31 July 2019

Mr Phil Warner
Manager Assets and Major Projects
Byron Shire Council

Attention: Joshua Winter

Dear Sir,

Re: DA10.2016.77.1 Byron Bay Bypass

Council has considered the various detail and plans submitted on 7 May 2019 addressing conditions 12, 14, 15, 16, 17, 23, and 24. The following comments are provided in relation to each of those conditions and including Condition 26.

Condition 12 Construction Environmental Management Plan

Comment: The submitted plan prepared by GHD titled Report for Byron Shire Council – Byron Bay Bypass 22/19047 dated November 2018 satisfactorily addresses condition 12 of the development Consent. The temporary Construction Compound to be sited in accordance with the CEMP (It is noted the compound is located in the Butler Street reserve outside of the development area for the Bypass as approved by this consent)

Requirements within the other approved management plans are to be complied with at all times including the Construction Noise and Vibration MP, Acid Sulfate Soils MP, Contamination Assessment and Soils MP, Erosion and Sediment Control Soil and Water MP, Dewatering MP and Waste Minimisation MP, and the Aboriginal Cultural Heritage Management Procedure.

The contractors to be advised and briefed of their responsibilities under these plans prior to work commencing. The CEMP is to be adhered to at all times during the construction phase of the Bypass.

Condition 14 Contamination Assessment and Soils Management Plan

Comment: The Contaminated Soils Management Plan prepared by GHD on behalf of Byron Shire Council for the Byron Bypass satisfies Condition 14 of the development consent. It is noted that other works outside the scope of the consent should have regard to the Detailed Site Investigation Butler Street Reserve (Cavvanba April 2019, Ref. 18077 R02) when undertaking works near the Butler Street Reserve.

Condition 15 Acid Sulfate Soils

Comment: The Acid Sulfate Soil Management Plan prepared by GHD on behalf of Byron Shire Council for the Byron Bypass has satisfies condition 15 of the development consent. It is noted the method of construction limits the level of excavation required as discussed below under

Condition 16. Notwithstanding, Council is reminded that excavated trenches are not to be left open overnight and are to be managed as nominated within the Acid Sulfate Soils Management Plan at all times.

Condition 16 Dewatering Management Plan

Comment: The Dewatering Management Plan (GHD November 2017) and the Dewatering Management Sub-plan (Hazellbros, 24 July 2019) on behalf of Byron Shire Council for the Byron Bypass complies with condition 16 of the Development Consent. In this regard the method of construction limits the level of dewatering required to the installation of the culvert only with construction to proceed on the basis of a rock working platform with limited excavation into the water table elsewhere along the route of the Bypass.

Condition 17 Site Waste Minimisation and Management Plan

Comment: The Site Waste Minimisation Management Plan prepared by GHD on behalf of Byron Shire Council for the Byron Bypass complies with condition 17 of the development consent. The plan to be adhered to at all times during the construction of the Bypass.

Condition 23 Construction Noise and Vibration Management Plan

Comment: The Construction Noise Vibration Management Plan prepared by GHD on behalf of Byron Shire Council for the Byron Bypass complies with Condition 23. Please note and as stipulated within the plan and condition 23(a) the Dilapidation Survey is to be carried out prior to works commencing, and that necessary vibration monitoring be carried out as noted in the Section 58 Heritage Act 1977 approval (Condition 6).

Condition 24 Noise Mitigation Plan

Comment: The Noise Mitigation Plan prepared by Renzo Tonin & Associates on behalf of Byron Shire Council for the Byron Bypass complies with Condition 24 of the development consent. It is noted the noise walls / acoustic barriers as proposed need to be 2.4 metres in height.

Condition 26 Aboriginal Cultural Heritage

Comments: Recommendations included in the Aboriginal Cultural Heritage Management Procedure as part of the CEMP to be adhered to at all times. Any further consultation as nominated in the plan to be carried out prior to works commencing.

Should you have any further queries please contact me in the first instance.

Yours faithfully

Chris Larkin
Manager Sustainable Development

CAL/NFSx#E2019/62245

22 August 2019

Mr Phil Warner
Manager Assets and Major Projects
Byron Shire Council

Attention: Joshua Winter

Dear Sir,

Re: DA10.2016.77.1 Byron Bay Bypass

Further to our letter of 31 July 2019, Council confirms the approved CEMP as required under Condition 12 is the submitted plan prepared by GHD and titled “Report for Byron Shire Council – Byron Bay Bypass 22/19971 dated March 2019”. It is considered this updated plan satisfies the requirements of Condition 12 of the consent. The comments provided in our previous letter of 31 July 2019 remain relevant to the proposal.

Should you have any further queries please contact me in the first instance.

Yours faithfully

Chris Larkin
Manager Sustainable Development

ALL COMMUNICATIONS TO BE
ADDRESSED TO THE GENERAL MANAGER
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RENZO TONIN & ASSOCIATES
inspired to achieve

Acoustics
Vibration
Structural Dynamics

BYRON BAY BYPASS

Construction and Operational Noise and Vibration Assessment

3 August 2017

Byron Shire Council

TJ016-04F01 Noise & Vibration Assessment (r0)

30 1982 2012 ACOUSTIC EXCELLENCE
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Document details

Detail	Reference
Doc reference:	TJ016-04F01 Noise & Vibration Assessment (r0)
Prepared for:	Byron Shire Council
Address:	PO Box 219 Mullumbimby NSW 2482
Attention:	MR PHIL WARNER

Document control

Date	Revision history	Non-issued revision	Issued revision	Prepared	Instructed	Authorised
03.08.2017	Generate report	-	0	MCH	MCH	MCH

Contents

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1 Introduction

Renzo Tonin & Associates was engaged by Byron Shire Council to undertake an environmental noise assessment for the construction and operation of the proposed Byron Bay Bypass to be located to the west of the former rail corridor in Byron Bay. More specifically, this report models the potential noise impact on sensitive receivers from road traffic and construction activity associated with the proposed bypass and determines appropriate noise mitigation measures.

This study identifies sensitive locations and assesses potential noise and vibration impacts against noise and vibration criteria presented in the NSW Environment Protection Authority's (EPA) 'Road Noise Policy' (RNP), 'Interim Construction Noise Guideline' (ICNG) and the NSW Roads & Maritime Service's (RMS) 'Environmental Noise Management Manual' (ENMM), 'Noise Criteria Guideline' (NCG) and 'Noise Mitigation Guideline' (NMG). The issues addressed in this study include:

- Noise and vibration emissions during construction of the project; and
- Noise emissions from traffic impacting on residences in the vicinity of the bypass, during the operation of the bypass.

The existing ambient noise environment was previously monitored by GHD and presented in a noise and vibration assessment report (ref. 22/17484, dated June 2015), which formed part of the Environmental Impact Statement for the project. Noise emissions from the proposed bypass were calculated at the potentially most affected residential receivers for both the construction and operational phases.

The work documented in this report was carried out in accordance with the requirements of the EPA's 'Road Noise Policy' (RNP), 'Interim Construction Noise Guideline' (ICNG), RMS's 'Environmental Noise Management Manual' (ENMM), 'Noise Criteria Guideline' (NCG), 'Noise Mitigation Guideline' (NMG) and Renzo Tonin & Associates Quality Assurance System, which is based on Australian Standard / NZS ISO 9001.

Appendix A of this report presents a description of acoustic terms.

2 Project Description

2.1 Site Description

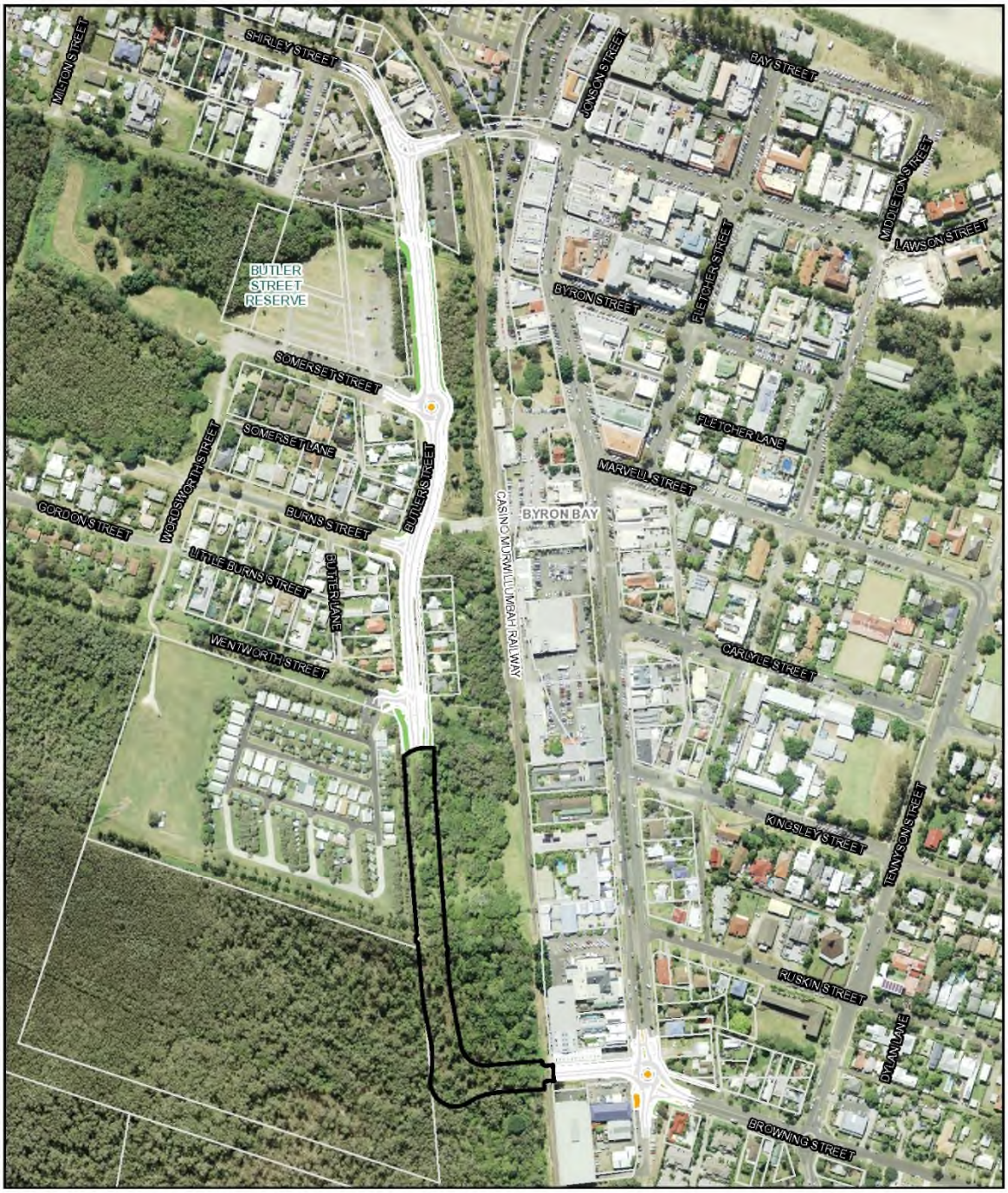
Byron Shire Council (Council) proposes to build a town centre road bypass to the west of the former rail corridor in Byron Bay. Key features of the proposal would include:

- Upgrade of the existing roundabout at the junction of Shirley Street, Lawson Street and Butler Street.
- Upgrade of Butler Street to the southern extent of the existing pavement (approximately 600 metres), including a new roundabout at Somerset Street.
- Construction of a new section of road from the former rail corridor to Jonson Street (Browning Street extension).
- A new roundabout at the intersection of the new Browning Street extension, Jonson Street and the existing Browning Street.
- Installation of noise treatment at a number of properties on Butler Street and one property on Browning Street.

It is noted that a section of the proposal would pass through an area of coastal wetlands mapped under State Environmental Planning Policy No. 14 – Coastal Wetlands (SEPP 14). A development application was submitted for the entire bypass proposal in 2016 and was approved by the Northern Joint Regional Planning Panel (NJRPP) on 22 June 2016. Following the NJRPP approval, only the works within the SEPP 14 area were approved by the Land and Environment Court on 2 June 2017. Therefore, this noise and vibration assessment does not apply to the SEPP 14 area that was subject to these approvals and the documents pertaining to that approval ('the approved project') can be viewed online at Council's website (http://www.byron.nsw.gov.au/projects/byron-bay-bypass).

A figure showing the proposed road bypass is presented in Figure 1.

Figure 1 – Proposed Byron Bay Town Centre Road Bypass



During a site inspection, the nearest affected noise sensitive receivers were observed to be located on the western side and parts of the eastern side of the proposed bypass and surrounding the Browning Street / Jonson Street intersection. The receivers have been grouped into the following Noise Catchment Areas (NCAs):

- **NCA 1 –** Noise catchment area located on the western and eastern side of Butler Street between the culvert over the Byron Street Reserve and Somerset Street. The Byron Bay aged care facility, Byron Motor Lodge and Butler Street Reserve are located within this NCA.

- **NCA 2 –** Noise catchment area located on the western side of Butler Street between Somerset Street and Wentworth Street. Residential receivers are located within this NCA.

- **NCA 3 –** Noise catchment area surrounding the Browning Street and Jonson Street intersection. Residential and commercial type receivers are located within this NCA.

- **NCA 4 –** Noise catchment area to the east of Butler Street between Burns Street and Wentworth Street. Residential receivers are located within this NCA.

- **NCA 5 –** Noise catchment area to the east of the proposed bypass. Only commercial type receivers are located within this NCA.

Error! Reference source not found. presents the NCAs along the proposal bypass route.

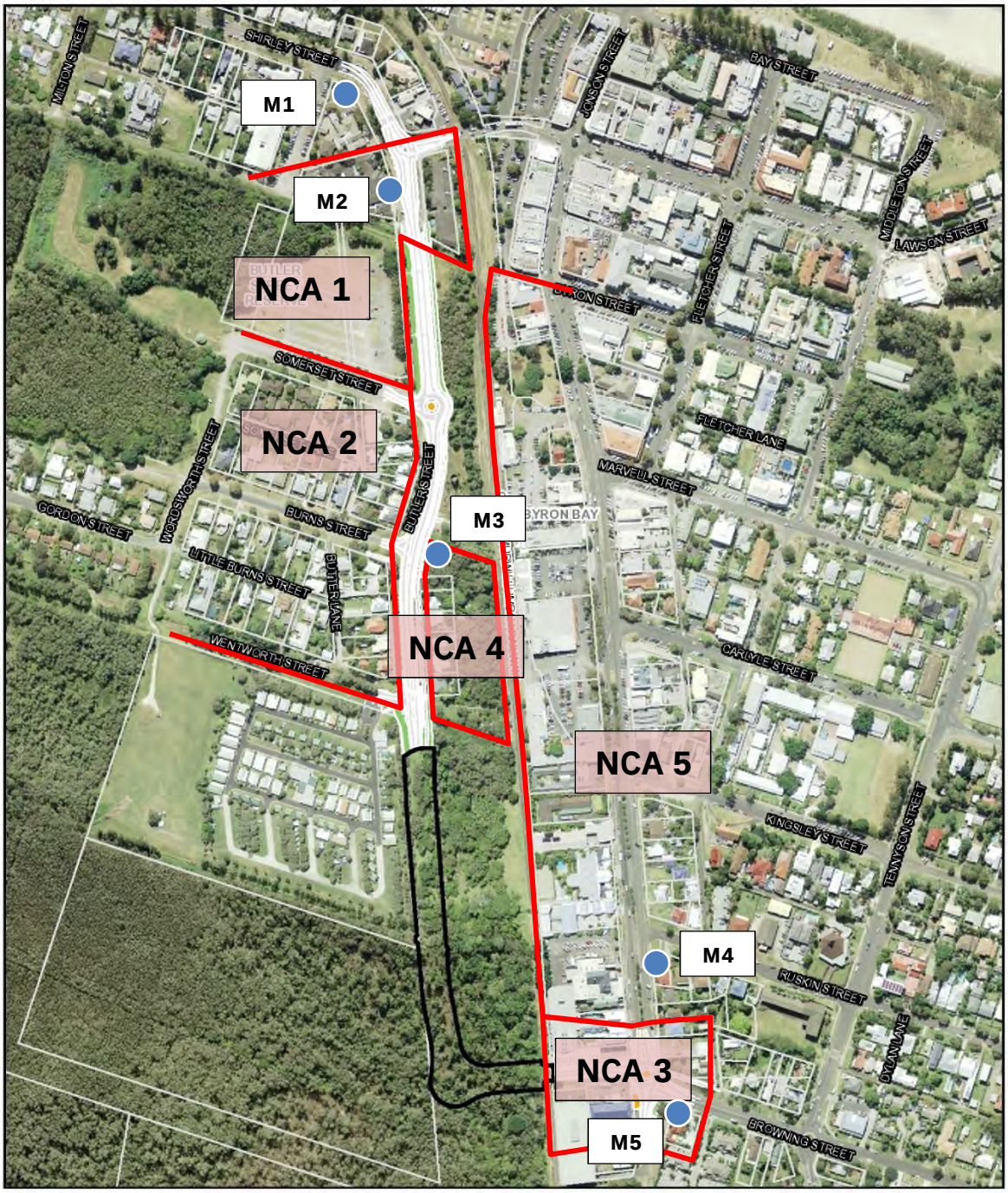
2.2 Construction Hours

It is anticipated that the hours of construction would generally occur during standard construction hours, as follows:

- 7:00am to 6:00pm, Monday to Friday
- 8:00am to 1:00pm on Saturdays
- No works on Sundays and Public Holidays

However, due to safety issues and/or to minimise traffic delays and disruptions to the surrounding road network, there is potential for out of hours (evening and/or night) works to be undertaken during the construction period.

Figure 2 – Locality Map Showing Site, Surrounds, NCAs and Monitoring



3 Existing Noise Environment

As the noise environment of an area almost always varies over time, background noise levels need to be determined for the purpose of determining construction noise goals. The NSW 'Industrial Noise Policy' (INP – Environment Protection Authority NSW 2000) outlines the following standard time periods over which the background noise levels are to be determined:

- **Day** is defined as 7:00am to 6:00pm, Monday to Saturday and 8:00am to 6:00pm Sundays & Public Holidays.
- **Evening** is defined as 6:00pm to 10:00pm, Monday to Sunday & Public Holidays.
- **Night** is defined as 10:00pm to 7:00am, Monday to Saturday and 10:00pm to 8:00am Sundays & Public Holidays.

For the assessment of operational noise, traffic noise levels are assessed separately for daytime and night time periods, defined by the RNP as follows:

- **Day** is defined as 7:00am to 10:00pm;
- **Night** is defined as 10:00pm to 7:00am.

3.1 Noise Monitoring Locations

To determine existing L_{eq} traffic noise levels and background L_{90} noise levels at various locations surrounding the proposed bypass, long-term noise monitoring was undertaken by GHD. The descriptions presented below for each location are obtained from the GHD noise and vibration report (ref. 22/17484, dated June 2015).

- **Location M1 – 2 Shirley Street (Byron Bay Police Station)**

  Noise monitor was located in the front yard, approximately in the free field (ie. away from any buildings) and facing Shirley Street. Noise levels are dominated by traffic noise from Shirley Street and Lawson Street.

- **Location M2 – 1 Butler Street (Byron Bay Aged Care)**

  Noise monitor was located in the front yard, approximately in the free field (ie. away from any buildings) and facing Butler Street. Noise levels are dominated by traffic noise from Shirley Street and Lawson Street and intermittent traffic noise from Butler Street. The noise environment at this location is considered representative of the receivers in NCA 1.

- **Location M3 – Butler Street (Vacant Land Opposite Burns Street)**

  Noise monitor was located approximately in the free field (ie. away from any buildings) and opposite the Butler Street and Burns Street intersection. Noise levels are dominated by intermittent traffic noise from Butler Street and Burns Street, natural sounds (eg. insect and frog noise) and distant CBD hum. The noise environment at this location is considered representative of the receivers in NCAs 2 and 4.

- **Location M4 – 131 Jonson Street (Ruskin House)**

  Noise monitor was located in the front yard, approximately in the free field (ie. away from any buildings) and facing Jonson Street. Noise levels are dominated by traffic noise from Jonson Street and Ruskin Street and nearby mechanical plant noise. The noise environment at this location is considered representative of the receivers in NCA 5.

- **Location M5 – Corner of Browning Street and Jonson Street (Vacant Land adjacent to Jasmine House)**

  Noise monitor was located approximately in the free field (ie. away from any buildings) and facing Browning Street. Noise levels are dominated by traffic noise from Browning Street and Jonson Street and intermittent noise from nearby commercial / industrial premises. The noise environment at this location is considered representative of the receivers in NCA 3.

To quantify the existing ambient noise environment, long-term (unattended) noise monitoring was conducted by GHD from 24th April to 6th May 2015 at the monitoring locations.

The raw noise monitoring data was obtained from GHD and analysed using Renzo Tonin & Associates' proprietary noise monitoring analysis spreadsheets.

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

The graphical recorded output from the long-term noise monitoring is included in Appendix C of this report. The graphs in Appendix C were analysed to determine a single assessment background level (ABL) for each day, evening and night period, in accordance with the NSW 'Industrial Noise Policy'.

3.2 Existing Traffic & Background Noise Levels

Long-term noise monitoring was conducted to quantify existing traffic and background noise levels. The purpose of the noise monitoring was to establish:

- Existing traffic noise levels for benchmarking and validation of the operational noise model; and
- Background noise levels for the setting of construction noise goals for the project.

Existing road traffic and background noise levels at the noise monitoring locations are presented in Table 3.1 below.

Table 3.1 – Measured Existing Traffic (L_{eq}) & Background (L_{90}) Noise Levels, dB(A)

Noise Monitoring Location	L_{Aeq} Traffic Noise Levels[1]		L_{A90} Background Noise Levels		
	Day $L_{Aeq,15hr}$	Night $L_{Aeq,9hr}$	Day	Evening	Night
M1 – 2 Shirley Street	65	59	55	45	40
M2 – 1 Butler Street	62	57	52	46	41
M3 – Butler Street (Vacant Land)	56	50	42	44	40
M4 – 131 Jonson Street	67	61	53	48	39
M5 – Cnr Browning & Jonson Street	65	58	50	40	34

Notes: 1. Traffic noise levels measured in the free-field have been façade corrected [ie. +2.5dB(A)] to provided representative traffic noise levels at 1m from a facade

4 Construction Noise and Vibration Assessment

4.1 Construction Noise Objectives

4.1.1 Construction Noise Management Levels at Residences

Construction noise management levels are determined by the NSW 'Interim Construction Noise Guideline' (ICNG, DECC 2009). 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 management level. 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.
	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 noise management levels 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 noise management levels, all feasible and reasonable work practices will be applied to meet the management levels.

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

Table 4.2 identifies the adopted construction noise management levels (NMLs) for the nearest affected residential receivers identified. The NMLs for the residential receiver are derived from the RBLs represented by the background noise levels measured at the monitoring locations and presented in Section 3.2.

Table 4.2 – Summary of Construction Noise Management Levels

Time of Day	Noise Management Level $L_{Aeq(15min)}$	Noise Management Level $L_{Aeq(15min)}$ at Nearest Residential Receivers			
		NCA 1	NCA 2	NCA 3	NCA 4
During recommended standard hours (day period)	RBL + 10dB(A)	52 + 10 = **62dB(A)**	42 + 10 = **52dB(A)**	50 + 10 = **60dB(A)**	42 + 10 = **52dB(A)**
Outside recommended standard hours (evening)	RBL + 5dB(A)	46 + 5 = **51dB(A)**	44 + 5 = **49dB(A)**	40 + 5 = **45dB(A)**	44 + 5 = **49dB(A)**
Outside recommended standard hours (night)		41 + 5 = **46dB(A)**	40 + 5 = **45dB(A)**	34 + 5 = **39dB(A)**	40 + 5 = **45dB(A)**

4.1.2 Sensitive Land Uses and Commercial Premises

Butler Street Reserve is considered to be an active recreation area and therefore, in accordance with the ICNG, should be assessed for construction noise impacts. Furthermore, there are also commercial premises within the vicinity of the proposed bypass in NCAs 3 and 5; and therefore, should also be assessed for construction noise in accordance with the ICNG.

Table 4.3 sets out the ICNG noise management levels for active recreation areas and commercial type receivers. As identified for residential receivers, a 'highly affected' noise objective of $L_{Aeq(15min)}$ 75dB(A) is adopted for all noise sensitive receivers, with exceedances addressed as described in Table 4.1.

Table 4.3 – Noise Management Levels for Sensitive Land Uses and Commercial Receivers

Land Use	Where Objective Applies	Management Level $L_{Aeq\ (15\ min)}$
Active recreation areas	External noise level	65 dB(A)
Commercial premises	External noise level	70 dB(A)

Notes: 1. Noise management level applies when receiver is in use only

4.1.3 Sleep Disturbance Criteria

Given that there is potential for out of hours works during the night time period (ie. 10pm to 7am), the assessment of sleep disturbance is to be undertaken.

The ICNG recommends that where construction works are planned to extend over two or more consecutive nights, the assessment should consider maximum noise levels and the extent and frequency of maximum noise level events exceeding the RBL.

Noise emanating from the construction works 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 $L_{A1, (1\ minute)}$ not exceeding the $L_{A90, (15\ minute)}$ 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 $L_{A1, (1\ minute)}$, 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 $L_{A1, (1\ minute)}$ descriptor is meant to represent a maximum noise level measured under 'fast' time response. The EPA will accept analysis based on either $L_{A1, (1\ minute)}$ or $L_{A, (Max)}$."*

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 (see NSW 'Industrial Noise Policy' page 17), the above references indicate that external noise levels of L_{Amax} 55 to 65dB(A) are unlikely to cause awakening reactions.

Based on the above, 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 $L_{A1(1min))}$ 65 dB(A).

The sleep disturbance criteria for the project are presented in Table 4.4.

Table 4.4 – Sleep Disturbance Criteria, dB(A)

Noise Catchment Area	Sleep disturbance criteria, 10:00pm - 7:00am, $L_{A1,1minute}$	
	Initial Screening Level – $L_{A90(15min)}$ + 15	Awakening Reaction Level
NCA 1	**56**	**65**
NCA 2	**55**	**65**
NCA 3	**55**[1]	**65**
NCA 4	**55**	**65**

Notes: 1. Background noise level is less than 40dB(A) resulting in an initial screening level <55dB(A); therefore, minimum screening level set at 55dB(A)

4.2 Construction Vibration Objectives

4.2.1 Disturbance to Buildings Occupants

For disturbance to human occupants of buildings, we refer to the NSW EPA's (ex DECC) 'Assessing Vibration; a technical guideline', published by DECC in February 2006. This document provides criteria which are based on the British Standard BS 6472-1992, 'Evaluation of human exposure to vibration in buildings (1-80Hz)'.

Vibration sources are defined as Continuous, Impulsive or Intermittent. Table 4.5 below provides a definition and examples of each type of vibration.

Table 4.5 – 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.

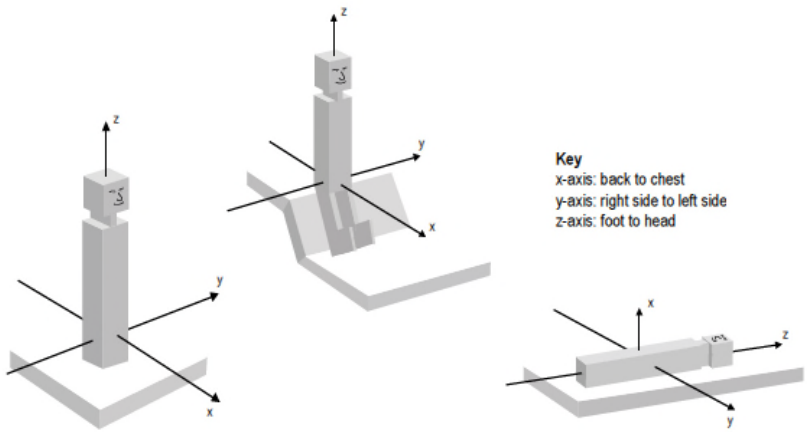
Source: Assessing Vibration; a technical guideline, (Department of Environment & Climate Change, 2006)

The criteria are to be applied to 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 3. 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 3 – Orthogonal Axes for Human Exposure to Vibration



Source: Assessing Vibration; a technical guideline, Department of Environment & Climate Change 2006 p4

The preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and the locations applicable to receivers surrounding the site are reproduced below.

Table 4.6 – 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
Intermittent vibration (Vibration Dose Values, VDV, $m/s^{1.75}$, 1-80Hz)					
Residences	Daytime	0.20		0.40	
	Night-time	0.13		0.26	
Offices, schools, educational institutions and places of worship	Day- or night-time	0.40		0.80	
Workshops	Day- or night-time	0.80		1.60	

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

4.2.2 Structural Damage to Buildings

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

Safe limits for construction generated vibration have been determined using the vibration limits set out in the German Standard DIN 4150 Part 3-1999 'Structural Vibration in Buildings – Effects on Structures'.

The minimum 'safe limit' of vibration at low frequencies for commercial and industrial buildings is 20mm/s. For dwellings it is 5mm/s and for particularly sensitive structures (eg. historical with preservation orders etc), it is 3mm/s. These limits increase as the frequency content of the vibration increases. These values are presented in Table 4.7 below and are generally recognised to be conservative.

Table 4.7 – DIN 4150-3 Structural Damage Criteria

Group	Type of Structure	Vibration Velocity, mm/s			
		At Foundation at Frequency of			Plane of Floor Uppermost Storey
		Less than 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

4.3 Construction Noise and Vibration Sources

4.3.1 Construction Noise Source

The following table lists the proposed construction plant and equipment likely to be used by the contractor to carry out the necessary construction works for this project with their corresponding sound power levels. This list of plant and equipment and their corresponding sound power levels have been obtained from the GHD noise and vibration report (ref. 22/17484, dated June 2015).

Table 4.8 – Typical Sound Power Levels for Construction Plant & Equipment, dB(A)

Plant Description	Sound Power Level, dB(A) re. 1pW	
	L_{Aeq}	L_{Amax}
Mulcher	114	117
Chainsaw	112	118
Mobile Crane	110	115
Grader	110	115
Delivery Trucks	108	113
Rollers	108	113
Dozer	108	118
Excavator	107	115
Hand Tools	105	115
Backhoe	104	108
Compressor	102	105
Generator	100	106
Light Vehicle	98	103

Notes: 1. Plant and equipment list and L_{Aeq} sound power levels obtained from GHD noise and vibration assessment report (ref. 22/17484, dated June 2015)

2. L_{Amax} sound power levels obtained from past projects and information held in our library

The L_{Aeq} sound power levels for the plant and equipment presented in the table above were obtained from the GHD noise and vibration report (ref. 22/17484, dated June 2015), while the L_{Amax} sound power levels are based on maximum levels given in Table A1 of Australian Standard 2436 - 2010 "Guide to Noise Control on Construction, Demolition and Maintenance Sites", ICNG, information from past projects and information held in the Renzo Tonin & Associates library files.

4.3.2 Construction Vibration Sources

The vibration generated from construction works will vary depending on the level and type of activity carried out at the site during the construction works.

Typical vibration levels from vibration inducing construction equipment most likely to cause significant vibration are summarised below. The information was sourced from a variety of reference materials available in the Renzo Tonin & Associates library.

Table 4.9 – Typical Ground Vibration Generated by Construction Plant

Activity	Typical Ground Vibration
Vibratory rollers	Ground vibration caused by vibratory rollers can range up to 1.5mm/s at distances of 25m. The highest levels of vibration usually occur as the roller is brought to rest and the frequency of the centrifugal forces passes through resonance with the natural frequency of the roller/ground/structure. Machinery should therefore not be brought to rest when in the vicinity of susceptible buildings, especially dwellings. Higher levels could occur at closer distances; however, no damage would be expected for any building at distances greater than approximately 12m (for a medium to heavy roller).

Activity	Typical Ground Vibration
Excavators	Typical ground vibration from excavators range from 1mm/s to 2mm/s at distances of approximately 5m and at distances greater than 20m, vibration levels are usually below 0.2mm/s.
Truck traffic	Typical vibration from heavy trucks passing over normal (smooth) road surfaces generate relatively low vibration levels in the range of 0.01 - 0.2mm/s at the footings of buildings located 10 - 20m from a roadway. Very large surface irregularities can cause levels up to five to ten times higher. In general, ground vibration from trucks is usually imperceptible in nearby buildings. The rattling of windows and other loose fittings that is sometimes reported is more likely to be caused by airborne acoustic excitation from very low frequency (infrasonic) noise radiated by truck exhausts and truck bodies. While this may cause concern to the occupants, the phenomenon is no different from the rattling caused by wind or people walking or jumping on the floor and fears of structural damage or even accelerated ageing are usually unfounded.

Site specific buffer distances for vibration significant plant items (e.g. rock breakers) should be measured on site. Unlike noise, vibration cannot be 'predicted'. There are many variables from site to site, for example soil type and conditions; sub surface rock; building types and foundations; and actual plant on site. The data relied upon in this assessment (tabulated above) is taken from a database of vibration levels measured at various sites or obtained from other sources (e.g. BS5228-2:2009) and should not be considered specific for this project.

4.4 Construction Noise and Vibration Assessment

4.4.1 Construction Noise Assessment

Construction work is anticipated to be carried out during standard daytime hours whenever practicable; however, there may be periods of evening or night time works.

Noise emissions were determined by modelling the noise sources, receiver locations, topographical features of the intervening area and buildings surrounding the study area using the CadnaA (version 4.4) noise modelling program. The program calculates the contribution of each noise source at each specified receptor point and allows for the prediction of the total noise from a site.

The noise prediction model takes into account:

- Location of noise sources and receiver locations;
- Height of sources and receivers;
- Separation distances between sources and receivers;
- Ground type between sources and receivers; and
- Attenuation from barriers (natural and purpose built).

Noise levels at any receptors resulting from construction works would depend on the location of the receptor with respect to the area of construction, shielding from intervening topography and structures, distance between the receptor and noise source and the type and duration of construction being undertaken. Furthermore, noise levels at receivers would vary over the total construction program due

to the transient nature of the construction works and the range of plant and equipment that could be used.

Construction noise impacts were predicted to the receiver locations identified in the GHD noise and vibration report and grouped into the NCAs identified in Section 2. Noise emissions were determined by modelling the noise sources, receiver locations and operating activities as outlined above. The predicted noise ranges shown in the table represents the plant item operating at a location furthest from the affected receiver (lower range) and a location closest to the affected receiver (upper range). Noise levels ranges were also predicted for the three noisiest plant items operating concurrently, which is considered to be a worst-case scenario. This approach is conservative and has been adopted to ensure the full extent of possible noise impacts are assessed (what might occur in the worst-case). Therefore, the noise generated during construction works would generally be below the predictions presented below.

The results in Table 4.10 have been highlighted the following colours to represent exceedances of the noise management levels for specific time periods:

- Predicted noise levels highlighted **blue** exceeds the day, evening and night noise management levels.
- Predicted noise levels highlighted **green** exceeds the evening and night noise management levels.
- Predicted noise levels highlighted **pink** exceeds the night noise management levels only.
- Predicted noise levels highlighted **red** exceeds the highly affected noise objective of 75dB(A).

Table 4.10 – Predicted L_{Aeq} Construction Noise Levels, dB(A)

Receiver ID	Receiver Address	NML	Predicted $L_{Aeq(15min)}$ Construction Noise Levels												
			Mulcher	Chain Saw	Grader	Mobile Crane	Truck	Dozer	Roller	Excavator	Hand tools	Backhoe	Compressor	Generator	Light Vehicles
NCA 1															
R7	11 Butler Street	*Day 62 / Evening 51 / Night 46*	19-72	17-70	15-68	15-68	13-66	13-66	13-66	12-65	10-63	9-62	7-60	5-58	3-56
R8	1 Butler Street		22-72	20-70	18-68	18-68	16-66	16-66	16-66	15-65	13-63	12-62	10-60	8-58	6-56
O1	Butler Street Reserve	*65*	22-71	20-69	18-67	18-67	16-65	16-65	16-65	15-64	13-62	12-61	10-59	8-57	6-55
NCA 2															
R9	54 Butler Street	*Day 52 / Evening 49 / Night 45*	23-74	21-72	19-70	19-70	17-68	17-68	17-68	16-67	14-65	13-64	11-62	9-60	7-58
R10	56 Butler Street		26-80	24-78	22-76	22-76	20-74	20-74	20-74	19-73	17-71	16-70	14-68	12-66	10-64
R11	58 Butler Street		24-77	22-75	20-73	20-73	18-71	18-71	18-71	17-70	15-68	14-67	12-65	10-63	8-61
R12	60 Butler Street		25-75	23-73	21-71	21-71	19-69	19-69	19-69	18-68	16-66	15-65	13-63	11-61	9-59
R13	62 Butler Street		25-76	23-74	21-72	21-72	19-70	19-70	19-70	18-69	16-67	15-66	13-64	11-62	9-60
R14	66 Butler Street		25-70	23-68	21-66	21-66	19-64	19-64	19-64	18-63	16-61	15-60	13-58	11-56	9-54
R15	68 Butler Street		25-73	23-71	21-69	21-69	19-67	19-67	19-67	18-66	16-64	15-63	13-61	11-59	9-57
R16	70 Butler Street		25-77	23-75	21-73	21-73	19-71	19-71	19-71	18-70	16-68	15-67	13-65	11-63	9-61
R17	72 Butler Street		24-73	22-71	20-69	20-69	18-67	18-67	18-67	17-66	15-64	14-63	12-61	10-59	8-57
R18	74 Butler Street		28-79	26-77	24-75	24-75	22-73	22-73	22-73	21-72	19-70	18-69	16-67	14-65	12-63
R19	76 Butler Street		27-81	25-79	23-77	23-77	21-75	21-75	21-75	20-74	18-72	17-71	15-69	13-67	11-65
NCA 3															
R27	140 Jonson Street	*Day 60 / Evening 45 / Night 39*	26-80	24-78	22-76	22-76	20-74	20-74	20-74	19-73	17-71	16-70	14-68	12-66	10-64
R28	131 Jonson Street		37-65	35-63	33-61	33-61	31-59	31-59	31-59	30-58	28-56	27-55	25-53	23-51	21-49
R29	133 Jonson Street		27-67	25-65	23-63	23-63	21-61	21-61	21-61	20-60	18-58	17-57	15-55	13-53	11-51
R30	135 Jonson Street		35-71	33-69	31-67	31-67	29-65	29-65	29-65	28-64	26-62	25-61	23-59	21-57	19-55
R31	137 Jonson Street		35-74	33-72	31-70	31-70	29-68	29-68	29-68	28-67	26-65	25-64	23-62	21-60	19-58
R32	139 Jonson Street		26-66	24-64	22-62	22-62	20-60	20-60	20-60	19-59	17-57	16-56	14-54	12-52	10-50
R33	3 Browning Lane		27-72	25-70	23-68	23-68	21-66	21-66	21-66	20-65	18-63	17-62	15-60	13-58	11-56
R34	5 Browning Street		20-71	18-69	16-67	16-67	14-65	14-65	14-65	13-64	11-62	10-61	8-59	6-57	4-55
R35	6-8 Browning Street		31-72	29-70	27-68	27-68	25-66	25-66	25-66	24-65	22-63	21-62	19-60	17-58	15-56
C5	144 Jonson Street	*70*	18-82	16-80	14-78	14-78	12-76	12-76	12-76	11-75	9-73	8-72	6-70	4-68	2-66
C6	156 Jonson Street		27-73	25-71	23-69	23-69	21-67	21-67	21-67	20-66	18-64	17-63	15-61	13-59	11-57
C7	148 Jonson Street		32-72	30-70	28-68	28-68	26-66	26-66	26-66	25-65	23-63	22-62	20-60	18-58	16-56
C8	4 Browning Street		30-81	28-79	26-77	26-77	24-75	24-75	24-75	23-74	21-72	20-71	18-69	16-67	14-65
NCA 4															
R20	69 Butler Street	*Day 52 / Evening 49 / Night 45*	24-74	22-72	20-70	20-70	18-68	18-68	18-68	17-67	15-65	14-64	12-62	10-60	8-58
R21	71 Butler Street		24-75	22-73	20-71	20-71	18-69	18-69	18-69	17-68	15-66	14-65	12-63	10-61	8-59
R22	73 Butler Street		24-74	22-72	20-70	20-70	18-68	18-68	18-68	17-67	15-65	14-64	12-62	10-60	8-58
R23	75 Butler Street		25-72	23-70	21-68	21-68	19-66	19-66	19-66	18-65	16-63	15-62	13-60	11-58	9-56
R24	77 Butler Street		25-75	23-73	21-71	21-71	19-69	19-69	19-69	18-68	16-66	15-65	13-63	11-61	9-59

Receiver ID	Receiver Address	NML	Predicted $L_{Aeq(15min)}$ Construction Noise Levels												
			Mulcher	Chain Saw	Grader	Mobile Crane	Truck	Dozer	Roller	Excavator	Hand tools	Backhoe	Compressor	Generator	Light Vehicles
NCA 5															
C4	Jonson Street (Railway Station)	*70*	23-62	21-60	19-58	19-58	17-56	17-56	17-56	16-55	14-53	13-52	11-50	9-48	7-46

Notes:
1. Predicted level exceeding the highly affected noise objective of 75dB(A) are in red font
2. Predicted level exceeding the Day, Evening and Night Noise Management Levels are in blue font
3. Predicted level exceeding the Evening and Night Noise Management Levels are in green font
4. Predicted level exceeding only the Night Noise Management Level are in pink font

The results presented in the above table indicate that construction noise levels generally exceed the day, evening and night construction noise management levels at the residential receiver locations when the plant and equipment are operating closest to the receiver locations. For the commercial type receiver and the Butler Street Reserve, construction noise levels generally comply with the noise management levels applicable to these receivers. However, some exceedances are predicted, particularly for the noisier plant and equipment.

Receivers in NCAs 2 and 3 are also predicted to be highly noise affected [ie. >75dB(A)].

In light of the predicted noise levels and exceedances, it is recommended that a feasible and reasonable approach towards noise management measures be applied to reduce noise levels as much as possible to manage the impact from construction noise. For the highly noise affected receiver locations, the approach presented in Table 4.1 (eg. respite periods), should be considered as part of the reasonable and feasible noise management measures applied.

Further details on construction noise mitigation and management measures are provided in Section 4.5.

Sleep Disturbance Assessment

In addition to the above predicted noise levels, Table 4.11 presents a summary of the predicted L_{Amax} noise levels at residential receivers during potential night time works. 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.

The results in Table 4.11 have been highlighted the following colours to represent exceedance of the sleep disturbance criteria:

- Predicted noise levels highlighted **blue** exceeds the initial screening level [ie. $L_{A90(15min)}$ + 15dB(A) or 55dB(A)].
- Predicted noise levels highlighted **red** exceeds the awakening reaction level of 65dB(A).

Table 4.11 – Predicted L_{Amax} Construction Noise Levels for Night Works, dB(A)

Receiver ID	Receiver Address	Sleep Disturbance Criteria	Predicted L_{Amax} Construction Noise Levels												
			Mulcher	Chain Saw	Grader	Mobile Crane	Truck	Dozer	Roller	Excavator	Hand tools	Backhoe	Compressor	Generator	Light Vehicles
NCA 1															
R7	11 Butler Street	*56 (initial screening) / 65 (awakening reaction)*	22-75	23-76	20-73	20-73	18-71	18-71	23-76	20-73	20-73	13-66	10-63	11-64	8-61
R8	1 Butler Street		25-75	26-76	23-73	23-73	21-71	21-71	26-76	23-73	23-73	16-66	13-63	14-64	11-61
NCA 2															
R9	54 Butler Street	*55 (initial screening) / 65 (awakening reaction)*	26-77	27-78	24-75	24-75	22-73	22-73	27-78	24-75	24-75	17-68	14-65	15-66	12-63
R10	56 Butler Street		29-83	30-84	27-81	27-81	25-79	25-79	30-84	27-81	27-81	20-74	17-71	18-72	15-69
R11	58 Butler Street		27-80	28-81	25-78	25-78	23-76	23-76	28-81	25-78	25-78	18-71	15-68	16-69	13-66
R12	60 Butler Street		28-78	29-79	26-76	26-76	24-74	24-74	29-79	26-76	26-76	19-69	16-66	17-67	14-64
R13	62 Butler Street		28-79	29-80	26-77	26-77	24-75	24-75	29-80	26-77	26-77	19-70	16-67	17-68	14-65
R14	66 Butler Street		28-73	29-74	26-71	26-71	24-69	24-69	29-74	26-71	26-71	19-64	16-61	17-62	14-59
R15	68 Butler Street		28-76	29-77	26-74	26-74	24-72	24-72	29-77	26-74	26-74	19-67	16-64	17-65	14-62
R16	70 Butler Street		28-80	29-81	26-78	26-78	24-76	24-76	29-81	26-78	26-78	19-71	16-68	17-69	14-66
R17	72 Butler Street		27-76	28-77	25-74	25-74	23-72	23-72	28-77	25-74	25-74	18-67	15-64	16-65	13-62
R18	74 Butler Street		31-82	32-83	29-80	29-80	27-78	27-78	32-83	29-80	29-80	22-73	19-70	20-71	17-68
R19	76 Butler Street		30-84	31-85	28-82	28-82	26-80	26-80	31-85	28-82	28-82	21-75	18-72	19-73	16-70
NCA 3															
R27	140 Jonson Street	*55 (initial screening) / 65 (awakening reaction)*	24-84	25-85	22-82	22-82	20-80	20-80	25-85	22-82	22-82	15-75	12-72	13-73	10-70
R28	131 Jonson Street		40-68	41-69	38-66	38-66	36-64	36-64	41-69	38-66	38-66	31-59	28-56	29-57	26-54
R29	133 Jonson Street		30-70	31-71	28-68	28-68	26-66	26-66	31-71	28-68	28-68	21-61	18-58	19-59	16-56
R30	135 Jonson Street		38-74	39-75	36-72	36-72	34-70	34-70	39-75	36-72	36-72	29-65	26-62	27-63	24-60
R31	137 Jonson Street		38-77	39-78	36-75	36-75	34-73	34-73	39-78	36-75	36-75	29-68	26-65	27-66	24-63
R32	139 Jonson Street		29-69	30-70	27-67	27-67	25-65	25-65	30-70	27-67	27-67	20-60	17-57	18-58	15-55
R33	3 Browning Lane		30-75	31-76	28-73	28-73	26-71	26-71	31-76	28-73	28-73	21-66	18-63	19-64	16-61
R34	5 Browning Street		23-74	24-75	21-72	21-72	19-70	19-70	24-75	21-72	21-72	14-65	11-62	12-63	9-60
R35	6-8 Browning Street		34-75	35-76	32-73	32-73	30-71	30-71	35-76	32-73	32-73	25-66	22-63	23-64	20-61
NCA 4															
R20	69 Butler Street	*55 (initial screening) / 65 (awakening reaction)*	27-77	28-78	25-75	25-75	23-73	23-73	28-78	25-75	25-75	18-68	15-65	16-66	13-63
R21	71 Butler Street		27-78	28-79	25-76	25-76	23-74	23-74	28-79	25-76	25-76	18-69	15-66	16-67	13-64
R22	73 Butler Street		27-77	28-78	25-75	25-75	23-73	23-73	28-78	25-75	25-75	18-68	15-65	16-66	13-63
R23	75 Butler Street		28-75	29-76	26-73	26-73	24-71	24-71	29-76	26-73	26-73	19-66	16-63	17-64	14-61
R24	77 Butler Street		28-78	29-79	26-76	26-76	24-74	24-74	29-79	26-76	26-76	19-69	16-66	17-67	14-64

Notes:
1. Sleep Disturbance assessment is applicable to residential receivers only
2. Predicted level exceeding the upper sleep disturbance limit of 65dB(A) are in red font
3. Predicted level exceeding the sleep disturbance criterion of $L_{A90(15min)}$ + 15dB(A) are in blue font

For the assessment of sleep disturbance, it can be seen that the predicted L_{Amax} noise levels would exceed the initial screening level at all residential receiver locations for all the proposed construction plant and equipment when the plant item is operating closest to the affected receiver location. Furthermore, the awakening reaction limit of 65dB(A) is also predicted to be exceeded all receiver locations for most of the plant and equipment items. Therefore, in accordance with the requirements of the ICNG, construction works should not occur over more than two consecutive nights to allow respite to nearby residences.

Nevertheless, a reasonable and feasible approach towards noise management measures would be required to reduce noise levels as much as possible to manage the impact from construction noise during night time periods.

4.4.2 Construction Vibration Assessment

The relationship between vibration and the probability of causing human annoyance or damage to structures is complex. This complexity is mostly due to the magnitude of the vibration source, the particular ground conditions between the source and receiver, the foundation-to-footing interaction and the large range of structures that exist in terms of design (eg. dimensions, materials, type and quality of construction and footing conditions). The intensity, duration, frequency content and number of occurrences of vibration, are all important aspects in both the annoyances caused and the strains induced in structures.

Vibration generated by construction plant was estimated at various distances and expected vibration impacts to the residential and commercial receivers are shown in Table 4.12 below.

Table 4.12 – Potential Vibration Impact Assessment

NCA	Approx. distance to works	Type of receivers potentially affected	Assessment on Potential Vibration Impacts		
			Structural Damage Risk	Human Disturbance	Vibration Monitoring
NCA 1	10m – 15m	Commercial / Residential	**Medium** risk of structural damage from vibratory rolling **Low** risk of structural damage from other activities	**High** risk of adverse comment as a result of vibratory rolling	Vibration monitoring should be conducted
NCA 2	10m – 15m	Residential	**Medium** risk of structural damage from vibratory rolling **Low** risk of structural damage from other activities	**High** risk of adverse comment as a result of vibratory rolling	Vibration monitoring should be conducted
NCA 3	10m – 15m	Commercial / Residential	**Medium** risk of structural damage from vibratory rolling **Low** risk of structural damage from other activities	**High** risk of adverse comment as a result of vibratory rolling	Vibration monitoring should be conducted
NCA 4	10m – 15m	Residential	**Medium** risk of structural damage from vibratory rolling **Low** risk of structural damage from other activities	**High** risk of adverse comment as a result of vibratory rolling	Vibration monitoring should be conducted
NCA 5	>50m	Commercial	**Very Low** risk of structural damage	**Very Low** risk of adverse comment	Not required

From the above table, there is a low to medium risk of structural damage from the use of a heavy vibratory roller at the nearest affected residences from the construction works and vibration monitoring is recommended, should a heavy vibratory roller be used within the vicinity of the nearest affected

buildings or structures. Furthermore, a high risk of adverse comments as a result of using a heavy vibratory roller is also possible at residences nearest to the construction works.

At receivers greater than 50m from the construction works there is a very low risk of structural damage or adverse comment due the construction works and as a result vibration impacts at these residences is highly unlikely.

Nevertheless, recommendations for reducing potential vibration impacts, including minimum working distances for construction plant are provided in Section 0 of this report.

4.5 Construction Noise and Vibration Mitigation

4.5.1 Construction Noise Mitigation

The following recommendations provide in-principle noise control solutions to reduce construction noise impacts to noise affected 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, buildability, fitness for purpose and the like.

General Noise Management Measures

Table 4.13 sets out general noise mitigation measures to be implemented as part of the upgrade works, as required.

Table 4.13 – General Mitigation Measures to Reduce Construction Noise

Action Required	Details
Management Measures	
Implement community consultation measures – inform community of construction activity and potential impacts	Incorporate into Community Liaison Plan
Site inductions	All employees, contractors and subcontractors are to receive a Project induction. The environmental component may be covered in toolboxes and should include: • all relevant project specific and standard noise mitigation measures as detailed in the construction noise & vibration management plan prepared by the contractor; • 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); and • environmental incident procedures.

Action Required	Details
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.
Monitoring	Noise monitoring should be considered for the duration of the works.
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 if practicable.
Construction respite period	Noise generating activities with impulsive, tonal or low frequency characteristics (such as jack hammering, etc) should only be carried out: • in continuous blocks, up to but not exceeding 3 hours each; and • with a minimum respite period of one hour between each block.
Equipment selection	Use quieter and less noise emitting construction methods where feasible and reasonable.
Maximum noise levels	All plant and equipment to be appropriately maintained to ensure optimum running conditions, with periodic monitoring.
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 applicable criteria.
Use and siting of plant	Simultaneous operation of noisy plant within discernible range of a sensitive receiver is to be limited/ avoided where possible. The offset distance between noisy plant and adjacent sensitive receivers is to be maximised where practicable. Plant used intermittently to be throttled down or shut down when not in use where practicable. Noise-emitting plant to be directed away from sensitive receivers where possible.
Plan worksites and activities to minimise noise	Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site.
Non-tonal reversing alarms	Non-tonal reversing beepers (or an equivalent mechanism) should be fitted and used on all construction vehicles and mobile plant regularly used on site for periods of over two months where practicable.
Minimise disturbance arising from delivery of goods to construction sites	Ensure all deliveries occur during standard construction hours.
Path Controls	
Shield sensitive receivers from noisy activities	Where reasonable and feasible, use structures to shield residential receivers from noise such as: • site shed placement; • earth bunds; • temporary or mobile noise screens (where practicable) • enclosures to shield fixed noise sources such as pumps, compressors, fans etc (where practicable); and • consideration of site topography when situating plant.

Noise Control Measures

Implementation of noise control measures, such as those suggested in Australian Standard 2436-2010 "Guide to Noise Control on Construction, Demolition and Maintenance Sites", are expected to reduce

predicted construction noise levels. Reference to Australian Standard 2436-2010, Appendix C, Table C1 suggests possible remedies and alternatives to reduce noise emission levels from typical construction equipment. Table C2 in Appendix C presents typical examples of noise reductions achievable after treatment of various noise sources. Table C3 in Appendix C presents the relative effectiveness of various forms of noise control treatment.

Table 4.14 below presents noise control methods, practical examples and expected noise reductions according to AS2436 and according to Renzo Tonin & Associates' opinion based on experience with past projects.

Table 4.14 – Relative Effectiveness of Various Forms of Noise Control, dB(A)

Noise Control Method	Practical Examples	Typical Noise Reduction Possible in Practice	
		AS 2436	Renzo Tonin & Associates
Distance	Doubling of distance between source and receiver	6	6
Screening	Acoustic barriers such as earth mounds, temporary, mobile or permanent noise barriers	5 to 10	5 to 10
Acoustic Enclosures	Engine casing lagged with acoustic insulation and plywood	5 to 10	5 to 10
Engine Silencing	Residential class mufflers	15 to 25	10 to 20
Substitution by alternative process	Use electric motors in preference to diesel or petrol	-	15 to 25

The Renzo Tonin & Associates' listed noise reductions are conservatively low and should be referred to in preference to those of AS2436, for this project.

Table 4.15 below identifies possible noise control measures, which are applicable for the construction plant likely to be used on site.

Table 4.15 – Noise Control Measures for Likely Construction Plant

Plant Description	Screening	Acoustic Enclosures	Silencing	Alternative Process
Mulcher	✔	✖	✔	✖
Chain Saw	✔	✖	✖	✖
Grader	✔	✖	✔	✖
Mobile Crane	✔	✖	✔	✖
Trucks	✔	✖	✔	✖
Dozer	✔	✖	✔	✖
Rollers	✔	✖	✔	✖
Excavator	✔	✖	✔	✖
Hand Tools	✔	✖	✖	✔
Backhoe	✔	✖	✔	✖
Compressor	✔	✔	✔	✖

Plant Description	Screening	Acoustic Enclosures	Silencing	Alternative Process
Generator	✔	✔	✔	✖
Light Vehicles	✔	✖	✖	✖

Managing High Noise Impact Activities

Construction noise levels presented in Table 4.10 indicate predicted noise levels at the receiver locations may potentially at times exceed the ICNG 'highly noise affected' noise management level of 75dB(A). In addition to the noise mitigation and management measures discussed above, it is recommended that extensive consultation be carried out with residences experiencing noise above the highly noise affected level of 75dB(A), to manage the potential noise impacts to these properties.

It may be necessary to restrict the times during which construction activities occur in the immediate vicinity of these properties or to offer respite periods by taking into account:

- Times identified by the residents when they are less sensitive to noise, for example between 9am and 3pm when residents are likely to be at work/ school etc; and
- If the residents are prepared to accept a longer period of construction in exchange for restrictions on construction times (ie. respite periods).

Regular Periodic Noise Monitoring

The following approach should be adopted with regard to noise monitoring procedures during the construction works.

- Where potential noise impacts are predicted to be within 10 to 15dB(A) of the noise management level (as presented in Table 4.10), the potential construction noise nuisance is considered to be moderate. Noise monitoring should be carried out to confirm predicted noise impacts within two weeks of commencement of construction. Reasonable and feasible noise reduction measures should be investigated, where necessary.
- Where potential noise impacts are predicted to be more than 15dB(A) above the noise management levels (as presented in Table 4.10), the potential construction noise nuisance is considered to be high. All reasonable and feasible noise control measures should be implemented prior to the commencement of construction works. Noise compliance monitoring for all major equipment and activities on the sites should be undertaken prior to their commencement of work on site. Finally, noise levels during construction should be monitored when required (eg. to address complaints) and where exceeded, further noise reduction measures (where reasonable and feasible) should be implemented eg. restrict working hours, use silencing equipment, etc.

4.5.2 Construction Vibration Mitigation

Recommended Minimum Buffer Distances

The pattern of vibration radiation is very different to the pattern of airborne noise radiation, and is very site specific. Accordingly, based on our database containing vibration measurements from past projects and library information, Table 4.16 below presents indicative safe working distances for high vibration generating plant impacting residential type buildings. For commercial and industrial type buildings, it is expected that the safe working distances would be reduced significantly.

Table 4.16 – Indicative Minimum Working Distances for Vibration Intensive Plant

Plant Item	Rating / Description	Minimum Working Distance (m)	
		Cosmetic Damage	Human Response
Excavators [2]	< 30 Tonne (travelling/ digging)	10	15
Vibratory Roller [2]	<50 kN (Typically 1-2 tonnes)	5	15 - 20
	<100 kN (Typically 2-4 tonnes)	6	20
	<200 kN (Typically 4-6 tonnes)	12	40
	<300 kN (Typically 7-13 tonnes)	15	100
	>300 kN (Typically 13-18 tonnes)	20	100
	>300 kN (Typically >18 tonnes)	25	100
Truck Movements[1]	-	-	10

Notes: 1. Renzo Tonin & Associates project files, databases & library
2. TCA Construction Noise Strategy, October 2010

Given that the nearest affected residences are approximately 10m from the proposed construction works, site specific buffer distances should be determined once vibration emission levels are measured from vibration significant plant items (e.g. vibratory rollers) and prior to the commencement of their regular use on site. Where construction activity occurs in close proximity to sensitive receivers, minimum buffer distances to affected receivers shall be determined by site measurements and maintained in order to comply with relevant vibration limits. It should be noted that the buffer distances identified above are a guide only.

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 structural 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.
- 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. 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. Details of the procedures for vibration monitoring are presented in Appendix C.
- Dilapidation surveys should be conducted at all buildings within the vicinity of the construction works. These surveys are used to address potential community concerns that perceived vibration may have caused damage to property.

4.5.3 Complaints Handling Procedure

In addition to the noise and vibration mitigation measures outlined above, it is recommended that a management procedure be put in place to deal with noise and vibration complaints that may arise from the construction works. Each complaint would need to be investigated and appropriate noise and/or vibration amelioration measures be put in place to mitigate future occurrences, where the noise and/or vibration in question is in excess of allowable limits.

5 Operational Noise Assessment

5.1 Noise Assessment Criteria

This section presents the relevant noise criteria and limits related to road traffic noise emissions from the project.

The key reference documents relevant to road traffic noise management for this project include:

- NSW Road Noise Policy (RNP), NSW EPA (ex DECCW), March 2011
- Noise Criteria Guideline (NCG), NSW RMS, April 2015
- Noise Mitigation Guidelines (NMG), NSW RMS, April 2015
- Environmental Noise Management Manual (ENMM), NSW RMS (ex RTA), 2001
- Byron Bay Bypass Noise and Vibration Assessment, GHD, June 2015
- L&EC Proceedings 2016/227775 – Byron Bay Bypass: Expert Report of Renzo Tonin (ref. TJ016-03F04 Statement of Evidence (r0), dated 29 March 2017)

Noise criteria are assigned to sensitive receivers using RMS's 'Noise Criteria Guideline (NCG). The NCG provides guidance on how to apply the NSW 'Road Noise Policy' (RNP). The assessment timeframe for the criteria are in the year of opening and 10 years after opening.

The project assessment area extends to where noise levels are dominated by other roads that are not being assessed as part of this project, as defined in the NCG. This is up to a maximum distance of 600 metres from the project works.

Butler Street is currently classed as local road in that it handles local traffic only and has low and intermittent traffic flows. As a result of the bypass, the traffic carrying capacity of Butler Street will be increased significantly and its functional class will be changed from a local road to a collector road. According to the NCG, the proposed widening of Butler Street to accommodate the new bypass is classed as a 'new road' because Butler Street has changed its functional class from a local road to a collector road.

Transition Zones

The NCG defines two types of transition zones for establishing project noise goals at residential receivers. These are:

1. A junction between a new road and a redeveloped road
2. An intersection between the road project and an existing road

For the Byron Bay Bypass project, a Type 1 Transition Zone is applicable at the southern end of the bypass where the Browning Street extension joins the existing Browning Street and Jonson Street

intersection. The intersection is to be redeveloped in that some kerb widening is proposed to accommodate a new roundabout. Therefore, for the receivers surrounding this intersection a transition zone between a new road and a redeveloped road is applicable.

To determine the applicable traffic noise criteria to use for affected receivers located within the transition zone, the noise contributions from the new road section and the redeveloped road section are calculated and the contribution difference (new road contribution – redeveloped road contribution) is used to determine the applicable traffic noise criteria in accordance with Table 1 of the NCG.

Following a review of the proposed 2028 traffic volumes (see Section 5.3.4) for Browning Street extension west (new road) and Browning Street east (redeveloped road), the contribution difference is less than -3.0dB(A). Therefore, for residences surrounding the intersection (ie. within NCA 3) the applicable criteria would be based on the upper levels presented in Table 1 of the NCG.

Relative Increase Criteria

The traffic noise impact from the proposed bypass would need to also comply with the 'Relative Increase Criteria' as discussed in Section 2.4 of the RNP. The relative increase criteria are to be applied to the external areas of existing residential and sensitive land uses impacted upon by the proposed bypass.

The relative increase criteria as set out in the NCG and RNP applicable to this project are reproduced below and apply for all NCAs.

Table 5.1 – Relative Increase Criteria

Type of development	Total traffic noise level increase, dB(A)
Redevelopment of existing road	Existing traffic $L_{Aeq(period)}$ + 12 dB (external)

Note: 1. 'Existing traffic' refers to the traffic noise levels for the relevant 'no build' option

Given that the bypass results in Butler Street changing its functional class, there is a possibility that the relative increase criteria may apply for some receiver locations. Results of the noise modelling has considered the requirements for determining the relative increase criteria in accordance with Table 5.1 above.

5.1.1 Traffic Noise Criteria for Residential Receivers

The applicable traffic noise criteria in accordance with the NCG for residential receivers is presented in the table below. It is noted that in accordance with the RNP and NCG, the aged care facility in NCA 1 will also be assessed against the noise criteria for residential receivers.

Table 5.2 – NCG Criteria (Residential)

Road Category	Type of Project/Land Use	Assessment Criteria (dB)	
		Daytime (7 am - 10 pm)	Night-time (10 pm - 7 am)
Freeway/ arterial/ sub-arterial roads	1. Existing residences affected by noise from new freeway/arterial/sub-arterial road corridors	$L_{Aeq(15hour)}$ 55 (external)	$L_{Aeq(9hour)}$ 50 (external)
	2. Existing residences affected by both new roads and the redevelopment of existing freeway/arterial/sub-arterial roads in a Transition Zone[1]	$L_{Aeq(15hour)}$ 60 (external)	$L_{Aeq(9hour)}$ 55 (external)
	3. Existing residences affected by increases in traffic noise of 12dBA or more from new freeway/arterial/sub-arterial roads[2]	Between $L_{Aeq(15hour)}$ 42-55 (external)	Between $L_{Aeq(9hour)}$ 42-50 (external)

Notes: 1. Applicable transition zone criteria determined based on traffic volumes for new road and redeveloped road
2. The criteria at each facade are determined from the existing traffic noise level plus 12dBA.

5.1.2 Traffic Noise Criteria for Sensitive Land Use

The NCG also sets guidelines for the assessment of traffic noise on sensitive land uses such as schools, hospitals, places of worship and recreation areas. Butler Street Reserve is located on the western side of the proposed bypass and is considered as an active open space given that the Byron Bay Community Market is typically held at the reserve. Therefore, the applicable road traffic noise criterion for Butler Street Reserve is presented in the following table.

Table 5.3 – NCG Criteria (Other Sensitive Land Uses)

Existing sensitive land use	Assessment Criteria, dB(A)		Additional considerations
	Day (7am-10pm)	Night (10pm-7am)	
1. Open space (active use)	$L_{Aeq,15hour}$ 60 (external) when in use	–	Active recreation is characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion.

5.1.3 Traffic Noise Criteria for Byron Motor Lodge

Byron Motor Lodge located in NCA 1 is not considered to be a sensitive land use according to the NCG; rather, it is considered to be a commercial type receiver. The RNP recommends that for commercial type premises, information on desirable internal noise levels is contained in Australian Standard 2107:2000. According to the standard, the recommended internal design levels for guest accommodation in hotels and motels is shown in Table 5.4.

Table 5.4 – Applicable Internal Noise Levels for Hotels and Motels (AS/NZS 2107:2016)

Type of Occupancy/Activity	Design Sound Level ($L_{Aeq,t}$) range
Hotels and motels in inner city areas or entertainment districts or near major roads	35 to 40
Hotels and motels in suburbs or near minor roads	30 to 35

Notes: 1. Applicable to sleeping areas during the night time period

As Byron Motor Lodge is sited at the junction of two major roads, namely Shirley Street and Lawson Street, the "major road" category in the table above would apply and the internal night-time design goal would be 35-40dB(A) $L_{Aeq(9hr)}$. Typically, there would be a 20dB(A) difference between outside and inside noise levels with windows closed, which would translate to a level of 55-60dB(A) $L_{Aeq(9hr)}$ when measured outside.

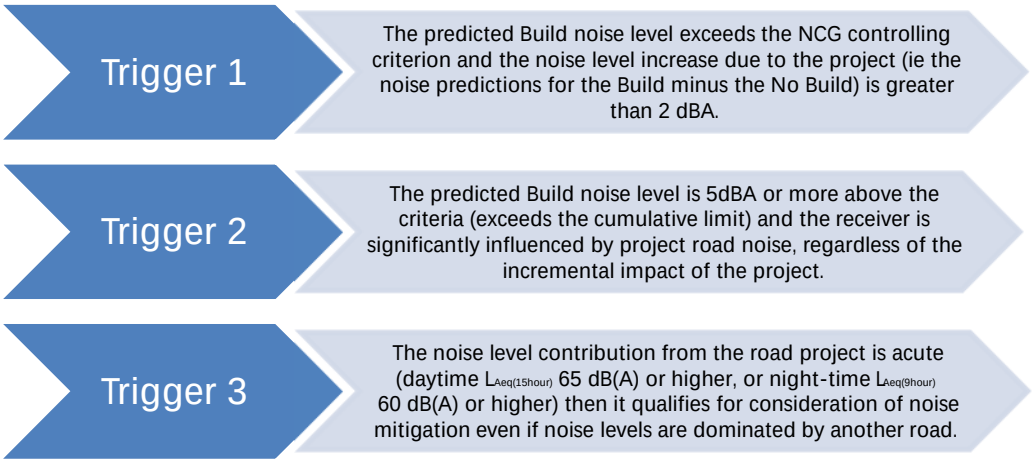
There is no criterion in AS2107 for the daytime period. However, for residential apartments near major roads, the acceptable design level for living areas is 35-45 $L_{Aeq(t)}$. Therefore, an acceptable external noise level would be 55-65dB(A) $L_{Aeq(15hr)}$.

5.2 Guidance on the Evaluation of Noise Mitigation Measures

The Noise Mitigation Guideline (NMG) provides guidance in managing and controlling road traffic generated noise and describes the principles to be applied when reviewing noise mitigation. The NMG recognises that the criteria recommended by the NCG are not always practicable and that it is not always feasible or reasonable to expect that they should be achieved.

The NMG notes that the most effective way of minimising noise from vehicles and traffic is to control vehicle noise at the source. Where source measures are not practical, or do not provide sufficient noise reduction, additional methods are required to reduce levels to within acceptable margins. Such additional methods may include the use of noise barriers and/or consideration for at-property treatment of residences.

The NMG provides three triggers where a receiver may qualify for consideration of noise mitigation (beyond the adoption of road design and traffic management measures). These triggers are:



The eligibility of receivers for consideration of additional noise mitigation is determined before the benefit of additional noise mitigation (quieter pavement and noise barriers) is included. The requirement for the project is to provide reasonable and feasible additional mitigation for these eligible receivers to meet the NCG controlling criterion. If the NCG criterion cannot be satisfied with quieter pavement and noise barriers, then the receiver is eligible for consideration of at-property treatment.

5.3 Noise Modelling Inputs

5.3.1 Building Heights

Detailed information of the heights of individual buildings surrounding the bypass route was unavailable. Therefore, residences were input into the noise model as either 3m or 6m high building blocks, representing single and double storey dwellings, respectively. Photogrammetry techniques and site inspection notes were used to identify which properties were double storeys.

It is noted that the assessment points at the facades of the affected receivers are generally set at 1.5m above the ground level on the basis of a dwelling located on top of a concrete slab. However, for this project, assessment points have been set at 2m above the ground level to account for the majority of dwellings being constructed on raised piers, which a conservatively assumed to be 0.5m in height. For first floor levels of double storey dwellings, the assessment points have been set at 5m above the ground level.

5.3.2 Road Pavement

When pavement surfaces are not dense graded asphalt or similar, corrections are included in the noise model, typically reflecting a noise increase for concrete pavements, and a noise decrease for quiet pavements such as open graded asphalt (OGAC) or stone mastic asphalt (SMA). The road pavement surface for this project is to be dense graded asphalt and therefore, a correction of 0dB(A) was used in the prediction of future noise levels.

5.3.3 Noise Barriers

A 2.4m high noise barrier is to be located along the western edge of the bypass road to mitigate traffic noise impacts to the Glen Villa Resort located within the SEPP 14 area. Although the proposed barrier forms part of the approval for the SEPP 14 area, it has been included in the noise modelling as it would provide some noise shielding to the receivers at the southern end of Butler Street.

5.3.4 Traffic Volumes, Compositions and Speeds

The traffic volumes and compositions used for the noise assessment has been based on traffic data provided by Byron Shire Council and data presented in Section 4.2 of the GHD noise and vibration report.

A traffic classification survey was not undertaken concurrently with the long-term noise monitoring conducted by GHD. Instead reliance has been made on Average Annual Daily Traffic (AADT) data provided by Council and presented in the GHD noise and vibration report.

The following assumptions have been made to determine the daytime (7am to 10pm) and night time (10pm to 7am) traffic volumes.

- Daytime traffic volumes are 85% of the AADT
- Night time traffic volumes are 15% of the AADT
- Heavy vehicle percentages of 4% and 5% for the day and night periods, respectively, have been based on information in the GHD noise and vibration report and data provided by Council.
- Vehicle speeds are based on posted speed limits – typically 50km/hr

Therefore, based on the above assumptions 15 hour and 9 hour volumes, compositions and vehicle speeds used for validation of the noise model are presented in Table 5.5 below.

Table 5.5 – 2015 Traffic Volumes, Compositions and Speeds

Road	7am – 10pm (15 hour)			10pm – 7am (9 hour)		
	Total Vehicles	% Heavy Vehicles	Speed (km/h)[1]	Total Vehicles	% Heavy Vehicles	Speed (km/h)[1]
Browning Street	6,936	4%	50	1,224	5%	50
Jonson Street	7,803	4%	50	1,377	5%	50
Lawson Street	16,473	4%	50	2,907	5%	50
Shirley Street	18,207	4%	50	3,213	5%	50
Butler Street	1,734	4%	50	306	5%	50

Notes: 1. Based on posted speed limits

The 15 hour and 9 hour traffic volumes, compositions and vehicle speeds necessary for the calculation of $L_{Aeq, 15\ hour}$ and $L_{Aeq, 9\ hour}$ traffic noise levels are presented in Table 5.6 and Table 5.7 below for the 'no build' and 'build' options, respectively.

Table 5.6 – Future 2018 & 2028 Volumes, Compositions and Speeds – 'No Build'

Road	Year	7am – 10pm (15 hour)			10pm – 7am (9 hour)		
		Total Vehicles	% Heavy Vehicles	Speed (km/h)[1]	Total Vehicles	% Heavy Vehicles	Speed (km/h)[1]
Browning Street	2018	7,344	4%	50	1,296	5%	50
	2028	8,813	4%	50	1,555	5%	50
Jonson Street	2018	8,262	4%	50	1,458	5%	50
	2028	9,914	4%	50	1,750	5%	50
Lawson Street	2018	17,442	4%	50	3,078	5%	50
	2028	20,930	4%	50	3,694	5%	50
Shirley Street	2018	19,278	4%	50	3,402	5%	50
	2028	23,134	4%	50	4,082	5%	50
Butler Street	2018	1,836	4%	50	324	5%	50
	2028	2,203	4%	50	389	5%	50

Notes: 1. Vehicles speeds based on the proposed posted speed
2. 'Design year' is 10 years after 'opening year'

Table 5.7 – Future 2018 & 2028 Volumes, Compositions and Speeds – 'Build'

Road	Year	7am – 10pm (15 hour)			10pm – 7am (9 hour)		
		Total Vehicles	% Heavy Vehicles	Speed (km/h)[1]	Total Vehicles	% Heavy Vehicles	Speed (km/h)[1]
Browning Street	2018	7,344	4%	50	1,296	5%	50
	2028	8,813	4%	50	1.555	5%	50
Jonson Street	2018	5,508	4%	50	972	5%	50
	2028	6,610	4%	50	1.166	5%	50
Lawson Street	2018	13,770	4%	50	2,430	5%	50
	2028	16,524	4%	50	2.916	5%	50
Shirley Street	2018	19,278	4%	50	3,402	5%	50
	2028	23,134	4%	50	4.082	5%	50
Butler Street (north)	2018	4,590	4%	50	810	5%	50
	2028	5,508	4%	50	972	5%	50
Butler Street (south)	2018	2,754	4%	50	486	5%	50
	2028	3,305	4%	50	583	5%	50

Notes: 1. Vehicles speeds based on the proposed posted speed
2. 'Design year' is 10 years after 'opening year'

5.3.5 Noise Model

Noise modelling was undertaken using the Road Traffic Noise Module in the CadnaA noise modelling software. This model is recognised and accepted by both the RMS and the EPA.

The traffic noise prediction model adopted by CadnaA is based on a method developed by the United Kingdom Department of Environment 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 model predicts noise levels for free flowing traffic and a modified method has been developed which enables an accurate prediction of noise from high truck exhausts to be taken into account.

The method predicts the $L_{10,1\ hour}$ noise levels, and a correction of -3dB(A) is applied to obtain the $L_{eq,\ 1\ hour}$ noise levels. The $L_{eq,1\ hour}$ noise levels for the day time period 7am to 10pm are used to determine the daily $L_{eq,\ 15\ hour}$ noise levels. Similarly, the $L_{eq,\ 1\ hour}$ noise levels for the night time period 10pm to 7am are used to derive the night time $L_{eq,\ 9\ hour}$ noise levels.

The noise prediction model takes into account the following inputs.

Table 5.8 – Summary of CadnaA Noise Modelling Inputs

Input Parameters	Data Acquired From
Traffic volumes, compositions and speeds	Noise model verification: traffic data obtained from Byron Shire Council and GHD. No traffic survey was conducted concurrently with long-term noise monitoring (see Table 5.5) Noise prediction modelling: 2018 and 2028 predicted traffic volumes provided by Byron Shire Council and GHD and based on AADT data with assumptions made. Vehicle speeds based on posted speeds of 50km/h for all roads (see Table 5.6 and Table 5.7)
Gradient of roadway	Design drawings provided by Byron Shire Council
Source height	0.5 metre for car exhaust, 1.5 metres for car and truck engines and 3.6 metres for truck exhaust as detailed within CoRTN88
Ground topography at receiver and road	2m ground contours provided by Byron Shire Council
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 drawings. No significant structures or cuttings identified
Air and ground absorption	Detailed within CoRTN88. Numeric values varied between 0 (hard surface) to 1 (soft ground). A value of 0.75 was used for all areas
Receiver heights	1.5 metre above ground level for ground floor and 4.5 metre above ground level for 1st floor
Facade correction	+2.5dB(A)
Correction for Australian conditions	The Austroads Research Report (ARR), "An Approach to the Validation of Road Traffic Noise Models" (2002): • -1.7 dB(A) for 'at façade' conditions • -0.7 dB(A) for 'free field' conditions
Acoustic properties of road surfaces	Dense graded asphalt – no corrections applied

Input Parameters	Data Acquired From
Roadside barriers	No existing roadside barriers Existing boundary fences included for calibration purposes, where applicable
Existing traffic noise levels (L_{Aeq})	Based on long term monitoring data provided by GHD and analysed by Renzo Tonin & Associates

5.3.6 Model Validation

The model was validated and calibrated using the long-term traffic noise monitoring results at the monitoring locations. Furthermore, it is general practice to undertake traffic classification counting concurrently with the long-term noise monitoring so that the traffic classification data can be used as part of the validation process. However, it is noted that no concurrent traffic counts were undertaken during the long-term noise monitoring. Therefore, in order to complete the validation process, the AADT data was provided by Byron Shire Council and assumptions were made in order to obtain appropriate traffic data to be used. It is noted that this process was also undertaken by GHD.

Table 5.9 summarises the results of the traffic noise model validation, providing a comparison between the modelled traffic noise levels for existing conditions and the measured traffic noise levels.

Table 5.9 – Noise Model Verification Results

Location	$L_{Aeq, 15\ hour}$ Daytime Noise Level			$L_{Aeq, 9\ hour}$ Night Time Noise Level		
	Measured	Modelled	Variation	Measured	Modelled	Variation
M1 – 2 Shirley Street	62.9	64.5	1.6	56.6	57.7	1.1
M2 – 1 Butler Street	59.7	60.7	1.0	54.1	53.8	-0.3
M3 – Vacant Land cnr Butler Street & Burns Street	53.4	54.3	0.9	47.6	48.2	0.6
M4 – 131 Jonson Street	64.4	63.2	-1.2	58	56.4	-1.6
M5 – Vacant Land adjacent to Jasmine House	62.2	62.4	0.2	55.3	55.1	-0.2
Mean Variation			**0.7**			**0.2**

The noise model validation results presented in Table 5.9 above 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 mean variation between measured and modelled results is 0.7dB(A) and 0.2dB(A), respectively, which is within the ±2dB(A) allowance for traffic noise validation and within the ±1dB(A) allowance for not including a calibration factor in future traffic noise predictions. Therefore, for the prediction of day and night time traffic noise levels, no calibration factor is included when generating the operational noise predictions for future traffic noise scenarios.

5.4 Traffic Noise Model Prediction

Operational noise modelling has been conducted based on the traffic volumes provided by Byron Shire Council and presented in the GHD noise assessment report. In accordance with the RNP and NCG, the scenarios predicted are:

- **'Opening Year' –** where noise levels are predicted for the year 2018 for both the 'build' and 'no build' options, for the day and night periods.
- **'Design Year' –** where noise levels are predicted for the year 2028 (ie. 10 years after opening of the project) for both the 'build' and 'no-build' options, for the day and night periods.

Noise modelling for the above scenarios was completed at residential assessment locations potentially worst affected by the proposed bypass.

Following a review of the modelling results, receivers identified to require noise treatment are presented in the table below.

Table 5.10 – Receivers Identified for Noise Treatment

No	Address	Map Ref	Description
R7	11 Butler Street	Lot 1 DP 781101	Byron Motor Lodge
R8	1 Butler Street	Lot 388 DP 728536	The Australian Orthodox Home for the Aged
R9	54 Butler Street	SP 35568	Residential dwelling
R10	56 Butler Street	Lot 1 DP 316229	Residential dwelling
R11	58 Butler Street	Lot 2 DP 316229	Residential dwelling
R12	60 Butler Street	Lot 10 DP 1027557	Residential dwelling - Heritage item
R13	62 Butler Street	Lot 11 S34 DP 758207	Residential dwelling - Heritage item
R14	2 Burns Street	Lot 2 DP 232172	Residential dwelling
R15	68 Butler Street	Lot 3 on DP 232172	Residential dwelling
R16	70 Butler Street	Lot 10 S41 DP 758207	Residential dwelling
R17	72 Butler Street	Lot 11 S41 DP 758207	Residential dwelling
R18	74 Butler Street	Lot 12 S41 DP 758207	Residential dwelling
R19	76 Butler Street	Lot 13 S41 DP 758207	Residential dwelling
R20	69 Butler Street	Lot 1 on DP 38981	Residential dwelling
R21	71 Butler Street	Lot 2 DP 38981	Residential dwelling
R22	73 Butler Street	Lot 3 DP 38981	Residential dwelling
R23	75 Butler Street	Lot 4 DP 38981	Residential dwelling
R24	77 Butler Street	Lot 5 DP 38981	Residential dwelling
R27	140-142 Jonson Street	SP 83280	Beachside Butter Apartments
R28	131 Jonson street	Lot 18 DP 247289	Ruskin House Accommodation
R36	52 Butler Street	Lot 7 S34 DP 758207	Industrial site (not a residential dwelling)
O1	Butler Street Reserve	Lot 389 DP 728537	Public Reserve

5.5 Consideration of Noise Mitigation Options

The NMG states that priority should first be given to reducing noise during corridor planning and road design where there may be greater opportunity to provide cost effective integrated outcomes with better urban design. Following corridor planning and road design, Section 7 of the NMG indicates the following priority order for noise mitigation:

"Options for noise mitigation measures ae listed below in the order of preference…":

1. *Quieter pavement surfaces*
2. *Noise mounds*
3. *Noise walls*
4. *At-property treatments*

All reasonable and feasible traffic management and road design options to minimise noise were considered in the early phase of the design process and are incorporated into the final design. This included location of traffic lanes, elevation of the road surface and speed limits. Therefore, the following sections assess the feasible and reasonableness of the remaining mitigation options in accordance with the order of priority stated above.

5.5.1 Quieter Pavement Surfaces

The NMG sets out that a quieter pavement surface is the preferred form of noise mitigation as it reduces source noise levels and provides protection to both external and internal sensitive areas and also has the least visual impact. Quieter pavements should be considered where there are groups of four or more receivers that exceed the NCG criteria.

'Quieter' road pavement surfaces such as Stone Mastic Asphalt (SMA) and Open Graded Asphaltic Concrete (OGAC) could be laid along the proposed bypass. However, this treatment is most effective for high speed roads such as freeways. The ENMM states that;

> *"…in areas with posted speeds of 70km/h or more, the reduction of road tyre noise can be a useful noise reduction treatment"*

Application of a quiet pavement is not recommended for this proposal for the following reasons:

- The posted speed limit for the project will be 50km/h, and the noise reductions achieved from this mitigation measure would be minimal.
- There are intersections along the bypass where traffic may slow down and then accelerate, which is not ideal for quiet pavements and can cause increased wear and maintenance.

5.5.2 Noise Barriers

The NMG sets out that like quieter pavement surfaces, a noise mound or noise wall provides protection to both external and internal sensitive areas. Noise mounds are preferred over a noise barrier because a noise wall typically has a higher visual impact. Noise walls are often more feasible than a mound as the site footprint can be much smaller. Noise barriers should be considered where there are four or more closely spaced receivers.

Noise barriers are reasonable and feasible where residences are closely grouped, where the barriers do not cause access difficulties to properties, and where they are visually acceptable. In accordance with the NMG, barriers are not cost-effective for isolated dwellings. In addition, where driveway access is required it is preferred not to use road-side noise barriers as the overall noise reduction provided by the barrier is compromised by the need to have breaks in the barrier to allow access.

As discussed previously in Section 5.3.3, a 2.4m high noise barrier which forms part of the approval for the SEPP 14 area, has been incorporated in the noise modelling.

The receivers identified in Table 5.10 for noise treatment typically front onto the proposed bypass or associated roads and therefore, would require driveway access and a noise barrier along the edge of the road is not a feasible and reasonable option.

5.5.3 At-Property Treatments

At-property treatment would only be considered for dwellings where other noise mitigation measures are either exhausted or are not feasible or cost effective. Therefore, for all the receivers identified in Table 5.10, at-property treatment is considered to be the most reasonable and feasible option.

At-property treatment for the receivers identified in Table 5.10 has been detailed in a report prepared by Renzo Tonin & Associates titled 'Byron Bay Bypass – Preliminary specification for noise mitigation works' (ref. TJ016-03F03 Preliminary Specification for Noise Mitigation Works (r0), dated 29 March 2017). The preliminary noise mitigation report is annexed in APPENDIX B of this report.

The following range of feasible at-property treatments have been considered in the preliminary noise mitigation report.

- 1.8m high acoustically rated feature fence along the front property boundary with 1.8m high lapped and capped timber side fences at the common boundaries of each property;
- acoustically rated motorised sliding gate with remote control for each property;
- blown-in acoustic insulation in the cavity of dwellings with light weight construction (timber chamferboard, weatherboard and fibro) and repair of any acoustic defects in the facade;
- replacement of or upgrading windows with acoustically rated glass or, in the case of the heritage listed properties, a secondary window panel on the inside;
- replacement of external doors with solid core doors and acoustic seals;

- acoustic insulation in the ceiling;
- sealing of the perimeter under-floor openings under the bearers; and,
- the provision of ducted fresh air ventilation.

Based on the above feasible at-property treatments and the information provided in the preliminary noise mitigation report, the following table presents the predicted day and night time traffic noise levels within the front yard and at the affected facades of the identified receivers along Butler Street on the northern end of the project, with and without the proposed 1.8m high fencing.

Table 5.11 – Predicted Day $L_{Aeq,15hr}$ & Night $L_{Aeq,9hr}$ Noise Levels With and Without 1.8m Fence, dB(A)

Receiver ID	Address	Floor Level	Orientation	Front Yard (1.5m above ground – free field)						Façade (2m above ground – facade corrected)							
				Build 2028 (no fence)		Build 2028 (with fence)		Fence Reduction		Existing		Build 2028 (no fence)		Build 2028 (with fence)		Fence Reduction	
				Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R7	Byron Motor Lodge	Ground	North	63	55.4	57.7	50.2	-5.3	-5.2	58	51	67.1	59.7	63.8	56.5	-3.3	-3.2
		Ground	West	-	-	-	-	-	-	58	51	64.1	56.6	61.9	54.5	-2.2	-2.1
R8	Byron Aged Care	Ground	East	-	-	-	-	-	-	58	52	65.5	58.2	65.6	58.3	-	-
R9	54 Butler St	Ground	East	59.9	52.1	56	48.3	-3.9	-3.8	-	-	61.3	53.6	59.7	52.1	-1.6	-1.5
		First	East	-	-	-	-	-	-	57	50	62.5	54.8	62.5	54.8	-	-
		Ground	North	-	-	-	-	-	-			55.8	48.5	55.8	48.5	-1.6	-1.5
		First	North	-	-	-	-	-	-	57	50	57.5	50.3	57.6	50.3	-	-
		Ground	South	-	-	-	-	-	-	-	-	52.6	45.3	49.6	42.4	-1.6	-1.5
		First	South	-	-	-	-	-	-	-	-	54.8	47.5	54.3	47	-	-
R10	56 Butler St	Ground	East	61.4	53.1	55	46.9	-6.4	-6.2	60	53	63.1	54.9	60.1	52	-3.0	-2.9
R11	58 Butler St	Ground	East	57.9	50	53	45.2	-4.9	-4.8	60	53	62.7	54.5	61.7	53.5	-1.0	-1.0
R12	60 Butler St	Ground	East	59.2	51.3	53.8	46	-5.4	-5.3	58	51	60.6	52.8	58.1	50.4	-2.5	-2.4
R12	60 Butler St - New 2 Storey	Ground	East	-	-	-	-	-	-	-	-	51.8	44.6	49.7	42.5	-2.5	-2.4
		First	East	-	-	-	-	-	-	-	-	55.1	47.8	54.8	47.6	-	-
R13	62 Butler St	Ground	East	58.8	50.9	53.5	45.7	-5.3	-5.2	57	50	60.3	52.5	57.8	50.1	-2.5	-2.4
		Ground	South	-	-	-	-	-	-	-	-	54.7	47.4	53.2	45.9	-2.5	-2.4
R14	2 Burns St	Ground	East	56.4	48.9	52.1	44.7	-4.3	-4.2	51	45	57.2	49.8	54.8	47.5	-2.4	-2.3
R15	68 Butler St	Ground	East	56.8	49.2	52.6	45	-4.2	-4.2	50	44	57	49.6	54.5	47.1	-2.5	-2.5
R16	70 Butler St	Ground	East	58.5	50.6	52.9	45	-5.6	-5.6	51	45	60.3	52.4	58.2	50.4	-2.1	-2.0
R17	72 Butler St	Ground	East	57.7	49.9	52.7	45	-5.0	-4.9	50	44	58.1	50.5	54.9	47.4	-3.2	-3.1
R18	74 Butler St	Ground	East	59.1	51	53.6	45.6	-5.5	-5.4	51	44	60.8	52.8	58.6	50.6	-2.2	-2.2
R19	76 Butler St	Ground	East	56.8	48.9	51.3	43.4	-5.5	-5.5	51	45	61.2	53.1	59.8	51.7	-1.4	-1.4
		Ground	South	-	-	-	-	-	-	51	45	55.6	48.1	52.6	45.1	-3.0	-3.0
R20	69 Butler St	Ground	West	57.9	50.1	53.7	46	-4.2	-4.1	51	44	60.8	52.8	58.6	50.6	-2.2	-2.2
R21	71 Butler St	Ground	West	56.3	48.7	53.9	46.3	-2.4	-2.4	49	43	59.3	51.6	58.4	50.7	-0.9	-0.9
R22	73 Butler St	Ground	West	57.2	49.5	55	47.2	-2.2	-2.3	49	43	58.3	50.7	56.8	49.2	-1.5	-1.5
		First	West	-	-	-	-	-	-	49	43	60	52.4	60.3	52.7	-	-

Receiver ID	Address	Floor Level	Orientation	Front Yard (1.5m above ground – free field)						Façade (2m above ground – facade corrected)							
				Build 2028 (no fence)		Build 2028 (with fence)		Fence Reduction		Existing		Build 2028 (no fence)		Build 2028 (with fence)		Fence Reduction	
				Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
R23	75 Butler St (house)	Ground	West	-	-	-	-	-	-	49	42	56.8	49.1	55.4	47.8	-1.4	-1.3
R23	75 Butler St (portico)	Ground	West	57	49.3	54.5	46.7	-2.5	-2.6	49	42	59.9	52.1	60.3	52.4	-	-
R23	75 Butler St (house)	Ground	West	-	-	-	-	-	-	49	42	57.8	50.1	56.5	48.8	-1.3	-1.3
R24	77 Butler St	Ground	West	57.5	49.7	54.5	46.7	-3.0	-3.0	49	42	59.4	51.6	59.2	51.5	-0.2	-0.1
		Ground	South	-	-	-	-	-	-	49	42	54.9	47.5	55	47.6	-	-

6 Conclusion

Renzo Tonin & Associates has completed a construction and operational noise and vibration assessment for the proposed Byron Bay Bypass to be located to the west of the former rail corridor in Byron Bay.

Results of the traffic noise modelling and assessment indicate that a number of receivers may potentially exceed the noise criteria established in accordance with the NCG. Receivers predicted to exceed the noise criteria would require at-property treatment due to access requirements which would render a road-side noise barrier to not be a reasonable and feasible option.

A summary of at-property treatment for the identified receivers have been presented and detailed treatment information is provided in a preliminary noise mitigation report annexed in APPENDIX B of this report.

Furthermore, predicted noise levels with and without the proposed 1.8m high fence along the property boundaries of the identified receivers along Butler Street have been determined and presented in this report.

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.

Adverse weather	Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period of time (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of the nights in winter).
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.
Assessment period	The period in a day over which assessments are made.
Assessment point	A point at which noise measurements are taken or estimated. A point at which noise measurements are taken or estimated.
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, when extraneous noise is removed. 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 L90 noise level (see below).
Decibel [dB]	The units that sound is measured in. The following are examples of the decibel readings of every day sounds: 0dB The faintest sound we can hear 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 100dBThe sound of a rock band 115dBLimit of sound permitted in industry 120dBDeafening
dB(A)	A-weighted decibels. 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 switched on 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.
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.
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.
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.
L_{Max}	The maximum sound pressure level measured over a given period.
L_{Min}	The minimum sound pressure level measured over a given period.

L_1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L_{10}	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.
L_{90}	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).
L_{eq}	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time.
Reflection	Sound wave changed in direction of propagation due to a solid object obscuring its path.
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 through its conversion into thermal energy.
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 pressure level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone.
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.
Tonal noise	Containing a prominent frequency and characterised by a definite pitch.