise environment representative of the nearest affected sensitive receivers surrounding Site 2.
M3	1458 Pacific Highway, Turramurra (residence)	Noise monitor was located in the free field on the eastern side of the property, facing the Pacific Highway, with line of sight to the Pacific Highway and at a distance of approximately 9m from the edge of the existing Pacific Highway carriageway. Noise environment representative of the nearest affected sensitive receivers surrounding Site 1.
M4	1334 Pacific Highway, Turramurra (car park area / Hillview Community Care Centre)	Noise monitor was located in the free field on the eastern side of the property, facing the Pacific Highway, with line of sight to the Pacific Highway and at a distance of approximately 10m from the edge of the existing Pacific Highway carriageway. Noise environment representative of the nearest affected sensitive receivers surrounding Site 4.
S2	1558 Pacific Highway, Wahroonga (residence)	Short term noise measurement location was in the free-field, with a clear line of sight to the Pacific Highway and approximately 15m from the edge of the existing carriageway. Noise environment was considered to be representative of the nearest affected sensitive receivers on the Pacific Highway on the northern end of Site 2.
S2A	Mahratta / School of Practical Philosophy - Wahroonga	Short term noise measurement location was in the free-field, with a partial line of sight to the Pacific Highway and partial line of sight to Fox Valley Road. The location was approximately 100m from the edge of the existing carriageway of the Pacific Highway and approximately 15m from the edge of the carriageway of Fox Valley Road. Noise environment representative of the nearest affected sensitive receivers along Fox Valley Road for works undertaken at Site 2.

Figure 1 to Figure 4 above show the noise monitoring locations.

Long term (unattended) noise monitoring was conducted between Friday 1st and Wednesday 13th June 2018.

The monitoring positions were selected to be representative of the nearest potentially impacted sensitive receivers (residential properties). The monitoring locations were outside the areas of where the proposed intersection upgrade works would occur, and therefore, the monitoring locations would

be unaffected by any widening of the carriageways. This allows the exact monitoring locations to be re-established should it be necessary to replicate the measurements once the upgrades are completed to aid in determining any relative change in traffic noise levels due to the upgrades.

Weather information was obtained from the Bureau of Meteorology for the area over the monitoring period and any data adversely affected by rain, wind or extraneous noise were excluded.

The graphical output from long term noise monitoring is included in Appendix D of this report. The monitoring data was analysed to determine a single assessment background level (ABL) for each day, evening and night period, in accordance with the NSW 'Noise Policy for Industry' (NPfI, 2017).

Additionally, the $L_{Aeq(15\ hour)}$ and $L_{Aeq(9\ hour)}$ traffic noise descriptors were determined in order to assess existing traffic noise.

3.2 Existing Traffic & Background Noise Levels

Existing road traffic and background noise levels at the monitoring locations are presented in Table 3.2 below.

Table 3.2 – Measured Existing Traffic (L_{eq}) & Background (L_{90}) Noise Levels, dB(A)

Location	Address	L_{Aeq} Traffic Noise Levels		L_{A90} Background Noise Levels		
		Day $L_{Aeq(15\ hour)}$	Night $L_{Aeq(9\ hour)}$	Day	Evening	Night
M1	1630 Pacific Highway, Wahroonga	73	70	60	56	41
M2	2 Fox Valley Road, Wahroonga	74	71	61	59	44
M3	1458 Pacific Highway, Turramurra	73	70	60	58	40
M4	1334 Pacific Highway, Turramurra	71	69	60	58	41
S2	1558 Pacific Highway, Wahroonga[1]	67	64	-	-	-
S2A	Mahratta / School of Practical Philosophy - Wahroonga[1]	57	54	-	-	-

Notes: 1. Short term measurement results correlated with long term monitoring results at Location M2 to determine equivalent $L_{Aeq,(15\ hour)}$ and $L_{Aeq(9\ hour)}$ traffic noise levels

4 Construction Noise Assessment

4.1 Construction Noise Criteria

4.1.1 Construction Noise Management Levels at Residences

The Roads and Maritime Services' 'Construction Noise and Vibration Guideline' (CNVG – April 2016) provides guidance for the establishment of construction noise management levels (NMLs) and the methods for assessing construction noise. There are two parts to the CNVG that are used to determine the type of assessment required to be undertaken:

- Duration of the impact to affected receivers; and
- Number of affected receivers.

The proposed intersection works are anticipated to occur for a duration of more than six weeks and the number or receivers potentially affected by the noise impacts would be many, in accordance with the CNVG.

Based on the proposed duration of works and many affected receivers, a quantitative assessment in accordance with the noise objectives of the NSW 'Interim Construction Noise Guideline' (ICNG, DECC 2009) is to be undertaken. Table 4.1 below (reproduced from Table 2 of the ICNG) sets out the noise management levels for residences and how they are to be applied.

The guideline intends to provide respite for residents exposed to excessive construction noise outside the recommended standard hours whilst allowing construction during the recommended standard hours without undue constraints.

The rating background level (RBL) is used when determining the NMLs. The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours).

Table 4.1 – Noise Management Levels at Residential Receivers

Time of Day	Management Level $L_{Aeq\ (15\ min)}$*	How to Apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10dB(A)	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq\ (15\ min)}$ 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.

Time of Day	Management Level $L_{Aeq\ (15\ min)}$*	How to Apply
	Highly noise affected 75dB(A)	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: • 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	Noise affected RBL + 5dB(A)	A strong justification should 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 ICNG.

* Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 metres above ground level. If the property boundary is more than 30 metres from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 metres of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Residential receivers are considered 'noise affected' where construction noise levels are greater than the NMLs identified in Table 4.1 above. The noise affected level represents the point above which there may be some community reaction to noise. Where predicted and/or measured construction noise levels exceed NMLs, all feasible and reasonable work practices will be applied to meet the management levels.

During standard construction hours, a highly affected noise objective of $L_{Aeq(15min)}$ 75 dB(A) applies at all receivers.

Table 4.2 presents the construction NMLs established for the nearest affected noise sensitive residential receivers based upon the noise monitoring results outlined in Section 3.2, the proposed construction hours and the above ICNG requirements.

Table 4.2 – Construction Noise Management Levels at Residential Receivers, dB(A)

Receiver Location	Assessment Period	Noise Management Level $L_{Aeq(15\ min)}$
All residential receivers surrounding **Site 1**	Evening (outside standard hours)[1]	58 + 5 = **63**
	Night (outside standard hours)[2]	40 + 5 = **45**
All residential receivers surrounding **Site 2**	Evening (outside standard hours)[1]	59 + 5 = **64**
	Night (outside standard hours)[2]	44 + 5 = **49**
All residential receivers surrounding **Site 3**	Evening (outside standard hours)[1]	56 + 5 = **61**
	Night (outside standard hours)[2]	41 + 5 = **46**
All residential receivers surrounding **Site 4**	Evening (outside standard hours)[1]	53 + 5 = **58**
	Night (outside standard hours)[2]	41 + 5 = **46**

Notes: 1. Evening period represents the construction hours period from 8pm to 10pm
2. Night period represents the construction hours period from 10pm to 5am

4.1.2 Sleep Disturbance

Given that night works are to occur, noise emanating from construction works associated with the project has been assessed for its potential to disturb sleep. The NSW EPA has made the following policy statement with respect to sleep disturbance:

"Peak noise level events, such as reversing beepers, noise from heavy items being dropped or other high noise level events, have the potential to cause sleep disturbance. The potential for high noise level events at night and effects on sleep should be addressed in noise assessments for both the construction and operational phases of a development. The INP does not specifically address sleep disturbance from high noise level events.

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 LA1, (1 minute) not exceeding the LA90, (15 minute) 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 detailed analysis should cover the maximum noise level or LA1, (1 minute), that is, the extent to which the maximum noise level exceeds the background level and the number of times this happens during the night-time period. Some guidance on possible impact is contained in the review of research results in the NSW Road Noise Policy. Other factors that may be important in assessing the extent of impacts on sleep include:

- *how often high noise events will occur*

- *time of day (normally between 10pm and 7am)*

- *whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).*

The LA1, (1 minute) descriptor is meant to represent a maximum noise level measured under 'fast' time response. The EPA will accept analysis based on either LA1, (1 minute) or LA, (Max)."

Source: http://www.epa.nsw.gov.au/noise/applicnotesindustnoise.htm Downloaded: 04.12.2014

Where the background noise levels are less than 40dB(A), some studies indicate that the above approach may result in noise limits that are unnecessarily strict.

In relation to maximum noise level events, the NSW 'Road Noise Policy' (NSW EPA, 2012) identifies several investigations into the impacts of intermittent and emerging noise sources on the disturbance of

sleep. Reference is made to enHealth report (2004) which notes the following in relation to maximum noise level events:

> *"As a rule in planning for short-term or transient noise events, for good sleep over 8 hours the indoor sound pressure level measured as a maximum instantaneous value should not exceed approximately 45 dB(A) LAmax more than 10 or 15 times per night."*

The NSW 'Road Noise Policy' summaries the research on sleep disturbance to date as follows:

- *maximum internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep*
- *one or two noise events per night, with maximum internal noise levels of 65–70 dB(A), are not likely to affect health and wellbeing significantly*

The above references identify that internal noise levels of 45dB(A) and up to 55dB(A), may have the potential to impact sleep but are unlikely to cause awakenings. On the assumption that there is a 10dB(A) outside-to-inside noise loss through an open window, the above references indicate that external noise levels of L_{Amax} 55 to 65dB(A) are unlikely to cause awakening reactions.

To assess the likelihood of sleep disturbance, an initial screening level of (L_{Amax} or $L_{A1(1min)} \leq L_{A90(15min)}$ + 15dB(A) is used. In situations where this results in an external screening level of less than 55dB(A), a minimum screening level of 55dB(A) is set. Note that this is equivalent to a maximum internal noise level of 45dB(A) with windows open.

Where there are noise events found to exceed the initial screening level, further analysis is made to identify:

- the likely number of events that might occur during the night assessment period
- Whether events exceed an 'awakening reaction' level of $L_{A1(1min))}$ 65dB(A).

Therefore, based on the measured RBLs for the night period the initial screening levels applicable for each site are as follows:

- Site 1 Initial Screening level - $L_{A90(15min)}$ + 15 = (40+15) = **55dB(A)**
- Site 2 Initial Screening level - $L_{A90(15min)}$ + 15 = (44+15) = **59dB(A)**
- Site 3 Initial Screening level - $L_{A90(15min)}$ + 15 = (41+15) = **56dB(A)**
- Site 4 Initial Screening level - $L_{A90(15min)}$ + 15 = (41+15) = **56dB(A)**

Therefore, based on the above information, the sleep disturbance assessment levels for the project are presented in Table 4.3.

Table 4.3 – $L_{A1,1min}$ (or L_{Amax}) Sleep Disturbance Assessment Levels

Receiver Location	External Screening Level ($L_{A90,15min}$ + 15)	Awakening Reaction Level
All residential receivers surrounding **Site 1**	55dB(A)	65dB(A)
All residential receivers surrounding **Site 2**	59dB(A)	65dB(A)
All residential receivers surrounding **Site 3**	56dB(A)	65dB(A)
All residential receivers surrounding **Site 4**	56dB(A)	65dB(A)

4.2 Construction Noise Sources

The following table lists major plant and equipment likely to be used by the contractor to carry out the necessary construction activities for this project and their corresponding sound power levels.

Table 4.4 – Typical Activities & Sound Power Levels, dB(A) re. 1pW

Construction Activity	Associated Plant and Equipment	Activity Total L_{Aeq} Sound Power Levels	
		L_{Aeq}	L_{Amax}
Corridor Clearing / Vegetation Removal			
General land clearing. Tree and stump removal, topsoil stripping, loading	Bulldozer	121[1]	126[2]
	Excavator (tracked) 35T		
	Chainsaw		
	Tub Grinder / Mulcher		
	Dump Truck		
Corridor Clearing / Demolition			
House / building demolition	Excavator (tracked) 35T	122[1]	126[2]
	As above with Hydraulic Hammer		
	Front End Loader 23T		
	Dump Truck		
Site Establishment			
Installing construction boundary fences and traffic barriers	Truck (medium rigid)	115[1]	116[1]
	Road Truck		
	Scissor Lift		
	Franna Crane		
Utility, Property & Service Adjustment			
Relocate underground and above ground utilities including adjusting utility covers; property adjustments	Excavator (tracked) 35T	116[1]	116[1]
	Dump Truck		
	Franna Crane		
	Concrete Saw		
	Power Generator		

Construction Activity	Associated Plant and Equipment	Activity Total L_{Aeq} Sound Power Levels	
		L_{Aeq}	L_{Amax}
Drainage Infrastructure			
Stormwater drainage works and installation	Excavator (tracked) 35T	115[1]	116[1]
	Franna Crane		
	Concrete Truck		
	Truck Compressor		
	Vibratory Roller		
	Road Truck		
Re-surfacing Works			
Re-surfacing of road surfaces	Daymakers	118[1]	123[1]
	Pavement Profiler		
	Dump Truck		
	Front End Loader		
	Pavement Laying Machine		
	Asphalt Truck & Sprayer		
	Smooth Drum Roller		
Retaining walls			
Construction of retaining walls	Piling rig – bored	116[1]	130[1]
	Power Generator		
	Mobile Crane		
	Concrete Vibrator		
	Concrete Pump		
	Welding equipment		
	Excavator (tracked) 35T		
	Air Track Drill		
Paving / Asphalting			
Construction of new kerbs, gutters and driveways; construct new road pavement including subgrade improvements, sub base / base material placements; laying concrete and asphalt over widened section of road	Paving Laying Machine	118[1]	130[1]
	Dump Truck		
	Asphalt Truck & Sprayer		
	Concrete Truck		
	Smooth Drum Roller		
	Concrete Saw		
Road Furniture Installation			
Install traffic signals and associated equipment; Removal of redundant signage and installation of new signage; line marking	Road Truck	110[1]	116[1]
	Scissor Lift		
	Franna Crane 20T		
	Line Marking Truck		
Compound Operation			
	Front end loader	114[1]	116[1]

Construction Activity	Associated Plant and Equipment	Activity Total L_{Aeq} Sound Power Levels	
		L_{Aeq}	L_{Amax}
Delivers; plant and equipment; maintenance; office areas; storage areas	Excavator (tracked) 35t		
	Road truck		
	Compressor		
	Welding equipment		
	Light vehicles		
	Power generator		

Notes:
1. Sound power level based on data presented in the Roads and Maritime Services Construction Noise Estimator Spreadsheet tool
2. Sound power level based on data from previous projects and/or data from Renzo Tonin & Associates library

The sound power levels for the construction activities presented in the above table are typically based on the source list presented in the 'Roads and Maritime Services Construction Noise Estimator' spreadsheet tool. Where data was not available from the Roads and Maritime Services tool, then data was obtained from previous projects or Renzo Tonin & Associates' library database.

4.3 Construction Noise Assessment

As discussed previously, construction work is anticipated to be undertaken outside of standard construction hours, typically between 8pm and 5am from Sunday to Thursday.

Based on the proposed construction activities presented in Table 4.4, the relevant activities for each site, with the highest total L_{Aeq} sound power levels, used for a conservative assessment are as follows:

- Site 1, Site 2 and Site 3: Corridor Clearing, Re-surfacing and Paving / Asphalting
- Site 4: Compound Operation

Construction noise impacts were predicted using the 'Roads and Maritime Services Construction Noise Estimator' spreadsheet tool to determine the distances where the corresponding NCAs listed in Table 2.1 would be applicable for the activity described above and are presented in Figures 5 to Figure 11.

Figure 5 – Site 1: NCAs Based on $L_{Aeq(15min)}$ Noise Levels for Corridor Clearing Roadworks

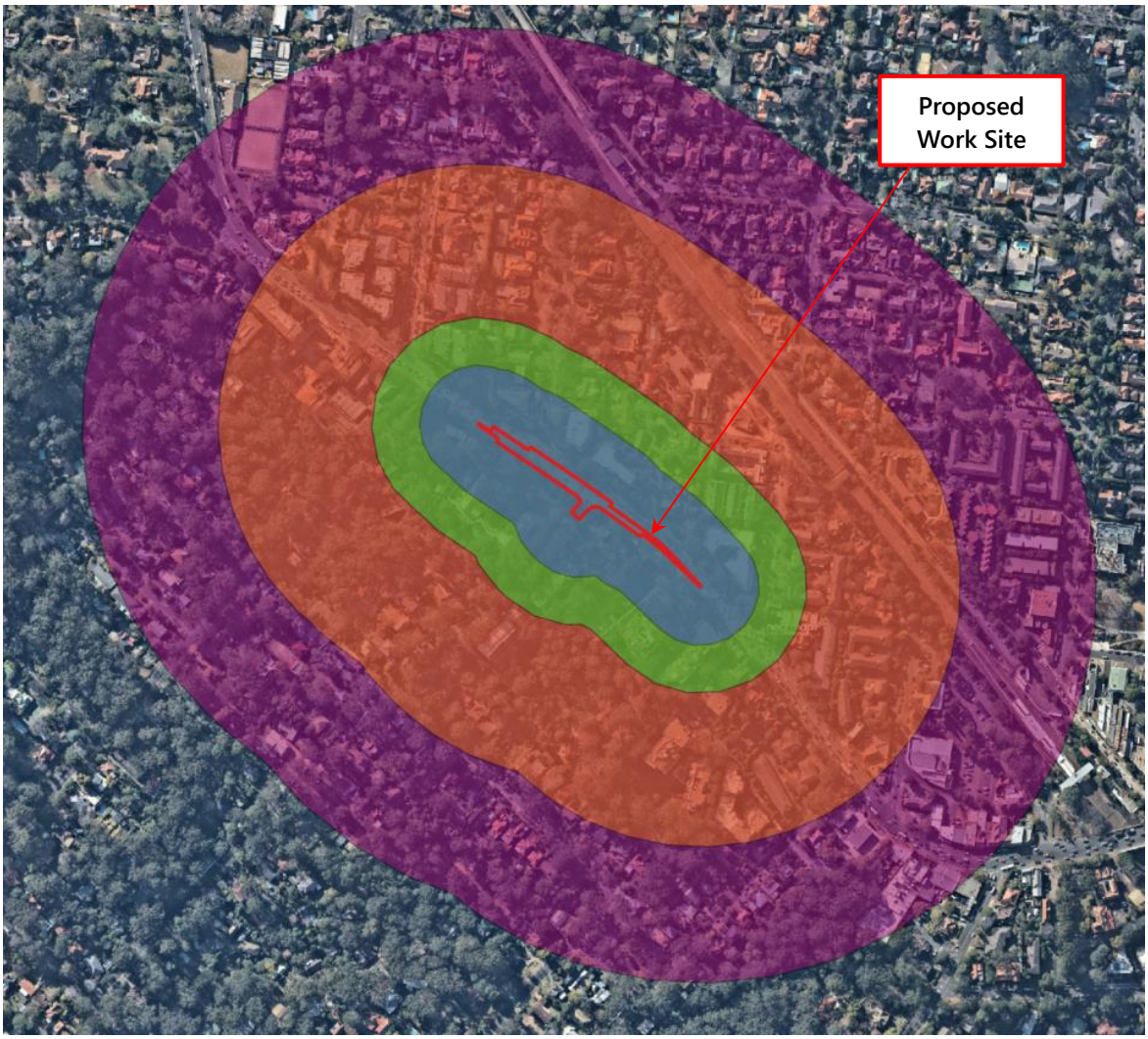
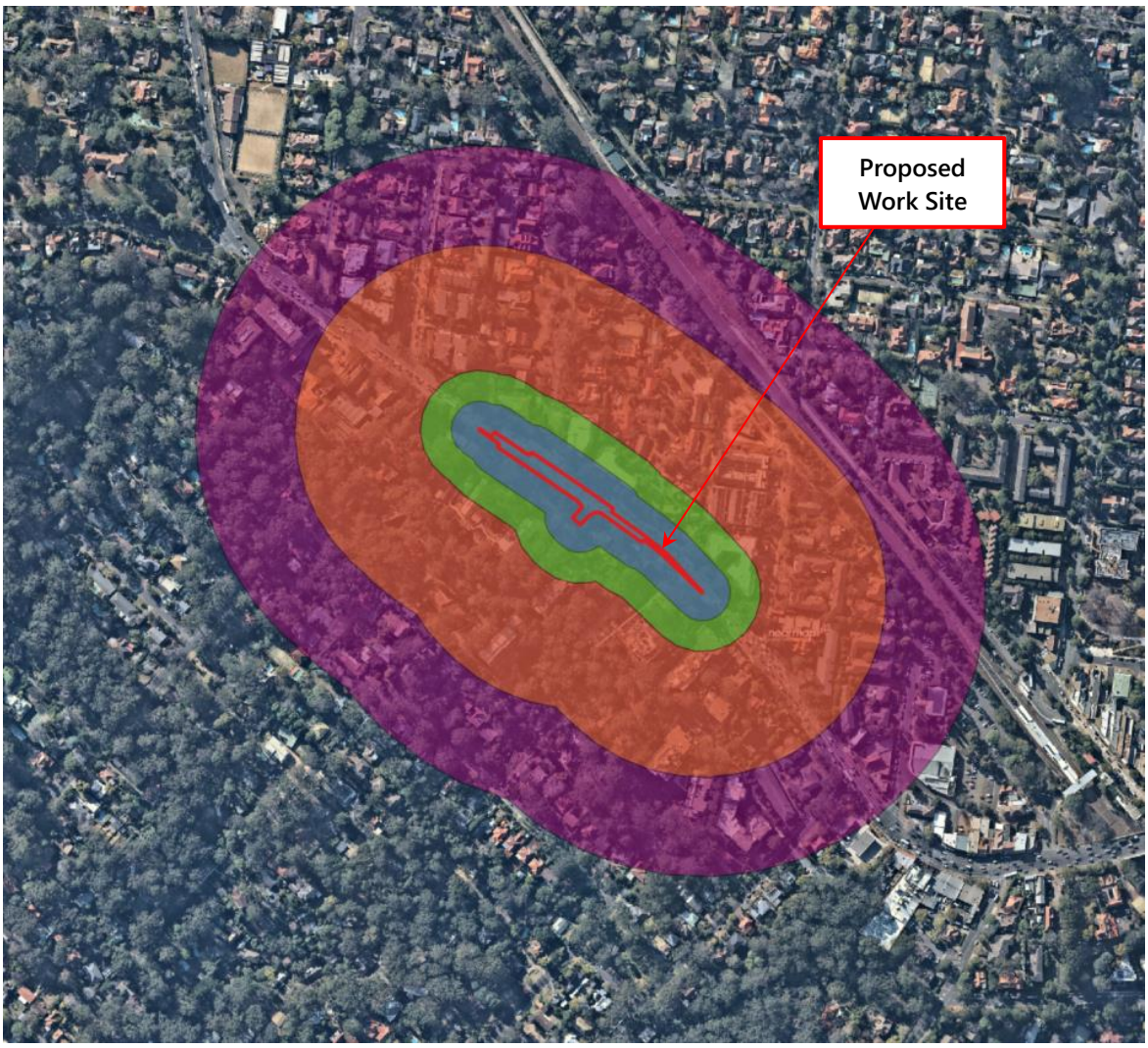


Figure 6 – Site 1: NCAs Based on $L_{Aeq(15min)}$ Noise Levels for Re-surfacing or Paving / Asphalting Roadworks



NCA 1A: 70dB(A) @ 32m [>25dB(A)]

NCA 1B: 60dB(A) @ 65m [15-25dB(A)]

NCA 1C: 50dB(A) @ 179m [5-15dB(A)]

NCA 1D: 45dB(A) @ 276m [<5dB(A)]

Figure 7 – Site 2: NCAs Based on $L_{Aeq(15min)}$ Noise Levels for Corridor Clearing Roadworks

Figure 8 – Site 2: NCAs Based on $L_{Aeq(15min)}$ Noise Levels for Re-surfacing or Paving / Asphalting Roadworks

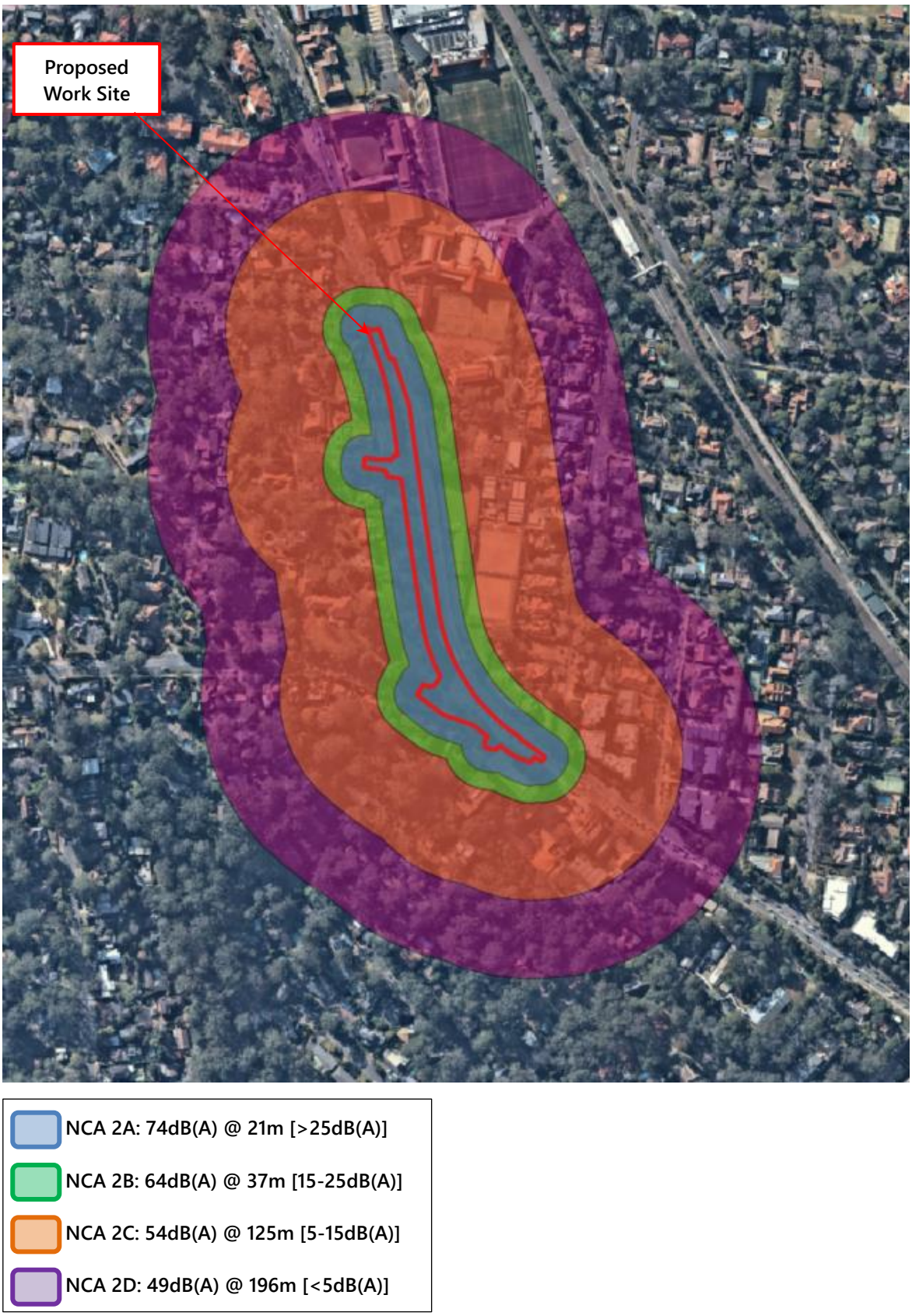


Figure 9 – Site 3: NCAs Based on $L_{Aeq(15min)}$ Noise Levels for Corridor Clearing Roadworks

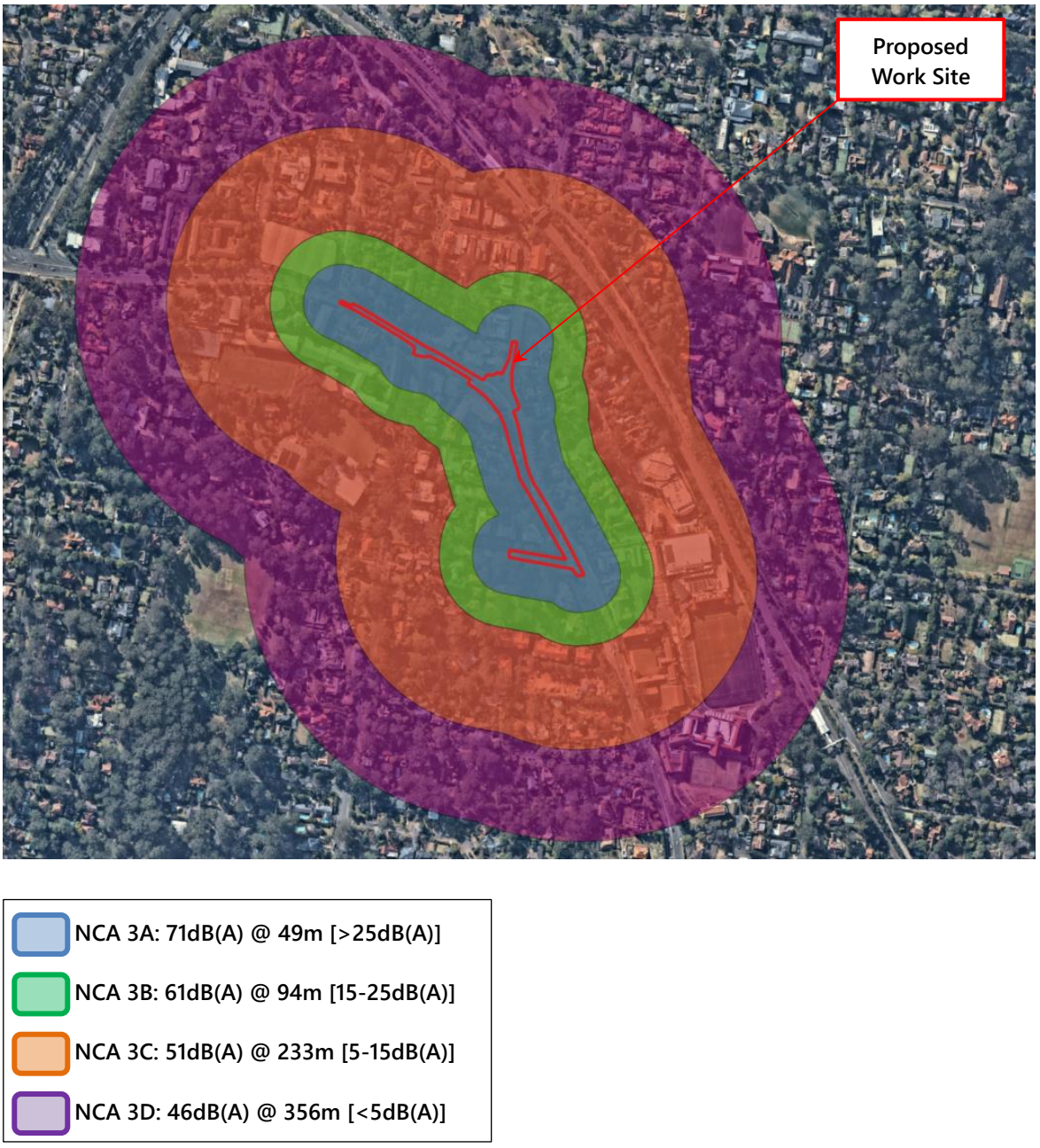


Figure 10 – Site 3: NCAs Based on $L_{Aeq(15min)}$ Noise Levels for Re-surfacing or Paving / Asphalting Roadworks

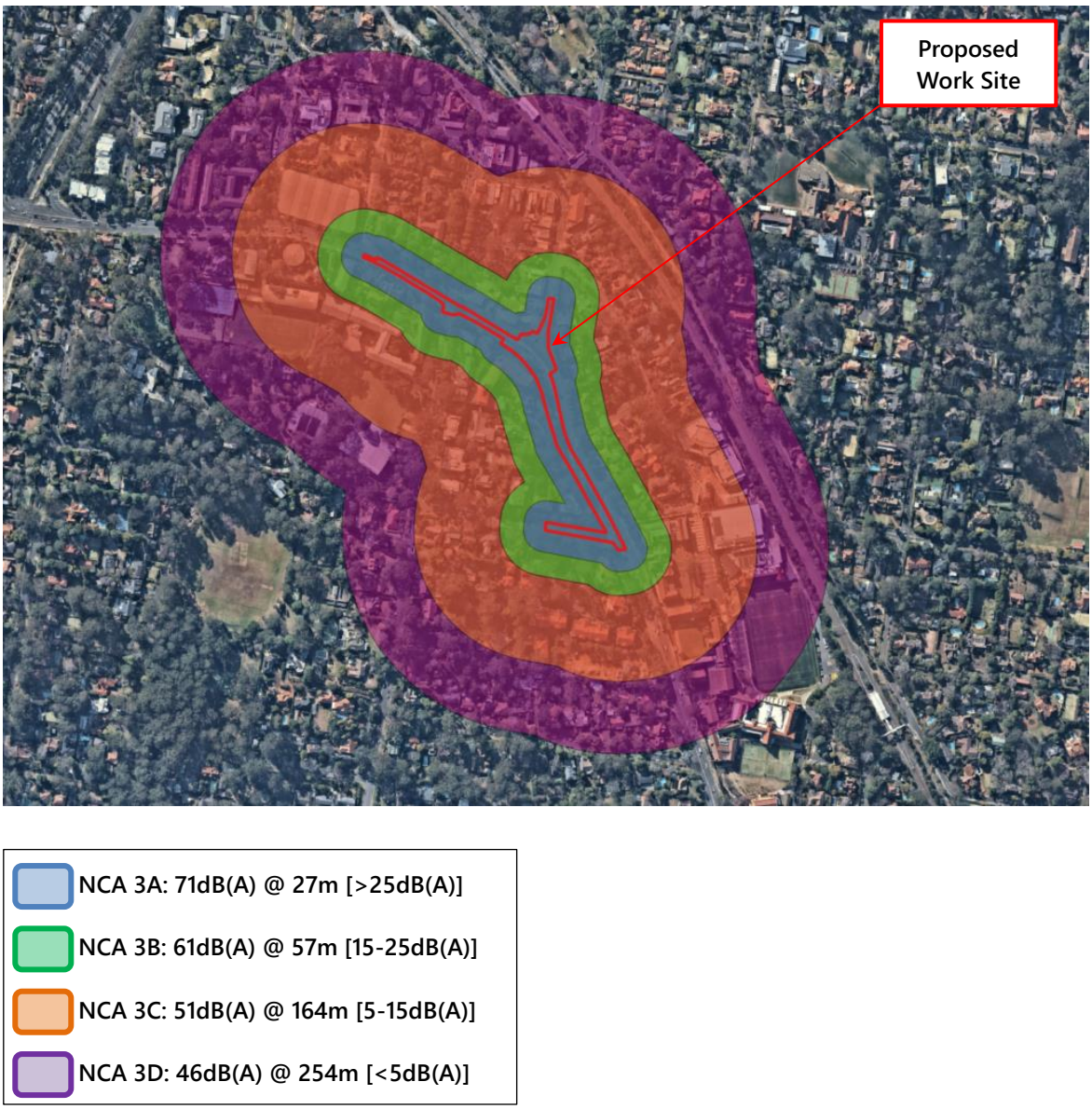
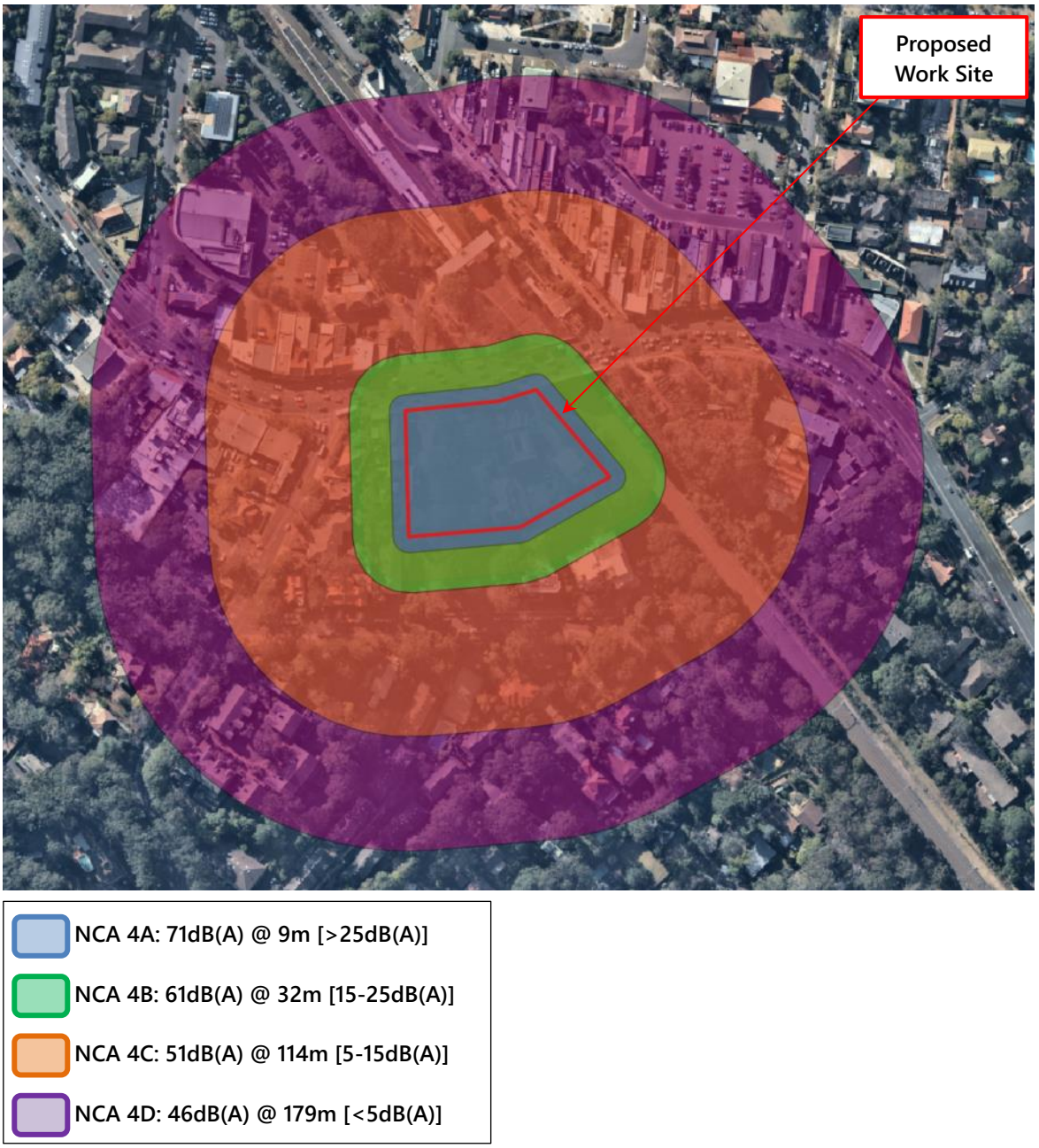


Figure 11 – Site 4: NCAs Based on $L_{Aeq(15min)}$ Noise Levels for Compound Operation



Based on predicted construction noise levels and the corresponding NCAs, a feasible and reasonable approach towards noise management measures is to be applied to reduce noise levels as much as possible to manage the impacts from construction noise.

Further details on construction noise mitigation and management measures are provided in Section 4.4.

4.3.1 Sleep Disturbance Assessment

In addition to the above predicted $L_{Aeq(15min)}$ noise levels for the corresponding NCAs, areas where the L_{Amax} noise levels at residential receivers during night time works would cause sleep disturbance [ie. >65dB(A)] are presented in Figure 12 to Figure 15.

As discussed previously, in accordance with the ICNG the sleep disturbance assessment is only applicable where construction works are planned to extend over more than two consecutive nights.

For the night time works, the maximum noise level predictions have been based on the L_{Amax} levels for paving / asphalting (Site 1, Site 2 and Site 3) and site compound operation (Site 4) noise to produce a conservative assessment for each area of the project.

Figure 12 – Site 1: Areas Impacted by Maximum Noise Levels Due to Roadworks

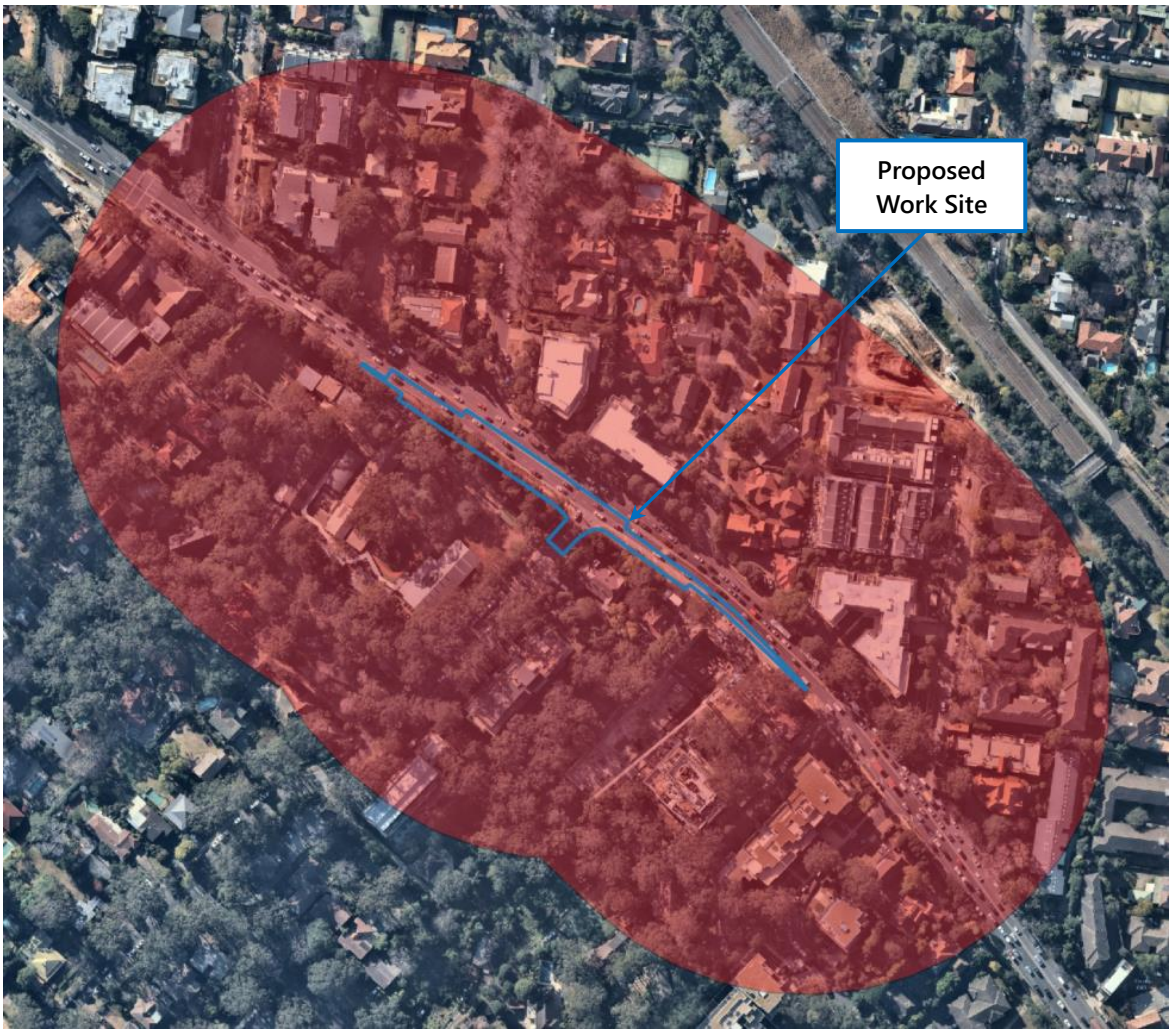


Figure 13 – Site 2: Areas Impacted by Maximum Noise Levels Due to Roadworks

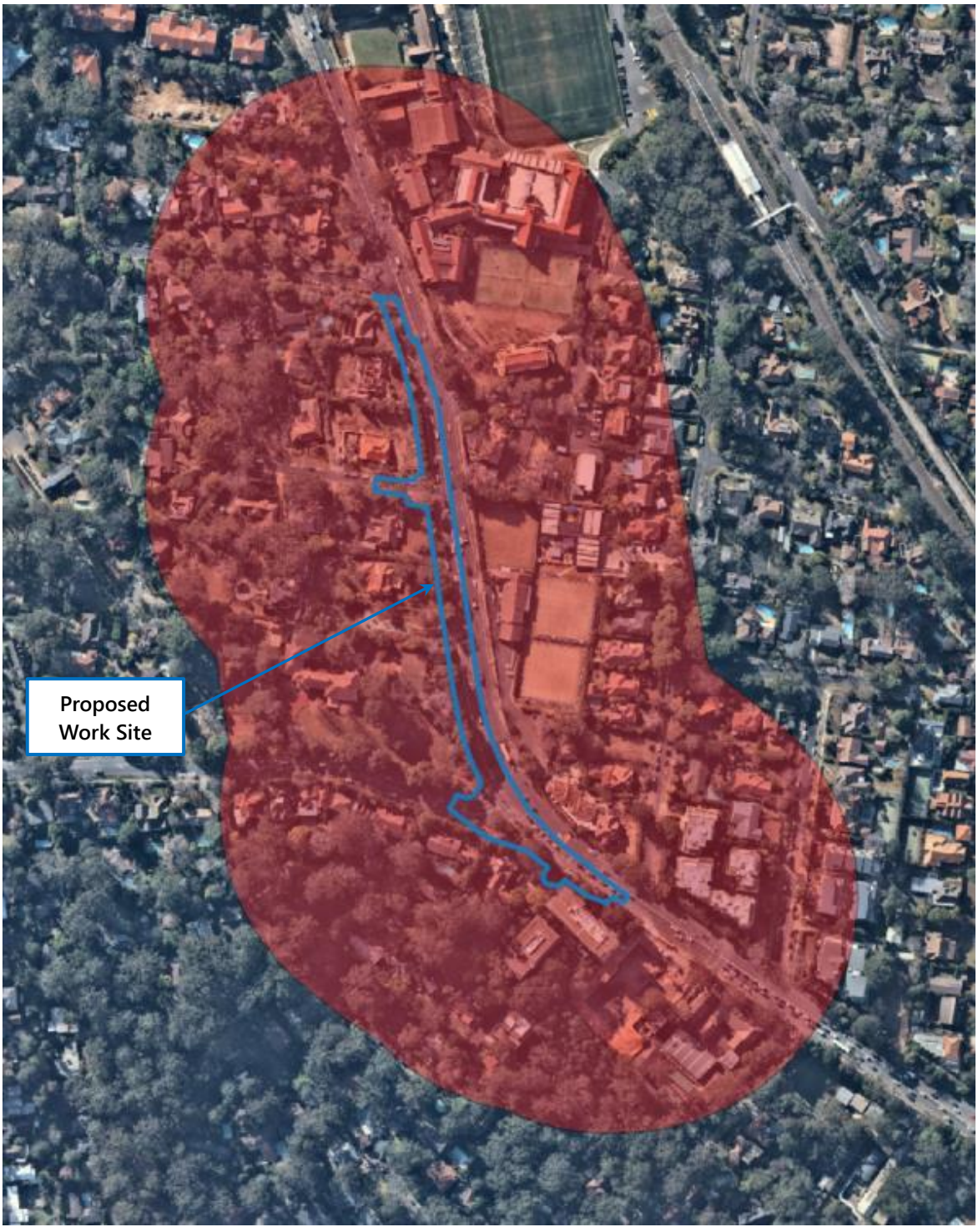


Figure 14 – Site 3: Areas Impacted by Maximum Noise Levels Due to Roadworks

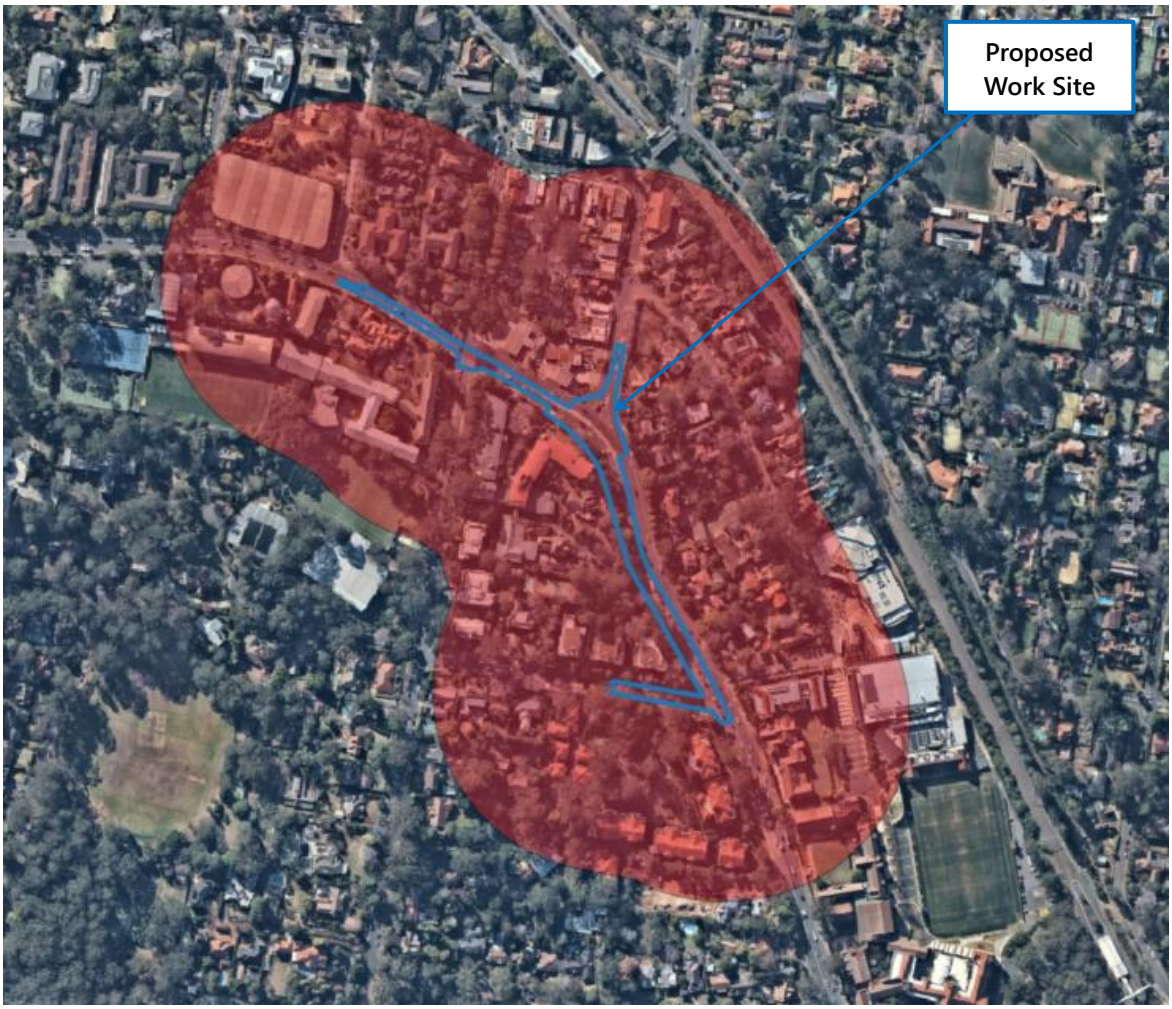
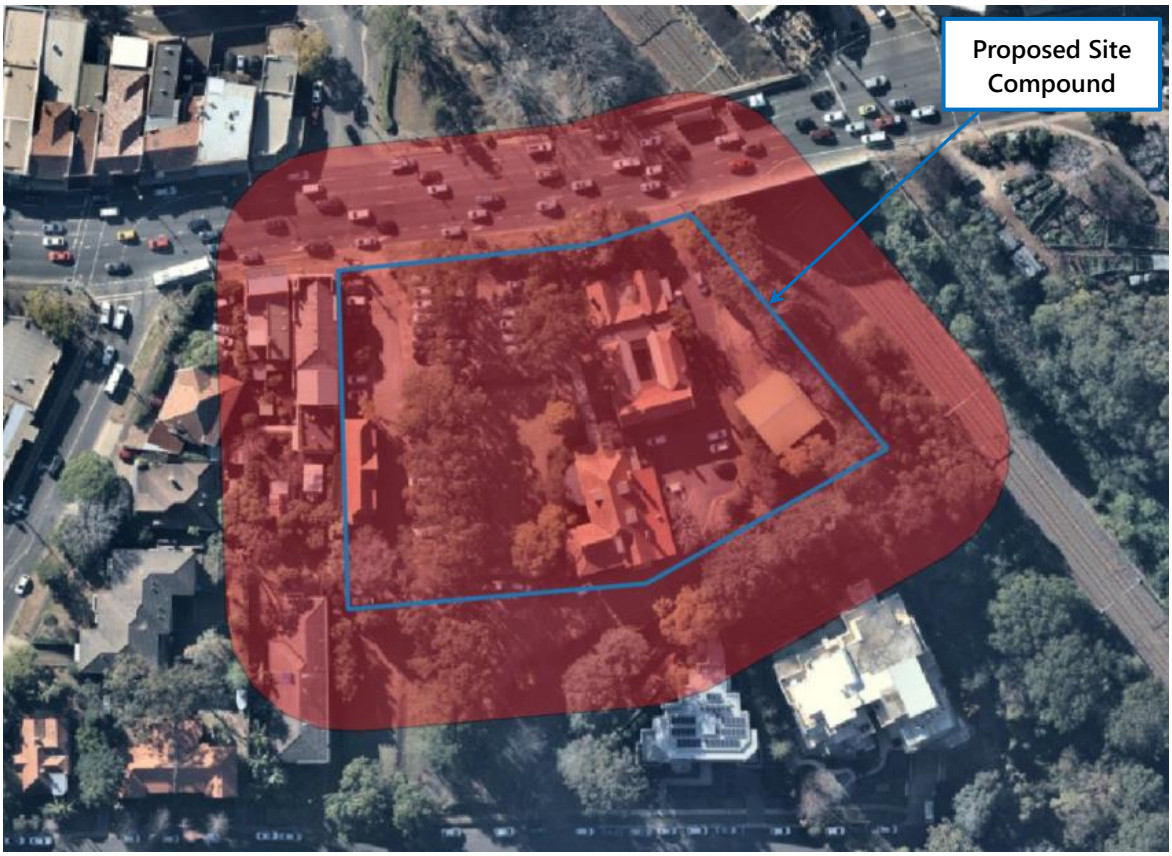


Figure 15 – Site 4: Areas Impacted by Maximum Noise Levels from Site Compound



It is recommended that attended noise measurements be undertaken at the nearest affected receivers once equipment is introduced on site at the beginning of night works to establish and quantify actual L_{Amax} noise levels on site. Where L_{Amax} noise levels are measured to exceed the sleep disturbance limit, then a reasonable and feasible approach towards noise management measures should be considered to reduce noise levels as much as possible to manage the impact from construction noise during night time periods. For example, noisier works such as jack hammering and saw cutting should be undertaken before 12am and the quieter works be undertaken after 12am.

4.4 Construction Noise Mitigation

The following recommendations provide in-principle noise control solutions in accordance with the CNVG to reduce construction noise impacts to the affected residential receivers. Where actual construction activities differ from those assessed in this report, more detailed design of noise control measures may be required.

The advice provided here is in respect of noise only. Supplementary professional advice may need to be sought in respect of fire ratings, structural design, constructability, fitness for purpose and the like.

4.4.1 General Noise Management Measures

Appendix B of the CNVG presents standard noise mitigation measures, which are reproduced in Table 4.5 below.

Table 4.5 – Standard Noise Mitigation Measures

Action Required	Details
Management Measures	
Implementation of any project specific mitigation measures required	Implementation of any project specific mitigation measures required
Implement community consultation or notification measures	Notification detailing work activities, dates and hours, impacts and mitigation measures, indication of work schedule over the night period, any operational noise benefits from the works (where applicable) and contact telephone number. Notification should be a minimum of 7 calendar days prior to the start of works. For projects other than maintenance works more advanced consultation or notification may be required. • Website (if required) • Contact telephone number for community • Email distribution list (if required) • Community drop in session (if required by approval conditions)

Action Required	Details
Site inductions	All employees, contractors and subcontractors are to receive an environmental induction. The induction must at least include: • all project specific and relevant 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	No swearing or unnecessary shouting or loud stereos/radios on site. No dropping of materials from height where practicable, throwing of metal items and slamming of doors.
Update Construction Environmental Management Plans	The CEMP must be regularly updated to account for changes in noise management issues and strategies
Source Controls	
Construction hours and scheduling	Where feasible and reasonable, construction should be carried out during the standard daytime working hours. Work generating high noise levels should be scheduled during less sensitive time periods.
Equipment selection	Use quieter and less noise emitting construction methods where feasible and reasonable. Ensure plant including the silencer is well maintained.
Plant noise levels	The noise levels of plant and equipment must have operating Sound Power or Sound Pressure Levels compliant with the criteria in Appendix F of the CNVG. Implement a noise monitoring audit program to ensure equipment remains within the more stringent of the manufacturers specifications or Appendix F of the CNVG.
Rental plant and equipment	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 the CNVG
Use and siting of plant	The offset distance between noisy plant and adjacent sensitive receivers is to be maximised. Plant used intermittently to be throttled down or shut down. Noise-emitting plant to be directed away from sensitive receivers. Only have necessary equipment on site.

Action Required	Details
Plan worksites and activities to minimise noise	Locate compounds away from sensitive receivers and discourage access from local roads. Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site. Where additional activities or plant may only result in a marginal noise increase and speed up works, consider limiting duration of impact by concentrating noisy activities at one location and move to another as quickly as possible. Very noisy activities such as jack hammering and saw cutting should be scheduled for normal working hours. If the work cannot be undertaken during the day, it should be completed before midnight. If programmed night works is postponed the work should be re-programmed and the approaches in the CNVG apply again.
Reduced equipment power	Use only the necessary size and power
Non-tonal and ambient sensitive reversing alarms	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 out of hours work. Consider the use of ambient sensitive alarms that adjust output relative to the ambient noise level.
Minimise disturbance arising from delivery of goods to construction sites	Loading and unloading of material/deliveries is to occur as far as possible from sensitive receivers. Select site access points and roads as far as possible away from sensitive receivers. Dedicated loading/unloading areas to be shielded if close to sensitive receivers. Delivery vehicles to be fitted with straps rather than chains for unloading, wherever possible. Avoid or minimise these out of hours movements where possible.
Path Controls	
Shield stationary noise sources such as pumps, compressors, fans etc.	Stationary noise sources should be enclosed or shielded where feasible and reasonable whilst ensuring that the occupational health and safety of workers is maintained. Appendix D of AS 2436:2010 lists materials suitable for shielding.
Shield sensitive receivers from noisy activities	Use structures to shield residential receivers from noise such as site shed placement; earth bunds; fencing; erection of operational stage noise barriers (where practicable) and consideration of site topography when situating plant.

4.4.2 Additional Noise Mitigation Measures

Appendix C of the CNVG provides details of additional noise mitigation measures to be applied when there are still exceedances of the NMLs after all the appropriate standard mitigation measures from Section 4.4.1 have been applied. Based on the NCAs established and presented in Figure 5 to Figure 10, the appropriate additional mitigation measures for each NCA are shown in Table 4.6.

Table 4.6 – Additional Noise Mitigation Measures for NCAs

Noise Catchment Area	NML, dB(A)	Predicted Noise Levels, dB(A)	Recommended Additional Mitigation Measures
Site 1 – Pacific Highway at Finlay Road, Warrawee/Turramurra			
Construction Noise from Work Site			
NCA 1A @ 57m	45	70	AA, N, PC, SN, R2, DR
NCA 1B @ 104m	45	60	N, PC, SN, R2, DR
NCA 1C @ 254m	45	50	N, R2, DR
NCA 1D @ 387m	45	45	N
Site 2 – Pacific Highway at Fox Valley Road, Wahroonga/Warrawee			
Construction Noise from Work Site			
NCA 2A @ 32m	49	74	AA, N, PC, SN, R2, DR
NCA 2B @ 65m	49	64	N, PC, SN, R2, DR
NCA 2C @ 179m	49	54	N, R2, DR
NCA 2D @ 276m	49	49	N
Site 3 – Pacific Highway at Coonanbarra and Redleaf Avenue, Wahroonga			
Construction Noise from Work Site			
NCA 3A @ 49m	46	71	AA, N, PC, SN, R2, DR
NCA 3B @ 94m	46	61	N, PC, SN, R2, DR
NCA 3C @ 233m	46	51	N, R2, DR
NCA 3D @ 356m	46	46	N
Site 4 – Site compound at 1334 Pacific Highway, Turramurra			
Construction Noise from Site Compound			
NCA 4A @ 9m	46	71	AA, N, PC, SN, R2, DR
NCA 4B @ 32m	46	61	N, PC, SN, R2, DR
NCA 4C @ 114m	46	51	N, R2, DR
NCA 4D @ 179m	46	46	N

A review of the recommended additional mitigation measures presented in the above table has been undertaken and the outcomes of the review are as follows.

- Letterbox drop (**N = notification**) has been recommended for receivers within NCA 1D, NCA 2D, NCA 3D and NCA 4D. The Roads and Maritime Services construction noise estimator tool indicates that **specific notification (SN)** should be delivered to the residences within NCA 1B, NCA 2B, NCA 3B and NCA 4B. The specific notification provides additional information and is provided to more highly affected receivers than covered in general letterbox drops. However, it is not reasonable to undertake separate notifications (one to residences within NCA 1B, NCA 2B, NCA 3B and NCA 4B, and the other residences within NCA 1C, NCA 2C, NCA 3C, NCA 4C, NCA 1D, NCA 2D, NCA 3D and NCA 4D) as this would likely cause community upset and confusion. Instead, a single coordinated message should be delivered to the affected community.

- **Phone calls (PC)** detailing relevant information made to identified / affected stakeholders within NCA 1B, NCA 2B, NCA 3B and NCA 4B are not considered to be practical due to high density of receivers which includes apartment buildings.

- **Respite offer (RO)** should be considered where there are high noise and vibration generating activities near receivers. RO proposes that works should be carried out in continuous blocks that do not exceed 3 hours each, with a minimum respite period of one hour between each block. The purpose of such offer is to provide residents with respite from an ongoing impact. However, this is not applicable to projects that are predominantly constructed at night as this would only cause nuisance to the residences and prolong the construction schedule. As such this mitigation offer is not recommended.

- **Respite period 2 (R2)** implies that works should be limited to two consecutive nights except for where there is a **Duration Respite (DR)**. For night works these periods of work should be separated by not less than one week and 6 nights per month.

- **Duration respite (DR)** is offered when works are unable to comply with R2. 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 completed more quickly. For this project it is proposed that the night works would occur in five-night blocks to reduce the overall works duration.

- **Alternate accommodation (AA)** may be offered to residents living in close proximity to construction works that are likely to experience highly intrusive noise levels. A review of whether **AA** is reasonable and feasible has been undertaken as follows:

  - Are works required beyond midnight? If so has a justification been provided?

    Yes. The night works are necessary to avoid peak traffic conditions during the day which would generate traffic impacts (as well as potential greater hazard and higher risk to worker safety). However, high noise generating activities such as jackhammering and saw cutting will be completed before 12am.

  - Does the surrounding area have a high density of receivers?

    Yes. The surrounding environment includes high density residential area with two multi-level apartment buildings.

  - Could temporary alternate accommodation be consistently applied?

    No, due to the high number of noise receivers within the noise catchment areas it would be impractical and difficult to consistently deliver alternate accommodation arrangements.

  - Will the application of duration respite mitigate noise impact?

    Yes, the works program has been condensed to reduce the overall duration of the works. The works are scheduled to be undertaken over five consecutive nights (weather permitting), respite generally on Friday and Saturday.

- Will receivers receive detailed information on the proposed work activities and mitigation measures to be applied?

  Yes, the letterbox drop contains information on the proposed works as well as the proposed mitigation measures including the scheduling of works and contact details for more information.

- Has the relevant Roads and Maritime Services Communications officer been consulted??

  Yes, the Communications officer verbally concurred with the above during the development of the communications plan.

Outcome of the evaluation process:

Alternate accommodation is not considered feasible or reasonable to implement. This would be reviewed in response to receiving a complaint.

Based on the above review of the recommended additional mitigation measures, the following additional mitigation measures are considered to be feasible and reasonable to implement in addition to the standard measures for the proposed intersection upgrade works.

1. Letterbox drop (**N = notification**) for receivers within NCA 1D, NCA 2D, NCA 3D and NCA 4D. Notifications should be detailing work activities, dates and hours, impacts and mitigation measures, indication of work schedule over the night time period, any operational noise benefits from the works (where applicable) and contact telephone number. Notification will be sent a minimum of seven (7) calendar days prior to the start of works.
2. Works are unable to comply with **Respite Condition 2 (R2)** which implies that works should be limited to two consecutive nights except for where there is a **Duration Respite (DR)**. It is considered beneficial to increase the work duration (up to five nights per week) so that the project can be completed more quickly. This additional mitigation measure would be adopted and captured within the pre-works community notifications materials. This will allow to condense the night work into five night blocks to reduce the overall works duration.

5 Construction Vibration

5.1 Vibration Criteria

Construction vibration is associated with three main types of impact:

- disturbance to building occupants;
- potential damage to buildings; and
- potential damage to sensitive equipment in a building.

Generally, if disturbance to building occupants is controlled, there is limited potential for structural damage to buildings.

Vibration amplitude may be measured as displacement, velocity, or acceleration.

- Displacement (x) measurement is the distance or amplitude displaced from a resting position. The International System of Units (SI) unit for distance is the metre (m), although common industrial standards include mm.
- Velocity ($v=\Delta x/\Delta t$) is the rate of change of displacement with respect to change in time. The SI unit for velocity is metres per second (m/s), although common industrial standards include mm/s. The Peak Particle Velocity (PPV) is the greatest instantaneous particle velocity during a given time interval. If measurements are made in 3-axis (x, y, and z) then the resultant PPV is the vector sum (i.e. the square root of the summed squares of the maximum velocities) regardless of when in the time history those occur.
- Acceleration ($a=\Delta v/\Delta t$) is the rate of change of velocity with respect to change in time. The SI unit for acceleration is metres per second squared (m/s2).

Construction vibration goals are summarised below.

5.1.1 Disturbance to Buildings Occupants

Assessment of potential disturbance from vibration on human occupants of buildings is made in accordance with the DECC '*Assessing Vibration; a technical guideline*' (DECC, 2006). The guideline provides criteria which are based on the British Standard BS 6472-1992 '*Evaluation of human exposure to vibration in buildings (1-80Hz)*'. Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent'. Table 5.1 provides definitions and examples of each type of vibration based on this guideline.

Table 5.1 – Types of Vibration

Type of Vibration	Definition	Examples
Continuous vibration	Continues uninterrupted for a defined period (usually throughout the day-time and/or night-time)	Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).
Impulsive vibration	A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading.
Intermittent vibration	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer, this would be assessed against impulsive vibration criteria.

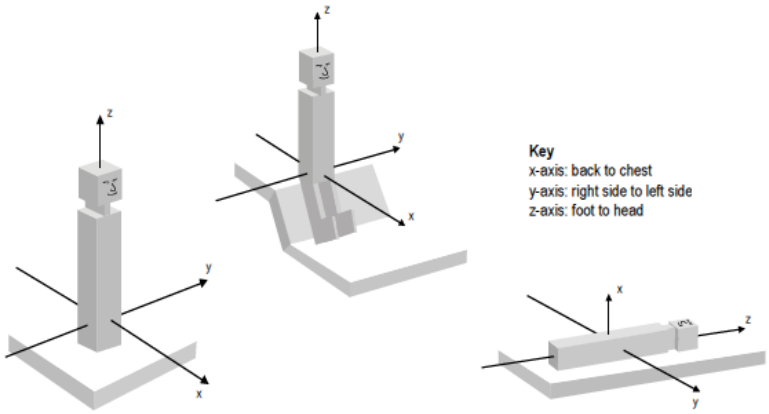
Source: Assessing Vibration; a technical guideline, Department of Environment & Climate Change, 2006

The vibration criteria are defined as a single weighted root mean square (rms) acceleration source level in each orthogonal axis. Section 2.3 of the guideline states:

> *"Evidence from research suggests that there are summation effects for vibrations at different frequencies. Therefore, for evaluation of vibration in relation to annoyance and comfort, overall weighted rms acceleration values of the vibration in each orthogonal axis are preferred (BS 6472)."*

When applying the criteria, it is important to note that the three directional axes are referenced to the human body, i.e. x-axis (back to chest), y-axis (right side to left side) or z-axis (foot to head). Vibration may enter the body along different orthogonal axes and affect it in different ways. Therefore, application of the criteria requires consideration of the position of the people being assessed, as illustrated in Figure 16. For example, vibration measured in the horizontal plane is compared with x- and y-axis criteria if the concern is for people in an upright position, or with the y- and z- axis criteria if the concern is for people in the lateral position.

Figure 16 – Orthogonal Axes for Human Exposure to Vibration



The preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and values for the type of receivers surrounding the site are reproduced in Table 5.2.

Table 5.2 – Preferred and Maximum Levels for Human Comfort

Location	Assessment Period[1]	Preferred Values		Maximum Values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous Vibration (Weighted RMS Acceleration, m/s^2, 1-80Hz)					
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and places of worship	Day- or night-time	0.020	0.014	0.040	0.028
Workshops	Day- or night-time	0.04	0.029	0.080	0.058
Impulsive Vibration (Weighted RMS Acceleration, m/s^2, 1-80Hz)					
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and places of worship	Day- or night-time	0.64	0.46	1.28	0.92
Workshops	Day- or night-time	0.64	0.46	1.28	0.92

Notes: 1. Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am

The acceptable Vibration Dose Values (VDV) for intermittent vibration are defined in Table 2.4 of the guideline and values for the type of receivers surrounding the site are reproduced in Table 5.3

Table 5.3 – Acceptable Vibration Dose Values for Intermittent Vibration ($m/s^{1.75}$)

Location	Daytime[1]		Night-time[1]	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
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

Notes: 1. Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am

5.1.2 Building Damage

Potential structural damage of buildings due to vibration is typically managed by ensuring vibration induced into the structure does not exceed certain limits and standards, such as British Standard 7385 Part 2 and German Standard DIN4150-3. Currently there is no existing Australian Standard for assessment of structural building damage caused by vibration energy.

Within British Standard 7385 Part 1: 1990, different levels of structural damage are defined:

- *Cosmetic - The formation of hairline cracks on drywall surfaces, or the growth of existing cracks in plaster or drywall surfaces; in addition, the formation of hairline cracks in mortar joints of brick/concrete block construction.*
- *Minor - The formation of large cracks or loosening of plaster or drywall surfaces, or cracks through bricks/concrete blocks.*
- *Major - Damage to structural elements of the building, cracks in supporting columns, loosening of joints, splaying of masonry cracks, etc.*

The vibration limits in Table 1 of British Standard 7385 Part 2 (1993) are for the protection against cosmetic damage; however, guidance on limits for minor and major damage is provided in Section 7.4.2 of the Standard:

"7.4.2 Guide values for transient vibration relating to cosmetic damage

Limits for transient vibration, above which cosmetic damage could occur are given numerically in Table 1 and graphically in Figure 1. In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to line 2 are reduced. Below a frequency of 4 Hz, where a high displacement is associated with a relatively low peak component particle velocity value a maximum displacement of 0.6 mm (zero to peak) should be used.

Minor damage is possible at vibration magnitudes which are greater than twice those given in Table 1, and major damage to a building structure may occur at values greater than four times the tabulated values."

Within DIN4150-3, damage is defined as "*any permanent effect of vibration that reduces the serviceability of a structure or one of its components"* (p.2). The Standard also outlines:

"that for structures as in lines 2 and 3 of Table 1, the serviceability is considered to have been reduced if

- *cracks form in plastered surfaces of walls;*
- *existing cracks in the building are enlarged;*
- *partitions become detached from loadbearing walls or floors.*

These effects are deemed 'minor damage." ***(DIN4150.3, 1990, p.3)***

While the DIN Standard defines the above damage as 'minor', based on the definitions provided in BS7385, the DIN standard is considered to deal with cosmetic issues rather than major structural failures.

British Standard

British Standard 7385: Part 2 '*Evaluation and measurement of vibration in buildings*', can be used as a guide to assess the likelihood of building damage from ground vibration. BS7385 suggests levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur.

The cosmetic damage levels set by BS 7385 are considered 'safe limits' up to which no damage due to vibration effects has been observed for certain particular building types. Damage comprises minor non-structural effects such as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls. 'Minor' damage is considered possible at vibration magnitudes which are twice those given and 'major' damage to a building structure may occur at levels greater than four times those values.

BS7385 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4Hz to 250Hz, being the range usually encountered in buildings. At frequencies below 4Hz, a maximum displacement value is recommended. The values set in the Standard relate to transient vibrations and to low-rise buildings. Continuous vibration can give rise to dynamic magnifications due to resonances and may need to be reduced by up to 50%. Table 5.4 sets out the BS7385 criteria for cosmetic, minor and major damage.

Regarding heritage buildings, British Standard 7385 Part 2 (1993) notes that "*a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive*" (p.5).

Table 5.4 – BS 7385 Structural Damage Criteria

Group	Type of Structure	Damage Level	Peak Component Particle Velocity[1], mm/s		
			4Hz to 15Hz	15Hz to 40Hz	40Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	Cosmetic		50	
		Minor[2]		100	
		Minor[2]		200	
2	Un-reinforced or light framed structures Residential or light commercial type buildings	Cosmetic	15 to 20	20 to 50	50
		Minor[2]	30 to 40	40 to 100	100
		Minor[2]	60 to 80	80 to 200	200

Notes: 1. Peak Component Particle Velocity is the maximum Peak particle velocity in any one direction (x, y, z) as measured by a tri-axial vibration transducer.

2. Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2

German Standard

German Standard DIN 4150 - Part 3 '*Structural vibration in buildings - Effects on Structure*' (DIN 4150-3), also provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration and are generally recognised to be conservative. This standard is typically applied to heritage buildings which are generally considered more sensitive to vibration.

DIN 4150-3 presents the recommended maximum limits over a range of frequencies (Hz), measured in any direction, and at the foundation or in the plane of the uppermost floor of a building or structure. The vibration limits increase as the frequency content of the vibration increases. The criteria applicable to the receiver structure types surrounding the site are presented in Table 5.5.

Table 5.5 – DIN 4150-3 Structural Damage Criteria

Group	Type of Structure	Vibration Velocity, mm/s			
		At Foundation at Frequency of			Plane of Floor Uppermost Storey
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 or 2 and have intrinsic value (eg buildings under a preservation order)	3	3 to 8	8 to 10	8

5.2 Potential Vibration Impacts

Based on the proposed plant items presented in Table 4.4, vibration generated by construction plant was estimated and potential vibration impacts are summarised in Table 5.6 below. The assessment is relevant to the identified residential type buildings.

Table 5.6 – Potential Vibration Impacts to Residential Receivers

Approx. distance to nearest buildings from works	Type of nearest sensitive buildings	Assessment on potential vibration impacts	
		Structural damage risk	Human disturbance
10 – 15m	Residential	Medium risk of structural damage from construction works	High risk of adverse comment as a result of construction works
15 – 30m	Residential	Low risk of structural damage from construction works	Medium risk of adverse comment as a result of construction works
30 – 50m	Residential	Very low risk of structural damage from construction works	Low risk of adverse comment as a result of construction works

Approx. distance to nearest buildings from works	Type of nearest sensitive buildings	Assessment on potential vibration impacts	
		Structural damage risk	Human disturbance
>50m	Residential	Very low risk of structural damage from construction works	Very low risk of adverse comment as a result of construction works

For heritage structures, dilapidation surveys should be conducted by the contractor prior to works to determine the sensitivity of the structure to vibration and assess the risk of structural damage.

Recommendations for reduction of potential vibration impacts, including minimum working distances for construction plant are provided in Section 5.3 below.

5.3 Vibration Mitigation

5.3.1 Recommended Minimum Buffer Distances

The pattern of vibration radiation is very different to the pattern of airborne noise radiation and is very site specific as final vibration levels are dependent on many factors including the actual plant used, its operation and the intervening geology between the activity and the receiver. Accordingly, based on a database containing vibration measurements from past projects and library information, Table 5.7 below presents the recommended minimum working distances for high vibration generating plant.

Table 5.7 – Recommended Minimum Working Distances for Vibration Intensive Plant

Plant item	Rating / description	Minimum working distance	
		Cosmetic damage	Human response
Vibratory Roller[1]	< 50 kN (Typically 1-2 tonnes)	5 m	15m – 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 (Typically > 18 tonnes)	25 m	100 m
Excavators[2]	< 30 Tonne (travelling/ digging)	10 m	15 m
Grader[3]	≤ 20 tonne	2 m (nominal)	10 m
Loaders[2]	-	-	5 m
Small Hydraulic Hammer[1]	300 kg (5-12 tonne excavator)	2 m	7 m
Medium Hydraulic Hammer[1]	900 kg (12-18 tonne excavator)	7 m	23 m
Large Hydraulic Hammer[1]	1600 kg (18-34 tonne excavator)	22 m	73 m
Jackhammer[1]	Hand held	1 m (nominal)	2 m
Pile Boring[1]	≤ 800 mm	-	10 m

Notes: 1. Roads and Maritime Services' Construction Noise and Vibration Guideline (CNVG)
2. Renzo Tonin & Associates project files, databases & library
3. TCA Construction Noise Strategy (Rail Projects) November 2011

Site specific buffer distances should be determined once vibration emission levels are measured from each plant item prior to the commencement of their regular use on site. Where construction activity occurs in close proximity to sensitive receivers, minimum buffer distances for building damage should be determined by site measurements and maintained.

5.3.2 Vibration Management Measures

The following vibration management measures are provided to minimise vibration impact from construction activities to the nearest affected receivers and to meet the relevant human comfort and building damage vibration limits:

- A management procedure should be implemented to deal with vibration complaints. Each complaint should be investigated and where vibration levels are established as exceeding the set limits, appropriate amelioration measures should be put in place to mitigate future occurrences. An example of a construction vibration management procedure is presented in Appendix C.
- Where vibration is found to be excessive, management measures should be implemented to ensure vibration compliance is achieved. Management measures may include modification of construction methods such as using smaller equipment, establishment of safe buffer zones as mentioned above, and if necessary, time restrictions for the most excessive vibration activities. These management measures should be addressed in a Vibration Management Plan prepared by the Contractor as part of the Construction Environmental Management Plan. Time restrictions are to be negotiated with affected receivers.
- Where construction activity occurs in close proximity to sensitive receivers, vibration testing of actual equipment on site would be carried out prior to their commencement of site operation to determine acceptable buffer distances to the nearest affected receiver locations.
- Building dilapidation surveys should be conducted at residential receivers determined, by the contractor, to be sensitive to vibration impacts. The determination should be based on the results of a vibration risk assessment plan for the project prior to construction, where the results of this will also feed into the Vibration Management Plan. These measures are to address potential community concerns that perceive vibration may cause damage to buildings.

5.3.3 Additional Vibration Mitigation Measures

Appendix C of the CNVG provides details of additional vibration mitigation measures to be applied when predicted vibration levels at receivers exceed the criteria for human comfort after all the appropriate standard mitigation measures from Section 5.3.2 have been applied. The additional mitigation measures to be applied for this project are shown in Table 5.8.

Table 5.8 – Additional Vibration Mitigation Measures

Predicted vibration level VDV, $m/s^{1.75}$ at receiver	Additional mitigation measures
Standard hours: Mon - Fri (7am - 6pm), Sat (8am - 1pm), Sun/Public Holiday (Nil)	
Predicted vibration exceeds maximum levels	N

Predicted vibration level VDV, m/s$^{1.75}$ at receiver	Additional mitigation measures
OOHW Period 1: Mon - Fri (6pm - 10pm), Sat (7am - 8am & 1pm - 10pm), Sun/Public Holiday (8am - 6pm)	
Predicted vibration exceeds maximum levels	N
OOHW Period 2: Mon - Fri (10pm - 7am) Sat (10pm - 8am), Sun/Public Holiday (6pm - 7am)	
Predicted vibration exceeds maximum levels	N

Notes: N = Notification (letterbox drop or equivalent)

The additional mitigation measures shown above apply to all affected receivers.

Prior to the commencement of work, receivers around the site would be notified to advise that vibration from the works may at times be perceptible. All potentially impacted receivers would be kept informed of the nature of works to be carried out, the expected vibration levels and duration, and be given contact details for enquiries and noise complaints.

5.4 Minimum Buffer Distances

Site-specific minimum working distances should be determined whenever significant vibration generating plant will be working close to or within the recommended minimum working distances listed in Table 5.7. The structural damage site-specific minimum working distances should be determined based on the DIN4150-3 limits listed in Table 5.5.

Further attended vibration monitoring should be conducted whenever significant vibration generating plant items are operating close to or within the determined minimum working distances. Locations for vibration monitoring during particular works would be determined by the construction contractor.

6 Road Traffic Noise Assessment

6.1 Traffic Noise Criteria

The EPA's 'Road Noise Policy' (RNP) sets out criteria to be applied to particular types of road and land uses. These noise criteria are to be applied when assessing noise impact and determining mitigation measures for developments that are potentially affected by road traffic noise, with the aim of preserving the amenity appropriate to the land use. However, the RNP states the following on page 5 of the policy:

> *"Some works that are either minor or required to improve safety are not covered by this RNP."*

The project involves upgrading the existing intersections with the introduction of additional lanes, widening of the road and the reconfiguration of lane widths along Pacific Highway, to improve safety and alleviate traffic congestion. Therefore, the project is not specifically assessed against the RNP.

The Roads and Maritime Services' 'Noise Criteria Guideline' (NCG) further states the following;

> *"Some works may be primarily to improve safety. This may include minor straightening of curves, installing traffic control devices, intersection widening and turning bay extensions or making minor road realignments.*
>
> *These works are not considered redeveloped or new as they are not intended to increase the traffic carrying capacity of the overall road or accommodate a significant increase in heavy vehicle traffic"*

In accordance with the above statement from the NCG, the project is considered to be minor works. For minor works, the NCG states the following regarding noise level targets:

> *"Roads and Maritime applies the existing road criteria (RNP Table 8) where the minor works increase noise levels by more than 2.0dBA relative to the existing noise levels at the worst affected receiver."*

Table 8 of the RNP (Section 4.4) has the following target noise abatement levels for existing roads not subject to redevelopment.

- **$L_{Aeq,15hr}$ 60dB(A) Day**
- **$L_{Aeq,9hr}$ 55dB(A) Night**

Additionally, Roads and Maritime Services' 'Noise Mitigation Guideline' (NMG) states the following:

> *"For minor works Roads and Maritime applies the criteria from the NCG if noise levels increase by more than 2.0dBA at the worst affected receiver.*
>
> *When this is demonstrated, all sensitive receivers must be assessed where noise levels exceed the controlling criterion within the minor works study area (NCG). Where the total noise level for the 'build' year exceeds the criterion and there is an increase of more than 2.0dBA (ie 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)."

Therefore, based on the NMG, affected receivers qualify for noise mitigation treatment, where reasonable and feasible, only if traffic noise levels predicted for the 'build' year (ie. the year the upgrade is completed and opened) exceed the existing road criteria (Table 8 of RNP) and the increase in traffic noise between the 'build' and 'no-build' years is greater than 2.0dB(A).

6.2 Traffic Flow and Composition Summary

Traffic count surveys was undertaken at four (4) locations by Matrix Traffic and Transport Data along the Pacific Highway near the noise monitoring locations but at a distance so that it did not affect the noise monitoring results. The surveys were conducted concurrently with the long term noise monitoring from Friday 1st to Wednesday 13th of June 2018. The traffic data obtained from the surveys were used to validate the traffic noise prediction tool.

The surveyed traffic volumes and compositions for the 15 hour (daytime – 7am to 10pm) and 9 hour (night time – 10pm to 7am) periods were used for the validation of the noise prediction tool and are presented in Table 6.1 below.

Table 6.1 – Existing 2018 Traffic Volumes and Composition

Road	Period	Northbound		Southbound	
		Total Vehicles	% Heavy Vehicles	Total Vehicles	% Heavy Vehicles
Site 1 – Pacific Highway at Finlay Road, Warrawee/Turramurra					
Pacific Highway	Day (7am to 10pm)	26,398	5%	26,193	7%
	Night (10pm to 7am)	3,915	5%	5,095	7%
Site 2 – Pacific Highway at Fox Valley Road, Wahroonga					
Pacific Highway	Day (7am to 10pm)	34,116	5%	14,616	7%
	Night (10pm to 7am)	5,223	5%	3,106	7%
Site 3 – Pacific Highway at Coonanbarra and Redleaf Avenue, Wahroonga/Warrawee					
Pacific Highway	Day (7am to 10pm)	24,544	5%	23,563	7%
	Night (10pm to 7am)	3,771	5%	4,784	7%

Notes: 1. Traffic counts from 1st to 13th June 2018 undertaken by Matrix Traffic and Transport Data

Traffic flow data for future operations were set out in the traffic and transport analysis reports provided by Roads and Maritime Services. The future (2027) morning (6:30am to 7:30am) and evening (5.15pm to 6.15pm) peak hour traffic volumes were used for the assessment of potential operational noise impacts from the project.

Traffic volumes and compositions for the 15 hour (daytime – 7am to 10pm) and 9 hour (night time – 10pm to 7am) periods were determined using the 24 hour traffic flow data obtained from the traffic counting surveys undertaken by Matrix Traffic and Transport Data. The following statistics were used for the determination of the future (2027) traffic data for the 15 hour and 9 hour periods.

Table 6.2 – Statistics Determined from Traffic Count Results

Assessed parameters	% of total daily volume (all vehicles)[1]	
	Northbound	Southbound
Site 1 – Pacific Highway at Finlay Road, Warrawee/Turramurra		
6:30am to 7:30am	5%	7%
5:15pm to 6:15pm	7%	6%
15-hour assessment period (7am to 10pm)	87%	84%
9-hour assessment period (10pm to 7am)	13%	16%
Site 2 – Pacific Highway at Fox Valley Road, Wahroonga		
6:30am to 7:30am	5%	7%
5:15pm to 6:15pm	7%	6%
15-hour assessment period (7am to 10pm)	87%	82%
9-hour assessment period (10pm to 7am)	13%	18%
Site 3 – Pacific Highway at Coonanbarra and Redleaf Avenue, Wahroonga/Warrawee		
6:30am to 7:30am	4%	7%
5:15pm to 6:15pm	7%	6%
15-hour assessment period (7am to 10pm)	87%	83%
9-hour assessment period (10pm to 7am)	13%	17%

Based on the future (2027) peak hour traffic volumes presented in Appendix B of the Roads and Maritime Services traffic reports and the statistics presented in Table 6.2, the future (2027) 15 hour (day time) and 9 hour (night time) volumes and compositions used for the noise predictions are presented in Table 6.3 below.

It is noted that the Roads and Maritime Services traffic reports do not provide the breakdown of heavy vehicles in their predictions; therefore, it is assumed that the heavy vehicle percentage from Table 6.1 would be applicable for future predictions of traffic.

Furthermore, as the works are considered to be a minor upgrade, the future traffic volumes and compositions for the 'build' and 'no build' scenarios are expected to be identical.

Table 6.3 – 2027 Traffic Volumes and Composition

Traffic Direction	7am to 10pm (15 hour)		10pm to 7am (9 hour)	
	Total Vehicles	% Heavy Vehicles	Total Vehicles	% Heavy Vehicles
Site 1 – Pacific Highway at Finlay Road, Warrawee/Turramurra				
Pacific Highway - Northbound	26,622	5%	3,943	7%
Pacific Highway - Southbound	34,358	5%	6,691	7%
Site 2 – Pacific Highway at Fox Valley Road, Wahroonga				
Pacific Highway - Northbound	23,742	5%	3,642	7%
Pacific Highway - Southbound	29,402	5%	6,237	7%
Site 3 – Pacific Highway at Coonanbarra and Redleaf Avenue, Wahroonga/Warrawee				
Pacific Highway - Northbound	22,504	5%	3,452	7%

Traffic Direction	7am to 10pm (15 hour)		10pm to 7am (9 hour)	
	Total Vehicles	% Heavy Vehicles	Total Vehicles	% Heavy Vehicles
Pacific Highway - Southbound	29,930	5%	6,087	7%

All traffic noise predictions in Section 6.3 below are based on the traffic volume and heavy vehicle proportion data set out in the above tables.

6.3 Traffic Noise Prediction Modelling

6.3.1 Noise Prediction Model

Noise modelling was undertaken using a Renzo Tonin & Associates developed prediction tool that incorporates the United Kingdom of Environment's method of calculating traffic noise entitled 'Calculation of Road Traffic Noise (1988)' known as the CoRTN88 method. This method has been adapted to Australian conditions and extensively tested by the Australian Road Research Board. The CoRTN88 method predicts noise levels for free-flowing traffic.

Table 6.4 following sets out the inputs and assumptions used in the traffic noise prediction model.

Table 6.4 – Summary of Prediction Tool Inputs

Input Parameters	Data Acquired From
Traffic volumes, compositions	Noise model verification: 2018 traffic data provided by Matrix Traffic and Transport Data (see Table 6.1) Noise prediction modelling: 2027 assumed traffic classification data based on information provided by Roads and Maritime Services (see Table 6.3)
Speeds	Noise model verification: 2018 traffic data provided by Matrix Traffic and Transport Data Noise prediction modelling: posted speeds for 'No Build' and 'Build' scenarios
Ground topography	Determined during site inspection and online mapping site
Angles of view from receiver	Determined during site inspections and aerial photos
Structures and cuttings on opposite side of road	Determined during site inspections and review of aerial photos. No significant structures or cuttings identified
Ground absorption	Detailed within CoRTN88, ground absorption varied along route. Numeric values varied between 0 (hard surface) to 1 (soft ground). A value of 0.5 was used for this project
Receiver heights	1.5 metre above ground level for ground floor, 4.5 metre above ground level for 1st floor, 7.5 metre above ground level for 2nd floor and 10.5 metre above ground level for 3rd floor
Facade correction	+2.5dB(A)
Correction for Australian conditions	-1.7 dB(A) for 'at facade' conditions and -0.7 for free field
Acoustic properties of road surfaces	Dense graded asphalt – no corrections applied
Roadside barriers	No existing roadside barriers

6.3.2 Model Validation

The prediction tool was validated and calibrated using the noise monitoring results and the concurrent traffic survey. Table 6.5 summarises the results of the traffic noise prediction tool validation, providing a comparison between the predicted traffic noise levels for existing conditions and the measured traffic noise levels.

Table 6.5 – Noise Prediction Tool Verification Results, dB(A)

Location	$L_{Aeq, 15\ hour}$ Daytime Noise Level			$L_{Aeq, 9\ hour}$ Night Time Noise Level		
	Measured	Modelled	Variation	Measured	Modelled	Variation
1630 Pacific Highway, Wahroonga	70.5	71.4	0.9	67.4	66.7	-0.7
2 Fox Valley Road, Wahroonga	71.7	72.6	0.9	68.8	67.9	-0.9
1458 Pacific Highway, Turramurra	70.0	71.0	1.0	67.4	66.4	-0.9
1558 Pacific Highway, Wahroonga	64.7	65.6	0.9	61.8	60.9	-0.8
Mahratta / School of Practical Philosophy - Wahroonga	54.5	55.4	0.9	51.6	51.3	-0.3
Median Variation			**0.9**			**-0.8**

Notes: 1. Noise measurements at S1 undertaken in the free field; therefore, the noise level presented are free-field noise levels (ie. no facade corrections)
2. Variation = Modelled – Measured
3. Based on noise monitoring and traffic survey period from 1st to 13th June 2018

The noise model validation results presented in Table 6.5 show that the noise model predicts results that are generally in good agreement with the noise monitoring and there is a reasonable level of confidence that can be placed on the noise model for predicting future traffic noise levels.

For the $L_{Aeq, 15\ hour}$ day and $L_{Aeq, 9\ hour}$ night time noise levels, the median variation between measured and modelled results is 0.9dB(A) and -0.8dB(A), respectively, which is within the ±1dB(A) allowance for traffic noise validation without including a calibration factor in future traffic noise predictions. Therefore, no calibration factor is applied for the prediction of operational noise predictions for future traffic noise scenarios.

6.3.3 Traffic Noise Model Prediction Result

Noise impacts were predicted for the most affected receiver locations where the project would result in the traffic moving closer to the receivers. The predicted traffic noise levels for the 'build' and 'no build' scenarios for the year 2027 are presented in the table below.

Table 6.6 – Predicted 2027 Traffic Noise Levels, dB(A)

Receiver	Floor Level	Approx. distance closer to road with upgrade	$L_{Aeq(15\ hour)}$ Daytime Noise Level			$L_{Aeq(9\ hour)}$ Night Time Noise Level		
			Build	No Build	Diff.	Build	No Build	Diff.
1630 Pacific Hwy, Wahroonga	Ground	7	72.7	70.8	1.9	67.8	66.0	1.8

Receiver	Floor Level	Approx. distance closer to road with upgrade	$L_{Aeq(15\ hour)}$ Daytime Noise Level			$L_{Aeq(9\ hour)}$ Night Time Noise Level		
			Build	No Build	Diff.	Build	No Build	Diff.
1630 Pacific Hwy, Wahroonga – Option with 1.2m wall[1]	Ground	7	72.4	70.8	1.6	67.6	66.0	1.6
2 Fox Valley Rd, Wahroonga	Ground	6	70.3	68.7	1.6	65.6	64.1	1.6
1458 Pacific Hwy, Turramurra	Ground	3	70.1	69.3	0.9	65.2	64.4	0.8
1558 Pacific Hwy, Wahroonga	Ground	3	65.1	64.5	0.6	60.5	59.9	0.6
Mahratta School of Practical Philosophy - Wahroonga	Ground	3	59.2	59.0	0.2	55.1	54.9	0.2
	First	3	61.2	60.8	0.4	57.1	56.7	0.4

Notes: 1. Option for installing a solid retaining wall of 1.2m height on the receiver property

The predicted noise levels presented in Table 6.6 show that the worst affected residential receivers are predicted to incur a minor increase of up to 1.9dB(A) for the daytime period and up to 1.8dB(A) for the night time period if the intersections are to be upgraded ('build' scenario) compared to if they were not upgraded ('no build' scenario). This is below the 2dB(A) increase allowance presented in the NCG and NMG.

For the receiver at 1630 Pacific Highway, Wahroonga, comparison of noise levels with and without the 1.2m high retaining wall shows a negligible difference of noise levels of up to 0.3dB(A).

Therefore, no feasible and reasonable noise mitigation measures are required for any residential properties.

7 Noise Assessment of Proposed Pedestrian Traffic Signals

Roads and Maritime Services proposes to install traffic signals servicing the Pacific Highway at Coonanbarra Road and Redleaf Avenue intersection with the installation of new pedestrian audio tactile push buttons to be incorporated into the traffic signals. Two audio tactile push buttons will be installed into the traffic signals to allow pedestrians to safely cross Redleaf Avenue.

The intersection is surrounded by commercial and residential dwellings. The following residence was identified during a site inspection to be the nearest affected residential receiver.

Table 7.1 – Sensitive Receiver Locations

Receiver	Address	Type	Description
R1	1565 Pacific Highway	Residential	Double storey residential property located approximately 15m to the west of the proposed traffic signals

7.1 Audio-Tactile Noise Assessment Guidelines

The Roads and Maritime Services' management framework provides details of the applicable noise goals that are required to be achieved for impacts due to tactile noise associated with the proposed pedestrian audio tactile push buttons of the existing traffic signals. A section of the management framework states the following:

> *"As the audio-tactile push buttons produce short duration high noise levels, an EIA maximum noise goal of 15dB(A) over the assumed internal sleeping accommodation noise level of 35dB(A) should be applied.*
>
> *As most houses, regardless of the construction type, will achieve 10dB(A) noise level reduction through the building façade with windows open, the appropriate external noise performance standard for evaluating environmental impacts associated with new traffic signal installations is 35 + 15 + 10 = 60dB(A) L_{max}."*

It is noted that the above noise goal is primarily used to protect bedrooms of a residential dwelling and thus would typically be applicable for the night time period only.

Therefore, based on the above requirements, the applicable noise goal for the assessment of tactile noise from the pedestrian push buttons is 60dB(A), outside an affected bedroom window of a dwelling during the night time period.

In addition to the above noise goal, a compliance noise goal is provided for the assessment of tactile noise during the compliance stage once the installation of the traffic signals is completed. The compliance noise goals are stated as:

"…the L_{max} 'walk' phase audio signal noise level exceeds the L_{90} background noise level by greater than 15dB(A)."

It is noted that the above requirement would be used to evaluate intrusiveness during the day, evening and night periods.

Based on the L_{A90} background noise levels for each period as presented in Table 3.2, the applicable compliance noise goals directly outside the facade of a dwelling are presented below.

Table 7.2 – L_{Amax} 'Background + 15dB' Noise Goals, dB(A)

Day	Evening	Night
60 + 15 = **75**	56 + 15 = **71**	41 + 15 = **56**

Notes: 1. Noise goals are assessed directly outside the facade of a dwelling

From the above table, the compliance noise goal for the night period is more stringent than the EIA maximum noise goal of 60dB(A). Therefore, the compliance noise goal of **56dB(A)** will be used for the assessment of the night time period from herein.

7.2 Noise Assessment

7.2.1 Pedestrian Push Button Noise Source

The RMS's management framework provides an applicable source noise level during the 'walk' phase of the pedestrian push buttons. The source noise level is stated as:

"the loudest producible noise level is 88 dB(Lin) or 85 dB(A) at a 'walk' phase signal frequency of 500Hz and at a distance of 1m from the push button device."

However, it is understood that at the start of the walk phase there is a tonal noise component. In accordance with acceptable regulatory policies (eg. NSW 'Noise Policy for Industry'), a 5dB(A) correction is typically added to the source noise level where a tonal component is present. Therefore, the 'loudest' source noise level that will be used for a conservative assessment of tactile noise is:

- 85dB(A) plus 5dB(A) = **90dB(A) at 1m**

7.2.2 Pedestrian Push Button Noise Predictions

Noise predictions were undertaken for the residential receiver closest to the intersection, namely Receiver R1 as described in Table 7.1.

For a conservative assessment, noise levels for the receivers have been predicted to a facade nearest to the proposed push button locations.

As stated in the Roads and Maritime Services' management framework, a three setting volume switch (ie. high, medium and low) is available inside the push button housing. The source noise level presented in Section 7.2.1 above is based on the highest volume setting.

It is understood that the volume switch provides a 3dB(A) reduction per switch setting. Therefore, on the low setting up to 6dB(A) reduction is achievable.

Starting from the loudest source noise level and applying a 3dB(A) sound level reduction for each volume adjustment setting going from 'high to medium' and then from 'medium to low', the tactile noise impacts from the pedestrian push buttons during the 'walk' phase have been predicted for the nominated receiver locations and are presented in Table 7.3.

Table 7.3 – Predicted L_{Amax} Noise Levels, dB(A)

Receiver	Compliance Noise Goals			Predicted Noise Level		
	Day	Evening	Night	High[1]	Medium[1]	Low[1]
R1 – 1565 Pacific Highway Wahroonga	*75*	*71*	*56*	**69**	**66**	**63**

Notes: 1. It is understood that a 3dB(A) reduction is achieved for each volume adjustment setting going from 'high to medium' and then from 'medium to low' setting

2. **Bold** font represents exceedance of the day, evening and/or night time compliance noise goals

From the above table, it can be seen that noise from the audio tactile push buttons will exceed the compliance noise goals during the night time period for all three volume settings at the nearest receiver location. The noise levels from the audio tactile push buttons are predicted to comply with the day and evening period noise goals for all three volume settings at the nearest receiver location.

Therefore, feasible and reasonable noise management strategies should be implemented in accordance with Road and Maritime Services' management framework.

7.3 Noise Management Strategies

7.3.1 Automatic Gain Control

In addition to the three setting volume switch available inside the push button housing, the push button unit also incorporates an automatic gain control (AGC), which actively reduces the noise source level based on the instantaneous ambient noise level immediately prior to the walk phase signal being activated. The worst case maximum output of the unit, which is controlled by the AGC, occurs when the ambient noise level immediately prior to the walk phase signal is 74dB(A) or more. This may occur for example when a car passes through the intersection just prior to the walk phase.

In the absence of a car passby, the AGC will track the longer term ambient noise level reducing the worst-case output by up to 29dB(A) when the ambient noise level is 44dB(A) or less. Assuming a source noise reduction of 1dB(A) for each 1dB(A) reduction in ambient noise level below 74dB(A), the table below presents predicted noise levels with the implementation of the AGC, for each of the high, medium and low volume settings, based on the monitored ambient noise levels presented in Table 3.2.

Table 7.4 – Predicted Noise Levels with AGC, dB(A)

Receiver	Period	Compliance L_{Amax} Noise Goal	L_{Aeq} Ambient Noise Level	Expected Noise Reduction from AGC[1]	Predicted Noise Level / Volume Setting		
					High	Medium	Low
R1 – 1565 Pacific Highway Wahroonga	Day	75	73	1	68	65	63
	Evening	71	73	1	68	65	63
	Night	56	70	4	**65**	**62**	**59**

Notes: 1. Reduction based on 74dB(A) minus ambient noise level
2. **Bold** font represents exceedance of the compliance noise goal

From the above table, it can be seen that the noise levels are predicted to comply during the day, and evening periods with the push buttons operating on any setting (low, medium or high) and with the AGC activated. The noise goals were exceeded at the nearest receiver location with AGC activated during the night period by up to 9dB(A) with high volume setting and by 3dB(A) with the low volume setting.

The audio tactile push buttons may still be audible inside the bedroom of the affected residences, particularly if the resident keeps the windows open at night. Therefore, additional noise management strategies are identified below should they be required to address community concerns once the push buttons are operational.

7.3.2 Additional Noise Management Strategies

The following noise management strategies are presented in the Roads and Maritime Services' management framework, which can be implemented to further reduce noise impacts from pedestrian audio tactile push buttons. A feasible and reasonable investigation into the available noise management strategies would need to be undertaken in order to determine the most appropriate management measure.

The noise management strategies outlined in the Roads and Maritime Services' management framework include:

- Restrict operation of the audio signal;
- Architectural acoustic treatment of noise sensitive receivers; and
- Screen walls and barriers.

7.3.3 Recommendations

The operation of the push button audio signal could be restricted to operate only during the day and evening periods if the accessibility needs assessment does not identify a warrant for audible push buttons during the night time period.

The Roads and Maritime Services' management framework states that the closing of windows would reduce internal noise levels by a further 10-15dB(A), depending on the building construction. It is

expected that given Receiver R1 (1565 Pacific Highway Wahroonga) is a dwelling of brick construction and is in close proximity to an arterial Road (Pacific Highway), windows would more than likely be closed and the noise reduction from the audio tactile push buttons would be greater than the stated 10dB(A) with windows closed. Thus, a conservative 10dB(A) reduction would result in compliance at Receiver R1 during the night period at all volume settings.

It is noted that in order to leave windows closed in affected areas of a dwelling, fresh air ventilation would be required in order to comply with the ventilation requirements of the Building Code of Australia. Therefore, the provision of fresh air ventilation would be required should the option of having windows closed be considered.

Furthermore, roadside noise barriers are likely impractical due to space limitations and would create negative visual impacts.

8 Conclusion

Renzo Tonin & Associates has completed a noise assessment for the proposed upgrade of intersections along the Pacific Highway from Turramurra to Wahroonga.

Noise emissions from evening and night time construction works associated with the proposed intersection upgrades were predicted to potentially exceed the applicable noise management levels at the nearest affected receivers. The surrounding receivers may also potentially be highly noise affected [ie. >75dB(A)]. Furthermore, maximum noise levels for the assessment of sleep disturbance may exceed the applicable sleep disturbance limit for awakening reactions at the nearest affected residences.

Therefore, in-principle feasible and reasonable noise mitigation measures have been provided in accordance with the CNVG to aid in reducing construction noise impacts. In-principle recommendations have also been provided to limit the potential impact of vibration generated by construction activities to acceptable levels. In addition, buffer distances for vibration compliance have been provided as guidance; however, should be determined in more detail prior to the start of construction works through on site measurements of vibration.

Noise emission from day time and night time operation of the existing intersections and the proposed upgraded intersections were predicted to the nearest most affected sensitive receivers. Operational noise impacts from the proposed upgraded intersections were predicted to increase by up to 1.9dB(A) in the day and 1.8dB(A) in the night at the potentially most affected residential receivers, which are less than the 2dB(A) increase allowance presented in the NCG and NMG. Therefore, there is no requirement for any further operational noise mitigation measures.

APPENDIX A Glossary of terminology

The following is a brief description of the technical terms used to describe noise to assist in understanding the technical issues presented.

Absorption Coefficient α	The absorption coefficient of a material, usually measured for each octave or third-octave band and ranging between zero and one. For example, a value of 0.85 for an octave band means that 85% of the sound energy within that octave band is absorbed on coming into contact with the material. Conversely, a low value below about 0.1 means the material is acoustically reflective.
Adverse weather	Weather effects that enhance noise (particularly wind and temperature inversions) occurring at a site for a significant period of time. In the NSW INP this occurs when wind occurs for more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of nights in winter.
Air-borne noise	Noise which is fundamentally transmitted by way of the air and can be attenuated by the use of barriers and walls placed physically between the noise source and receiver.
Ambient noise	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
Amenity	A desirable or useful feature or facility of a building or place.
AS	Australian Standard
Assessment period	The time period in which an assessment is made. e.g. Day 7am-10pm & Night 10pm-7am.
Assessment Point	A location at which a noise or vibration measurement is taken or estimated.
Attenuation	The reduction in the level of sound or vibration.
Audible Range	The limits of frequency which are audible or heard as sound. The normal hearing in young adults detects ranges from 20 Hz to 20 kHz, although some people can detect sound with frequencies outside these limits.
A-weighting	A filter applied to the sound recording made by a microphone to approximate the response of the human ear.
Background noise	Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the LA90 noise level if measured as an overall level or an L90 noise level when measured in octave or third-octave bands.
Barrier (Noise)	A natural or constructed physical barrier which impedes the propagation of sound and includes fences, walls, earth mounds or berms and buildings.
Berm	Earth or overburden mound.
Buffer	An area of land between a source and a noise-sensitive receiver and may be an open space or a noise-tolerant land use.
Bund	A bund is an embankment or wall of brick, stone, concrete or other impervious material, which may form part or all of the perimeter of a compound.
BS	British Standard
CoRTN	United Kingdom Department of Environment entitled "Calculation of Road Traffic Noise (1988)"

Decibel [dB]	The units of sound measurement. The following are examples of the decibel readings of every day sounds: 0dB The faintest sound we can hear, defined as 20 micro Pascal 30dB A quiet library or in a quiet location in the country 45dB Typical office space. Ambience in the city at night 60dB CBD mall at lunch time 70dB The sound of a car passing on the street 80dB Loud music played at home 90dB The sound of a truck passing on the street 100dB The sound of a rock band 110dB Operating a chainsaw or jackhammer 120dB Deafening
dB(A)	A-weighted decibel. The A- weighting noise filter simulates the response of the human ear at relatively low levels, where the ear is not as effective in hearing low frequency sounds as it is in hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter is denoted as dB(A). Practically all noise is measured using the A filter.
dB(C)	C-weighted decibels. The C-weighting noise filter simulates the response of the human ear at relatively high levels, where the human ear is nearly equally effective at hearing from mid-low frequency (63Hz) to mid-high frequency (4kHz), but is less effective outside these frequencies. The dB(C) level is not widely used but has some applications.
Diffraction	The distortion of sound waves caused when passing tangentially around solid objects.
DIN	German Standard
ECRTN	Environmental Criteria for Road Traffic Noise, NSW, 1999
EPA	Environment Protection Authority
Field Test	A test of the sound insulation performance in-situ. See also 'Laboratory Test' The sound insulation performance between building spaces can be measured by conducting a field test, for example, early during the construction stage or on completion. A field test is conducted in a non-ideal acoustic environment. It is generally not possible to measure the performance of an individual building element accurately as the results can be affected by numerous field conditions.
Fluctuating Noise	Noise that varies continuously to an appreciable extent over the period of observation.
Free-field	An environment in which there are no acoustic reflective surfaces. Free field noise measurements are carried out outdoors at least 3.5m from any acoustic reflecting structures other than the ground.
Frequency	Frequency is synonymous to pitch. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
Ground-borne noise	Vibration propagated through the ground and then radiated as noise by vibrating building elements such as wall and floor surfaces. This noise is more noticeable in rooms that are well insulated from other airborne noise. An example would be vibration transmitted from an underground rail line radiating as sound in a bedroom of a building located above.
Habitable Area	Includes a bedroom, living room, lounge room, music room, television room, kitchen, dining room, sewing room, study, playroom, family room, home theatre and sunroom. Excludes a bathroom, laundry, water closet, pantry, walk-in wardrobe, corridor, hallway, lobby, photographic darkroom, clothes drying room, and other spaces of a specialised nature occupied neither frequently nor for extended periods.
Heavy Vehicle	A truck, transporter or other vehicle with a gross weight above a specified level (for example: over 8 tonnes).
IGANRIP	Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects, NSW DEC 2007

Impulsive noise	Having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.
INP	NSW Industrial Noise Policy, EPA 1999
Intermittent noise	The level suddenly drops to that of the background noise several times during the period of observation. The time during which the noise remains at levels different from that of the ambient is one second or more.
Intrusive noise	Refers to noise that intrudes above the background level by more than 5 dB(A).
ISEPP	State Environmental Planning Policy (Infrastructure), NSW, 2007
ISEPP Guideline	Development Near Rail Corridors and Busy Roads - Interim Guideline, NSW Department of Planning, December 2008
L1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L10	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
L10(1hr)	The L10 level measured over a 1 hour period.
L10(18hr)	The arithmetic average of the L10(1hr) levels for the 18 hour period between 6am and 12 midnight on a normal working day.
L90	The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L90 noise level expressed in units of dB(A).
LAeq or Leq	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time, which would produce the same energy as a fluctuating sound level. When A-weighted, this is written as the LAeq.
LAeq(1hr)	The LAeq noise level for a one-hour period. In the context of the NSW EPA's Road Noise Policy it represents the highest tenth percentile hourly A-weighted Leq during the period 7am to 10pm, or 10pm to 7am (whichever is relevant).
LAeq(8hr)	The LAeq noise level for the period 10pm to 6am.
LAeq(9hr)	The LAeq noise level for the period 10pm to 7am.
LAeq(15hr)	The LAeq noise level for the period 7am to 10pm.
LAeq (24hr)	The LAeq noise level during a 24 hour period, usually from midnight to midnight.
Lmax	The maximum sound pressure level measured over a given period. When A-weighted, this is usually written as the LAmax.
Lmin	The minimum sound pressure level measured over a given period. When A-weighted, this is usually written as the LAmin.
Loudness	A rise of 10 dB in sound level corresponds approximately to a doubling of subjective loudness. That is, a sound of 85 dB is twice as loud as a sound of 75 dB which is twice as loud as a sound of 65 dB and so on. That is, the sound of 85 dB is four times or 400% the loudness of a sound of 65 dB.
Microphone	An electro-acoustic transducer which receives an acoustic signal and delivers a corresponding electric signal.
NCA	Noise Catchment Area. An area of study within which the noise environment is substantially constant.
Noise	Unwanted sound
Pre-construction	Work in respect of the proposed project that includes design, survey, acquisitions, fencing, investigative drilling or excavation, building/road dilapidation surveys, minor clearing (except where threatened species, populations or ecological communities would be affected), establishing ancillary facilities such as site compounds, or other relevant activities determined to have minimal environmental impact (e.g. minor access roads).
Reflection	Sound wave reflected from a solid object obscuring its path.
RING	Rail Infrastructure Noise Guideline, NSW, May 2013

RMS	Root Mean Square value representing the average value of a signal.
Rw	Weighted Sound Reduction Index A measure of the sound insulation performance of a building element. It is measured in very controlled conditions in a laboratory. The term supersedes the value STC which was used in older versions of the Building Code of Australa. Rw is measured and calculated using the procedure in ISO 717-1. The related field measurement is the DnT,w. The higher the value the better the acoustic performance of the building element.
R'w	Weighted Apparent Sound Reduction Index. As for Rw but measured in-situ and therefore subject to the inherent accuracies involved in such a measurement. The higher the value the better the acoustic performance of the building element.
RNP	Road Noise Policy, NSW, March 2011
Sabine	A measure of the total acoustic absorption provided by a material. It is the product of the Absorption Coefficient (alpha) and the surface area of the material (m2). For example, a material with alpha = 0.65 and a surface area of 8.2m2 would have 0.65 x 8.2 = 5.33 Sabine. Sabine is usually calculated for each individual octave band (or third-octave).
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound	A fluctuation of air pressure which is propagated as a wave through air.
Sound absorption	The ability of a material to absorb sound energy by conversion to thermal energy.
Sound Insulation	Sound insulation refers to the ability of a construction or building element to limit noise transmission through the building element. The sound insulation of a material can be described by the Rw and the sound insulation between two rooms can be described by the DnT,w.
Sound level meter	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound power level	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power of 1 pico watt.
Sound pressure level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone referenced to 20 mico Pascal.
Spoil	Soil or materials arising from excavation activities.
STC	Sound Transmission Class A measure of the sound insulation performance of a building element. It is measured in controlled conditions in a laboratory. The term has been superseded by Rw.
Structure-borne Noise	Audible noise generated by vibration induced in the ground and/or a structure. Vibration can be generated by impact or by solid contact with a vibrating machine. Structure-borne noise cannot be attenuated by barriers or walls but requires the isolation of the vibration source itself. This can be achieved using a resilient element placed between the vibration source and its support such as rubber, neoprene or springs or by physical separation (using an air gap for example). Examples of structure-borne noise include the noise of trains in underground tunnels heard to a listener above the ground, the sound of footsteps on the floor above a listener and the sound of a lift car passing in a shaft. See also 'Impact Noise'.
Tonal Noise	Sound containing a prominent frequency and characterised by a definite pitch.

Transmission Loss	The sound level difference between one room or area and another, usually of sound transmitted through an intervening partition or wall. Also the vibration level difference between one point and another. For example, if the sound level on one side of a wall is 100dB and 65dB on the other side, it is said that the transmission loss of the wall is 35dB. If the transmission loss is normalised or standardised, it then becomes the Rw or R'w or DnT,w.

APPENDIX B Specification for Construction Noise Monitoring

B.1 Scope

This document specifies methods for undertaking noise monitoring during the construction phase of the project.

B.2 Referenced Standards and Guidelines

- Australian Standard AS IEC 61672.1 2004 '*Electroacoustics - Sound Level Meters - Specifications*'
- Australian Standard AS 1259.2-1990 '*Acoustics - Sound Level Meters*'
- Australian Standard AS 1055-1997 '*Acoustics - Description and Measurement of Environmental Noise*'
- NSW '*Interim Construction Noise Guideline*' (Department of Environment and Climate Change 2009)
- NSW '*Industrial Noise Policy*' (Environment Protection Authority 2000)

B.3 Testing Procedures

The following procedures are to be followed by personnel suitably qualified and experienced in undertaking acoustic measurements.

All noise monitoring equipment used must be at least Type 2 instruments as described in AS 1259.2-1990 and calibrated to standards that are traceable to Australian Physical Standards held by the National Measurement Laboratory (CSIRO Division of Applied Physics). The calibration of the monitoring equipment shall also be checked in the field before and after the noise measurement period, and in the case of long-term noise monitoring, calibration levels shall be checked at minimum weekly intervals.

Long-term noise monitoring equipment or Noise Loggers, consist of sound level meters housed in weather resistant enclosures. The operator may retrieve the data at the conclusion of each monitoring period in person or remotely if the logger is fitted with mobile communications.

All environmental noise measurements shall be taken with the following meter settings:

- Time constant: FAST (ie 125 milliseconds)
- Frequency weightings: A-weighting
- Sample period: 15 minutes

All outdoor noise measurements shall be undertaken with a windscreen over the microphone. Windscreens reduce wind noise at the microphones.

Measurements of noise should be disregarded when it is raining and/or the wind speed is greater than 5m/s (18km/h).

B.4 Long-Term (Unattended) Monitoring

Noise monitoring shall be undertaken in accordance with the environmental noise measurement requirements stipulated in the reference standards and documents listed above.

Noise monitoring equipment shall be placed at positions which have unobstructed views of general site activities, while acoustically shielded as much as possible from non-construction site noise (eg. road traffic, rail noise and other surrounding noise).

Noise levels are to be recorded at a minimum rate of 10 samples per second. Every 15 minutes, the data is to be processed statistically and stored in memory. The minimum range of noise metrics to be stored in memory for later retrieval is the following A-weighted noise levels: L_{min}, L_{90}, L_{eq}, L_{10}, L_1 and L_{max}.

Where the noise monitors are placed within 3.5 metres of building facades, walls or cliffs, then a reflection correction of up to -2.5dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

Meteorological conditions including wind velocity, wind direction and rainfall shall be monitored over the entire noise monitoring period, either on site or recorded from the nearest weather station to the project site.

B.5 Short-Term (Attended) Monitoring

Where noise complaints or requests from relevant authorities are received, attended short-term noise monitoring shall also be conducted at the requested outdoor location (unless the issue is related to regenerated noise from tunnelling and driveage works) and at any other relevant noise receiver location with closest proximity to the construction activities.

Short-term noise monitoring shall be used to supplement long-term noise monitoring undertaken at nearby locations, and to establish whether noise levels measured by the long-term noise monitors are determined by construction activities carried out on site.

All attended short-term noise monitoring shall be recorded over 15 minute sample intervals. Noise levels are to be recorded at a minimum rate of 10 samples per second. Every 15 minutes, the data is to be processed statistically and stored in memory. The minimum range of noise metrics to be stored in memory and reported is the following A-weighted noise levels: L_{min}, L_{90}, L_{eq}, L_{10}, L_1 and L_{max}.

In addition to measuring and reporting overall A-weighted noise levels, statistical L_{90}, L_{eq}, L_{10} noise levels shall be measured and reported in third-octave band frequencies from 31.5Hz to 8kHz.

Where the noise monitors are placed within 3.5 metres of building facades, walls or cliffs, then a reflection correction of up to -2.5dB(A) shall be applied to remove the effect of increased noise due to sound reflections from such structures.

Outdoor noise monitoring is to be undertaken with the microphone at a height of 1.2 – 1.5m from the ground, unless noise measurements are taken from a balcony or veranda, in which case the same microphone height shall apply off the floor.

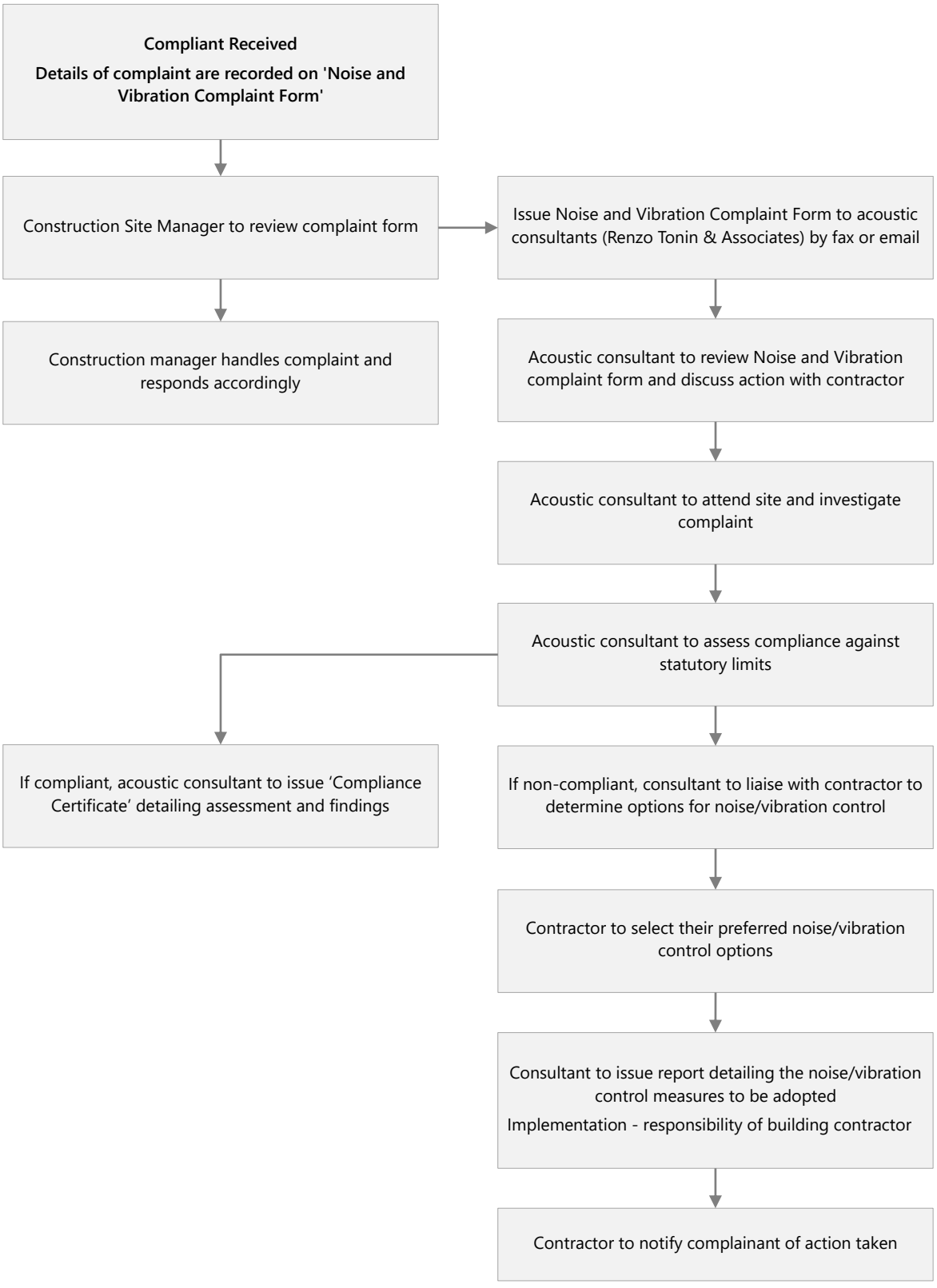
Noise measurements inside buildings should be at least 1m from the walls or other major reflecting surfaces, 1.2 m to 1.5m above the floor, and 1.5m from windows.

Noise monitoring shall be undertaken in accordance with the environmental noise measurement requirements stipulated in the reference standards and documents listed above.

The following information shall be recorded:

- Date and time of measurements;
- Type and model number of instrumentation;
- Results of field calibration checks before and after measurements;
- Description of the time aspects of each measurement (ie sample times, measurement time intervals and time of day);
- Sketch map of area;
- Measurement location details and number of measurements at each location;
- Weather conditions during measurements, including wind velocity, wind direction, temperature, relative humidity and cloud cover
- Operation and load conditions of the noise sources under investigation
- Any adjustment made for presence or absence of nearby reflecting surfaces; and
- Noise due to other sources (eg traffic, aircraft, trains, dogs barking, insects etc).

APPENDIX C Noise/Vibration Complaint Management Procedure



NOISE/ VIBRATION COMPLAINT FORM

Project title: _____ **Date:** _____

Site contractor: _____ **Phone:** _____

Site contact: _____ **Email:** _____

Complaint details

Received by (circle): Phone / Email / In person / Other: _____

Name: _____ H Ph: _____

Address: _____ W Ph _____

Email: _____ M Ph _____

Describe when the problem occurred (date and time), what equipment caused the complaint (if known) and where person was standing when he/she experienced the noise/vibration:

Investigation

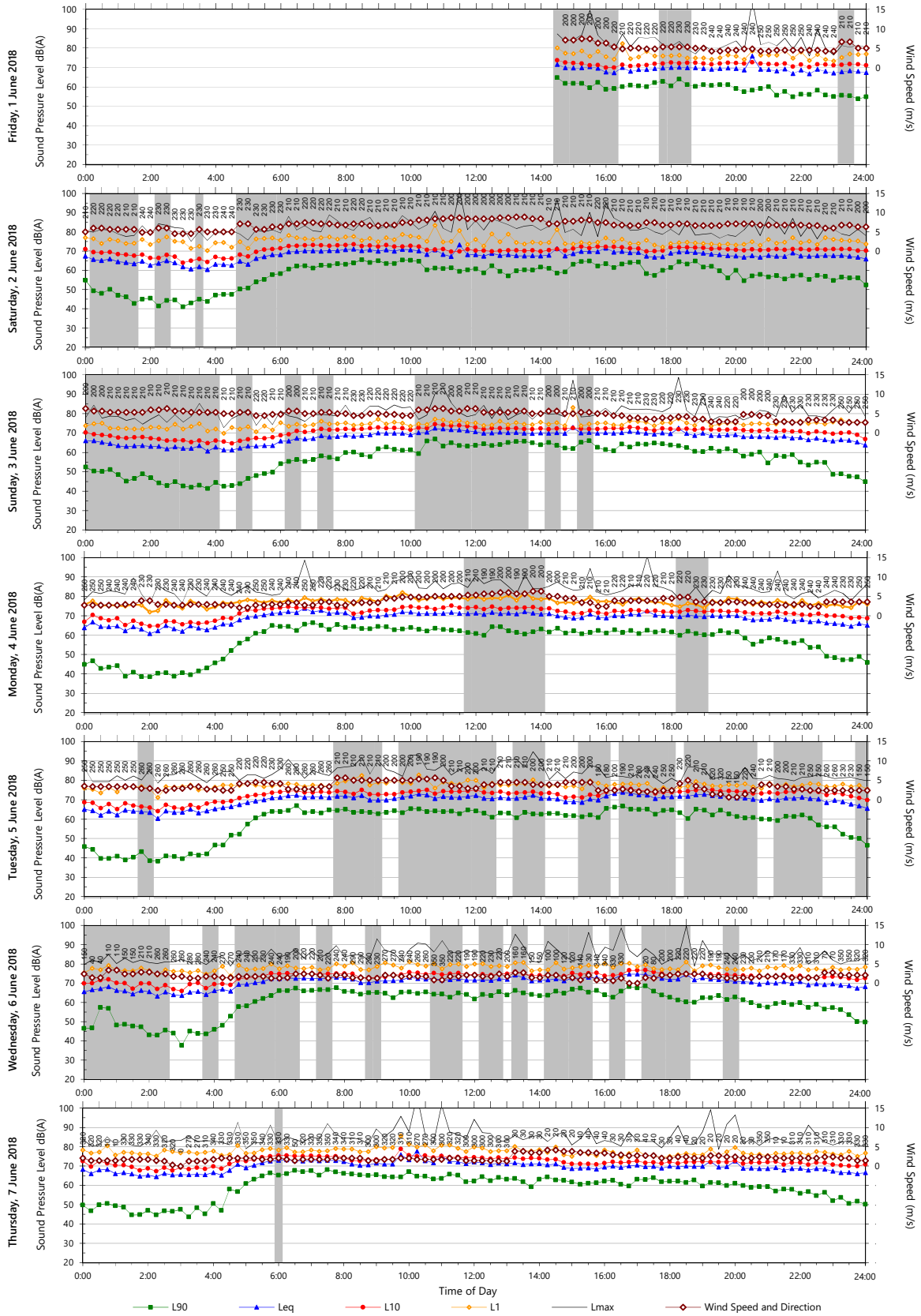
Question foreman responsible on site and obtain information on what equipment or processes would most likely have caused the complaint:

Following approval from the Project Manager, email/fax this form to Renzo Tonin & Associates

APPENDIX D Noise Monitoring Results

Unattended Monitoring Results

Location: 1630 Pacific Highway, Wahroonga



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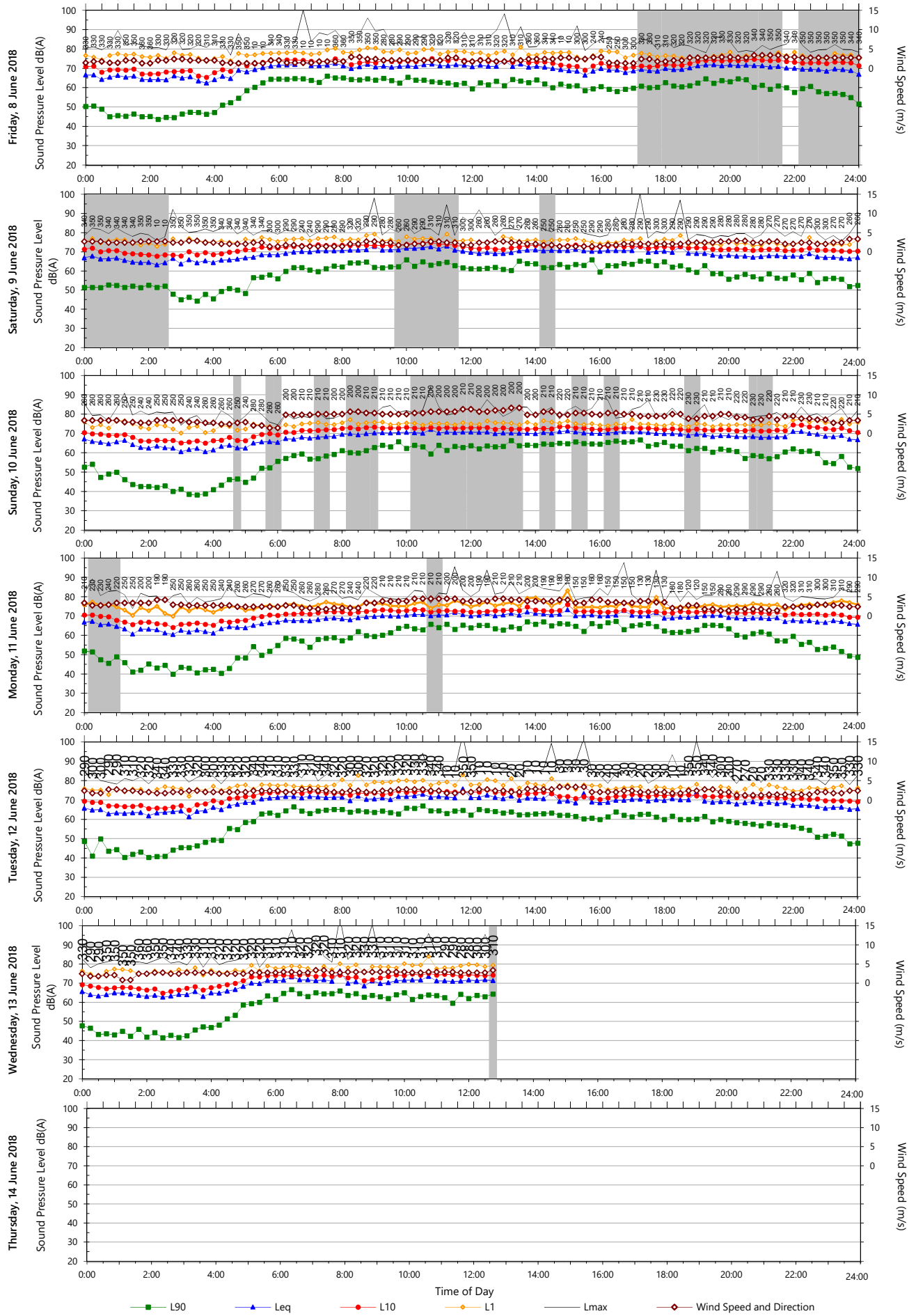
Template: QTE-26 (rev 17) Logger Graphs Program

Unattended Monitoring Results

Location: 1630 Pacific Highway, Wahroonga

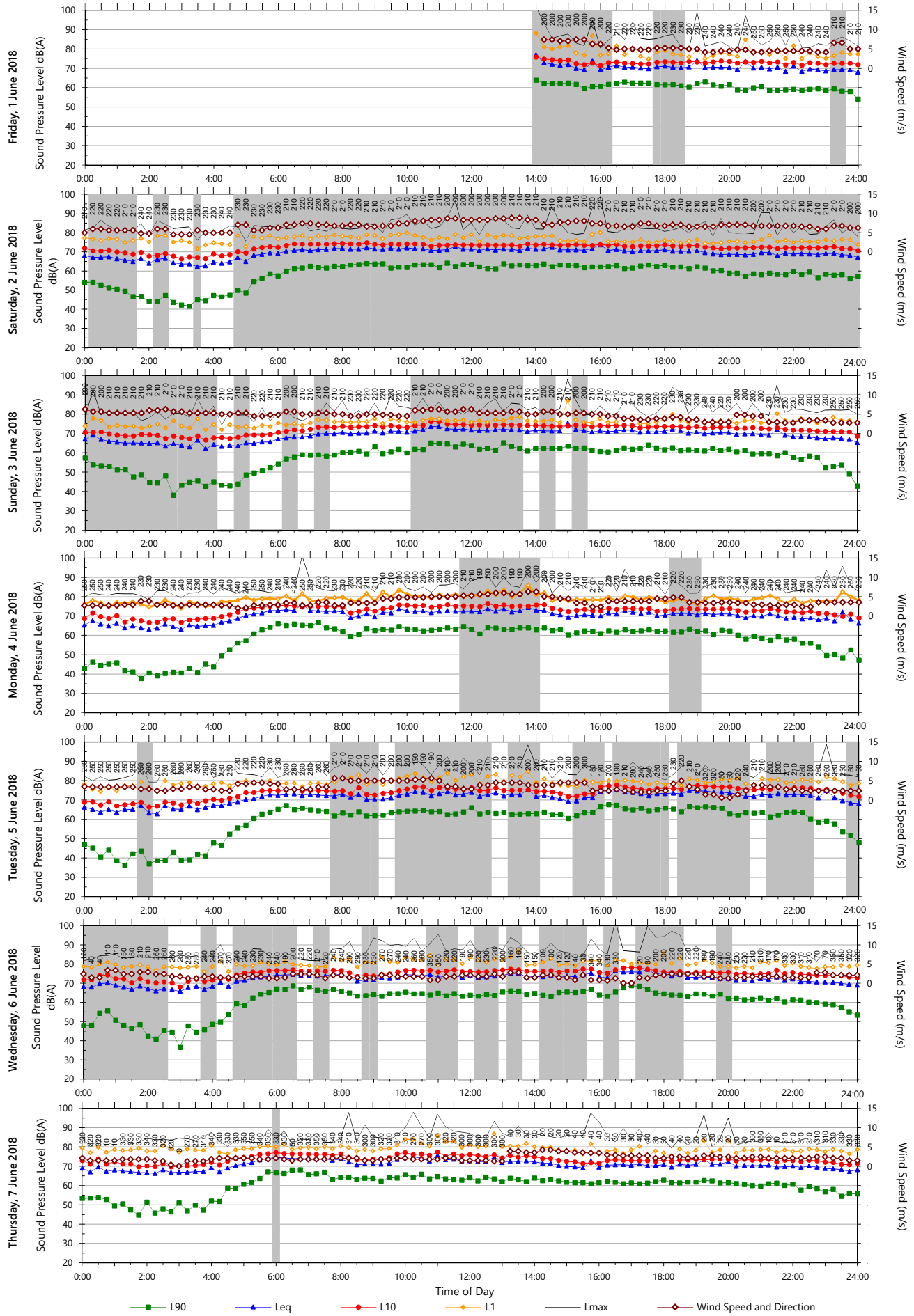


Data File: 2018-06-01_SLM_000_123_Rpt_Report.txt

Template: QTE-26 (rev 17) Logger Graphs Program

Unattended Monitoring Results

Location: 2 Fox Valley Road, Wahroonga



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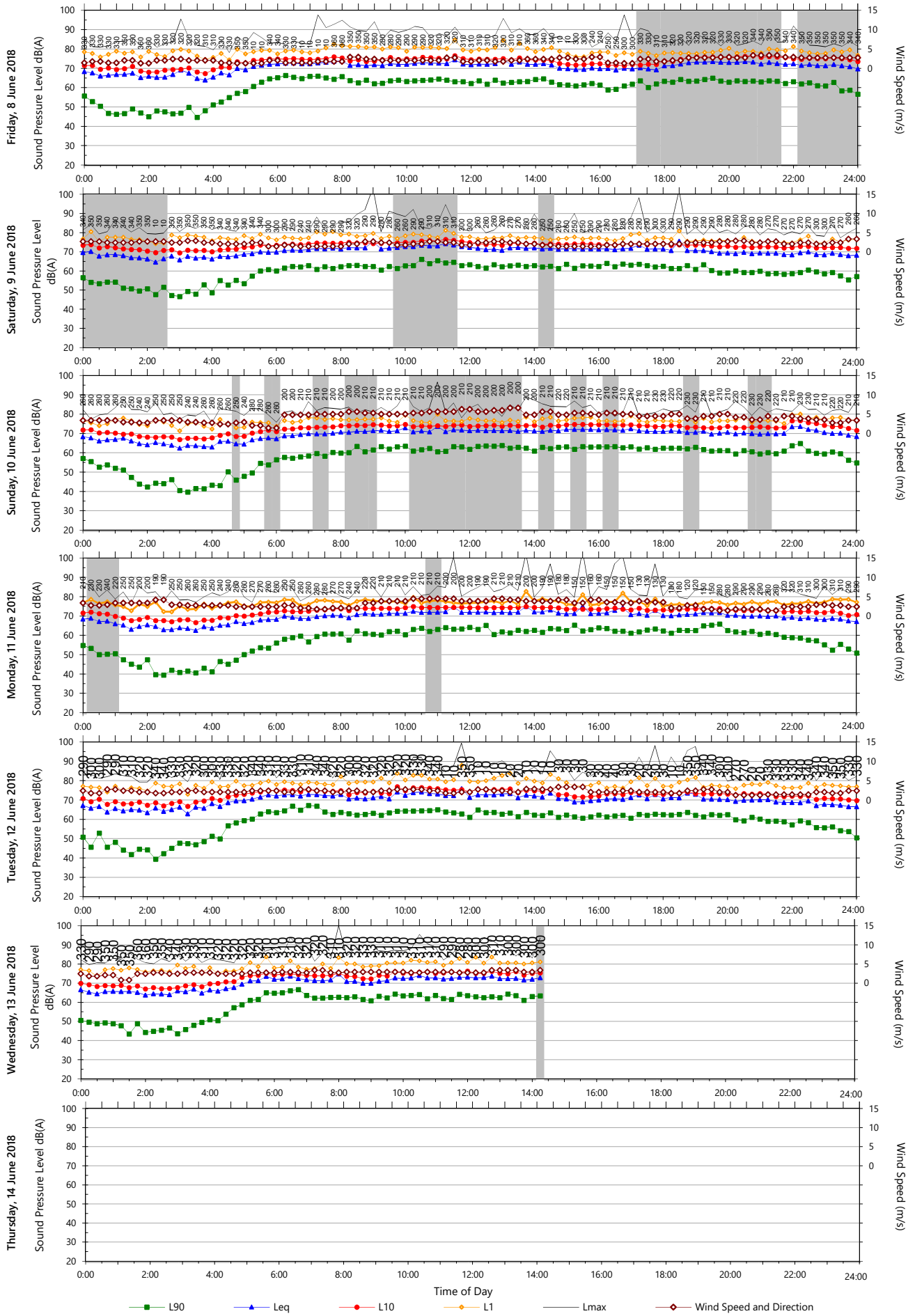
Template: QTE-26 (rev 17) Logger Graphs Program

Unattended Monitoring Results

Location: 2 Fox Valley Road, Wahroonga



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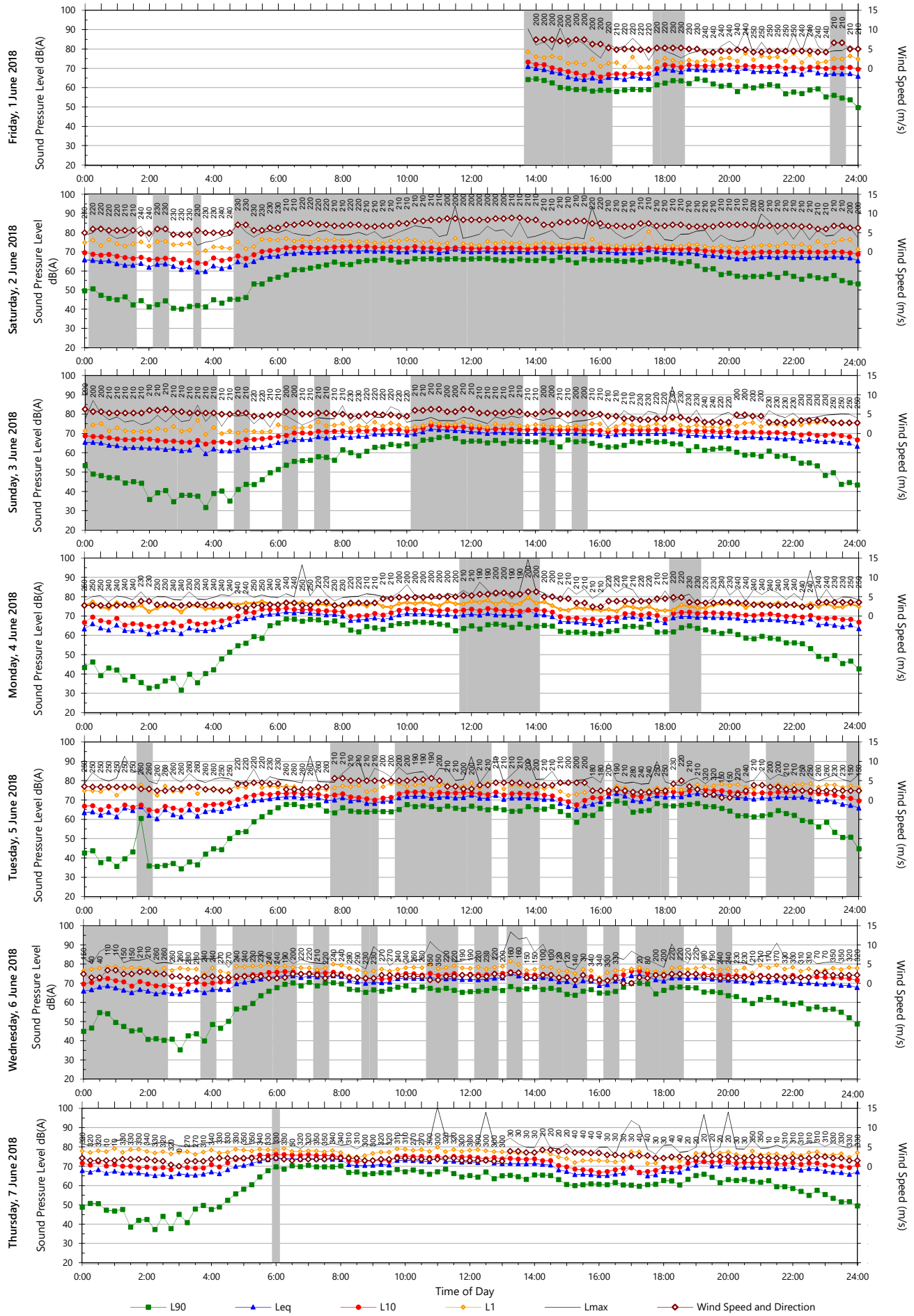
Template: QTE-26 (rev 17) Logger Graphs Program

Unattended Monitoring Results

Location: 1458 Pacific Highway, Turramurra



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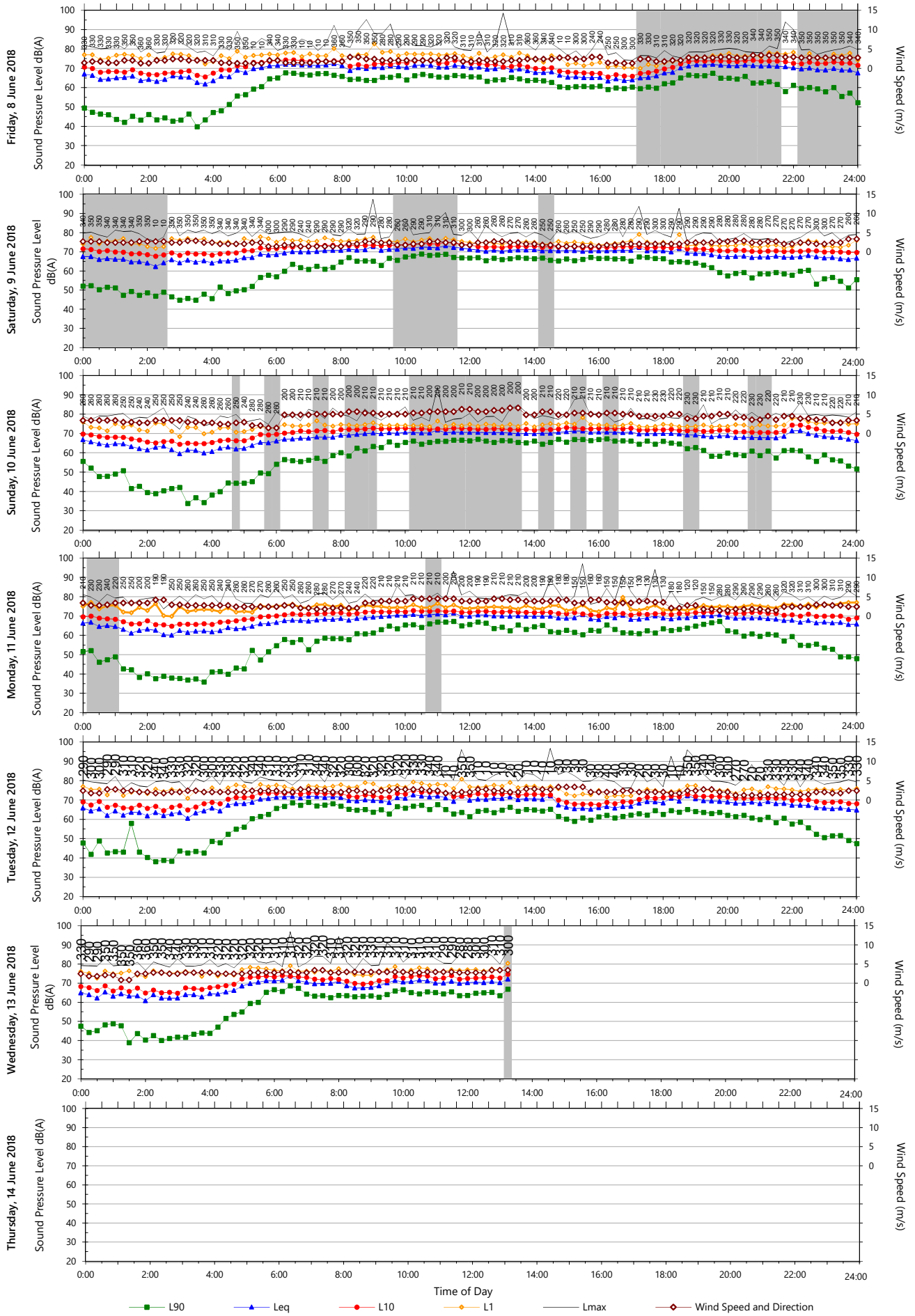
Unattended Monitoring Results

Location: 1458 Pacific Highway, Turramurra



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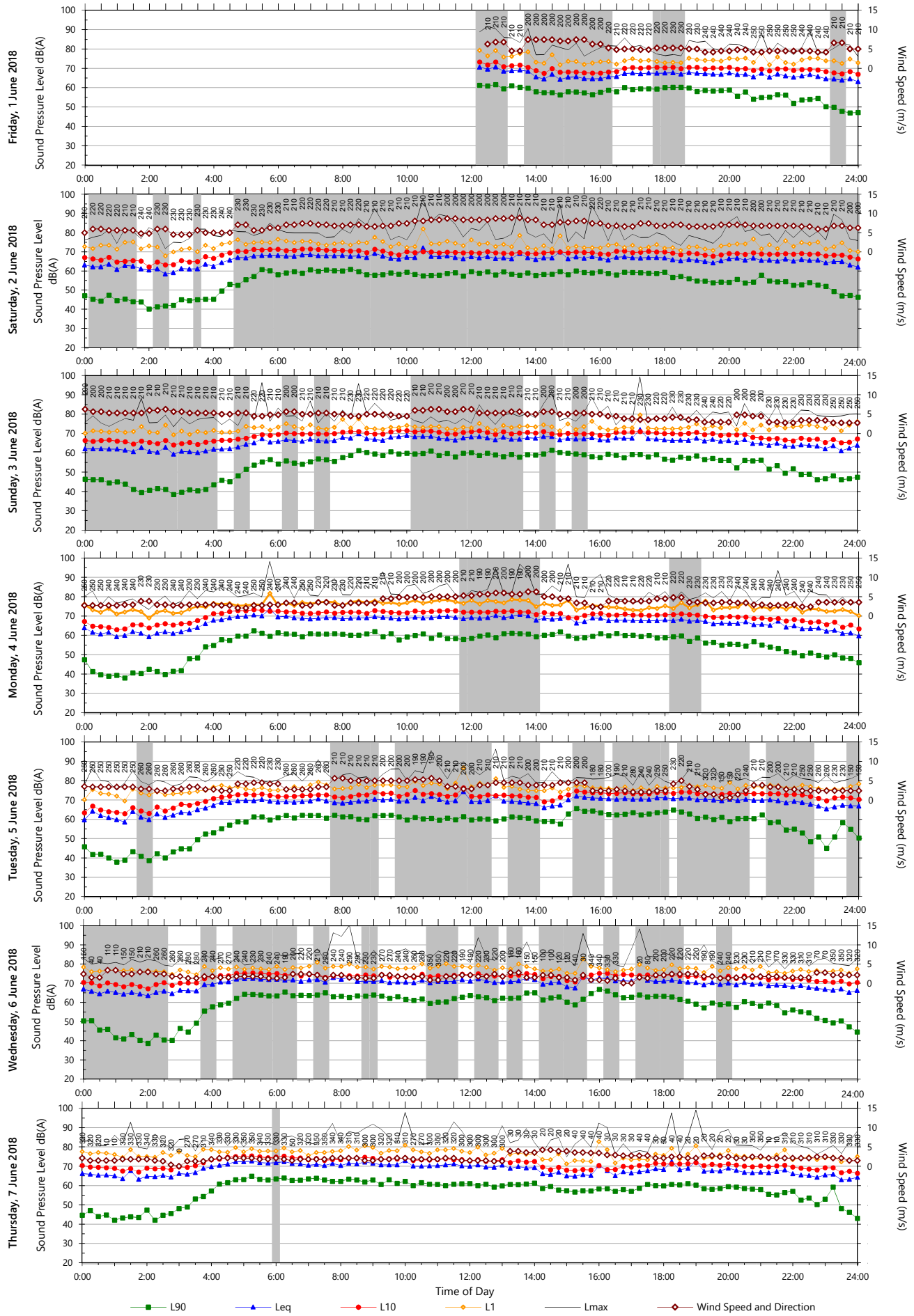
Template: QTE-26 (rev 17) Logger Graphs Program

Unattended Monitoring Results

Location: 1334 Pacific Highway, Turramurra



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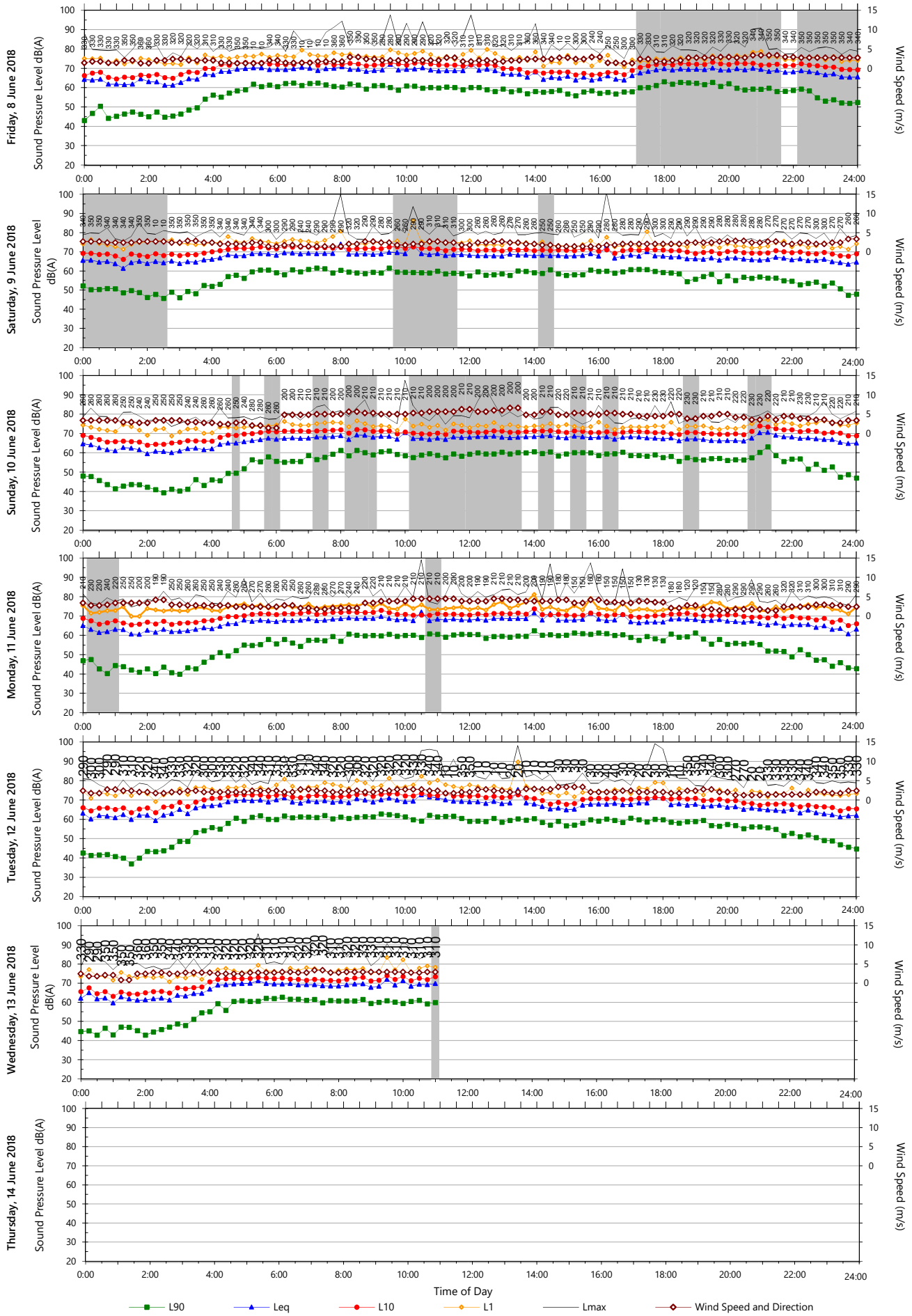
Template: QTE-26 (rev 17) Logger Graphs Program

Unattended Monitoring Results

Location: 1334 Pacific Highway, Turramurra



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Template: QTE-26 (rev 17) Logger Graphs Program